ADVANCES IN PSYCHOLOGY

5

Cognition and Memory

Edited by

F. Klix

and

J. Hoffmann

NORTH-HOLLAND

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Editors

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Preface

This volume comprises reports given at an international symposium on the subject "Cognition and Memory" held in Berlin in October 1978.

In the course of the past ten years the connexion between traditional memory research and analyses of processes of human information processing has had a fruitful effect on the development of psychology in theory and practice. Many new problems have arisen which had their origin not only in psychological disciplines but also in linguistics or psycholinguistics, in neuro-physiology and in mathematics. New experimental paradigma have come to the fore through which new cognitions of the still hardly determinable correlations between memory performance and cognitive processes were gained.

It was difficult to categorize clearly the contributions, since the problems, which form in each case the centre of the individual research reports, are in many ways linked with the subjects of the symposium as a whole. Each investigation of language processing also supplies a contribution to the problem of the processing of semantic information and each analysis of the structure of the semantic memory also contains data on the representation of linguistic information. In spite of these manifold concatenations of the reports we attempted to categorize the reports according to certain focal points.

In the first section reports are gathered which endeavour to differentiate in their survey or even in detail cognitive functions of the memory.

The three following sections of the book are extremely close interconnected. They contain reports with investigations by which various experiments were carried out with linguistic materials. All of them proceed, more or less explicitly, from questions concerned with the processing and storing of semantic information. The search for process and structure qualitites of cognitive performances can hardly be separated in these investigations, from one another owing to the nature of the topic. Differences in setting focal points of the individual reports have eventually determined their classification. The second part comprises investigations which are more strongly concerned with the elements and the structure of storing knowledge within the human memory. Section 3 comprises reports which place greater emphasis on the process analysis in receiving and regaining semantic information. Section 4 finally contains investigations which treat as central issue the processes of receiving and storing naturally-linguistic sentences and texts.

Many contributions to the Symposium have, we are pleased to say, demonstrated how investigations on the connexion between cognition and memory beyond the pale of basic research enliven beginnings of investigations on dealing with problems of practical tasks in diagnostics, in developmental and social psychology or in the analysis of complex decision processes. These contributions are combined in the

5th section of the book. Thus the disposition of the contributions most probably present to the reader a certain help in finding his way.

In the course of the Symposium and actually in each report there have been lively, interesting and mostly also fruitful discussions. The possible framework of this volume of reports would have been greatly exceeded if we had tried to include even the especially characteristic contributions to the discussion.

We express our gratitude to the administration of the Humboldt University and the Academy of Sciences of the GDR for making possible the holding of the Symposium by granting generous support. We also thank the Psychology Section of the Deutsche Verlag der Wissenschaften, above all Mrs. SCHULZ and Mr. HERTZFELDT for the certainly difficult publishing work.

May the report on this interesting Symposium help in disseminating knowledge on the interrelations between the cognitive processes and the representation forms of information in the memory and further stimulate thinking about the psychical foundations of the mental capabilities of human.

Berlin, January 29. 1979

F. KLIX
J. HOFFMANN

On Structure and Function of Semantic Memory

F. KLIX

1. Memory within information circulation

Memory, according to a thesis held for decades unchallenged—memory is an available quantity of data, facts, and conceptions. Human memory, however, is not a static container of corpuscles called items, neither is it a store in a technical sense. It is, on the contrary, a highly dynamic and active organ, the function of which serves the orientation and regulation of all behaviour.

In order to be able to grasp the natural mode of operation of human memory, it has to be looked upon as incorporated in the communicative processes taking place between organism and environment. Seen in their respective situational context, the information units of the memory as results of perceptions are, at the same time, bearers of decisions. Frequently, memory also guides perception in the reception of

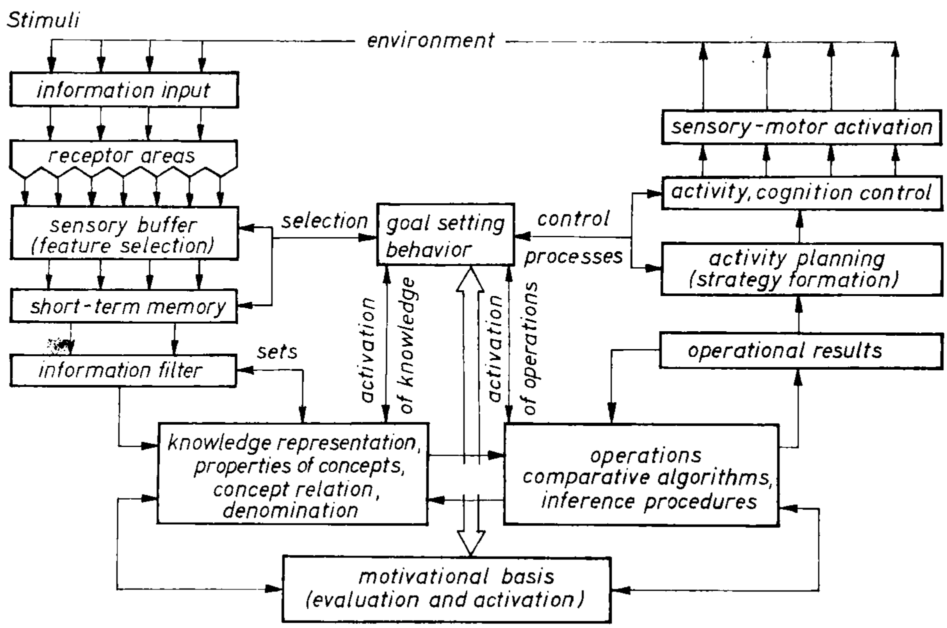

Fig. 1: Information circulation between organism and environment. Left: sensoric processing steps: ultra short-term and short-term memory with selective reception (filtering from long term memory and by motivation).
The present report emphasizes the interaction between stationary information storage and operative structures (bottom of figure). The generation of strategies for instance of information obtaining is organized via actions or verbal inquiries (right).

information, determining location and subject of perceptive inquiries. But memory also guides the motoric system in action. Control over the more or less successful conduct of the motion programmes is effected by the action and activity programmes of memory. The internal cognitive operations are located between perception and action. They, too, as procedures, are elements of memory. Figure 1 gives a brief, condensed version of these introductory remarks.

2. On the origin of information stored in human memory

The origin of informations stored in human memory is to be regarded as a triple one. They originate from (1) the history of species through the biological function of information storage in particular, as well as through fundamental types of decisions based on experience of the species, thus originating from the history of evolution; (2) the information stored in human memory originate from the history of society: knowledge of phenomena of nature and their internal correlations has been imparted by instruction, through lecture and education, via language; (3) it receives information through the individual life history, through experiences made by the "ego" in dealing with the things of perceptible reality. The different ways in which these three classes of information are imparted also seem remarkable: memory of the species is inherited, knowledge obtained by society is transferred via the sign system of language, whereas individual experience is obtained through the coordinated function of sensomotoric perception on figuratively experienced correlations.

3. Stationary and operative memory contents

It so happens, however, that memory is not only the bearer of *stationary knowledge*. By means of its natural integration into communication between organism and environment, it is the bearer of decisions, of operations and algorithms, i.e. of procedures of comparison or transformation of information. The most general *and* the most important operation of memory appears to be that of comparing or matching. It effects the determination of identities and facilitates to grasp the meaning. The identification of a meaning is a process of cognition. It is based upon the comparison between two informations—a (usually) sensorically offered one, and a stored one. If the process of comparison yields equivalence (i.e. matches), recognition takes place. Just this is the comprehension of meaning, regardless of whether recognition of an object or recognition of a sign or symbol for an object is concerned. Hence it follows: The volume of information bearers of a memory which react to incoming information is what amounts to the meaning containing, semantic memory. This quantity is identical with the cognitively available knowledge on reality and its correlations.

It therefore seems pointless, also, to look for a special definition of semantic information. It receives its specific nature through the verification of perceptive and mnestic structures as signs for something, but not through the specific nature of the cognitive process e.g. in the comprehension of the meaning of signs.

4. Two classes of knowledge

In literature, it is attempted to test and verify the hypothesis that there are two fundamentally different types of information storage in human memory: one figurative-iconic, and one discrete, logico-conceptual. We have originally also been guided by this hypothesis. In the process of verification (METZLER, 1978), however, we came to the conclusion that this hypothesis can at present not be decided on. For the time being, it therefore has to be left aside as not verifiable. METZLER was able to show that the experimentally verifiable differences between picture and word representation can be ascribed to a more discriminative, receptor oriented property representation. Each singular picture can also be described by a discrete set of properties, the same applies to any concept. The difference, as already stated, lies in the character of properties and not necessarily in the entirely different memory representation.

Of course, the consequences resulting from the different property characteristics are very decisive. The essential difference is that singular events perceived by means of observationcan only be reproduced to the degree to which they remain expli citly stored.[1] It is d ifferent in the case of categorial knowledge arranged according to logical rules. In this case, correlations, similarities, relations can be *derived* from the characteristics of the information bearers.

In the following, we shall concentrate on these two modes of knowledge representation—explicitly stored one compared to procedurally derived one. In this context we are guided by the assumption that the two classes constitute a memory-psychological reality. In the following, this is to be dealt with in greater detail and verified by giving some examples of experimentally achieved results.

5. Modalities of knowledge representation in human long-term memory

Meaning containing knowledge in human long-term memory consists of two basic quantities: (1) concepts, i.e. property representations for object classes, and (2) the relations between them, the semantic relations. Parallel to this, linguistic representations are attached to these basic entities.

5.1. Representation of concepts in human long-term memory

Concepts are collections of invariant object pecularities by properties (as memory quanta). When dealing with the question about the type of properties of natural, linguistically specified concepts, one first of all has to depart from those conceptions of properties as they have been induced e.g. by BRUNER, HUNT, MARIN, STONE and others through experiments with artificial concepts. As our experiments, among others those conducted by HÄUSER show, the properties of natural concepts have a quite different complexity. According to all we have so far been able to learn

[1] Thus, for instance, one must have seen a snake-like movement, must really have smelled sandelwood in order to understand the statements "to wriggle" or "sandelwood fragrance". On the other hand: given the statements "Hans is taller than Karin" and "Karin is taller than Renate", then the statements "Hans is taller than Renate" as well as "Renate is smaller than Hans" can be derived from it without having experienced the exact size relations between Hans and Renate.

about this, property characteristics of a super-concept are stored under the properties of natural concepts (of a lower degree of abstraction) as complex property together with them. In addition to this, there are complex properties for fuzzy class limitations and finally definite obligatory as well as optional (occasional) class properties. Figure 2 shall provide an example for the type of class representation referred to.

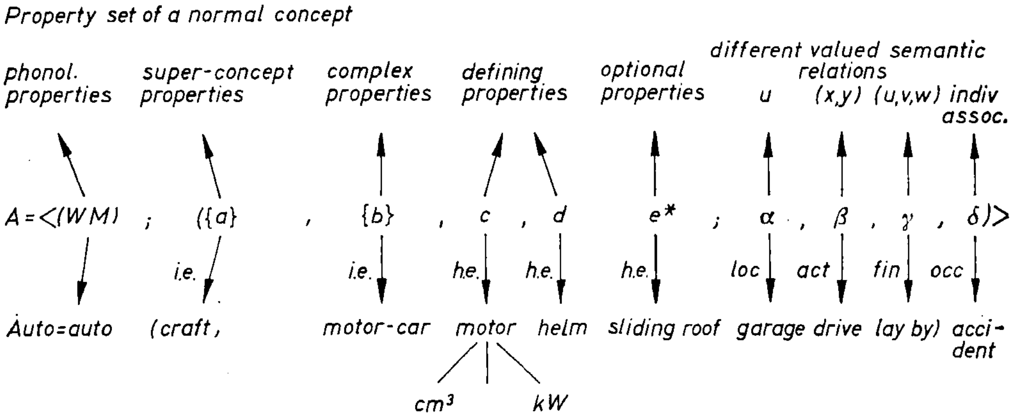

Fig. 2: General idea on property representation for natural concepts. Phonological properties represent the sign; in case of concept properties, distinction is made between descriptive and relational ones.

As STROBEL (1976) and KUKLA (1976) have shown, the fuzzy nature of complex properties is due to the fact that a great number of individual characteristics are merged into a global, general feature by means of pre-processing procedures. Naturally, this makes comparative processes for recognition (and coordination according to meaning) more difficult. We are indeed able to prove this in comparative processes between meaning-related concepts. So much, for the time being, on concepts. I now proceed to the

5.2. Relations between concepts

The fixed points of semantic long-term memory are the concepts. They classify the objects of reality. Dynamics of reality, however, its events, the dependences and connections, are predominantly reflected in relations between concepts. Here, on the one hand, we have the individually experienced, perceptive relations: thus, that the knife is for cutting (instrument property), that the motor runs (the actor property), that the teacher teaches (action bearer property), the boat is in the water (location relation), the patient is nursed in order to get cured (finality relation between concepts), the sun sets in the evening (time relation) or that its light makes the leaves grow green (causality)—all these relations reflect correlations which can be observed and experienced, i.e. they reflect objective correlations between objects in memory. The initially mentioned reasons lead us to assume that these classes of concept relations might be directly stored in memory; more specifically: that these properties of temporal, spatial, causal, effecting, intenting etc. relations are directly fixed in memory together with the respective pairs of concepts. We call these concept relations inter-concept semantic relations, i.e. connections among concepts. Their specific nature becomes more evident when we look at the other class of concept relations.

These are relations which are *not* extractable from reality by perception, but which are results of comparative processes. The fact that a chair is a piece of furniture, a hammer a tool, cannot be immediately perceived. That high is the opposite to low, development the opposite to deterioration, invalid a comparative to ill—all this presupposes cognitive matching processes, over and above pure perception, from which such concept relations can only then be derived. Comparative processes between emphasized properties are necessary. We are therefore guided by the assumption that recognition of such relations between concepts in memory is also actually based on cognitive comparative or matching processes. Since these are internal comparative processes and decision involving concept properties, we call these relations intra-concept relations, due to properties within concepts. By this we mean, more specifically speaking, relations among concepts which are determined by common properties or property relationships (especially by decisions about identical or similar properties) of the classified object quantities. Since the relevant informations for the determination of such relations are included within the concept properties and can therefore be derived therefrom, we assume that *in general* they are not, once again, explicitly recorded in memory, but that, depending on the respective demand, they are specifically derived or operatively generated. In memory-psychological research it would then be important to search for the specific algorithms for the determination of these concept relationships and to compare them with empirical data (viz. Klix and van der Meer' 1978 and in this volume).

Thus, we have derived two basically different types of knowledge representation and assumed their memory-psychological reality.

Figure 3 and fig. 4 give examples for illustrative explanation. The question now arises which experimental proofs we can revert to in support of these assumptions.

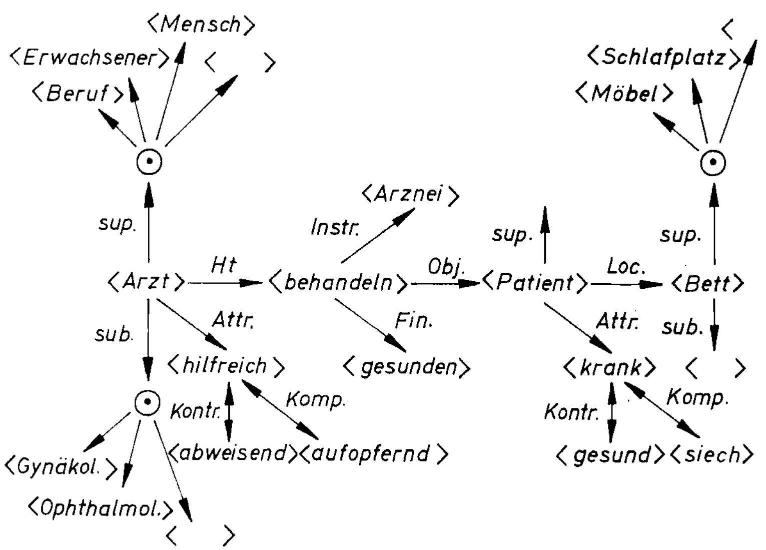

Fig. 3: Examples for two classes of semantic relations, in a semantic orientation area regarding school and education.
Inter-concept relations in the horizontal, intra-concept relations in vertical orientation (acc. to Klix, Kukla and Klein, 1976).

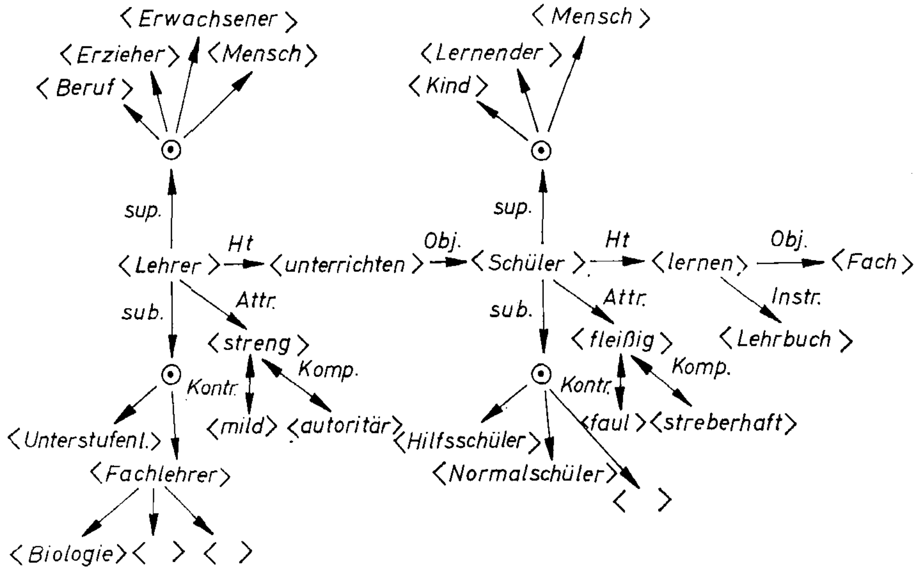

Fig. 4: Examples for two classes of semantic relations in a semantic orientation area regarding doctor and cure.
Inter-concept relations in the horizontal, intra-concept relations in vertical orientation (acc. to KLIX, KUKLA and KLEIN, 1976).

In this connection, I shall restrict myself to a few examples. In the papers by HOFFMANN; KRAUSE, LOHMANN and TESCHKE; KLIX and VAN DER MEER; PRZYBILSKI, SCHMIDT and SYDOW and others, further data in support of this assumption can be found.

5.3. Stationary and procedural representation of knowledge

The question now of course arises how these assumptions can be verified, how the reasons given can be proved as reality. (For the time being, it shall only be mentioned by the way that this, should it be successful can influence even neuro-biological hypothesis formation on the procedures of neuronal information storage.)

From the experimental-psychological point of view, of course, we are only able to furnish indirect evidence. We have therefore looked for a method to enable us to vary type and properties of semantic relations. As a criterion, we use the recognition time (as well as psycho-physiological parameters). The method employed by us is that of analogy recognition. In order to be able to prove the correlation with the hypotheses, we regard the principle first, followed by some explanatory examples.

Figure 5 shows the principle of analogy formation or analogy recognition. We have two structures $\mathfrak{A}$ and $\mathfrak{A}'$, as well as $\mathfrak{B}$ and $\mathfrak{B}'$. Whatever the semantic connotations of these structures may be, if the relation existing between $\mathfrak{A}$ and $\mathfrak{A}'$ is identical with the one existing between $\mathfrak{B}$ and $\mathfrak{B}'$, then the meaning correlation in the $\mathfrak{B}$-level is analogous to the one in the $\mathfrak{A}$-level. In fig. 6 we have given some examples for this statement. Here, we also recognize the two different classes of semantic relations, for which we assume the two different storing principles in memory. It is obvious: if, out of the described conceptual configuration, one takes a pair with identical semantic relation to another one, then this pair fulfills the analogy condition towards the first one. But, and this is where the specific nature of our hypothesis formation starts,

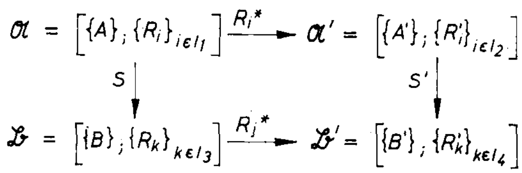

Fig. 5: Basic structure of analogy recognition. $\mathfrak{A}$ and $\mathfrak{A}'$, $\mathfrak{B}$ and $\mathfrak{B}'$ are concept structures with states (A_i, B_i etc.) and relational properties (R_i, R_j etc.). Certain relations also exist between these concept structures R_i^* R_j^*, (viz. fig. 6). If relations from R_i^* and relations R_j^* are at least partially identical, then the analogy condition between the two concept pairs is fulfilled.

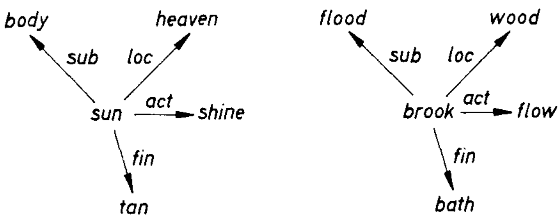

Fig. 6: Examples for semantic analogies. If one takes out two identical relations, the connected concept pairs are semantically analogous. This does not apply under other conditions.

the cognitive effort required for recognizing the existence of such an analogy, should differ in a characteristic way.

We start with the inter-concept relations. Figure 7 gives some examples for this (left side). It is evident in this connection that different degrees of interlacing exist

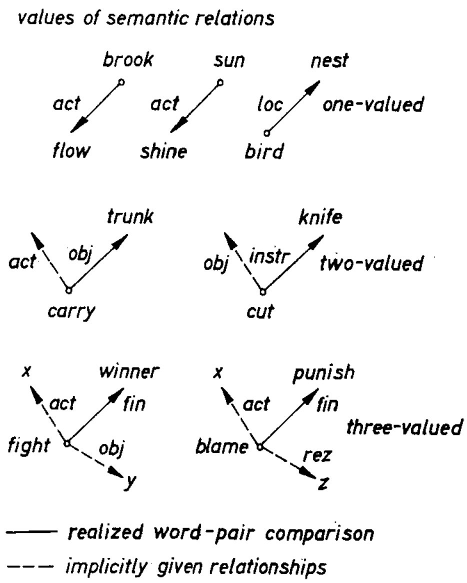

Fig. 7: Examples for different valences of semantic relations. They express different degrees of internal interlacing of the stored information bearers.

between the conceptual elements which must have an influence on the recognition time provided storage according to these relation characteristics exists, namely the relation as given in fig. 7 (bottom).

Figure 8 gives the recognition time necessary for accepting an analogy, depending on the complexity of the relation. The necessary time involved supports the hypo-

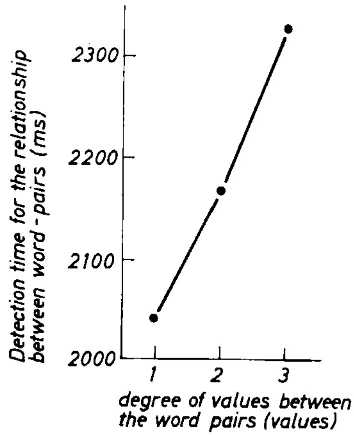

Fig. 8: Recognition times for analogies depend on the valence (and on the degree of interlacing, resp.) of the semantic units in memory (acc. to KLIX and VAN DER MEER).

thesis: the higher the degree of complexity of the (latent interlacing) storage structure, the more difficult becomes the isolation of *one* of its relations and the links belonging to it. (In the neuro-physiological level of explanation, reference could be made to the inhibition effort required in case of simultanuously exited storage structures.) As a whole, however, the result is only comprehendable if one assumes stationary information storage. This is intended as evidence for the assumption that interconcept semantic relations in a definite sense constitute stationary storage structures in long-term memory (viz. KLIX and VAN DER MEER, 1978).

Now an example from our investigations on intra-concept semantic relations which are derivable from the property characteristics of the concepts to be compared. One such characteristic relation is the super-sub and sub-super concept relation, respectively. This relation now became the object of analogy recognition. Figures 9 and 10

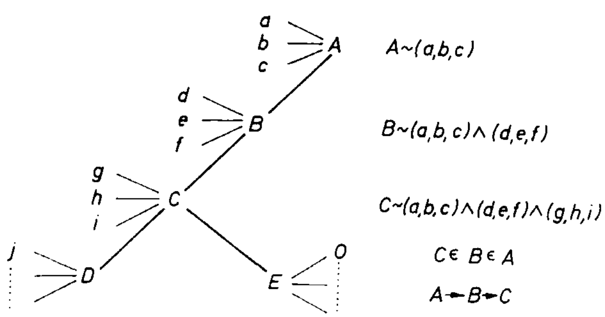

Fig. 9: Semantic and structural characteristics of sub-super-concept relations.

give examples which also illustrate the principle of analogy formation. The consequence from our hypothesis is obvious: if the super-sub concept relation is stationary

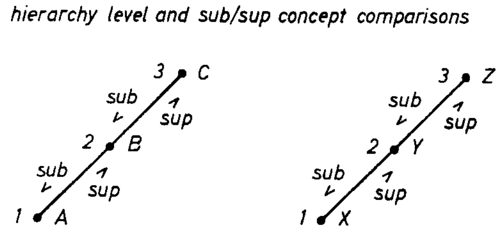

Fig. 10: Plan for experiment to test effort required for analogy recognition in case of sub-super-concept relations and vice versa. In case of stationary storage, determination of relation cannot depend on the hierarchy level:
t (ARB) = t (ARC). Furthermore, t (ARB) = t (BRA) should then also apply with regard to the cognitive effort involved.

stored, then the recognition of this relation *cannot* depend on the hierarchy level. More cannot be said, for the time being. Figure 11 gives *one* result of our experiments

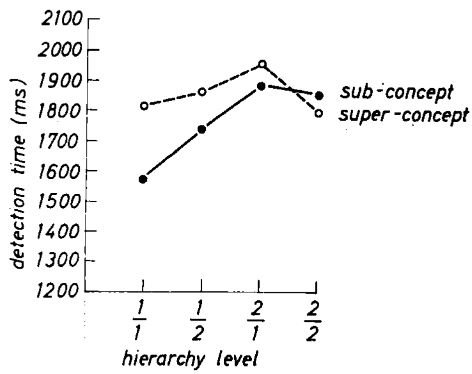

Fig. 11: If both sub-super-concept relations are one hierarchy level apart, $\left(\frac{1}{1}\right)$, then t (BRA) $\gg$ t (ARB). In case of a larger hierarchy distance $\left(\frac{2}{2}\right)$, this does not apply. This result is unexplainable, if we assume fixed storage of this concept relation. HÄUSER has furthermore pointed out that t (ARB) $\ll$ t (BRC). This is also incompatible with the assumption of fixed storage.

(HÄUSER and KLIX, 1978). Two aspects shall be emphasized:
(1) Recognition of the sub-super concept relation is unsymmetrical with regard to the cognitive effort involved. Recognition of relation from sub- to super-concept requires less time than vice versa.
(2) The unsymmetry depends on the abstraction level. In case of abstract categories it does not occur; differences are not significant.

(HÄUSER was able to show in his investigations that the decreasing unsymmetry is related to the complexity of properties in abstract concepts. I am not able to go into more detail in this place.) In the present context the conclusion is important that these (repeatedly verified) results are not compatible with the assumption of a fixed storage of these semantic relations. This brings us to the conclusion that this type of intra-concept relations is determined by means of cognitive operations (bearing in mind that under certain conditions the result of such operations is also stationary storable). This was verified in the studies conducted by KLIX and VAN DER MEER (1978) also for other types of intra-concept relations such as attribute, contrast, comparative relation. Hypothetic algorithms for the derivation of the experimentally measured times were developed and tested.

I have given two examples for the fact that knowledge available on a definite part of reality (and the correlations between concepts do constitute this available knowledge) is partly based on stationary entries (inter-concept relations) and partly on procedures of comparison or determination (intra-concept or property-dependent relations).

Explanation as to the type of co-operation between these two forms of mnestic information representation at present remains unsatisfactory. Developmental-psychological studies (PRZYBILSKI et al., in this volume) support the assumption that inter-concept relations as a result of sensorically imparted individual experience constitute the primary data basis for the reflection of correlations between events in reality in human memory.

We assume that such experience-coherent types of events at first form perceptively linked basic structures which we refer to as semantic cores. The examples of "to give" in fig. 12 at first gives the simple basic structure of the type of event. In further

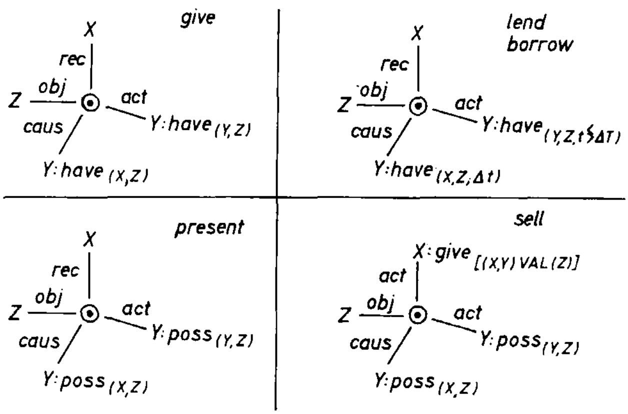

Fig. 12: Examples for a semantic core in which different concepts of the event type "to give" can be distinguished. Have designates the property of availability of an object to the actor; poss on the other hand, designates possession; ΔT designates limited duration of a condition (as property characteristic). Caus marks a cause; the appertaining property characteristic indicates change of availability or possession. Val designates the value of an object. The diagram has the purpose to clarify how different concepts in one type of event change their semantic charakteristic as a result of changes in the semantic relations, but also by accentuation of different properties.

illustrations, this basic structure for the type "to give" is further differentiated step by step. The example shows how the differentiation of conceptual property structures is related to the differentiation of semantic relations. This differentiation also classifies the forms of denomination. The different shadings of language comprehension and expressiveness refinement seem to have their cognitive basis in these processes of conceptual and inter-conceptual differentiation. These deliberations clearly show the difference between cognitive and lexical basis of memory: the property sets of concepts and the semantic relations between them describe real or possible situation properties in their spatial, temporal, causal and final properties; linguistic reflections denominate these situational properties.

We think we are able to show now that such types of situations with the events and forms of occurence typical for them are conductive to the formation of regions in semantic memory. In this connection we refer to orientation regions and assume that with their description and methodical registration we shall be able to approach a semantic topology of memory.

6. Orientation regions in semantic memory

By orientation region we mean information patterns which record space-time correlations and interactions in memory in the shape of scenes, events of forms of occurences. These are things and events which possess characteristic properties and belong into a quite definite situational frame by which—as we assume—they are defined in memory. Situational frames of this type are "school", "home", "professional life", "hobbies" and others. Orientation regions of this type are common to all people. In their concrete content they are characterized by *individual* experiences and behaviour. As semantically distinguishable region formations they determine frame-dependent meaning and importance of object properties as well as behaviour decisions depending on the bearers of meanings. Orientation regions have a comparatively homogeneous motivational basis. The concepts fixed in them (i.e. object properties compiled according to certain features) as a rule belong to *one* sphere of experience and as a coherent field of experiences also have an approximately identical emotional colouring.

Possibly, the uniform affective-emotional colouring conditioned by identical ego-experiences is really the reason for the relative conciseness of such structures. It could be assumed that neuro-chemical effects of the evaluation system has a region-forming impact on the storage structures. But that, for the time being, is purely speculative.

In their semantic substance, the orientation regions are determined by characteristic conceptual configurations. Figurative characteristics predominate in property representation of concepts. Relations between storage structures of concepts are predominantly or exclusively determined by inter-concept relations. Thus, the orientation region "school" includes the concepts teacher (with the characteristic teacher's properties and teacher's activities (as relations) such as teach, educate, praise, reprove); school and classroom (with their individual as well as general property and location characteristics); the pupils with their activities such as learn, read, write; the blackboard, chalk with their way-and-means properties and many others. The same applies to such coherent experience regions as leisure time, profession, family etc. Always, the individual characteristic has its specific property colouring but always, also, the semantic relations and *general* properties of the concepts are comparable or identical. There is hope, therefore, despite the individual specific nature of these regions or, better: penetrating their contents-individual specific nature to recognize *general* laws in the structure and function of these topological unities of semantic memory.

What hat been said so far suffices to derive first hypotheses on the organisation of orientation regions: coherences in space and time, activities and their consequences, causality properties, means and purpose relations, instrument or location characteristics, time references and such are conceptual structure properties which are determined by *inter-concept* semantic relations in the sense of our definition.

According to the first experimentally tested hypothesis, these are stationary information recordings. Their thematic specifics are determined by property characteristics of concepts *and* by the semantic relations linking them.

If it really applies that conceptual properties in one orientations region are attached to the semantic relations (however these relations may be neuronally coded), then identification of such a relation between two concepts within one orientation region should be easier or faster possible than between two different orientation regions (easier because the semantic connotation in the first case is similar to the one in the second: teacher—to teach and pupil—to learn refer to an experience complex with a high degree of relationship whereas teacher—to teach and doctor—to cure have the same relation (actor relation) but have different semantic connotations, due to different regions they belong to).

According to our hypothesis, intra-concept relations shall not be stationary stored, but based upon processes of comparison and decision. In this context, the location of the origin of a concept within semantic memory should not have an influence. Hence: it should make no difference whether birch—tree or carp—fish or grass—plant are compared with regard to sub-super-concept relation. It is evident that for the verification of this assumption we can again make use of the analogy recognition method. Figure 13 shows in some examples how the different semantic relations from one and the same or from two different orientation regions can be compared. From the results obtained, let two examples be mentioned here:

(1) If the orientation region changes in case of inter-concept relations, significant delays occur compared to the condition in which the pairs of concepts originate from the same orientation region. This finding was repeatedly tested and verified. It complies with the established hypothesis.

(2) In case of (1) it could be pointed out that different strength of association or frequency of use play a role in the two classes which could as a whole be understood as different degrees of typicality of the pairs of concepts. (teacher: to teach would then be more typical than teacher: profession or: teacher for a special subject.) For this reason, we have asked for estimates on the "typicality" of the concept pairs and we have compared strong connections on the one hand as well as weak connections on the other hand for both classes of semantic relations. The result is shown in fig. 14. It supports the statement made under (1). It is strengthened by the finding that even in case of low typicality, a change of the orientation region does not influence the speed of relation recognition. This is an indirect support of the assumption that these classes of relations are generally recognized by means of procedures and that they are not explicitly stored.

At the end of course, the question for the different functions of these two classes of semantic relations has to be raised. As a first approximation, an explanation offers itself: The one kind, the inter-concept relations fix the order of the experienced. They reflect in memory the correlation between the perceived and its classification. The intra-concept relation, on the other hand, is based to a high degree on the result of cognitive processes which can be conducted, principally speaking, between any, concretely, however, between information contents of memory, defined by decision demands.

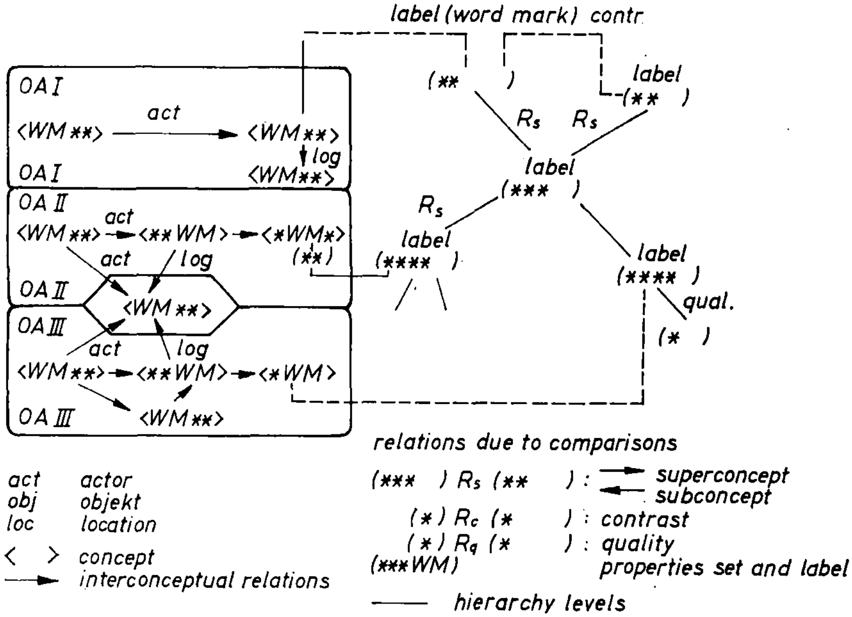

Fig. 13: Hypothetical diagram of three orientation regions in which fixed concept relations are embedded, conditioning a high degree of typicality, while change of the orientation region should result in abruptly increasing semantic distances. OA Orientation area.

By means of operative procedures, for instance comparison processes, similarities or property relationships between concepts or configurations of concepts can be established. Whatever may be the motivation for accentuating such memory struc-

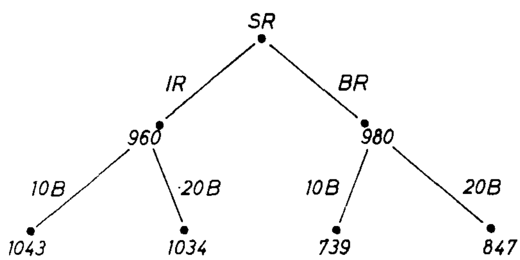

Fig. 14: Change of orientation region in its consequences for analogy recognition. Assuming fixed information storage (BR), the change of orientation region has a delaying effect on analogy recognition. OB Orientation area.
(IR intraconceptual relations; BR interconceptual or between relations.)

tures (as a rule, it will be the search for information for the purpose of behaviour decisions), distinguished from the network of non-conscious memory contents, they are available for cognitive comparison processes or transformative processes. In this connection, it can safely be assumed that the attachment to an orientation region is of somewhat minor importance. Nevertheless, results of such comparison and cognitive recognition processes on concept relations can themselves be explicitly stored, as for instance certain super-sub-concept relations, in the memory of, as an example, a taxonomically trained zoologist or botanist. Very abstract class formations as for instance the concepts value, guilt, merit etc. originate, with their property characteristics, from the most different regions of orientation. This becomes instantly evident if one considers the multitude of examples which are covered by such a concept. Categories of this kind are also results of cognitive operations and certainly not solely of perception. They are strongly disjunctive concepts with complex properties, each concrete example, however, belonging to one orientation region (guilt in court, moral guilt towards a partner, feelings of guilt in front of an accident etc.).

7. The double function of orientation regions

In view of the present results it is admitted that at the moment we know very little about the internal structure of the orientation regions. According to investigations made so far, the best approach to their function seems to be to regard them under two aspects: As definable regions they represent the order of the experienced by means of space-time correlated perception, experience and behaviour coherences. As a reservoir for elementary, perception-linked classification efforts they at the same time constitute the data basis for higher cognitive processes, in particular for the derivation of abstract categories such as, for instance, concepts of the second or third order, i.e. concepts which are derived from elementary concepts. But it is also possible to generate classes of situation properties, e.g. for behaviour decisions. Standards and rules of ethical behaviour could correspond to this. The assessment of categories which in the elementary range are formed according to the established behaviour decisions, in case of abstract classifications partly develop into elements of convictions.

Thus the considerations started quickly enter the most complex and inscrutable fields of psychology. Memory research here touches problems of personality or of social psychology. But it also touches essential problem aspects of cognitive development because the genesis of semantic memory reflects the individual history of its bearer.

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A Model of Memory with Storage Horizon Control

M. NOWAKOWSKA

1. Introduction

This paper will present a certain model of memory operation. The main purpose o the model will be to suggest a possible mechanism accounting for the human control (at least partial) of the variability of the storage time. In intuitive terms, the model will suggest a possible sequence of events which occurs when a person instructs himself: "This information I have to remember until..." In place of dots there may be either a specific time, or—more often—the time of occurrence of some specific event, marking the moment at which the stored information is to be recalled and utilized.

2. The model: general intuitions

The central concept here will be that of *metamemory*, which controls in a certain way the strength, direction and horizon of the operation of each memory unit. Specifically, in the present context of memory with variable storage horizon, the metamemory will cause from time to time the occurrence of *internal recalls* (to be abbreviated as IRCL) in specific memory compartments, each consisting of a number of memory units. At each IRCL, the content of one memory unit is copied down, so that the number of memory units containing the same information is increased. At the same time, each memory unit is subject to a risk of loss of its content.

Naturally, in reality the information stored in a set of memory units is heavily structured, so that loss of memory content of some units may be more "damaging" than loss of other memory units. Also, the outside events, which serve as horizons for some memory compartments, may trigger IRCLs for other memory compartments. In the model below, however, the considerations will concern a simple situation of a single memory compartment consisting of a number of units, which the metamemory assigns for storage and copying of one item of information.

3. Formal assumptions of the model

According to what was stated above, the memory constitutes a system

$$\langle M, C_1, C_2, \ldots \rangle$$

consisting of metamemory M and memory compartments $C_1, C_2, \ldots$ In turn, each C_i is a system of the form

$$C_i = \langle u_{i1}, u_{i2}, \ldots \rangle$$

where u_{ij} is the function describing the changes of state of the j-th unit of i-th memory compartment C_i. The units will be denoted by U_{ij}.

The basic interpretation is such that each C_i is designed to store some portion of information, say I_i.

Accordingly, each u_{ij} is a function of time t, with the possible values 0 and 1, such that

$$u_{ij}(t) = 1 \text{ if at time } t\text{, the unit } U_{ij} \text{ contains } I_i$$

and

$$u_{ij}(t) = 0 \text{ otherwise.}$$

Observe that each unit of C_i either contains no information, or contains the same information I_i.

Assumption 1: (Operation of C_i as a whole). The loss of I_i in C_i occurs if and only if all units lose I_i, i.e.

$$I_i \text{ is lost at } t \quad \text{if} \quad \sum_j u_{ij}(t) = 0.$$

Assumption 2: (Operation of individual units). Each unit U_{ij} is subject to the same constant risk of loss λ, so that the probability that information I_i stored in a given unit at time 0 will be still present at time t is $e^{-\lambda t}$.

Thus, if T denotes the duration of storage time in a given unit, then T has probability distribution function

$$P(T \leqq t) = 1 - e^{-\lambda t},$$

and $1/\lambda$ is the average storage time in a unit.

Assumption 3: (Independence). The losses in different units occur independently of one another.

Assumption 4: (Operation of IRCLs). The metamemory M may at any time t_0 cause the occurrence of IRCL in the compartment C_i. If at that time $\sum_j u_{ij}(t_0) = r > 0$, then one more unit receives information I_i, so that $\sum_j u_{ij}(t) = r + 1$ for all times t following t_0 and preceding the first loss. If $\sum_j u_{ij}(t_0) = 0$, then $\sum_j u_{ij}(t) = 0$ for all $t > t_0$.

The last assumption is a formal description of the process of "copying" the information I_i at times of IRCLs.

4. Analysis of the model: probability of loss at target time

The main problem of the analysis will be to determine the probability that the information stored at time 0 will be lost at target time t^*, given that at times $0 \leqq t_1 \leqq t_2 \leqq \dots \leqq t^*$ the IRCLs occur.

Let us agree to say that compartment C_i is in the state r at time t, if $\sum_j u_{ij}(t) = r$, i.e., if r among the units of C_i contain the information.

Let $p_{rs}(t - t_k)$ denote the probability of transition from the state r at the time immediately preceding the IRCL at time t_k to the state s at the time t preceding the moment t_{k+1} of next IRCL (so that there are no IRCLs between t_k and t).

Clearly, from the last part of Assumption 4 it follows that

$$p_{0s}(t - t_k) = \begin{cases} 1 & \text{for} \quad s = 0 \\ 0 & \text{for} \quad s \neq 0. \end{cases} \tag{1}$$

Let now $r > 0$. The probability $p_{rs}(t - t_k)$ is then 0 for $s > r + 1$. Moreover, the transition to the state $s \leqq r + 1$ occurs if among $r + 1$ units which contain I_i at the time immediately following the time t_k (Assumption 4), s retain the content at time t, and $r + 1 - s$ lose it. The probability of retaining the information at time t is, by Assumption 2, the same for all units, and equal

$$p = e^{-\lambda(t-t_k)}. \tag{2}$$

By Assumption 3 of independence, the probabilities $p_{rs}(t - t_k)$ are given by the binomial formula

$$p_{rs}(t - t_k) = \binom{r+1}{s} p^s q^{r+1-s}, \quad s = 0, 1, \ldots, r + 1, \tag{3}$$

with p given by (2) and $q = 1 - p$.

Combining (1) and (3) we obtain the transition matrix

$$P(t - t_k) = \begin{bmatrix} 1 & 0 & 0 & 0 & \ldots \\ q^2 & 2pq & p^2 & 0 & \ldots \\ q^3 & 3q^2p & 3qp^2 & p^3 & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \end{bmatrix}. \tag{4}$$

We have now

Theorem 1: *The transition matrix from the state at* $t = 0$ *to the state at the target time* t^*, *given the IRCLs at times* $0 \leqq t_1 \leqq t_2 \leqq \ldots \leqq t_N \leqq t$ (*multiple IRCLs are allowed*), *is the product*

$$P = P(t_1)\, P(t_2 - t_1) \ldots P(t_k - t_{k-1})\, P(t^* - t_k). \tag{5}$$

By Assumption 1, the probability of loss of information by the target time t^*, provided that at time $t = 0$ only one unit is occupied, equals the term p_{10} of the matrix (5), while the probability that the information is still present at time t^* is $1 - p_{10}$.

5. Optimization of moments of IRCLs

Suppose now that only a given fixed number of IRCLs is allowed. The question then is to find their optimal placements, so as to maximize the probability that information is still present at the target time, or equivalently, so as to minimize the probability of loss by time t^*.

Since the explicit formulas, though available from matrix (5), are somewhat involved, the problem will be solved for the cases of $N = 1, 2$ and 3 only.

Without loss of generality, we may assume further that $t^* = 1$.

(a) Case $N = 1$, i.e. only one IRCL is allowed. Suppose it occurs at time x with $0 \leqq x \leqq 1$. Let $p_0(x)$ be the probability that the information is lost by time $t = 1$. This may occur in two ways:

(i) the original unit loses its information before the time x of IRCL;

(ii) at time x the original information is not lost, so that immediately after x we have 2 units containing the information, but both of them lose it before time 1.

The probability of event (i) is $1 - e^{-\lambda x}$, while the probability of event (ii) is $e^{-\lambda x}(1 - e^{-\lambda(1-x)})^2$, we have therefore

$$P_0(x) = 1 - e^{-\lambda x} + e^{-\lambda x}(1 - e^{-\lambda(1-x)})^2.$$

To choose x which minimizes $P_0(x)$, we may differentiate with respect to x, obtaining

$$P_0'(x) = \lambda e^{-\lambda x} - \lambda e^{-\lambda x}(1 - e^{-\lambda(1-x)})^2 + 2e^{-\lambda x}(1 - e^{-\lambda(1-x)})\,\lambda\, e^{-\lambda(1-x)}.$$

Denoting $z = e^{-\lambda(1-x)}$, we get

$$P_0'(x) = \lambda e^{-\lambda x}(1 - (1 - z)^2 + 2z(1 - z)) = \lambda e^{-\lambda x} z(4 - 3z).$$

For $0 \leqq x \leqq 1$ we have $z \leqq 1$, hence $P_0'(x) > 0$. Consequently, the smallest value for $P_0'(x)$ is obtained at $x = 0$, and we have

Theorem 2: *If only one IRCL is allowed, then in order to minimize the probability of loss, it is best to make it at once.*

(b) Case $N = 2$. Suppose we decide to make the two allowed IRCLs at times $0 \leqq x \leqq y \leqq 1$, and let again $P_0(x, y)$ denote the probability of total loss at the target time $t^* = 1$. The total loss may occur in the following ways:

(i) the original is lost before the time x of the first IRCL; this occurs with probability $1 - e^{-\lambda x}$,

(ii) the original is not lost by the time x (probability $e^{-\lambda x}$). Then at the time y of the second IRCL we have 0, 1 or 2 copies present. Consequently, this case splits into:

(ii, 1) both copies are lost by time y; probability of this event is $(1 - e^{-\lambda(y-x)})^2$,

(ii, 2) one copy is lost and one is present at y. Probability of this is $2e^{-\lambda(y-x)} \cdot (1 - e^{-\lambda(y-x)})$. To have the total loss, the two copies existing immediately after y must be lost by the time 1; the latter event has probability $(1 - e^{-\lambda(1-y)})^2$.

(ii, 3) both copies are present at time t: this has probability $e^{-2\lambda(y-x)}$. Out of the three copies present at time immediately following y, all must be lost by time 1. This occurs with probability $(1 - e^{-\lambda(1-y)})^3$.

Combining these probabilities together, we obtain

$$P_0(x, y) = 1 - e^{-\lambda x} + e^{-\lambda x}[(1 - e^{-\lambda(y-x)})^2 + 2e^{-\lambda(y-x)}(1 - e^{-\lambda(y-x)})(1 - e^{-\lambda(1-y)})^2 + e^{-2\lambda(y-x)}(1 - e^{-\lambda(1-y)})^3].$$

Figure 1 gives the values of probability of recall at target time, i.e. $1 - P_0(x, y)$, for the value $\lambda = 1.5$ (hence in the case, when on the average, a unit retains the information only for 2/3 of the target time).

The particular curves correspond to selected values x and show the values $1 - P_0(x, y)$ for y lying on the right from x.

As may be seen, it is best to take $x = 0$ and $y = 0.3$ (this combination of values x, y yields the highest attainable probability of recall).

It can be shown that the choice $x = 0$ is always optimal. However, the optimal choice of y, the time of second IRCL, depends on the value of λ. Table 1 shows the changes of optimal y, and the changes of optimal probability of recall under the change of λ (here $x = 0$).

As might have been expected, for small λ, when the recall has high probability anyway, the optimal y is close to 0. As λ increases, the probability of recall decreases

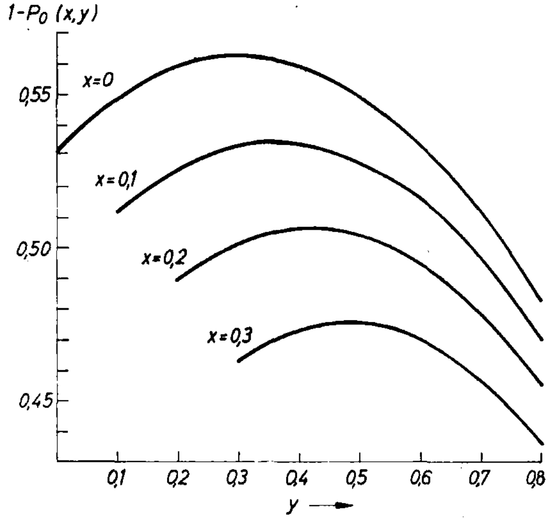

Fig. 1: Probability $1 - P_0(x, y)$ of correct recall as a function of the moment of the second ICRL y, for given moment x of the first ICRL, and $\lambda = 1.5$.

to 0, while the optimal y increases, gradually more and more slowly, to a value somewhere below 0.5.

(c) Case $N = 3$. Given that three IRCLs are allowed, let x, y, z with $0 \leqq x \leqq y \leqq z \leqq 1$ denote their times, and let $P_0(x, y, z)$ be the probability of total loss at the target

Tab. 1: *Optimal choices of the time y of second IRCL (the optimum time of first IRCL is 0), and the corresponding recall probabilities* $1 - P_0\,(x_{opt}, y_{opt})$ *for selected values* λ

λ	Optimal y	Maximum of $1 - P_0$
0.2	0,0830	0.9942
0.5	0.1680	0.9430
1.0	0,2546	0.7760
1.5	0.3082	0.5617
2.0	0.3440	0.3870
5.0	0.4305	0.0253
10.0	0.4651	0.0018

time $t^* = 1$. Denoting for simplicity $p = e^{-\lambda x}$, $q = e^{-\lambda(y-x)}$, $r = e^{-\lambda(z-y)}$ and $s = e^{-\lambda(1-z)}$, and proceeding as before we get

$$P_0(x, y, z) = 1 - p + p\{(1 - q)^2 + 2q(1 - q)\,[(1 - r)^2 + 2r(1 - r)\,(1 - s)^2 + r^2(1 - s)^3] + q^2[(1 - r)^3 + 3(1 - r)^2\,r(1 - s)^2 + 3(1 - r)\,r^2(1 - s)^3 + r^3(1 - s)^4]\}.$$

One can show that whatever the value of λ, the optimal choice of x is 0, i.e. it is best to make the first IRCL at once, thus ensuring the existence of two copies. The optimal choice of y and z (for $\lambda = 1.5$) is—as may be seen from Tab. 2—is $y = 0.20$ and $z = 0.50$, i.e. it is best to make the second IRCL at about 0.2 of the target time, and the third—at about half the target time. The probability of perfect recall is then about 0.7.

The comparison of the cases for $N = 1$, 2, and 3 for the same λ, shows that the possibility of IRCLs enhances considerably the probability of recall at target time: under optimal placings of the IRCLs, the chances of correct recalls are:

0.223 if no IRCL is allowed (here $\lambda = 1.5$),
0.396 if one IRCL is allowed, and it occurs at $x = 0$,
0.561 if two IRCLs are allowed, placed at $x = 0$ and $y = 0.3$,
0.699 if three IRCLs are allowed, placed at $x = 0$, $y = 0.2$ and $z = 0.5$.

Tab. 2: *Probabilities* $1 - P_0(x, y, z)$ *of recall at time* $t = 1$, *for* $x = 0$, *various* y, *and* z *ranging from* y *to* 1 ($\lambda = 1.5$)

z	y										
	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	0.636										
0.05	0.644										
0.10	0.652	0.660									
0.15	0.660	0.668									
0.20	0.667	0.676	0.671								
0.25	0.673	0.683	0.679								
0.30	0.679	0.689	0.686	0.669							
0.35	0.682	0.694	0.692	0.677							
0.40	0.684	0.697	0.696	0.682	0.656						
0.45	0.685	0.698	0.698	0.687	0.662						
0.50	0.683	0.697	**0,699**	0.689	0.666	0.631					
0.55	0.680	0.694	0.697	0.689	0.668	0.636					
0.60	0.674	0.689	0.693	0.686	0.668	0.639	0.597				
0.65	0.666	0.681	0.687	0.681	0.665	0.638	0.600				
0.70	0.655	0.671	0.677	0.674	0.660	0.636	0.600	0.554			
0.75	0.642	0.658	0.665	0.663	0.651	0.630	0.598	0.555			
0.80	0.626	0.643	0.651	0.650	0.640	0.621	0.592	0.554	0.504		
0.85	0.607	0.624	0.632	0.633	0.625	0.608	0.583	0.549	0.504		
0.90	0.585	0.602	0.611	0.613	0.607	0.593	0.571	0.540	0.500	0.450	
0.95	0.560	0.577	0.586	0.589	0.585	0.573	0.555	0.528	0.493	0.449	
1.00	0.531	0.548	0.558	0.562	0.559	0.550	0.534	0.512	0.482	0.444	0.396

6. Conclusions: experimental possibilities

The model analysed in the preceding sections may be regarded as a submodel of a larger one, describing generally the operation of metamemory and its internal organization, as well as logical and stochastic interrelations between various memory compartments.

The model differs in many respects from the conceptions of memory advanced so far (especially as regards recall; see, for instance BOWER, 1977, GLANZER, 1977). Firstly, it abandons to some extent the traditional division into a short term and long term memory (see, for instance, MONTAGUE, 1977), showing in which way the storage time may be subject to a partial control.

Secondly, despite the simplifications, the value of the model lies in the fact that it offers a novel mechanism of self-control of memory, a mechanism whose operation may be optimized. This opens up two possibilities. One of them lies in testing and estimation in controlled experiments, in which IRCLs are induced by the experimenter at certain times, and one estimates the recall probability. The results of these experiments, now in progress, will be published elsewhere.

The second possibility lies in opening up the ways of studying to which extent the subject apply automatically the optimal IRCLs strategies, and if they deviate from optimality—what are the causes and directions of these deviations. In some sense, the situation here is similar to that with decision theory, where one can observe the real behaviour in decision situations, and knowing the optimal decisions, one obtains a powerful source of information from the data on the observed deviations from optimality.

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Cognitive Production Systems: Toward a Comprehensive Theory on Mental Functioning

H. Ueckert

1. Introduction

Obviously, man is physically and informationally a continuously active system. *Perception* and *consciousness*, *thinking* and *performance*, *learning* and *memory*, *knowledge* and *proficiency* are psychological phenomena which operate in a thoroughly *interactive* way and which, in their fundamentals, constitute a truly *dialectical* system of physical structures and informational processes.

None of the hitherto developed theories of psychology—and also none of the models of computer simulation and "artificial intelligence" to date—really do justice to these facts: In the presence of myriad *quantities* of body cells—muscle cells, sensory cells, and nerve cells in particular—and in the presence of manifold *qualities* of interaction between those cellular systems, it seems hardly realistic to expect an adequate picture of psychological functioning if one confines oneself to a few pages of theoretical discussion of empirical findings or to some dozen lines of program code in computer simulation.

But then a crucial problem of basic research is posed: By *which* system architecture is there such a *resolution level* in psychological modelling so that it qualitatively *and* quantitatively corresponds to the physiological basis of human information processing?

A *comprehensive* answer to this question will be found only through an interdisciplinary cooperation between *neurophysiologists*, *cognitive psychologists*, and *Artificial Intelligence people*. *A programmatic* answer shall be given in the following six *theses*:

(1) The organization of the human brain is based on a functional division into *short-term*, *intermediate-term*, and *long-term memory*.

(2) *Sensory* and *motor buffer systems* link this memory organization to its internal and external environments.

(3) The human brain is a *dual processor* of parallel image processing and sequential symbol processing.

(4) *Physiological correlates* of both image processing and symbol processing consist of short-term neuroelectrical as well as of intermediate-term and long-term biochemical structures and processes.

(5) The organizational mode of human information processing (image and symbol) is realized in *cognitive production systems*, functioning on active data structures ("semantic entities") by assertive and procedural characteristics of operation ("program functions").

(6) *Psychological criteria* of cognitive production systems apply to decomposability into data-driven and/or goal-driven production rules as well as to adaptivity of systems by means of dynamic "program learning" vs. static availability of ready-made program catalogues.

Clearly, theses 1 through 4 relate to the *physical base structure* of cognitive activity whereas theses 5 and 6 refer to the, so to say, "*informational superstructure*" of this activity. Some empirical and theoretical evidence from recent research supporting these theses will be discussed in the following.

2. The physical basis of cognitive activity

Recent survey papers have dealt at length with the neurophysiological mechanisms of human information processing (e.g. SINZ, 1977, SOKOLOV, 1977, JOHN and SCHWARTZ, 1978) so that the following discussion will concentrate on some main aspects of the physical basis of cognitive activity.

The most comprehensive model of *human memory organization* compatible with theses 1 and 2 is the *Distributed Memory model* by HUNT (1971, 1973). This model distinguishes functionally—besides peripheral buffer systems (cf. below)—between three main parts:
(1) *Short-Term Memory* (STM) with limited capacity, rapid access, but short retention times (milliseconds to seconds);
(2) *Intermediate-Term Memory* (ITM) with larger capacity and longer retention times (minutes to hours);
(3) *Long-Term Memory* (LTM) with virtually unlimited capacity, long retention times (days to years, or life-long, respectively), but relatively slow access.
Physiological correlates of this functionally organized memory structure are (cp. thesis 4):
(1) *short-term*, within the range of milliseconds intracellularly established electrical activity of neurons (action potentials, excitatory and inhibitory postsynaptic potentials, etc.);
(2) *intermediate-term*, within the range of seconds through minutes occuring biochemical activity (DNA dependent RNA processes of protein and enzyme synthesis);
(3) *long-term* or life-long lasting effects of storage after successful syntheses of proteins and enzymes.

The transition from short-term storage to intermediate-term and long-term storage occurs in *intercellular neurophysiological activity* of synaptic junctions, reverberating circuits, frequency characteristics of potential distributions, etc.

These neuroelectrical and biochemical processes and structures are the *physical carriers of information* on which the human brain operates in its encoding of information.

Sensory buffer systems—also called "Ultra-Short-Term Memory" or "Sensory Information Store" (KLIX, 1976, 1977)—serve to encode *the input information* into the memory system. Widely confirmed are the *iconic buffer* for visual input and the *echoic buffer* for auditory input (cf. SIMON, 1976); respective buffer systems are to be assumed for the other receptor systems also.

Motor buffer systems operating on the motor apparatus of the organism not only represent the operational systems to *decode the output information* from the memory system but also serve as the crucial mechanisms of *feedback* and *feedforward control* of *sensory* buffers (cf. PRIBRAM, 1971). An example is the continuous adaption of the ocular motor apparatus to the instantaneous conditions and intentions of visual perception.

The *duality hypothesis* of separated image and symbol processing as stated in thesis 3 seems largely accepted, generally attached to the assumption of hemispheric division into *left-side dominant*, "conscious" (language) processing and *right-side subdominant*, "holistic" (Gestalt) processing.

Strong arguments for analogue and parallel image processing of perception result from PRIBRAM's (1971) *hologram hypothesis*: Holographic memories of physical interference patterns in the brain, on the basis of slow excitatory and inhibitory potentials, are characterized by large storage capacities, content addressability for rapid recognition, and associative storage and recall (see PRIBRAM, NUWER and BARON, 1974 for details).

The functional structure in which digital and sequential symbol processing of the human consciousness takes place is short-term memory (STM) on the one hand, and intermediate-term memory (ITM) on the other hand. ITM, as described in HUNT's Distributed Memory model, seems to be that context store in which the results of the informational interactions between long-term and short-term memory are temporarily held.

3. The 'informational superstructure'

Granted that human image and symbol processing is encodable in the physical carrier processes of the brain, the cognitive psychologist is primarily interested in the question of *which organizational mode* is to be assigned, on the informational level proper, to cognitive activity. The most fundamental approach to psychological describability of informational structures and processes can be found in the conception of *cognitive production systems* as developed by NEWELL and SIMON (1972).

The notion of cognitive production systems rests on the assumption of existence of three separable systems parts:

(1) a *working memory* which provides the *data base* of actual information processing;

(2) one or more *rule systems* which, taken together, constitute the *knowledge base* of a subject;

(3) an *interpreter* which interactively links the data base to the knowledge base.

In spite of a number of survey papers on production systems (e.g. NEWELL, 1973, DAVIS and KING, 1977, WATERMAN, 1977), a comprehensive treatment of the underlying theoretical concepts has not yet taken place. In connection with the organization of human memory, for example, what constitutes the *working memory* of cognitive production systems is treated differently by several authors: NEWELL and SIMON (1972) declare the *short-term memory* (STM) as the exclusive storage structure of actual information processing whereas HUNT, in virtue of his more detailed Distributed Memory model, utilizes both *short-term* (STM) and *intermediate-term memory* (ITM) to represent the informational data base of a subject (cp. HUNT, 1973, HUNT and POLTROCK, 1974); and in Artificial Intelligence research, application of the production system approach leaves out any strict specification of working memory, i.e. the storage structure is the active data part of the central processing unit of a computer (cp. DAVIS and KING, 1977). In any case, the *contents* of working memory are appropriately encoded information structures, i.e. *symbols* and *symbol structures*, to be processed by means of the underlying (programming) language.

Formally, a production system consists of a nonempty set of *production rules* (or *productions*, for short) each of which having the structure

$$C \to A$$

where C is a set of informational *conditions* (symbol structures in working memory) and A is a set of eventual *actions* (operations on symbol structures); both sides are associated to each other by the transition arrow "→" which, as a *meta-operator*, can be read by the interpreter of the production system differently according to whether reading of a production starts from *left*, condition side C, or from *right*, action side A, of the rule expression. The *first variant* would read "If C is given then do A." whereas the *second variant* would read "In order to do A attain C to be given."

A simple illustration of the operational mode of a production system is the following "Production System for Street Crossing at a Crosswalk with Traffic Light Control":

Production 1: "*Traffic light is green*" → *Walk.*
Production 2: "*Traffic light is red*" → *Wait*; *Observe traffic light.*

The interpretation of the productions of this system from left to right apparently describes the *actual* behavior run at a crosswalk with traffic light control whereas the interpretation from right to left would constitute the *planning*, so to say, of that behavior run.

The left part of a production always consists of active or to be activated *data structures*—originating from immediate perception or from momentary results of thought...which enter a production system as its "*semantic entities*". The right part of a production contains exclusively *operational functions* to be executed or to be made executable which, as the "*program functions*" of a production system, can serve two different purposes as

(1) *procedural functions* if they designate *processes* to be executed elementarily within that production system or to be called for by means of subordinate production systems, or as

(2) *assertive functions* if they serve to characterize the *knowledge state* which can be associated with the left-side data part of a production, i.e. assertive functions designate meaning to semantic entities within production systems.

An example of procedural functions are the actions "*Walk*", "*Wait*", and "*Observe traffic light*" in the above crosswalk example. A comparatively simple example of assertive functions can be found in the following "Production System for Meaning of Traffic Lights at a Crosswald":

Production 1: "*Traffic light is green*" → *Signal for* "*Walk*".
Production 2: "*Traffic light is red*" → *Signal for* "*Wait*".

With the concept of assertive and procedural functions in cognitive production systems it seems possible to develop a comprehensive and unified *theory of human memory*. On the one hand, it is plausible to assume that much of our cognitive *performance*—as, for instance, in problem solving, decision making, or scientific inquiry—depends on procedural functions. On the other hand, it seems quite feasible that the conception of *semantic networks* as recently developed by different authors to model language understanding and other topics of our cognitive *competence* (e.g. QUILLIAN, 1968, SCHANK, 1972, NORMAN and RUMELHART, 1975) could be easily incorporated in the production system representation, namely by means of assertive functions which state, for any node as the semantic entry of the network, the semantic relations to be associated with that node. Evidently, on the basis of assertive functions one can proceed from the usually *static representation* of semantic networks to a *dynamic* or *operational realization* of its node-link structure.

If NEWELL and SIMON (1972, p. 805) are right in their assertion that our long-term memory (LTM) constitutes nothing other than one large production system then its productions must necessarily contain assertive functions as well as procedural functions since we are clearly equipped with *both* factual know-how (*assertive knowledge*) and performance *know-how* (*procedural knowledge*).

The way in which we deal with this knowledge is described, in the frame of cognitive production systems, by the concept of the *interpreter* which we may well assume to be identical with our consciousness. According to the environmental circumstances and/or to the behavioral intentions of a subject, a cognitive production system can be utilized by its interpreter—our consciousness—in *different operational ways* as enabled by the above mentioned readings of productions (cp. WATERMAN, 1977, DAVIS and KING, 1977):

(1) as a *data-driven* production system if the interpretation proceeds from left to right, from the given conditions C to the actions A to be executed;

(2) as a *goal-driven* production system if the interpretation proceeds from right to left, from the desired actions A to the conditions C to be attained;

(3) as a data-driven *and* goal-driven production system if the interpretation proceeds at one time from left to right (*data-driven*) and at another time from right to left (*goal-driven*) depending on the state and the intentions of some cognitive activity.

4. The psychological importance of production systems

That the different modes of interpretation or utilization of production systems themselves can become subject to interpretation we owe to the *verbal naming or "pointing" function* of consciousness as it manifests itself, for instance, in self-reflection about ongoing cognitive activity (DÖRNER, 1968)—in "re-thinking of thinking", so to say. Obviously, this activity needs a proper storage structure besides short-term and long-term memory, namely an *intermediate-term* store where the "trace" of ongoing cognitive activity can be held temporarily.

Intermediate-term memory is particularly important when *phenomena* of *learning* are to be considered in the production system approach. The overall *adaptivity* of production systems to new or changing conditions of environment and performance is a simple process of *generating* or *changing* production rules (cf. WATERMAN, 1974). The actual construction or modification of such rules takes place in intermediate-term memory at first, and only after the emerging or changing production system has proved useful in the actual situation of its formation is it incorporated in the long-term store as part of the subject's already existing superstructure of production systems.

A further characteristic of the psychological importance of production systems is the ultimate *decomposability* of cognitive activity into elements of any desired size. Both simple and complex, network-like data structures can enter the condition part of a production (see, for instance, ANDERSON's "ACT system", cp. ANDERSON, 1976).

And in the action part of productions, assertive and procedural program functions can be allocated into subordinate production systems in such a way that with the resulting *modularity* and *hierarchy* a resolution level of cognitive activity can be achieved which closely corresponds to the actual given structures and ongoing processes in the human brain.

From *this*—so to say *elementary psychological*—level of description, the substantial and subject-matter oriented development of theories must proceed in cognitive psychology: *problem solving*, *decision making*, *language understanding*, *scientific inquiry*, *artistic imagination*, and many other phenomena of our cognitive activity will not really become explainable without ultimately paralleling the admittedly complex physical basis with an appropriately "informational superstructure"—*qua* cognitive production systems.

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A Functional View of Memory

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1. Theoretical considerations

For at least two decades memory research has been dominated by the view that there is a certain memory structure is need of study. This goes without saying for most information processing approaches and is representative of the views of, for example, ATKINSON and SHIFFRIN (1968), BROADBENT (1958) and WAUGH and NORMAN (1965). The main research strategy has been to specify the properties of this hypothetical structure. Such attempts imply that once facts about these properties have been obtained, it might become possible to integrate these facts into a coherent system of knowledge, resulting in a more complete discernment of human memory.

The extent to which we succeed in securing knowledge about these properties, consolidate the knowledge, and eventually arrive at a deeper insight into memory, will depend, in part, on whether or not memory can be viewed as a sequence of stores through which information passes. If this conceptualization is erroneous it follows that at the empirical level the research strategy employed also is incorrect. Thus failure will result from the standpoint of developing a more sophisticated appreciation of memory.

This brings us to the purpose of the present chapter, which is to present a functional approach to memory. The basic notion is that memory constitutes an interaction between the cognitive system and the particular demands of the environment. The framework proposed here is an elaboration of some ideas on future memory research recently suggested by NILSSON (1979).

The core assumption is that the cognitive system is a complete system and, in conjunction with the environment, works as an "open system" in interaction with each other. It is critical to stress here that by *cognitive system*, we refer to the system as a whole and not merely some smaller part of it (in the literature, this smaller system is typically conceived of as a memory system). Our argument for a holistic position is evolutionary in nature, the assumption being that the cognitive system has developed as a complex or unitary whole and therefore it should be treated as such when studying cognitively related functions.

In addition to the internal cognitive system, the environment is conceived of as the external system through which the memory function is also determined. More specifically, the particular demands in any given situation determine how the cognitive system will function. Thus, it is important to know what these demands entail in any given situation. As a first step, therefore, an analysis of the external situation is necessary in all experimental endeavours. A second step involves establishing those aspects of the cognitive system that might be in interaction with the exclusive demands of the situation. While these two steps are necessary in determining the particular memory function, they are not sufficient. A third step is required, namely an analysis of the interaction proper. How this might be accomplished is presented in the section dealing with three empirical studies conducted by the authors.

In principle, any memory experiment or memory phenomenon could be chosen for this purpose. We have chosen a finding commonly referred to as recognition failure, primarily because the phenomenon, first demonstrated by TULVING and THOMSON (1973), seems highly robust regardless of materials and procedural details used. It is viewed as essential that a phenomenon of wide generality is studied; for a specified change in the demands of the task that leads to a concomitant change in the phenomenon would be very critical for demonstrating the viability of the present functional approach.

2. Empirical application

Before proceeding any further a brief note defining recognition failure is needed. Recognition failure refers to cases in which subjects can recall previously studied words in the context of list-specific cues but fail to recognize the same words in an earlier recognition test. Furthermore, FLEXSER and TULVING (1978) have summarized results from 89 experimental conditions in 33 different experiments, showing that the relation between recognition failure and overall recognition hit rate, despite differences in methodological and material variables, is highly invariant.

Due to the generality of the phenomenon one may infer, according to an information processing view, that it reflects a basic underlying memory mechanism. In keeping with a verbal learning account of functionalism, recognition failure simply implies that a unique mathematical function has been detected for certain variables manipulated under certain experimental situations. Finally, in line with the present conception, the generality of the phenomenon suggests there is an underlying commonality between the situational demands present in these situations.

The most striking feature common with these "recognition failure" experiments regarding situational demands is that subjects are engaged in an episodic (as opposed to semantic) memory task (cf. TULVING, 1972), which is the idea that stimulus events are represented in memory as unique episodes or events. Typically, subjects are asked to study weakly associated word pairs as distinct episodes in which semantic features of the material are either not involved or not critical to the task requirements. One question which immediately arises is whether or not the level of recognition failure will differ when the experimental conditions necessitate semantic encoding and retrieval of information. Within the confines of the functionalism proposed here, it is predicted that recognition failure will be considerably lower than that normally found. In the next section three experiments are presented with the express purpose of testing this notion.

Experiment 1

Method:

One set and one critical list of stimulus materials were used. The set list consisted of 30 cue-target word pairs, with category names serving as the cues and an instance of the category serving as the target member. The subjects were asked to learn each cue-target pair and that at test they would be required to recall each target in the presence of its (category) cue. The soul purpose of the set list was to enduce subjects to encode the study pairs as integrated memory units. After cued recall of the set list, the critical list of 40 new, similarly constructed pairs, was presented and again subjects were told to learn the material for a later cued recall test. However, and in line with previous recognition failure experiments, an unexpected recognition test was given prior to recall, where subjects were asked to identify the target item from among three other words belonging to the same category as the target. Immediately after recognition, subjects were given the cued recall test.

The word pairs were presented visually at a 3-s rate and ample time was permitted for both recall and recognition. Twelve university undergraduates participated to fulfil a course requirement.

Results:

The mean proportions of items recalled and recognized and recognition failure are given in tab. 1. As can be seen, overall recognition greatly exceeds overall recall

Tab. 1: ***Proportions of Response Classes in Recognition and Recall***

Experiment and condition	Recognition performance			Cued recall	Recognition failure**
	Hits	False positives	Corrected score*		
Experiment 1	0.90	0.11	0.88	0.56	0.01
Experiment 2	0.78	0.22	0.70	0.41	0.01
Experiment 3 (Immediate test)	0.94	0.06	0.94	0.81	0.03
(Delayed test)	0.87	0.13	0.81	0.81	0.05

* Correction scores were obtained by dividing the difference between the hit and false positive rates by 1 minus the false positive rate.

** Recognition failure is the conditional probability of recognition miss given recall, after high-threshold correction for guessing.

performance; recognition failure was essentially zero. The lack of recognition failure is critical with respect to the purpose of the present experiment. That there was no recognition failure indicates boundary conditions of the phenomenon, i.e. situations of a more purely episodic nature. Moreover, the results are construed as supporting a dyadic relation between the cognitive system and its environment; situational factors in this experiment apparently affect the cognitive system differently than the demands present in previous experiments, and thus a different memory function was produced.

Experiment 2

It was suggested that the situational demands of Experiment 1 required semantic encoding and retrieval and that such processing resulted in no recognition failure. The purpose of Experiment 2 was to examine this matter further. We attempted to answer the question, it is possible to determine whether the *encoding* of a semantic relationship per se was the critical demand of that situation, whether the critical demand was the retrieval of the semantic relationship, or whether the demands were related to both encoding and retrieval?

Method:

The materials were the same as those used in Experiment 1; however, the target words appeared alone at study. The subjects were instructed to remember the words for later recall. The set list was excluded and hence subjects studied one list of 40 target words. At the end of presentation, subjects were given the same type of recognition task as in Experiment 1, followed by an extra-list cued recall test. Each cue was a category name related to one of the target words. Time allowed for study and the memory tests and number of subjects were the same as in Experiment 1.

Results:

The data from Experiment 2 appear in the second row of tab. 1. Again, recognition was superior to recall and recognition failure was quite low. Relative to Experiment 1, recognition performance is at about the same level, though recall was quite inferior. The latter result probably reflects the fact that the retrieval cues appeared for the first time at test. The most crucial aspect of the data, however, concerns the recognition failure finding. The finding suggests that situational demands present at test are considerably more important than at time of study, as there was no difference in the level of recognition failure between the two experiments.

Experiment 3

In the two previous experiments we have demonstrated that under certain circumstances, when subjects utilize properties other than those used in most previous recognition failure studies, the phenomenon of recognition failure does not materialize. These results are considered supportive of the functional approach discussed earlier. The data indicate that memory is not a matter of a single memory mechanism, but rather a complex interaction between the cognitive system as an integral whole and the demands of the environment. In effect, it is argued that memory functions are far more complex than previously suspected.

While the present findings seem to support our position, it could be argued that they have not helped in telling us how the integrated cognitive system might function. Since at the outset of this paper we considered this paramount, we have thus provided only superficial evidence for our view. It could still be argued that the current results merely reflect the involvement of a separate cognitive sub-system, a view held by information processing theorists.

Experiment 3 was designed to help overcome these shortcomings and hopefully provide some insights as to how the cognitive system functions. The idea behind the experiment was as follows: In experiments that have found recognition failure it is commonly assumed that the study cues are the primary source of retrieval information at recall and that the target items themselves constitute the only available cuing information at recognition. Such direct cuing effects could be handled quite easily by a simple sub-memory system, without recourse to the notion of an integrated cognitive system. The task of Experiment 3 was to manipulate the situational demands so that cognitive functions other than pure memory ones could be operative. By arranging the alternatives in the recognition test in a specific way, and by analyzing the incorrect responses, such a process could be conceivably inferred. The recognition test used in the previous experiments was also used here. The four alternatives in the recognition test consisted of the target word (T) and one alternative (Al) from the same semantic category (Cl) and two alternatives (A2 and A3) from a different category (C2), one not previously used during presentation.

The major assumption is that subjects who fail to recognize target words will attempt to use other cuing information. That is, the demands of this type of situation will guide the cognitive system to find the best possible solution to the problem. A possible cognitive function might be to infer from the four alternatives the particular category name that appeared with the target at study. Since category names were used as cues at study, and since the 4 alternatives are members of but two categories, it is quite easy for the subjects to infer what the two possible cues are (Cl and C2). The next step in the process is to remember which of these two category names was the list cue. There are two possibilities: The cue will either be remembered or it will not be remembered. If the cue is remembered the subject is limited to choose between the two alternatives of C1, i.e. the target item itself of A1. Since the analysis applies only to cases in which target words are not readily retrieved from memory, it is assumed that the response to the two alternatives will be made with equal probability, P(T) = P(A1) = 0.50. Choosing the two alternatives of C2 is also made with equal probabilities and in this case P(A2) = P(A3) = 0.00. If, on the other hand, the subject does not remember the appropriate cue he will choose all four alternatives with equal probability, P(T) = P(Al) = P(A2) = P(A3) = 0.25.

Because we are concerned only with incorrect responses, we exclude all cases where a correct response is given from further discussion. Thus our concern is retained for the three remaining alternatives, A1, A2, and A3. The overall probability of choosing any of these alternatives as an overt response in recognition is an algebraic function of the two cases where the subject does or does not retrieve the cue. That is, P(A1) = 0.50 + 0.25, P(A2) = 0.00 + 0.25, and P(A3) = 0.00 + 0.25. Thus we can observe that the probability of giving A1 as a response is three times that for A2 or A3. However, the absolute values presented are misleading since they are based on an analysis that includes the target item. If we adjust for this then P(A1) = 0.60, P(A2) = 0.20, and P(A3) = 0.20 are the absolute values for giving an incorrect response in recognition.

These probabilities should be contrasted to the case where no assumption is made that the demands of the situation will influence the function of the cognitive system. In this case the probabilities are: P(A1) = P(A2) = P(A3) = 0.33.

Method:

The materials and procedure were identical to that of Experiment 1, except that the 4 alternatives in recognition consisted of the target item and one alternative (A1) from the same taxonomic category (Cl) and two alternatives (A2 and A3) from another category (C2). Twelve subjects from the same source as in Experiments 1 and 2 participated in the experiment.

Results:

The chief results appear in row 3 of tab. 1. As in the previous experiments, recognition was higher than recall and the amount of recognition failure attained was at the same low level. Of more theoretical interest, however, are the data presented in tab. 2. Table 2 contains the number of incorrect responses for the three different alternatives. It is quite clear that incorrect responses to A1 occur with much greater frequency than to either A2 or A3. Also, the observed values are very close to those generated by the model. However, one problem associated with these data is the relatively small number of observations. In order to attenuate overall recognition performance and thereby increase the number of incorrect responses, the same subjects were asked to

Tab. 2: *Frequencies and Proportions of Incorrect responses to the Three Incorrect Alternatives in Experiment 3*

Alternative	Immediate test		Delayed test	
	Observed	Predicted	Observed	Predicted
A1	16 (0.59)	0.60	39 (0.62)	0.60
A2	6 (0.22)	0.20	12 (0.19)	0.20
A3	5 (0.19)	0.20	12 (0.19)	0.20

See text for the meaning of the symbols, A1, A2, and A3. The numbers given in parentheses are the proportions of observed incorrect responses.

return 1 week later, ostensibly for a new experiment. Subjects were tested for recognition and recall in exactly the same way as they had been in the immediate test; no study session was re-introduced. For comparison, the recall and recognition data for the delayed condition are displayed in row four of tab. 1, as well as the recognition failure measure. The general impression of these data, quite surprisingly, is that the delayed test apparently effected recognition but not recall performance. The lack of recognition failure, despite attenuation in recognition, supports further our functional view.

Support for the present approach is also mustered by the data for incorrect responses. Columns 4 and 5 of tab. 2 show that the number of absolute incorrect responses to each alternative has increased considerably, though the proportions closely approximate those found in the immediate test, and that the observed values again closely fit the expected values.

3. General discussion

Taken together, the three experiments provide rather strong support for the functional position taken in this paper. Two sources of data support this claim: (1) the lack of recognition failure in all three experiments, and (2) the incorrect response data in Experiment 3. Thus judged from these findings, it seems fruitful to regard memory as a function necessarily involving the interaction of the cognitive system and the particular demands of the environment. Because both the cognitive system and the environment are regarded as open systems in constant interaction with each other, and because the environmental demands determine the specific function to be utilized by the cognitive system, it could be argued that the cognitive system is a reflection of the environmental system. This view is consonant with evolutionary theory, which firmly asserts that the organism and the environment develop as mirror images of each other. The position adhered to here is also in line with the basic ideas of BRUNSWIK's (1952) functionalism.

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The Structure of Memory: Replacing Block Diagrammes by Multidimensional Spatial Models

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By the end of the sixties a great variety of structural models of memory had been proposed, which all had one characteristic in common. Storage of information was conceived of as involving three sequential stores treated as blocks (fig. 1). According to these models the information potentially accessible to the organism initially arrives at the corresponding sensory registers, where it stays for about one third of a second

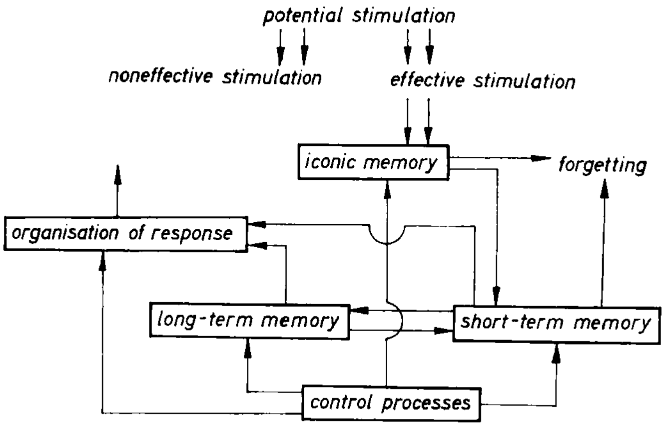

Fig. 1: Model of visual information processing (after ATKINSON, SHIFFRIN and many other workers).

in the format of a comparatively complete description of the physical characteristics of the stimulation. After that information is either lost from the register (forgotten) or transferred to the short-term store. The basic means for retaining it there and transferring it to the long-term store was considered to consist in overt or covert rehearsal. Finally, it was assumed that information, once in the long-term store, could be kept there indefinitely in what appears to be a format of abstract logical propositions.

In the past few years much evidence has been accumulated calling in question the validity of such kind of rigid approach to human memory. In particular, research into recognition of smells, intonation and colour shades has shown that difficulties of verbal report do not in any important way affect the possibilities of long-term retention of sensory information. On the other hand, an impact of semantic categorization on the very first stages of information processing has been discovered, stages which according to a body of data even precede the construction of a clear visual image of an object (ZINCHENKO, VELICHKOVSKY and VUCHETICH, in press). It turns out to be a major obstacle in the further development of "flexible" models of the functional organization of memory that in modern cognitive psychology new points of view and old positions continue to coexist. Among the most controversial issues are the genesis and subsequent storage of the perceptive description of stimulus material and likewise, the specificity of the information organization within semantic memory. The present report is concerned with an analysis of data which in our opinion might enable us to resolve the inconsistencies in question.

Until now the block of the "very short-term" or "iconic" memory has remained an obligatory constituent of virtually all models of visual information processing. Its separate treatment has been warranted by the well-known experiments of SPERLING (1960) using the partial report paradigm (fig. 2). A typical variant of the para-

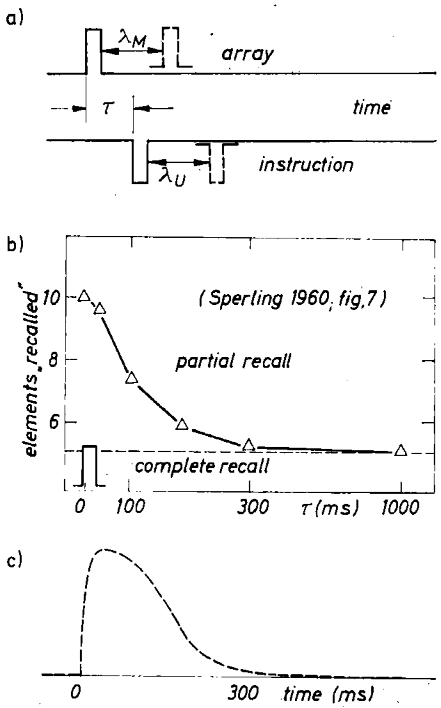

Fig. 2: SPERLING's partial report experiment. a) time pattern of presentation of array instructions: τ-instruction delay, λ_n and λ_m-perception delays for array and instruction, respectively; b) results with bright pre- and post-exposure fields; c) hypothetical process of the formation and decay of the iconic representation.

digm involves the following procedure. After tachistoscopic presentation of a display of characters (letters, digits) Ss are, by ear or eye (cf. AVERBACH and CORIELL, 1961), instructed from which part of the array (lines or columns) symbols are to be reported. It is assumed that successful reproduction of a part of the array indicates full perception of information with regard to the entire array. Provided the delay between visual exposure and instruction is not too long (i.e., not in excess of 300 ms, with bright pre- and postexposure fields) the product of the number of elements reported and the number of array parts to be checked with equal probability turns out to be remarkably higher than 4–6, which is the number of elements correctly reproduced in the complete report paradigm and presumably characterizing the volume of the short-term store.

However, the traditional interpretation of partial report findings does not seem the only explanation possible. Thus, in particular, in none of the critical studies of the subject (cf. HOLDING, 1975, TURVEY, 1978) has the implicit assumption of equal perceptual latencies for display and instruction been analysed, although it is this assumption that provides for the calculation of the dynamics of the icon in terms of physical time. Furthermore, evidence from some of our previous investigations (VELICHKOVSKY, 1973, 1977) suggests that the microgenesis of visual perception starts with the detection of object-like regions and assessment of their positions within three-dimensional space and time of, as it were, object-like regions. After this, specification of their general outlines takes place and not until much later the perception of the internal figural characteristics of a particular object. For the present purpose it suffices to describe this process as one developing from the global spatial localization of an object to the identification of its form, a sequence that appears from both phylo- and ontogenetic investigations (TREVARTHEN, 1968, SALAPATEK, 1975). It should be noted that whereas processes of spatial localization take a time of the order of several ten milliseconds and proceed more or less automatically, for distinct perception of object shape a time of the order of one third of a second and participation of focal attention are required (ROCK, SCHAUER and HALPER, 1976).

These findings justify a revision of argumentation used in support of the hypothesis of an "iconic" memory. As can be seen from fig. 3, a delay in presenting the spatial instruction in partial report experiments does not necessarily imply that its perception will have been preceded by the perception of the figural information relevant to resolving a given task. As it is known (LA BERGE, 1973) that Ss are able to adapt with excessive speed to a selective processing of information within a certain part of the display, the multiplication procedure for calculating the capacity of the iconic memory proves to be meaningless. Experiments have revealed (VELICHKOVSKY and KAPITSA, 1979) that the employment of a figural instruction in the partial report paradigm leads to the disappearance of features indicating the existence of "iconic" memory. The typical decay function, however, was observed for negative values of the instruction delay, i.e., in a temporal range where, from the traditional point of view, there has not yet been given any information about the elements of the display.

Thus, *in accordance with our interpretation, within 250–300 ms of the presentation* of objects the visual image is in one of the stages of its formation and has in no way ceased to exist. This conclusion fits in with data demonstrating the possibility of prolonged storage of perceptual experience. Evidence obtained by a great number of workers (MITCHELL, 1972, KROLL, 1975 etc.) confirms, in particular, the view that information picked up during brief exposures may be stored in a visual format for at least several ten seconds, which markedly exceeds the inertia of the hypothetical "visual sensory register", "very short-term" or "iconic" memory. Of special interest, however, in this context is the retention of complex visual material. Work by SHEPARD (1967), HABER and STANDING (1970) has convincingly shown that in a recognition task retention of complex natural scenes presented on slides is much superior to retention of similar verbal information. Unfortunately, the special choice of thematically highly variegated material and the pertaining low presentation rate do not permit to say to which degree these results necessitate a reconsideration of traditional rigid models of human information processing.

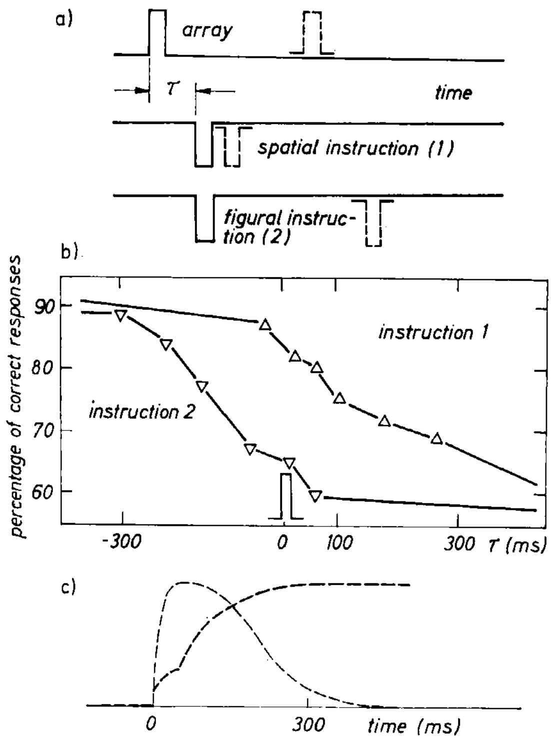

Fig. 3: Experiment done by VELICHKOVSKY and KAPITSA on partial recognition. a) time pattern of presentation of array and instruction (symbols used as in fig. 2); b) typical findings with bright pre- and post-exposure fields; c) hypothetical process of the formation of a visual image (to simplify matters, only two levels are distinguished).

A tentative answer to this question may be obtained by independent variation of the length of presentation time and interstimulus interval (SHAFFER and SHIFFRIN, 1972). This method was used by VELICHKOVSKY and SCHMIDT (1977) to study recognition of 960 slides that were semantically fairly similar (the majority of them showing residential parts of various cities). Observations during the experiment and analysis of Ss' reports indicated that there is covert and overt verbal description of the stimulus material during its presentation and the interstimulus interval. But at the same time the experimental results confirm (fig. 4) that this activity is not essential to subsequent recognition. In fact, as late as two and even five weeks after presentation recognition performance was well above chance, which by itself bears out the possibility of long-term retention of a vast mass of semantically homogeneous material. The dependence, in turn, of correct recognition on length of presentation rather than on interstimulus interval length demonstrates that the basic processes underlying such astonishingly extensive and lasting retention develop only for as long as the sensory material is available. In other words, long-term retention is possible without the participation of processes that are commonly referred to by the term "short-term memory". The same arguments apply to explanations relying on the possibility of nonverbal rehearsal (KROLL, 1975).

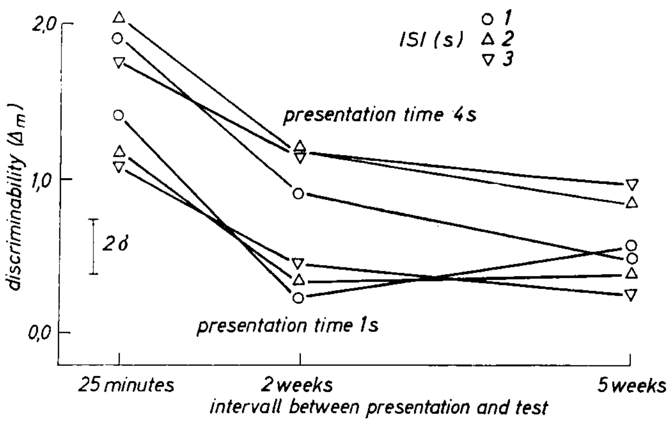

Fig. 4: Dependence of discriminability (Δ_m) of old and new slides on duration of presentation, interstimulus interval (ISI) and interval between presentation and test (after VELICHKOVSKY and SCHMIDT, 1977).

The logic of rigid models leads to the assumption that information from "iconic" memory is directly transferred to the long-term store. As is well known, such an approach has repeatedly been discussed recently, but so far no convincing support has been found. Leaving the question unanswered of whether it is desirable to retain the structural models of memory either by rearrangement of traditional blocks or by introduction of new ones, our intention is to suggest an alternative solution which is closely related to WICKELGREN's unitary view of memory (WICKELGREN, 1975).

We aim to extend it to the retention of complex perceptual material. To this end it is useful to introduce the notion of a multidimensional space for the representation of perceptual categories, which reflects the redundancy of the world surrounding us, i.e., those rules of its organization according to which, for instance, the major part of the contours of objects rising above the surface level of the earth coincide with the vertical or the horizontal, or, according to which closed, equidistant and symmetric contours are more likely to surround the objects than the spaces between them, etc. Such a multidimensional space is apparently characterized by a great number of spatial, dynamic, figural and colour dimensions, which should grant adequate differentiation and undisturbed recognition of the varying perceptual events. It is relatively irrelevant to successful identification of the elements of a vast mass of semantically highly organized visual material that the cognitive activity of the subject is above all directed towards the discovery of the content of a particular picture. Forming as an involuntary result of this activity (ZINCHENKO, 1961, SMIRNOV, 1964) the perceptual description proves to be thoroughly "long-term".

It is different with verbal material or material easy to verbalize. As a rule, traditional experiments do not take into account recall of words or meaningless syllables or such characteristics of common human speech as intonation. The perceptual description of a respective material, elaborating its phonematical pattern, is of low dimensionality bearing in mind that the number of phonemes in the different languages obviously does not exceed several dozens differing in a relatively small number of features (HALLE and STEVENS, 1972). This cannot but lead to considerable interference in retention and recall. Therefore the phonematic description turns, indeed, out to be highly unstable and, wherever possible, a transformation into a developed semantic representation seems necessary for prolonged retention.

Thus, the notion of a multidimensional spatial representation of the material to be stored has, to all appearances, remarkable explanatory power when compared with rigid models that describe the sequential circulation of information in terms of hypothetical memory blocks. The idea has in the last few years been rapidly developed within the range of "semantic memory" research. However, until now no agreement has been reached as to which spatial models reflect the specificities of organization of information for retention more adequately. The models of semantic memory so far proposed can tentatively be divided into two large classes, "feature" (componential or dimensional) and "cluster" (taxonomical or topological) models. Close to the latter are the "network" models which are most lucidly illustrated by the hierarchical structure model (COLLINS and QUILLIAN, 1969). Both the exponents of network models and their opponents (SMITH, SHOBEN and RIPS, 1974) rely for their constructs on the results of chronometric experiments. It should, however, be noted that this method of checking on the validity of the two classes of models is not free from apriori semantic interpretation of the lexical units selected for experimentation. Much the same is true of work specifically devoted to the reconstruction of the mental lexicon (FILLENBAUM and RAPOPORT, 1971), where actually the linguistic interpretability of the results of various multidimensional statistical procedures served as validity criterion.

An experiment was performed in our laboratory, in which an operational criterion for comparing the validity of models was tested that is independent of apriori or aposteriori interpretation. The material comprised 20 Russian words of high frequency taken from the common vocabulary of interpersonal relations. Twenty psychology undergraduates were instructed to judge the semantic similarity of all pairs of words possible. The group matrix of proximities was analysed by means of a centroid factor analysis (feature model) and a dichotomous hierarchical cluster analysis (cluster model). Following similarity judging we had Ss recall the word list from memory. Frequency of word adjacencies in the protocols was taken as indicator of "mnestic relatedness" (cf. KINTSCH, 1970).

An assessment of the validity of models of semantic memory in the above sense can be based on the degree to which semantic similarity of each pair of words according to the concrete model is proportional to their "mnestic relatedness" as determined by the free recall method. Goodness of fit was tested by χ^2. Results point to a closer correspondence between mnestic relatedness data and the cluster model of semantic memory. The higher validity of the cluster representation of the material has been confirmed in a replication with another group of Ss (20 undergraduates enrolled for a journalism course). In this experiment the matrix of proximities was obtained by employing a sorting method. A different clustering procedure was used (MILLER, 1969). Irrespective of these differences the tree diagrammes constructed from the data of the first and second series appeared to be almost identical (fig. 5).

How can the stable superiority of the cluster model be accounted for? At first sight it even seems paradoxical. As is well known, the centroid method of factor analysis splits the matrix of proximities (correlations) by maximizing the sum of interclass distances and hence results in a "feature" model, according to which the process of categorization constitutes an optimum information search reducing in each step the entropy roughly by one half. Cluster analysis uses a normed functional as a measure of goodness of the clustering solution, maximizing the mean interclass distance.

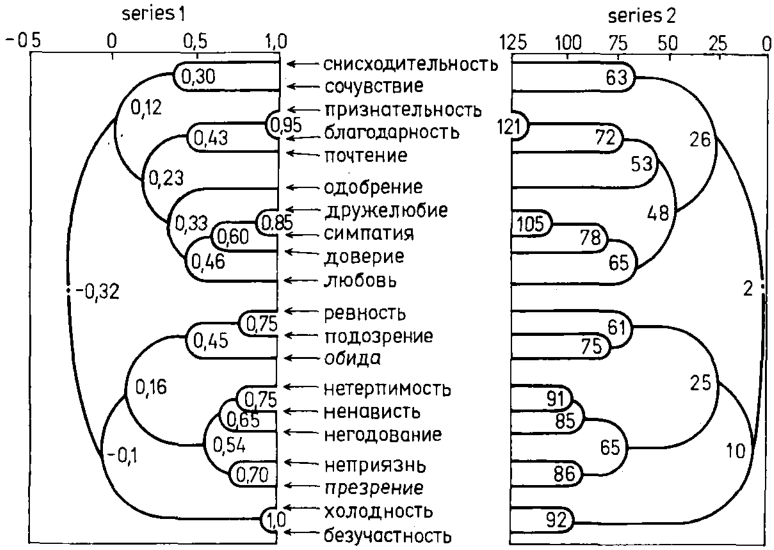

Fig. 5: Tree diagrammes constructed from data obtained in experiments on the reconstruction of the semantic structure of Russian vocabulary for interpersonal relations.

Thus the cluster model represents the categorization process (or search in memory) informationally in a nonoptimum way, permitting the separation from the entire space of objects represented in memory of small local areas.

But even the separation of such local areas can be effective, provided each area of the memory space (the choice of words in the case under consideration) has for the individual a certain subjective "weight" not proportional to the size of the given area. Such additional properties may include the diversity of the behaviour programmes connected to a given object and the emotional weight of the object. Thus features that are local for an experimenter may be globally meaningful to a subject. From this point of view semantic memory should not be conceived of as a purely stimulus-oriented, iconic representation (in the way Bruner uses the term), but as a system coordinating cognitive-informational fields with behaviour and emotional-motivational fields. This leaves open the question if the entire long-term memory, including visual memory, is in any sense semantic. But if so, everything said of semantic memory also holds of the structure of memory in general.

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Utterance Meaning and Mental States

M. Bierwisch

1. As a rough approximation, one might say that a verbal utterance normally expresses a thought, where a thought is the structure of a mental operation of a certain type. The aim of this paper is to reconcile more or less elaborate approaches in linguistics and intensional logic in order to deal with the formal aspect of this type of mental operation.

To begin with, I will clarify by way of a simple example the notion of utterance meaning, which is to be distinguished from the semantic structure of a sentence. Compare the following sentences:

(1) John greeted the boy with a flag.

(2) The sailer enjoyed the port.

(3) You will lose your money.

While (1) and (2) are ambiguous for syntactic and lexical reason, respectively, there is no ambiguity in this sense in (3). Nevertheless, (3) can be used to express rather different thoughts or to describe different situations, for that matter. One type of differences depends on the time and the addressee of an utterance of (3), that is on the interpretation of the 'deictic elements' "you", "your", and "will". This type of context dependent variation in the utterance meaning is fairly obvious and has been widely discussed both in linguistics and logic. A somewhat different type of variation is connected with the meaning of "lose"; an utterance of (3) might predict that the addressee will lose his money e.g. through a hole in his pocket, by playing at cards, or by speculative transactions. In each of these cases certain events are predicted to lead to a situation where someone does no longer have something he had before. This is a rough paraphrase of "lose" applying to all three imagined situations, which do not involve any ambiguity of "lose", just as there is no ambiguity involved if the word "table" is used to refer to square or round or green or white tables. Nevertheless, the variations turning on "lose" are systematically connected to another variation, which again does not involve semantic ambiguity: Loss of money because of a hole in the pocket must involve coins or notes, i.e. concrete physical objects, while loss of money by gambling or speculation involves merely the abstract value. Finally "your money" is likely to refer to the addressee's total wealth in the case of speculation, but not in the case of gambling. Observations of this type can easily be supported by further evidence. Thus only in the first case an utterance of (3) might be continued by something like

(4) And it is rather unlikely that you will find it again.

Observations of this type can be multiplied at will. What they are meant to show is simply that the semantic structure of a sentence must not be identified with the meaning of an utterance of this sentence. A further ramification results from the fact that different communicative intentions might be connected even with the same utterance meaning. Thus an utterance of (3) might be e.g. a comment on the addressees's behavior, a prediction of what is likely to happen, a warning, or an indirect request to give up gambling. I will not be concerned here with this aspect of the communicative sense of an utterance, but merely with one of its prerequisites, viz. the thought expressed by the utterance.

2. In order to formulate the indicated problem somewhat more precisely, I will define an utterance *u*—following a proposal of KASHER (1971)—as a physical event called an inscription *ins* that a person *p* relates at a time *t* to a linguistic structure *ls*:

(5) $$u = \langle ins, \langle ls, p, t \rangle \rangle .$$

This definition is neutral with respect to the perception or production of *ins*, it merely fixes the condition holding in both cases, viz. that certain acoustic or visual stimuli are a linguistic utterance if and only if they are related to a linguistic structure represented somehow in *p* at time *t*. I am not concerned here with the processes connecting this representation to the inscription. A linguistic structure *ls* must consist of at least a phonetic structure *pt* (or a corresponding graphemic structure *gm* in the case of written language) manifested by the inscription *ins*, a syntactic structure *syn*, and a semantic structure *sem*:

(6) $$ls = \langle pt, syn, sem \rangle .$$

The syntactic structure relates the phonetic and the semantic structure to each other in a systematic, but by no means simple way; *syn* determines in particular the way in which sequential components of *pt*, especially words and morphemes, correspond to the combinatorial structure of *sem*, and vice versa. The totality of possible structures of this type pertaining to a given language *L* is determined by the rules of the grammar *G* of *L* that must be part of the memory structure of *p*. Again, I am not concerned here with the organization and the general conditions holding for possible grammars. (In my opinion, the proposals due to CHOMSKY (1965, 1977) provide the most appropriate account developed so far, though nothing in what follows depends on this assumption.) What is essential is merely that *sem* must have a compositional structure determined by *syn*.

Now the crucial point of the initial considerations is that assigning a linguistic structure to an inscription does not yet determine the pertinent utterance meaning. This is rather the result of relating the utterance to a context *ct*, with respect to which it is to be interpreted. In other words, in order to determine the actual meaning *m* of a meaningful utterance one has to refer to a given context *ct*. We thus can define a meaningful utterance *mu* as follows:

(7) $$\begin{aligned} mu &= \langle u, ct, m \rangle \\ &= \langle \langle ins, \langle ls, p, t \rangle \rangle, ct, m \rangle \\ &= \langle \langle ins, \langle \langle pt, syn, sem \rangle, p, t \rangle \rangle, ct, m \rangle . \end{aligned}$$

In what follows, I am more specifically interested in the relation between the semantic structure *sem*, the actual context *ct* and the utterance meaning *m*. In other words, if α is a particular meaningful utterance as defined in (7), the question is how does the utterance meaning $m(\alpha)$ come about on the basis of the semantic structure $sem(\alpha)$ and the context $ct(\alpha)$ of the meaningful utterance?

3. The most elaborate framework to deal with this question has been developed, on the basis of certain ideas of FREGE and TARSKI, in model-theoretic semantics and intensional logic. I will briefly outline this framework in a rather oversimplified, though hopefully not distorted, manner.

As a first step, we may connect the distinction between semantic structure and utterance meaning to the Fregean distinction between 'Sinn' and 'Bedeutung', taken up by CARNAP (1952) in terms of intension and extension. On this account, the intension of an utterance would be its semantic structure $sem(\alpha)$, which in general is a proposition compositionally built up of concepts of various categories, and the extension of α would be its actual meaning $m(\alpha)$, which consists of a configuration of objects, classes of objects, etc. satisfying the concepts appearing in $sem(\alpha)$, forming as a whole a state of affairs that makes the proposition expressed by α true. In this first step we did not yet rely on the context $ct(\alpha)$.

In the next step we will use the availability of context to give a more precise specification of the notion of concept and proposition: Intensions—that is propositions and the concepts they consist of—are functions from contexts into extensions, that is they are rules which select for every context to which they are applicable at all the respective objects, classes, and states of affairs. In other words: $sem(\alpha)$ is a (fairly complex) rule that applies to $ct(\alpha)$ and yields $m(\alpha)$. Thus in functional terms we get

(8) $$[sem(\alpha)]\,(ct(\alpha)) = m(\alpha).$$

These rather general ideas have been made precise in slightly different ways e.g. in MONTAGUE (1974), LEWIS (1972), and CRESSWELL (1973). The common core of all pertinent proposals is that the context ct contains a possible world w with respect to which a given utterance is to be interpreted. In other words, a set W of possible worlds w is presupposed. Differences concern various additional specifications. Thus MONTAGUE assumes the context ct to be an ordered pair $\langle w, t\rangle$ of a possible world and a timepoint, LEWIS adds a specification of the utterer, the intended addressee, the particular verbal context, and certain other parameters. For the sake of exposition, I will simply assume that $ct(\alpha)$ is an index i containing at least a possible world w, leaving open what further information is to appear in i.

In order to provide this general characterization with a little bit more substance, I will sketch the construction of a pertinent formal system. There are two structures to be specified: The domain of extensions, i.e. of utterance meanings and contexts, and the system of intensions, i.e. of semantic representations.

First intensions are specified by a set E of complex structures based on a finite set K of constants and a (possibly infinite) set V of variables. Any element of E is a systematic configuration of elements of K and V. Each element of E, K, and V is assigned to a category c of a system C of categories, where c determines the combinability of a given element (i.e. its 'combinatorial value') as well as the type of its extension (i.e. the type of entity that can become its actual meaning). C is built up by the following conditions:

(9) (a) N, S $\in C$ are basic categories

(b) If $a, b_1, \ldots, b_n \in C$, then also $(a/b_1 \ldots b_n) \in C$

The two basic categories comprise individual concepts and propositions, respectively, i.e. intensions having individual objects and states of affairs as their extension. The complex categories defined in (9b) contain elements acting as functors which combine with elements of the categories $b_1, b_2, \ldots b_n$ to yield a complex element of category a. Hence the functor categories determine the combinatorial structure of the set E.

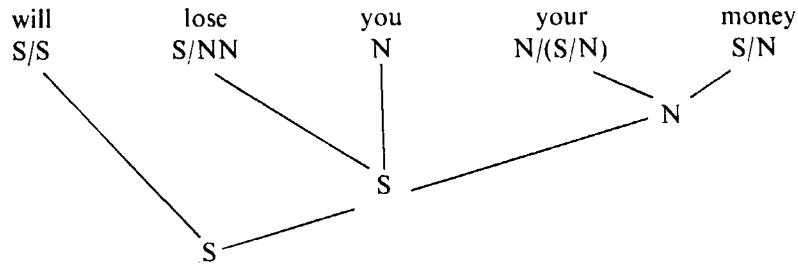
The following sample of elements of K might serve as a (highly oversimplified) illustration:

(10)

John, Mary, you, he	∈ N
money, blue, sleep	∈ S/N
lose, find, wake	∈ S/NN
the, your, his	∈ N/(S/N)
not, will	∈ S/S

Notice that *John, Mary, you, money* etc. in (10) represent intensional constants, not English words.[1] Furthermore an infinite set of variables for any category c is available. Now the semantic structure of the sentence (3) can be represented as follows:

(11)



According to the combinatorial principles connected to the category assignment, any proper subtree of a semantic structure like (10) is also an element of E. Hence *your money* and *lose you your money* are elements of E of the category N and S, respectively.

Secondly, extensions are specified by a domain D representing the structure of possible states of affairs and of the objects, classes, relations, etc. involved. More precisely, D is a set-theoretical structure based on a set W of possible worlds and a set A of objects, where any possible world $w \in W$ is a structured (proper or improper) subset of A, i.e. a set of objects bearing properties, relations, etc. thus forming the structure of an arbitrarily complex state of affairs. Hence any imaginable situation can be represented as some configuration in D. Thus D provides the domain from which utterance meanings can be selected.

Thirdly, the relation between E and D must be specified, that is the way in which an element of E selects its extension with respect to a given context. This is done by specifying for each element of K a function whose range is the set of possible contexts, and whose value is the extension of that element in D with respect to the context in question. Taking i as a variable over possible contexts (remember that i contains at

[1] Actually, they are meant to represent the semantic structure of the respective words which are triples of the relevant phonetic, morpho-syntactic, and semantic information. See below section 6.—It should be noted that the assignment of *the, your, his* to category N/(S/N) is not quite in line with the usual analysis, but rather an oversimplification for expository reasons.

least a possible world w), we get functions of the following kind:

(12) $John(i) = a$, if a is the individual John in w.
$you(i) = a$, if $a \in w$ and a is the addressee of the utterance at i.
$money(i) =$ the set of x such that x is a quantity of money in w.
$lose(i) =$ the set of pairs (x, y) such that x loses y in w at timepoint t specified in i.

From these functions the more complex functions corresponding to the elements of E can be derived compositionally according to the combinatorial structure induced by the category-membership of the combined elements. For example:

(13) $$lose\ you\ your\ money(i) = (you(i), your\ money(i)) \in lose(i).$$

In other words, the extension of the proposition expressed by an utterance of the sentence "you lose your money" is the fact holding in w that the pair of objects which are the extension of *you* and *your money*, respectively, belongs to the set of pairs that is the extension of *lose*.

4. What I have sketched here with many oversimplifications and omissions is in fact a precise, explicit, and strictly formalized framework of complete generality, which nevertheless has only reluctantly been recognized in linguistics, and is practically ignored in psychology. I will now discuss two problems which I believe to be major reasons for this situation. I will try to show thereby how model theoretic semantics might be developed and modified such that its advantages are preserved, while the shortcomings in question are removed, at least in principle. It will be seen that at the same time certain problems of interpreting the formal apparatus of possible world semantics can be resolved. My considerations are stimulated in part by the work of HINTIKKA (1975).

The first problem concerns the status of the domain D of possible extensions. In model theory, this is just an (arbitrarily complex) set-theoretical structure. Insofar as its ontological status is considered, e.g. in CRESSWELL (1973), it is construed as the structure of the real world and its individuals, together with all its possible alternatives, i.e. all non-real worlds and objects. Formally, in the set W an actual world w_0 is marked as corresponding to the real world in which the utterance is produced or perceived, and the individuals appearing in w_0 make up the set A_0 of real objects. What is left open on this account is the source and status of all non-actual worlds and objects as well as the particular nature of the actual world and its objects.

My proposal is now to restrict D in such a way that it becomes the structure of the internal, cognitive representation of the experience of a person p. In other words, D is to be construed as the formal structure of (a certain aspect of) the mental states of p. The internal structure of a possible world w as well as the relation between alternative worlds w and w' are thus restricted by the system of perceptual and cognitive operations ultimately based on phylogenetically evolved capacities. The actual world w_0 and its objects become now the internal representation of those states of affairs that are founded by p's actual experience. How this foundation results from sensory perception, practical action, and communication is a problem exceeding by far the scope of the present discussion. It is not created, however, by the proposal under discussion. It is rather a problem that has been existing all along and has to be solved anyway. The direction of such a solution is indicated by Marx's 2. Thesis on Feuerbach according to which it is the practice that decides. All other possible worlds are now internal representations resulting from w_0 by certain cognitive operations. Thus e.g. the world w_n of p's wishes is a world resulting from w_0 by modifying w_0 such that all and only the states of affairs p wishes to obtain are represented by w_n.

Under this interpretation, D does not yet contain arbitrary set-theoretical structures based on an unrestricted domain A of individuals. It is rather subject to the principles of perceptual and cognitive organization applying to structures given by experience or by cognitive projections based on it by various steps of mediation. And possible worlds turn out to be what they (unavowedly) have been all along: cognitive projections of real persons.

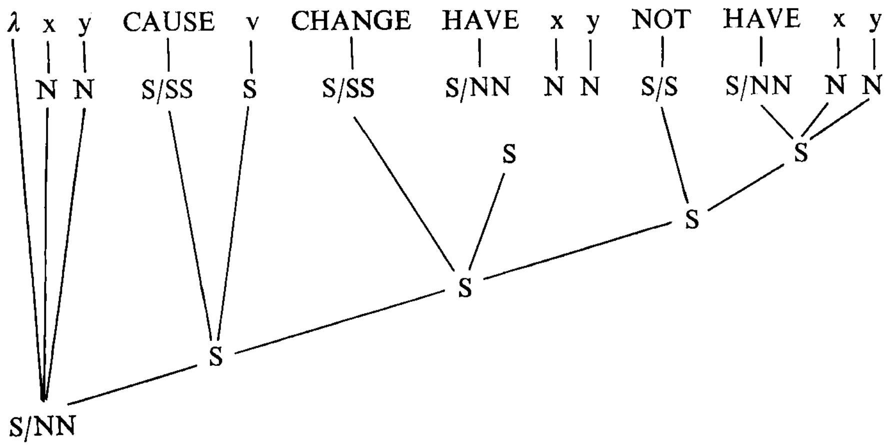
The actual meaning as well as the context of an utterance in the sense defined above can now reasonably be construed as particular configurations in D.

5. The second problem to be discussed consists in the purely formal characterization of the basic intensions. Thus it is usually postulated that there is e.g. a function specifying for any arbitrary world the set of pairs that is the extension of *lose* in that world; how this set is to be constructed, however, is left open—or rather transferred to the informal metalanguage. The examples in (12) are typical in this respect. In other words, the substantial specification of the intensional constants remains largely outside of the formal account. This is unsatisfactory for various reasons especially in linguistics and psychology, as any serious theory of lexical knowledge has to provide among others precisely that specification.

A first step towards an improvement results from the proposal just discussed: Since possible worlds must derive from each other by cognitive operations, extensions can vary from one world to another only within the limits set forth by these operations. And even within one world, extensions must be the product of effective cognitive schemes and operations. It remains, however, to characterize the functions determining the extension of the constants at least under these restricted conditions.

There are two ways available, which are equivalent under some, but not all points of view. The first originates from a proposal of CARNAP (1952), according to which the constants of the semantic structure, that is roughly the word meanings, are related to each other by meaning postulates. They are placed, so to speak, in a network of relations, and they determine their respective extensions according to their place in that network.

The second, more interesting way is to consider the constants not as elementary units, but rather as configurations of basic components. That brings in a long range linguistic tradition of which KATZ (1972) is a fairly elaborate example. What is to be gained by merging this tradition with model theoretic semantics is first a systematic framework to deal with the relation between semantic structure and utterance meaning, and second a systematic account of the formal aspect of the basic components and their combinatorial structure. As to the latter, we will use the system of categories as introduced in (9). What is to be added to the specification of intensions is only the assumption of a fixed system B of basic components categorized by C such that all former constants can be replaced by combinations over B. (See BIERWISCH, 1970 for an early version of this proposal.) Let me illustrate the consequences of this move by an oversimplified example. Assuming that CAUSE, HAVE, CHANGE, NOT are elements of *B* with the categorization indicated in (14), the former constant *lose* can now be replaced by something of the following kind[2]:

(14) 

Notice that because of the lambda operator binding the variables x and y, the whole structure is of the same category as the constant *lose* it is supposed to replace. (14) will furthermore yield the same result as *lose* if it enters more complex combinations—if it is e.g. substituted for *lose* in a structure like (11) above—, since x is the variable to be replaced by the loser and y the variable to be replaced by what is lost, provided the basic components are specified in an appropriate way.

It should be obvious that the specification of the system *B* of basic components is an intricate empirical task. It requires a universal characterization of the operations and schemes according to which the elements of *B* select their appropriate extension if applied to a given context *i*. It is in fact an empirical hypothesis that such a characterization is possible at all. There is however a fairly large amount of evidence that a program of this kind can reasonably be pursued. The most extensive survey can be found in Miller and Johnson-Laird (1976).[3]

6. Let me briefly summarize where we have got so far. First we presuppose a formal characterization of the structure of a certain aspect of mental states by reinterpreting the domain *D* of model theoretic semantics as characterizing internal representations. All we need to require in this respect is (a) that mental states can in fact be characterized in terms of set theoretical structures (which is guaranteed by the generality of set theory), (b) that the structure of *D* is substantially determined by the perceptual and

[2] I am using here the lambda operator in the usual way, i.e. as an abstractor binding a variable such that if x is a variable of category *a* and φ any (basic or complex) element of category *b*, then $\lambda x \varphi$ is a complex element of category *b*/*a*. From this the usual principles of lambda conversion follow immediately, i.e. $\lambda x(Px) = P$, hence $Pa = \lambda x(Px)\ a$. See Cresswell (1973) for extensive discussion.

[3] It might be noted that these authors, developing a framework of what they call procedural semantics, where semantic structures are interpreted as complex programs for internal computation, come up with representations that can directly be assimilated to the format developed here. We thus face the interesting perspective to reconcile in a well motivated fashion procedural and model theoretic semantics.

conceptual capacities of the human organism, and (c) that in *D* there is a designated world w_0 representing what a person *p* 'knows' about the reality on the basis of experience, practice, and communication. With respect to language, *D* provides the range of contexts and meanings of actual utterances.

Turning to language, we presuppose among others a system *B* of basic semantic components and a system *C* of categories determining the combinatorial structures that elements of *B* may enter. *B* and *C* again are determined by the capacities of the human organism, they are part of the ability to acquire a particular language, where the elements of *B* determine how the linguistic expressions are hooked on the structures in *D*.

During the process of language acquisition, a system of fixed combinations over *B* is built up and assigned to phonetic structures as well as morphosyntactic categories. (Notice that the semantic categories are by no means identical to the syntactic categories: In (10) e.g. *money*, *blue*, and *sleep* are assigned to the same category, which is obviously not the case for the words whose semantic structure these elements abbreviate.) These combinations replace now the elements of the set *K* of constants introduced in section 3. They make up in fact the semantic structure of the lexicon of a given language. Thus, while *B* is a universal set of basic components, *K* is the set of lexical meanings varying from language to language, and even from person to person.

The combinatorial principles inherent in *C* finally determine the way in which the elements of *K* are combined in order to form the semantic structure of complex expressions, i.e. the elements of *E*. These complex semantic structures lead to the utterance meaning with respect to the actual context in the manner discussed above. Notice that the relevant information of elements of *K* like e.g. (14) must be fixed somehow in the long term memory[4], which is by no means the case for elements of *E* in general. (See BIERWISCH, 1977 for some discussion of this problem.)

Two comments on the elements of *K* are still in order. First, is should be noted that the combinatorial structure we have assumed for the elements of *K* implicitely defines the relations connecting them. Thus whereas the meaning postulate approach would have to connect the constants *lose* and *have* by rules of the following type:

(15) (a) *lose* x y at time $t \supset$ *have* x y at $t - n$
(b) *lose* x y at $t \supset$ *not have* x y at $t + m$

these implications can be read off from (14) directly, provided that HAVE accounts for *have* and CHANGE determines the relevant time relations. In fact, many other relations such as hyponymy, antonymy, compatibility, etc. derive from the combinatorial structure of elements of *K* thus providing the lexical network mentioned above. It is a problem open to empirical investigation which types of relations inherent in *K* are crucial for the representation and possible activation of elements of *K* in memory. Systematic analysis of certain slips of the tongue e.g. indicates the importance of the antonymy relation for memory activation. More generally, experimental analysis of

[4] I say 'relevant information', since structures like (14) are redundant in a certain way. For example, in any configuration CHANGE x y it is predictable that x must determine a state of affairs complementary to the state of affairs specified by y. Hence this particular piece of information might be automatically supplied. I will not go here any further into these problems, though.

such semantic relations can show how the hypothetical elements of *B* are operative in organizing lexical memory.

The second comment concerns the relation of the semantic structure of lexical elements to other levels of structure. Clearly, the elements of *K*, being semantic structures, must be related to syntactic and phonetic information. Hence *K* represents only one aspect of the structure of lexical knowledge. The implications of this remark should be obvious. Notice, however, that elements of *K* are on the one side related to phonetic structures, and on the other side to the extensions they normally select. In the former respect, they are part of the structure of a given language, in the latter respect they relate linguistic units to components of factual knowledge, structures of believe, fiction, etc. Formally this status directly follows from the nature of intensions. Psychologically, however, it might be a highly intricate task to draw the distinction between the semantic structure of a word and the extension it (normally) determines. Dissociation of the two aspects in certain types of aphasia clearly indicates that there is a psychologically real distinction. Much experimental work, however, is hard to interpret with respect to the level of structure that is actually decisive.[5]

7. Returning to the problem of utterance meaning, we now have a better understanding of its dependence on semantic structure and context. Thus the three interpretations of "You will lose your money" discussed in the beginning result from different contexts on the background of which the utterance of (3) is interpreted. These contexts have now been reconstructed as (partial) structures of different mental states.

It should be added that the semantic structure of an utterance generally fixes certain conditions a possible context must meet. Thus any interpretation of (3) requires the availability of an addressee internally represented as the extension of the meaning of "you". It furthermore requires the identification of a certain amount of money in the world *w* of the utterance context. Moreover, the addressee must actually have this amount of money in *w*. (Otherwise he cannot lose it, and no meaning would be defined for the utterance of (3)). All these conditions must be a particular part of the semantic structure, called the semantic presupposition. In the case of our example they are determined by the semantic structure of the verb "lose", and it is easy to incorporate this aspect in the analysis given in (14). I will not go into the formal details, however. (For extensive discussion see KATZ, 1972.) The semantic presupposition of an utterance thus determines a class of possible contexts with respect to which the utterance can be interpreted, viz. all possible worlds satisfying the semantic presupposition. To put it the other way round: a world *w* that does not satisfy the semantic presupposition, does not provide an utterance context, and hence no utterance meaning can be derived from it.

We are now ready to make the last step in adapting model theoretic semantics. The usual way would be to say that if a given world *w* of the utterance context *i* satisfies the presupposition of the utterance, then the utterance meaning is a certain state of affairs belonging to *w*. I would now propose to change this static view in the following way: If the utterance is not redundant with respect to *w*, the state of affairs that is the

[5] To mention just one example: the interesting findings in HOFFMANN (1979), that the recall of word lists is determined by certain semantic relations among the items of the list, might be traced to the semantic structure of the words, but also (and perhaps more likely) to the structure obtaining in the domain of their extension.

utterance meaning with respect to the world w is not yet part of w. To understand (i.e. to produce or to perceive and interpret) an utterance therefore means to incorporate this state of affairs into w, changing thereby w into a modified world w'. Thus an utterance is in a sense an instruction to modify a given context w.

The 'dynamic' aspect thus introduced is not considered in model theoretic semantics (although it can easily be incorporated), it plays an important role, however, in the structure of natural languages, which possess fairly subtle means to mark off the distinction between what is supposed to be given and what is new. (These means are, incidentally, connected to elementary mechanisms from a psychological point of view.)

As I have interpreted a possible world w as (part of) the structure of a mental state, the meaning of an utterance can now be seen as an operation connecting two mental states, and thus the thought expressed by an utterance is a change in the structure of a mental state. This is a rather vague and metaphoric formulation which can be made precise in a fairly natural way, however.

My remarks have necessarily been fragmentary in various respects. There are many problems which have not even been touched, which can however, be captured to a reasonable extent by straightforward extensions of the framework I habe outlined. Such extensions as well as the remaining difficulties seem to me to call for a systematic integration of psychological approaches to problems of memory and cognition, linguistic analysis of semantic structures and the formal apparatus of model theoretic semantics.

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Mnemonic Components of Aim Formation

O. K. TIKHOMIROV and V. V. ZNAKOV

1. Introduction: State of the problem

Different approaches towards investigating the interaction of thought and memory have emerged. They include studies of the "functional fixation" of past experience, analyses of the role of knowledge for the development of thinking, investigations into the influence of the thinking process on the exploitation and change of knowledge and into the influence of thinking on storing efficiency. Comparatively little research, however, has been done on the influence of the operative memory on the efficiency of thinking activity.

In modern psychology of thinking more and more significance is being attached to transition from the analysis of solution processes of ready and well formulated tasks to the investigation of processes of putting new tasks independently, to the study of the formation of conscious aims. Various mechanisms of aim formation have been specified (2). In the subject's thinking activity the formation of aims acts as a truly productive process. The question arises as to what extent the process of aim formation depends on the characteristics of the operative memory. In this sense the traditional problems of thinking and memory, of productive and reproductive processes have been reformulated by us as the problem of mnemonic components of aim formation.

Regarding thinking we have been interested in the process of the forming of new aims, regarding memory we have restricted our field of investigation to short-term memory being involved in the activity of thinking.

2. Method

As an experimental task we chose the "hermit game" and as a variant the "Greek cross". On a board with 81 squares (9 × 9) nine pieces were arranged cruciformly (fig. 1). The demand was to leave one piece on the board by a series of moves. A move had to obey the following rules: each piece may be lept over from a neighbouring square, from the right, left, above or below; diagonal jumps are forbidden; each move has to be a jump over a neighbouring piece then removed from the board.

The pieces entering the configuration are divided into four groups by their functional characteristics: pieces moves can be done with, pieces which can be lept over, pieces changing the total position as a result of their move, pieces not allowed to do moves. Different groups of Ss solved this problem either by a clear-active plan, moving the pieces on the board really, or by a clear-pictorial plan, following possible moves with their eyes only. It was the comparison of specialities in solving one and the same task by the clear-active or clear-pictorial plan which formed our basic methodical approach towards deriving the role of operative memory, its overstraining in the case of the clearpictorial solution.

Recorded were: time for solving the problem, results of the solution, the verbal statements of the Ss, which emerged with their actions and the configurations and processes of their transformation objectively possible at the given moment, and which allowed to assess the aims formulated by the Ss. In a series the quantitative move-

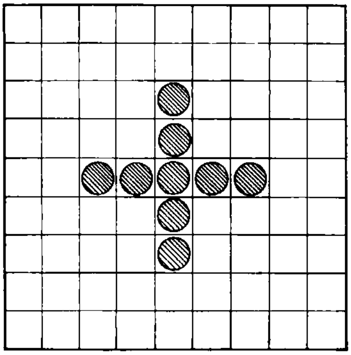

Fig. 1

ments of the Ss were registered (in this series the shifting of the pieces during the clear-active solution was done by the experimenter). 336 Ss aged from 17 to 32 took part in the different experimental series.

3. Results

3.1. General functions of the operative memory

In solving thinking problems the fixation and subsequent remembrance of task rules are essential. They determine the admissible and sufficient changes of conditions; the fixation and remembrance of a varying selection of demands for intermediate and final results during the course of solution; the fixation, transformation in memory and remembrance of intermediate and final results imaginable from the prospect of the achieved visual situation or the sequence of actions carried out; the fixation and remembrance of the dynamics of clearly elaborated task conditions.

3.2. General characteristic of aim formation

The processes of aim formation, investigated under the experimental situation, are classified into two kinds:

a) the determination of the final result under the condition of the variation of demands, — entering memory—for the final result (expl.: "The last piece is to be left in the centre");

b) derivation of partial aims that are independent with regard to the final aim and that are formulated on the basis of externally made demands for the final result (expl.: "The pieces must be concentrated in the centre").

The formation of aims can be divided into three stages:

At the first stage aims are formulated in a most general way: "Find a sequence of actions leading to the required result." At the second stage the imprecise partial aims of the first stage are differentiated and put precisely under gnostic and mnemonic aspects.

At the third stage of aim formation the Ss arrive at more precise ideas of the operative and figurative components of the solution.

3.3. Comparison of solution processes by clear-active and clear-pictorial plans

On the average the task is solved nearly seven times slower by a clear-figurative plan than by a clear-active one. Accordingly, the mean time for one move was 9 s and 41 s, respectively. In clear-pictorial solutions the number and variety of mnemonic mistakes is rising. With this type of solution the process of forming the final aim retards considerably (see tab. 1 and 2). Hence follows that the properties of human

Tab. 1: *The number of Ss (in %) that showed the correct starting point in answering the question for the last piece's place*

Thinking style	Stages of problem solving				
	after 2nd move	after 3d move	after 4th move	after 5th move	after 6th move
Clear-active thinking	61%	80%	100%		
Clear-pictorial thinking	47%	70%	85%	100%	

Tab. 2: *The number of Ss (in %) that showed the correct piece in answering the question which piece will remain on the board*

Thinking style	Stages of problem solution				
	after 2nd move	after 3d move	after 4th move	after 5th move	after 6th move
Clear-active thinking	40%	60%	83%	100%	
Clear-pictorial thinking	40%	45%	60%	100%	

memory, the pecularities of its perception may serve as presuppositions for the formation of aims to keep an image of the aim specific. These presuppositions include: preference to operating in the right and upper part of the board compared to the left and below part; the effort to choose "compact" configurations in which the members are specially close together; regularities of interference in memory; the difficulty of choosing actions from homogeneous visual structures and the ease in the case of choices from heterogeneous dissimilar configurations; the dislike to operate in directions which imply the reactivation of high cognitive effort.

As experiments show, the qualitative characteristics of aims depend on the degree of exactness of the Ss' imaginations being stored in memory, anticipated situations, their transformation and interactions.

The dynamics of aim transformation depends on transformations in memory: in problem solving the faster the dominance of image memory fixing the visual situation is transformed into the storage of actions the faster the transformation of aims takes place.

Transitions in memory (schematization) are realized during the repetition of earlier performed activities and the revision of the members of the visual task structure. Considerable stress on the memory involving mnemonic tendencies which arise and the setting of mnemonic aims, may disturb the formation of gnostic aims, which are directed towards the solution of problems of thinking. We established three stages of transforming aims in dependence on the character of situation images contained in memory and the procedure of their transition. The functions and interactions of conscious mnemonic components of aim formation were registered at each stage. Mainly arbitrary mnemonic components get into the first stage of aim formation which directs thinking activity. At the second stage the inclusion of conscious components leading to the origin of mnemonic partial aims takes place. At the third stage the coordination of arbitrary and non-arbitrary components takes place. There appeared to be three levels of material organisation connected to the problem situation in the subject's memory that serve to formulate aims during the three stages of aim formation:

1) Formulation of the spatial structure of the problem situation;
2) Addition of operative components of the solution;
3) Mutual functioning of spatial and operative components.

Two types of aim formation were found, and the dynamics of their relations was discovered. Aims, that are formed "from above", contain few images of visual structure and a large number of prognosticated activities. Aims that are formed "from below" contain detailed images of the configuration with few prognoses. During thinking search a tendency of the gradual transition of the aim formation "from below" to the aim formation "from above" can be observed. There were subjective units of thinking activity, that are formulated in memory on the basis of the creation of mutual connections of the activities for solving the task, operating steps as activity chains.

3.4. Characteristic of eye movements

More movements from field to field and a predominance of the short fixation (0.1–0.4 s) were observed in the clear-active search. Fixations taking more time (0.5–1.0 s) refer to pieces able to perform moves.

In clear-pictorial thinking a smaller number of movements from field to field became apparent; the number of fixations taking more time increased.

The confrontation of the eye movements and the data of the verbal report allowed to establish a connection between this activity and the studies on aim formation: The process of aim formation was characterized by a higher number of eye movements with short fixations; in aims already formed a smaller number of movements which can be characterized by following the moves little by little but with fixations taking longer time, became apparent.

Registration of the eye movements allowed to objectify some mistakes of memory, and to find out real units of the Ss' activities (schemes). The latter were reflected in stepwise limitations to field-to-field movements, in a total integration of the analysed situation, in a decrease in the amplitudes of movement.

The known correspondence between the eye movements during solving problems by a clear-pictorial plan and corresponding characteristics of aim formation is confirmed. This corroborates the existence of that additional difficulty of aim formation, that emerges when raising the stress on the operative memory.

4. Discussion

The experimental investigations carried out supported the hypothesis of the influence of memory stress on the processes of aim formation; they allowed to contribute to the characteristic of the contents of memory images, of dynamic transitions of these images, of the correlation between arbitrary and non-arbitrary mnemonic processes. All findings confirmed the fact that the study of mnemonic components of aim formation forms an important line of investigating thinking, memory and their correlations.

Today, the investigation of both thought and memory is carried out intensively in the context of so called Cognitive Psychology, which regards man as a structure for information processing. The information based starting point, however neglects such an important aspect of human activity as is the establishing of new aims (1). In this connection we should like to raise the question of the status of Cognitive Psychology at the present stages of development of our science; Should Cognitive Psychology be regarded as a direction covering a universal investigation of cognitive processes, or, on the contrary, as a partial line putting aside most significant characteristics of man's cognitive activity? The data we obtained in our investigation demand that a universal investigation of thinking and memory analyses such characteristics of human cognition which the informational starting point used by Cognitive Psychology leaves aside.

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Long-Term Memory Structure and the Productivity of Human Knowledge

M. MATERSKA

The interest in semantic memory, reflected in this paper, originates from studies on the functioning of human knowledge, which have been carried out in the Institute of Psychology, University of Warsaw. An approach presented in these studies is consistent with that in a theory of knowledge, which is being developed by TOMASZEWSKI (1972, 1976). The approach deals with a wide range of functions which human knowledge can fulfill, as well as with a wide range of situations to which the knowledge can be applied. One of the essential functions of knowledge is the generation of new information, while one of the essential types of situations includes problem situations in which the latter function is fulfilled.

Many authors concerned with the semantic memory functioning are interested in problem solving, regarded as a form of information retrieval. KINTSCH (1977), GREENO (1973), FEIGENBAUM (1971) REITMAN (1971), DE SCHONEN (1974) consider both problem solving and "simple" recall to be means of searching answers to questions asked to the individual in various situations. Although this approach is quite popular, nevertheless empirical studies on problem solving are not too numerous in the context of research into memory. This probably results from the difficulty in differentiation—on the operational level—between various forms of production and reproduction of knowledge. The quantitative comparison of input and output, which in the case of reproduction of knowledge yields a quite veritable picture of the accomplished level of the skill, in the case of knowledge production turns out to be oversimplified and unsatisfactory, as in the latter case the scale is virtually infinite. That's why qualitative criteria are used in addition to the quantitative ones both to describe and evaluate the outcome of the production process. In the literature on creative thinking the most often dealt with qualitative criteria are the following three: novelty, originality and utility of the information generated.

The term of "novelty" denotes a property of such information or informational arrays, which are not included in the individual experience, i.e. which can be neither recognized, reconstructed nor recalled by the subject. Novelty of information (also of the information generated by transformations performed by the subject) depends on the level of the cognitive tools organization. The better developed the tools, the more often the subject—when encountering new information—experiences its novelty. However, this novelty is limited to less and less numerous aspects of information, or informational arrays, as the data received are included in more and more comprehensive categories (PIAGET, cited by MOUNOUD, 1976). Therefore, when an outcome of the information generating process is evaluated in terms of novelty, such an evaluation must be highly subjective. Moreover, it is also highly liberal, as in this type of evaluation neither the so called secondary creativity, nor worthless results are excluded from the obtained body of data.

Originality of information is its novelty considered in terms of a group—no subjective feelings experienced by particular individuals are taken into account here. According to MALTZMAN (cited by BERLYNE' 1965) an original behavior is a behavior appropriate to situational requirements, but relatively rare, unusual. It is very difficult to specify what is meant under the term "appropriate to the situation". The most creative ideas are only very indirectly related to the task situation. Also nonsense ideas are in similar relation to the task. Originality is usually estimated on the basis of frequency of responses produced by a more or less numerous group of subjects. Such a procedure allows to eliminate the secondary creativity, i.e. the same solution achieved independently by more than one subject. However, the difficulty in differentiation between valuable and worthless ideas cannot be eliminated otherwise than by introduction of the third criterion, that of social utility. The criterion,

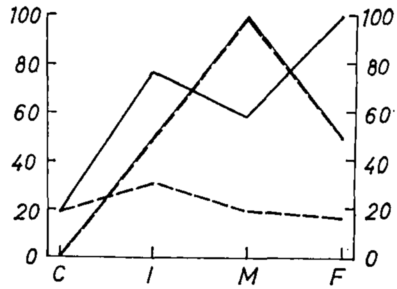

Fig. 1: Productive skills (heavy lines) and reproductive skills (light lines) developed on the basis of material ordered by either the formal rule (dashed lines) or by formal plus substantive rules (solid lines), in the control group (C) and at three stages of learning: initial (I), mastery (M), and forgetting (F). (Top performance = 100).

accepted by some authors (DE BONO 1972), allows to reject such products of transformations, which are subjectively new and highly original, but of no particular value.

It seems that the above discussed criteria of productivity do not exclude each other. By means of addition of these requirements successive grades on the scale of productivity can be obtained. However, it is extremely difficult to specify distances between the grades.

Besides, on the grounds of theories of semantic memory—in their present shape—it is most difficult to explain the complicated temporal relations between productive and reproductive functions of knowledge acquired in a learning process. If two skills rather distant on the productivity scale (e.g. fluency in open-problem solving and the free recall of verbal material acquired in the form of a written text) are compared, then in various stages of the material acquirement a discrepancy between the skills can be clearly seen. While in the learning process in the so called initial acquirement phase the reproductive skill systematically increases, which is followed by a decrease in the forgetting phase, then the productive skill may indicate a different course, which is expressed in the shift of the maximum productivity point, as compared with the respective point in the reproductive skill (fig. 1). A detailed discussion of conditions under which this phenomenon arises is presented elsewhere (MATERSKA, 1976).

An attempt was made to explain the experimentally obtained discrepancy between productive and reproductive functions of knowledge in various stages of its acquirement, on the grounds of various theoretical systems, including the traditional theories of learning and the more recent cognitive conceptions. Explanations in terms of learning theories turned out to be entirely unsatisfactory. In terms of cognitive conceptions the most frequently encountered interpretation was the following one: information is generated on the level of data replication, i.e. on the level of producing their copies according to the rules valid in the system in which the data are encoded. The higher the position of the system in the hierarchy, the larger amount of information can be generated by the system. However, in order to generate really new information, a partial rejection of the rules in force is necessary, according to BRUNER (1962). Similar idea was expressed by DE BONO (1972) in his considerations concerning lateral thinking, as opposed to schematic one. It is not known what part of the rules should be rejected, and what mechanism would be responsible for the further course of the information generating process. Even less is known about the temporal relations between production and reproduction in the process of acquirement of some specific knowledge.

In such a situation I have made an attempt to work out an in-ventory of properties of a multi-functional information generator. Some of these properties are ascribed to semantic memory, especially in theories in which semantic memory is regarded as a register of all questions which can be answered by means of information previously received. Other properties result from theories of mental development, and are not ascribed directly to memory, but to various operational and conceptual structures. A list of properties which shall be presented in a moment, is not complete from the point of view of the semantic memory functions as a whole. It is only a rather arbitrarily chosen part of a more extensive theoretical construct. I shall begin with some general premises pertaining to semantic memory, and I shall proceed to discuss the features indirectly ascribed to this type of memory. The latter features require a more detailed justification and comment.

Semantic memory is a system made up of units, constituted of schemata or concepts. The latter two are active organizations of the subject's past experience, on the basis of which his memory can construct or reconstruct information. *There are many rules governing the integration of subjective experience*, e.g. class inclusion, part-of relationship, location, probability, etc. *Mental operations serving to gather information are used also in the informational data processing and reconstruction* (KINTSCH, 1971, 1977, BOLTON, 1977, UZGIRIS and WEIZMAN, 1977, and others).

Generative potential of memory is generally determined by the type of rules by which the incoming information is processed. In terms of this potential it is not important whether the integrating schema deals with events of the physical world, or with those of the social one. Any concept can be formed either on the level of a simple cluster of experiences, resembling a complex in WYGOTSKI's theory (1962), or on the level of a matrix of properties which were distinguished in the course of socially elaborated transformations. The process of education of an individual determines what concepts shall be formed and on what of the above two (or any other possible) levels. It is in consequence of this process that the majority of persons gathered here have a highly formal, social concept of attitude, and a highly fuzzy concept of neutrino, as the latter term belongs strictly to the field of physics.

I am bound to think that the independence of generative potential of particular integrators (or their systems) from the type of information integrated, is a very important feature of memory. Another such important property consists in my opinion in *the correspondence between the level of organization of operations, on the one hand, and—on the other—levels of organization of concepts being tools and products of these operations.* There is no direct correspondence between the organization of concepts and the structure of the subject matter being learned, but rather between this organization and properties of operations which are to be performed on the material in order to store it in memory (KINTSCH, 1977, BOLTON, 1976, DE SCHONEN, 1974). This feature, though rather obvious from the point of view of the mental development theories, has not been fully taken into account by any of them. Even PIAGET's theory is guilty of one-sidedness in this respect, as his research was limited to a narrow class of concepts and he dealt with the structure of operations mostly. In WYGOTSKI's theory, which presents a differentiated picture of various levels of conceptual structures development, the operational aspect has been almost entirely left out. A mechanical combination of apparently complementary ideas of WYGOTSKI and PIAGET seems to be an unjustified speculation, unless a revision of premises of both these theories is made, and special research is carried out. The need of either such a revision, or of elaboration of a third theoretical system, seems to be rather evident.

The last of properties, most important in my opinion, is the wholistic character of semantic memory functioning. On the basis of this property the operations of data processing can be transmitted repeatedly over various areas and levels of memory until the transformations yield an outcome requested in the task. This idea originates from WYGOTSKI's theory, according to which the development consists essentially in that the structures of higher organization take over and bring to perfection the functions of lower-order structures. However, the latter become only subordinated to the higher-order structures (similar thesis concerning operational schemata can be found in studies of the Geneva school, published in the Seventies, MOUNOUD, 1976). This means that in an adult human being, in which the intellectual development is completed, a transmission of the data processing operations may occur both in the direction from the lower-order structures to the higher-order ones, as well as in the opposite direction. There is much correspondence between such a transmission of data processing in the problem-solving, and the description of various phases of creative thinking yielding both numerous and highly original products. The transmission in question seems also to explain quite satisfactorily the relations between the productive (P) and reproductive (R) skills.

It seems that in a problem situation the direction of search is determined at the highest subjectively available level of the conceptual system by the actualization of knowledge in its most integrated form. An original solution can be found at this level rather seldom, because of restrictions discussed earlier. The operations of data processing are transmitted to the level of lower-order structures constituting an ever-increasing store of individual experience. Such a transmission may include a complete change of the level of both integrators and transformations, or application of transformations typical of the lower-order structures to the higher-order ones, and vice versa. Any of these compromise contingencies promotes the free combination of data, as well as skipping the assumed restrictions and stereotype transformations (e.g. rejection of logical rules, according to BRUNER). In consequence, new constellations of information arise. However, the latter do not constitute the desired solutions yet. In order to be accepted they must be described in terms of concepts used in formulation of the problem task, and verified on the basis of transformations obligatory in the system from which the concepts were derived. The next stage consists in an inclusion of the verified solution in the system. The informational potential of the system is enriched by the consequences resulting from application of its transformations to qualitatively new elements. Thus it is possible to obtain a product both quantitatively and qualitatively richer than the data fed into the system.

Therefore, information processing which takes place successively on two different levels of the cognitive system yields better results than when the data processing is limited to one, even most integrated level. There still remains an open question—what should be the distance between the levels? On the basis of the creative process picture, which emerges from empirical research it can be supposed that in the change of level of structures within which successive stages of information processing take place, the following two levels are involved: the highest strata of conceptual system, and lower portions of pre-conceptual system. This is indicated by frequent references to such concepts as intuition, subconsciousness, creative imagination.

Having assumed that the same operational structures serve in the information integration, reproduction and processing, it is possible—on the basis of the hypothesis dealing with the transmission of information processing—to formulate some predictions concerning the relations between the P and R skills in the learning process. The shape of the latter relations is different, varying in dependence on whether the acquired data are integrated on one level, or on two different ones.

When the data integration takes place on only one level, both the amount and quality of the information generated depend upon the organization of the level. As the same operations are used both in the production and reproduction, and moreover, both these processes occur within the same integrative units, then their outcomes belong to the same class. In the case of reproduction the individual's task consists in the attainment of familiar results, of outcomes, with which he has already encountered in the phase of the acquirement of the material. In the case of production the attainment of new outcomes is required. New outcomes appearing in the reproduction stage indicate an error, similarly as familiar results obtained in tasks demanding production of new information. The P and R skills are differentiated by means of tasks. The information attainment process is the same in both the skills, thus *changes connected with learning take place in both simultaneously, which results in their parallel development.*

When the incoming data are integrated simultaneously at two levels, *the quantity and quality of the data produced do not depend upon any particular level of integration.* There is a difference between production and reproduction consisting in that in the first process concepts of rules from the additional level of integration can be used to generate information, or in that the data processing can be entirely transmitted to this level, while reproduction is effected on one level only. The discrepancy between the data processing and reproduction results in a possibility of mutual inhibitory influences between the two processes, when they occur simultaneously or in an immediate temporal succession. This means that the moment of maximum productivity should fall on the forgetting phase or on the initial phase of learning, when reproduction is not the prevailing form of the acquired knowledge functioning. The phase in which the maximum productivity occurs is determined by the moment at which two levels of integration attain their functional readiness. This depends upon such factors as: the necessity of mastering one of the levels (i.e. acquirement of concepts or transformation rules), the complexity of transformation rules at each of the levels, and the structure of the subject matter being learned. The latter factor determines the number of discernible criteria of integration. These factors may also determine that it is necessary to go through the phase of mastering the material in the process of learning.

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Selective Acitivities and Elective Forgetting in the Process of Understanding and in the Recall of Semantic Contents

J. F. Le Ny

It is widely accepted that understanding, memorizing and conserving semantic information all include a large number of related phenomena, which we shall call phenomena of differentiation. They may be assigned to two main classes: filtering of information and loss of information.

The first class includes *active* differentiation of information by the receiver, who accepts one portion and rejects another portion of the information received. The second class includes *passive* differentiation, which involves the retention of a part and the loss of another part of the information: forgetting may be conceived as a good illustration of the latter. To what extent this distinction between active and passive differentiation of information is valid is indeed a matter of controversy. As everybody knows, a theory such as psychoanalysis tends to greatly reduce the importance of the second class, and to state that every disappearance of information is a result of active processes in the subject. Nevertheless, psychoanalysis must for that employ a special *ad hoc* concept, that of the Unconscious, which we may reject. But some other theories of forgetting also imply the role of active, semi-active or quasi-active processes (for instance inhibition).

We believe that the distinction presented is a good research tool and we will use it in the present report; we invoke the term *selective* for the first class of phenomena and *elective* for the second class. The problem is now to discover the differences and similarities between these two postulated classes.

The first sub-question, that of differences, obviously pertains to the general study of processes taking place in semantic activities and we will not discuss it here in detail.

Concerning the second sub-question we may formulate the following general hypothesis: *differentiation of information in both selective and elective processes occurs according to the general cognitive structures of preexisting information and, in particular, of the content of semantic memory.* A consequence of this is that elective forgetting may offer a means to validate theories of semantic memory. A first step would be to have at our disposal hypotheses concerning the structure of semantic memory from which we could derive, in conjunction with theories on processes, predictions concerning elective forgetting. We could then subsequently compare the results of the latter process with manifestations of postulated selective activities. This implies of course that our theory of semantic memory is highly compatible with the facts observed in elective forgetting.

We will use here a very simple but not outmoded theory of forgetting, namely that occuring primarily from the *loss of information* and, in the present case, the loss of semantic information. This implies that after understanding, the meaning of specific sentences or texts is stored in the general semantic structures of memory. Although itself it is not such a general structure; we shall call this specific conserved meaning "meaning-trace". The loss hypothesis postulates that the meaning-trace will be mutilated at the time of recall.

What kind of mutilation may we suppose? Here we must introduce the general structures of semantic memory and propose one solution for them. For several reasons we give our preference to a componential, or analytic theory of semantic memory (see Le Ny' 1979) and we believe that elective forgetting offers strong new arguments in favor of such a theory.

Let us first consider the theory at its most general and most abstract level. It states then that lexical units ("lexemes") are not the elementary pieces of semantic information, *i.e.* that lexemes are decomposable. It is important to observe that, the componential theory states nothing more at this level: *whether* lexemes are indeed decomposable, and *in what kind of components* they would be decomposable—if they were so—are two separate questions; the answers to the second question ought not trouble the answer to the first, as is often the case in fact.

In this respect, by conjunction of the loss hypothesis and the componential theory, we are led to postulate that *losses concerning meaningtraces occur according to componential structures*, and that what is lost is precisely meaning pieces or components.

If it is actually so, we can assume that a subject who must recall the content of a sentence or of a text will reconstitute new sentences from his componentially mutilated meaning-trace. The sentences thus produced will be related to the original sentences by lexical substitution or change. An adequate analysis must enable us to identify these relationships.

We have performed experiments in which subjects were presented with a series of sentences and were later asked to report what they retained during a free recall period. The contents of the reports were then compared to that of the original sentences. The principle of this comparison includes segmentation of both texts, application of one set of segments to the other and detection of correspondences and differences. Although we also use two levels of structures in this segmentation which we believe to be relevant in analysis, namely into proposition (see paper of Denhiere in this symposium) and into words, the present study is focused on possible componential differences.

In this respect the most interesting observations of course concern lexico-semantic changes and we will present some qualitative examples of them. They can be assigned to four categories:

- omission of redundant information
- loss of specificity
- specification and overspecification
- introduction of erroneous meaning.

It seems that all these changes can be accounted for by a general notion: omission and displacement of semes—or of semantic components or features along the lines of general psychosemantic or idiosyncratic mnesic structures. Let us examine some instances in each class of changes. As a result of the original research we are compelled to present them in French, with an approximate English (or German) translation.

Omission of redundant information. It is obviously impossible to know whether the observed cases in this category are ascribable to forgetting or to summarizing. This

does not matter for a componential explanation, however, which would always say that some seme is present twice (or more) in the superficial original sentence, and that it is present one time less in the reproduced sentence.
For instance the sentence

(1) "Le plongeur remonta à la surface" ("the diver went up to the surface again") may be recalled as
(2) "Le plongeur regagna la surface" ("the diver returned to the surface").

Note that in French no particle is used in these sentences, and that the change affects full lexical units. What is omitted in the recalled sentence is, in the verb, the sems corresponding to "upwards", whereas the semes corresponding to "movement" and to "back" are conserved.

It is rather clear that "upwards" may be considered as redundant in respect to the information inferable[1] from "diver" and "surface"; thus the subject may let this seme be actually inferred by his reader.
Let us quote a second example in this category. The sentence
(3) "Le directeur tira le paquet de fruits de sa poche" ("The director drew out the packet of fruits from his pocket") is recalled as
(4) "Le directeur prit des fruits (dans sa poche)" ("The director took fruits (in his pocket)".

Note again in French the absence of particles, and then the pure substitution.

In the verb of the recalled sentence the seme corresponding to "outwards" has been omitted. But this piece of meaning may easily be inferred[1] in the recalled sentence from the starting-point of the movement, namely "in his pocket".

As can be seen, another omission affects sentence (4): the fruits were in a packet. However, a part of the meaning conveyed by this word, namely that the fruits were several, is conserved in the recalled sentence by use of "des", which in French is the plural of "un", and expresses a plural partitive (not expressed in English and in German).

This latter omission is obviously not pertaining to loss of redundant semes, but to loss of specificity, which will now be examined.
Loss of specificity. In this category most cases can easily be described in terms which would not imply a componential theory. That is the substitution of a superordinate for an infraordinate, otherwise called an hyponym. For instance the sentence
(5) "La servante aperçut l'insecte dans le placard" ("the maid perceived the insect in the cupboard") is recalled by one subject as
(6) "La femme vit l'insecte dans le placard" ("the woman saw the insect in the cupboard").

We find here two examples of super/infraordinate substitution. We indicated in our communication at Leipzig (see LE NY' 1976) how we generally treat the relationship superordinate/infraordinate, namely inclusion of semes. In the present first case, from "servante" to "femme" we shall then consider as lost all semes concerning the profession, or those related to it. In the second case, from "apercevoir" to "voir" is lost, a seme in French approximately equivalent to "briefly".

Let us incidentally observe the important following point: in common speech

[1] We dot not present here these analyses.

when a subject has to speak twice or more about the same referent, he frequently uses a superordinate for the second—or later—time.

This is particularly true in languages which, as French, detest repetitions of words. Thus, in a first sentence he could introduced a person as "la servante", and in a subsequent sentence designate her as "la femme".

In the same line of thought we must then also consider the common use of anaphors as a special case of omission of redundant semes. Although we consider this point to be important, we will not develop it here.

Returning to loss of specificity, we wish to underline that substitution of superordinates for infraordinates can be perfectly accounted for by a componential theory. Moreover, it may be interpreted as reflecting the ordering of the semes contained in the meaning of a lexeme according to their "importance". In general the less important semes are lost first. We will not develop the difficult and important problem of "importance".

Specification and overspecification. This third category may, at first glance seem to be contrary to the preceding one. It corresponds particularly to the substitution of infraordinates for superordinates, and thus at least apparently to an increase of specificity.

We call specification the following phenomenon: in the recalled sentence a more specific word is used than in the original sentence, but no new meaning is thus created. For instance the sentence

(7) "Le marin horrifié regardait le poisson dévorer son camarade". ("the horrified sailor looked at the fish which devoured his companion")

is often recalled by sentences containing the word "requin" ("shark") instead of "fish". It may easily be argued that there is only one common sort of fish which lives in the sea (as indicated in "sailor") and which eats men (as indicated in the last proposition of the sentence): a shark. This phenomenon of specification has been studied in itself (for instance by ANDERSON, PICHERT, GOETZ, SCHALLERT, STEVENS and TROLLIP, 1976 and by DANIEL' 1978); the interpretation presented here is briefly that it consists of the synthesis of several semes arising separately from the previous analysis of several words. In the present case, they are those semes contained in "fish", plus "marine" inferred from "sailor", plus "man-eating" arising from "devoured his companion". All these semes together yield "shark".

The validity of the inferences may of course be weaker. For instance the sentence

(8) "Le technicien recouvrit l'arbre de petites lumierès" ("the technician covered the tree with little lights")

is often recalled by sentences containing the word "fir" instead of "tree"; this specification corresponds to a plausible but non-necessary inferential synthesis.

We call *overspecifications* such specifications which add pieces of meaning to that strictly contained in the sentence. Of course the studies of E. ROSCH (1977) and other authors on "typicality" are directly relevant to this phenomenon (as are studies on imagery). There is no incompatibility between these latter and the concept of semic synthesis we referred to just before. Let us observe, however, that the infraordinate words recalled instead of superordinates are not always the most typical ones. A pure theory of typicality cannot account for this, as the concept of semic synthesis apparently does.

Introduction of erroneous meanings. Sometimes the recalled sentences are, partially or totally, rather far from the original ones.

The hypotheses with which we approach such cases are: a) some seme—or semes—has been lost; b) after this loss some specific slot(s) subsist(s); c) some new seme—or semes—not in the original meaning fills this—or these—slot(s).

We are conscious of the risk of using *ad hoc* explanations in applying these hypotheses, since they are difficult both to verify and to falsify.

Here are two examples. Sentence (3) ("The director drew out the packet of fruits from his pocket") was recalled by one subjet as

(9) "Le directeur prit des fruits sur le plateau" ("the director took fruits on the tray").

This error of the complement of location may be interpreted as follows. If the subject has forgotten that the fruits were located in the director's pocket, but if he remembers that they were somewhere and that it was stated where they were and if moreover he has conserved some non-specific features—for instance they were dry fruits, they did not come from a tree, or generally from the exterior—then he can tend to fill the slot "location" with a plausible content.

Another example is the sentence

(10) "Le plombier rapporta la feuille donnée par le militant syndical" ("the plumber brought back the sheet given by the militant trade unionist")

where "sheet" ist, of course, by normal specification often recalled as "leaflet". This sentence was recalled by one subject as follows:

(11) "Le mineur sortait après avoir vu son délégué syndical" ("the miner went out after having seen his shop steward").

In French, "délégué" is a specification of "militant". "Being given a sheet" has been lost, but it may be supposed that something as "entering into interpersonal relations with" has been conserved as a slot which was then filled by "having seen". "Went out" may have been inferred from the common fact that leaflets are often distributed on leaving factories. Finally, it was discovered by interviewing this subject that his former home district was Pas-de-Calais, an important mining district with frequent trade-union activities: "miner" is then an idiosyncratic filling of the postulated slot related to "worker".

In addition to these examples we have observed and analyzed many others and have found them compatible with the hypotheses presented.

An additional important phenomenon must be mentioned, concerning the possible loss of negation in the meaning of a sentence. This loss obviously must produce dramatic changes in the recalled sentences. Certain of these predicted changes have been observed and some more are currently being studied. Nevertheless, we consider loss of negation as a particular case of loss of a meaning component.

We may conclude only with questions. Even if we provisionally work on the basis of the two main hypotheses presented at the beginning, namely the general componential hypothesis and the loss hypothesis, and if we use their conjunction, *i.e.* the loss-by-components hypothesis, we must ask if the four previously described categories fully account for the observed facts. Do we have strict rules for assigning every observed fact to one or another category? What exactly can we consider as a seme, or in our terminology as a "meme". We have no definite answer to this although some convergent views can be traced (see Le Ny' 1979). We hope that studies of elective forgetting can help us find better answers.

On the other hand, as has been shown, it is often not possible to clearly distinguish what part of the observed losses or changes must be ascribed to information processing during the initial understanding of the sentences or of the texts, and what part must be ascribed to subsequent forgetting. Studies of selective processes, including short-term memory during or just after understanding, must thus be compared with those of elective forgetting.

We could, by this, know whether, in spite of the differences in the processes, they all actually operate according to the general structures of semantic memory. By analysis of selective and elective phenomena it seems then possible to discover how the organization of subject's preexistent mnesic structures determines "cleavage-planes" and differential "fragility" of meanings in semantic processing and forgetting.

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Sentence Comprehension: Structural and Processing Hypotheses

D. DUBOIS

Our main theoretical purpose is to arrive at an adequate description of Long-Term Memory representation of sentence meaning as the structural basis of comprehension processes. In the first part of our work, we used memorial procedures (recognition, recall, production and paraphrasing) in a "non processing" approach of sentence comprehension. This allowed us to test the hypothetical representation of sentence meaning as an invariant across different psychological activities. In the second part, we tried to link this hypothetical representation of meaning in memory to a more general conception of comprehension, as a set of processes acting on (or even from) that memory for meaning. In other words, we tried to complete the structural model of meaning representation with processing hypothesis.

1. The structure of sentence meaning in memory

The aim of the experiments reported here was to find hypothetical semantic invariants across a variety of different memory tasks. These invariants could then be considered as a permanent semantic structure of human memory "pre-existing" to processes such as comprehension which would operate on them.

Language comprehension is mainly depending on sentence comprehension. Our first attempt was then to determine how a complex linguistic object: such as a sentence could be represented in memory as a meaningful psychological event. Linguistic descriptions of sentences usually distinguish between the syntactic structure of a sentence—which assign syntactic functions to words—and the words themselves as content. One way of getting at the psychological representation of sentences in memory has traditionally been to prove the "psychological reality" of the linguistic descriptions; under CHOMSKY's influence, many experiments have been run to establish the psychological relevance of syntactic structures. Experiments in semantic memory had tried to demonstrate the existence of a hierarchical organisation in the internal (mental) lexicon. (DUBOIS' 1975 for a review). Even if we question the psychological adequacy of such linguistic concepts—separating syntactic structures from semantic content—we will still use them as descriptors of the material pending the elaboration of more precise psychological ones (LE NY 1978).

Material

In the first experiments reported here, our material (sentences) could then be described as:

a) a syntactic structure determining a subject, a verb, an object
b) lexical items.

Those items were selected according to a semantic criterion: each item was paired with a corresponding one in another sentence according to a general/specific relationship. We purposely used "general/specific" labelling instead of superordinate/subordinate because the latter could only be applied to a restricted set of lexical elements, those which fit in a taxonomic classification (i.e. nouns and not even all nouns). Our criterion of specificity was based on the possibility of giving an incomplete definition of the specific word using the general one (MILLER 1972). This criterion could be used equally with nouns and verbs.
ex: a *horse* is an *animal* which ...
ex: to *roast* is to *cook* in such a way ...

Our general goal was to find an answer to the following question: How could the syntactic structure and the lexical items of a sentence combine, through sentence comprehension, to generate a sentence meaning which is not reducible to a mere concatenation of each individual word.

Empirically, how the syntactic and semantic variables we controlled do affect the different psychological activities investigated?

Then, what concepts are required to adequately describe sentence meaning as a psychological event?

Recall task

In a recall task (DUBOIS' 1975b) it has been possible to recode the data in order to evaluate the structural and semantic constraints of the verb on the other elements of the sentence.

Method

The combination of specific and general with nouns and verbs variables gave 4 types of sentences which were orally presented to 20 subjects:
- Noun Specific + Verb Specific ex: They roast a chicken.
- Noun Specific + Verb General ex: They cook a chicken.
- Noun General + Verb Specific ex: They roast meat.
- Noun General + Verb General ex: They cook meat.

In half of the sentences, the noun was the object (as in the example); in the second half, the noun was the subject.

The subjects were asked to orally recall the whole sentence, the verb being given as a cue.

Results

The mean number of correct responses under all conditions was 0.54, but their distribution over the four types of sentences was inequal: 36% of the correct recalls were given when both the verb (cue) and the noun were specific ($\chi^2 = 24{,}33\ p < 0.01$). There was no interaction with the syntactic function of the noun (subject or object).

The constraints of the verb on a noun in a recall task appear to be mostly semantic rather than syntactic and can be interpreted in terms of selectional restrictions.

Production task

In order to more "directly" reach the permanent structures of memory for sentence meaning, we performed a production task with the same cues that were used in the recall task (in DUBOIS 1975b).

Method

One or two "prompting" words were presented in writing to the subjects ($N = 40$). From these words, they were asked to produce a simple sentence "the first one that came in their mind".

The prompting words were either a *verb alone*, specific or general according to the criterion already given, or *two nouns*, each one being either specific or general (the order of presentation determining their syntactic function in the sentence), subject or object.

Results

Two types of data were computed:

a) mean number of different responses for each prompting condition

b) frequency of the most frequently given words.

The results showed that the mean number of different responses was higher for general verbs (6,75) than for specific ones (4,17). We correlatively observed a greater similarity in the answers to specific verbs (the most frequent answer to specific verbs was given 0.50 time vs 0.34 for general verbs). In the case of the two nouns, the same general observations could be made, but there was an interaction with the syntactic function of the noun: the number of different answers was higher when one term was general, but still higher when this general noun was the object (see tab. 1).

Furthermore, it seemed that one single verb induced less variability than two nouns.

Tab. 1: *Mean number of different responses given to each prompting word*

Verb		Nouns**			
S	G	S + S	S + G	G + S	G + G
6,75	4,17	4,90	7,60	6,00	6,40

S: means Specific

G: means General

** The first noun cited refers to the subject of the sentence, the second one to the object. EX: S + S means: Subject Specific and Object Specific.

In this production task, we observed an interactive effect of the syntactic and semantic aspects of the words: verbs are more restrictive than nouns, specific terms than general ones. These results are in line with those of the recall task but they also tell us more about the critical role of the verb in the semantic organization of the sentence.

Paraphrasing task

To further evaluate the structural constraints between words in a sentence, a paraphrasing task was then presented to the subjects.

Method

8 types of "subject-verb-object" sentences corresponding to the 2 × 2 × 2 "specific/general" dimension of each word were used.

These sentences were typed on a 21 × 10 cm sheet booklet. For each sentence, the subjects were asked to produce another simple sentence with the same overall meaning but using different words (one or more words could be modified).

Tab. 2: *Paraphrasing task: Mean frequency of modification for each term of the sentence*

	Subject	Verb	Object	Overall
Specific	0.41	0.80	0.31	0.52
General	0.64	0.86	0.57	0.70

Results

Table 2 gives the mean frequency of modification for each word in the sentence. The effects of both syntactic and semantic variables could be observed:

- General terms are more frequently modified than specific ones.
- Verbs are (twice) more frequently modified than nouns.

Calculating the probability of modification of each item according to the specificity or generality of its context, led us to conclude that:

- the verbs were the first term to be modified,
- the more general they were in a context of general nouns, the more modified,
- then came the subject;
- then, at last the object.

Futhermore, we noticed that the "specification" (i.e. modification on a general term with a more specific one) generally went "beyond" the selectional restriction requirements: the subjects did not replace the general term by simply using a noun refering to the class delimited by selectional restrictions; they selected an instance of this class which can be considered as representative (prototypic) of the class. Ex: "animal" in "the animal was galloping" was replaced by "horse" which is, in our culture, the prototype of the animals which gallop.

The results of this third experiment are congruous with the preceding ones and suggested the following general conclusion:

1. the regularities in results between subjects and tasks allow to hypothesize the existence of a relatively invariant (permanent) sentence meaning representation in memory.
2. The verb seems to play a determinant role as a "semantic organizer".
3. The semantic variable labelled "general/specific" is also relevant in the analysis of the semantic constraints between words in a sentence. The descriptive model will then have to account for the more restrictive effect of specific terms.
4. The memory model will also have to include the "specification" effect we noticed. It will have to account in psychological concepts for the introduction of "prototypic" answers that linguistic constructs can no longer predict.

It is impossible within the limits of this paper to propose a definitive and satisfactory model encompassing all these conclusions. Nevertheless, I would like to outline the hypothesis we are working along in our laboratory.

1. For us, the descriptive model which seems to account best for the sentence meaning organisation is a "predicative-componential" type model. It is componential: the semantic units which can describe the sentence meaning in memory do not

overlap words; these have to be decomposed into smaller semantic components (memory components which can be considered as the psychological equivalents of the linguistic features) (LENY 1976, LENY 1978). It is predicative: we adapted BIERWISCH's hypothesis according to which a semantic component is not different from a predicate.

Such a model would give a unified description of both sentence structures (predicates and arguments) and lexical structures. It could also account for our results concerning the restrictive function of verbs (as predicates) and of specific items.

2. The model would be a cognitive one, different from a linguistic description of the sentences; it could then include pictorial components which would account for the observed "prototypic" answers.

We evidently have to validate with more experimental data such a conception of meaning structures in memory for sentences. We furthermore have to develop a processing model of sentence comprehension, i.e. the psychological events which start with a sentence perception and lead to a transitory representation of the sentence meaning—the subjective feeling of understanding—. Our assumption is that this transitory representation is highly depending on the permanent structures of memory we tried to study in our previous experiments. Nevertheless, the processes involved in the elaboration of this transitory representation still have to be fully understood.

We would like, then, to suggest a possible approach to this project by describing some preliminary results we got on inferential processes.

2. Inferential processes in sentence comprehension

The results from only two types of structures for sentence meaning will be presented here: selectional restrictions and cleft constructions.

a) Selectional restriction sentences: the main verb of the sentence was a specific item which highly restricted the arguments; it limited the possibility of substitution of the general term which was associated with it.
ex: the animal galloped ...

b) Specific noun in cleft sentences: the cleft construction was used to put emphasis on one specific noun of the sentence.
ex: it is a mosquito which teased the lad ...

Our goal was to evaluate possible differences in the processing of specific verbs and specific nouns as a way of understanding the syntactic/semantic interaction we observed in the memory tasks.

It was hypothesized that:

1. A specific verb which is known to be more restrictive will induce the processing of the general argument ("animal" in the example) as a specific animal at reading time. In other words, a specific verb would induce an inferential process (from animal to "horse") as the sentence comprehension is going on.
2. In the case of cleft constructions which emphasize the specific noun, the "symmetrical" inference (from the specific word—"mosquito" in the example—to the category word—"insect"—) would not be obligatory. This inferential process would then rather occur at question or comparison time than at reading time.

Method

The sentences were presented on a tarifold. A subject had first to read a sentence[1] at his own pace and then turn the page and decide whether a new sentence was semantically congruous with the preceeding one. Reading and decision times were recorded.

Results

	Specific Verb sentences	Noun specific sentences
Mean reading time	878 cs	841 cs
Mean decision time	235 cs	207 cs

The results only partially confirm the hypothesis: specific verb sentences indeed require more reading time, but also more decision time (for a discussion of these results: DUBOIS and KEKENBOSCH, in preparation).

We may conclude that the use of inferential processes operating on an hypothetical semantic structure for sentences seems to be a promising approach in the understanding of sentence comprehension processes. Nevertheless more experiments will have to be run in order to precisely analyse those processes and to confirm simultaneously our structural and processing hypotheses.

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[1] Actually, the subject reads a paragraphe of 3 sentences: Two fillers and a critical one; this explains why "reading time" is much more longer than decision time.

The Inter-Sentences Semantic Relations Nature: Verification Times and Mnemonic Performances

Ch. KEKENBOSCH

1. Problem and research principles

CRAIK and TULVING (1975) and CRAIK (1976) have recently reexamined the "depth of processing" approach to verbal memory previously presented by CRAIK and LOCKHART (1972). They emphasized the fact that retention critically depends on the qualitative nature of the task and that it was necessary to consider other factors such as: encoding context, elaboration of encoding, retrieval constraints.

A great number of studies appear to support the fact that the syntactic or acoustic analysis of words produces a poorer retention than a semantic one (e.g. HYDE and JENKINS 1973, WALSH and JENKINS 1973, TILL and JENKINS 1973). The results are interpreted in terms of superficial processing for syntactic or acoustic analysis, in contrast to meaningful processing for semantic analysis. Recent studies by ARBUCKLE and KATZ (1976), MORRIS, BRANSFORD and FRANKS (1976), HOPPE (1977) questioned such an interpretation. The notion of code elaboration appears to include two main principles:

1) breadth of analysis carried out on information within a specific encoding domain (acoustic, or syntactic or semantic),

2) congruity between encoding question and response which permits construction of integrated units between encoding question and target word.

We are specially interested in breadth of analysis. In a previous experiment we tried to identify different semantic processes which were supposed to require various breadth of semantic analysis.

CRAIK and TULVING (1975) manipulated the encoding elaboration by varying the complexity of the context in which the target word was embedded and the decision task, yes or no. They used three levels of sentence complexity ranging from simple to complex forms e.g.

"He dropped the "X".

"The old man hobbled accross the room and picked up the valuable "X" from the mahogany table".

The word presented was: "Watch".

The main difference between our study and Craik's and Tulving's is that we only manipulated the breadth of analysis by varying semantic relation between two verbs which were embedded in the same contextual sentence. We will briefly report this experiment.

The subjects were only required to compare the meanings of two sentences and to identify the semantic relation which linked them. They were instructed before the presentation of materials that there were four possible types of semantic relations: synonymy, contrast, implication, difference.

As this material was the same as in the following experiment, we will describe it in some detail. Sixteen sentences were constructed on the basis of the same general syntactic structure; for instance:

(1) The architect perfected his initial project.

(2) The landlord laid off an old server.

For the sake of convenience we will call the verb of these sentences "reference verb".

Each sentence was preceded by another sentence in which only the verb had changed. These verbs were chosen in order to be synonymous or contrasting or different or implicated by the reference verb. For instance, with the sentence (1) "The architect perfected his initial project" could be presented:

(1.s) The architect improved his initial project.

(1.c) The architect bungled his initial project.

(1.d) The architect presented his initial project.

(1.i) The architect changed his initial project.

We have defined:

1. The synonymy relation by a semantic equivalence relation: "perfected" is the equivalent of "improved" in presented sentence context.

2. The contrast relation by reference to the works of LYON: two words x and y are in contrast if and only if x implicates *non* y and y implicates *non* x, but it is not necessary that y is implicated by *non* x and x by *non* y. "Perfected" implicates "non bungled" and "bungled" implicates "non perfected" but it is not necessary for "bungled" to be implicated by "non perfected" and "perfected" by "non bungled".

3. The implication relation was defined as following: if we pose x, y is implicated, included in x; "changed" is implicated by "perfected".

4. The difference relation was presented as a semantic relation which was neither a synonymy, a contrast nor an implication relation. "Presented" is neither synonym nor contrast of "perfected" and is not implicated by this reference verb.

Thirty two subjects were individually tested. They were first given instructions on how to identify semantic relations and were trained to perform that task with twenty examples.

The presentation time was 6 seconds for the first sentence and was equal to subject's answering time for the second sentence. The sentence with the reference verb was always presented in second position.

We assume that time is a possible indicator of the extent of the information processing carried out.

Table 1 presents the average identification times for the three main relations. The effect of the type of semantic relation is highly significant ($p < 0.005$). The

Tab. 1

Relations	Synonymy	Contrast	Implication
Identification times (c/s)	407,4	435,7	556,5

results support the idea that the identification of an implication relation between two sentences requires a more extensive analysis than the identification of synonymy or contrast relation.

We will now describe an experiment in regard to the relationship between the breadth of encoding and retention. The purpose was to investigate the strategies used by subjects performing a verification task of semantic relations. This experiment was divided in two stages. In the first, Ss were placed in a situation which, by hypothesis, was supposed to lead them to differently process the presented information. The difference with the previous task was that the semantic relation which linked the sentences was given before the material presentation. The subjects were then instructed to verify the presence or the absence of this relation.

Thus, in reducing the difficulty of a semantic task, we hoped to obtain a more valid measure of processing times. We also hypothesized that an incidental memory storing of the presented information would take place during this processing stage.

In the second stage Ss were given a recognition test where they had to identify, among four distractors, the sentence with the reference verb.

A recall test was then presented. Ss were asked to complete, with the reference verb, the presented sentences. We assumed that there were two possible ways of solving the problem of the verification of semantic relations.

Subjects waited for the presentation of the second sentence before beginning the specific activities of processing required by the verification of the proposed relation.

Subjects informed of the type of semantic relation to verify, began specific activities of anticipation with the information contained in the first sentence. From these two strategies, it is now possible to make the following hypothesis and predictions.

2. First strategy

a) When a subject has to verify a synonymy relation, he searches for a semantic equivalence in comparing, at the time of presentation of the second sentence, the representations of meaning of two sentences. This search ends when S discovers the presence of this familiar relation and gives his response. Let us call "t_s" the time required by this response.

b) When a subject has to verify a contrast relation, he must find an inversion of the value of a meaningful element. For instance, in sentence (1).

"The architect perfected his initial project" the quality of the project changes and becomes better; in sentence (1.c).

"The architect bungled his initial project" the quality of the project also changes, but becomes worst. This inversion will then manifest itself in a small lengthening of response-time.

Let us call "t_c" this response-time.

c) When a subject has to verify an implication relation, he must make a simple reasoning such as: "if the architect perfected his initial project, then the architect changed his initial project". This necessary reasoning requires an extra processing time which will increase the response-time.

Let us call this response-time "t_i".

Thus, we obtain:

$$t_s < t_c < t_i.$$

We assume that the reading times of the first sentence will not be affected by the type of relation given to the subject.

3. Second strategy

After going through the specific activities of reading and comprehension of the first sentence, the Ss begin a semantic processing of anticipation in connection with the relation to verify. They do implicit hypotheses on the possible semantic content of the subsequent sentence.

Let us call L_s, L_c, L_i the times spent on the first sentences when they have been preceded by synonymy, contrast and implication.

We make the following predictions:

$L_c > L_s$ with a small lengthening caused by the inversion the subject must perform to generate this hypothesis.

$L_i > L_c$ with an important lengthening caused by a widening of the searched semantic area: indeed, several hypotheses are possible on the basis of the meaning of the first sentence.

In summary: $L_s < L_c < L_i$.

Moreover, we predict that the times spent on the second sentences are equivalent when the subject's hypotheses are confirmed; this is highly probable in the case of familiar relations such as synonymy and contrast. Concerning the relation of implication, it seems possible that the subjects continue their processing activities:

$$t_s \simeq t_c \simeq t_i$$

or

$$t_s \simeq t_c \quad \text{but} \quad t_i > t_s.$$

4. Predictions about mnemonic performance

a) If the subjects used the first strategy, they specially processed the "reference verb"; therefore we predict a correlation between the mnemonic performances and the processing-times.

b) If the subjects used the second strategy, they specially processed the verb of the first sentence, thus, we predict the tendency that recognition and recall of those verbs will be different according to the time spent on these sentences.

5. Method

Thirty three undergraduates were used as subjects in this experiment. They were informed that the experiment was about the understanding of semantic relations. They were not immediately told about the subsequent memory tasks. On each trial a relation word ("synonymy", "contrast" and "implication") was exposed on a screen for 3 seconds. Then, the first sentence appeared. The subjects read this sentence and pressed a buttom. The second sentence appeared and the subjects had to read it and decide whether the sentence meaning was in agreement with the previously presented relation by pressing a buttom "yes" or "no". The time spent on the two sentences were recorded.

5.1. Materials

The material used was the same one we already described for the previous experiment with the exception that the difference relation was only used as a filler to generate some negative responses and was not included in the analysis of data.

Thus, there were 12 experimental sentences which could be associated with thirty six sentences (12 synonym, 12 contrast, 12 implication) and six pairs of sentences involving negative responses.

5.2. Results

Table 2 presents the mean reading-time for the first sentences. An analysis of variance showed that the type of relation had no significant effect.

Tab. 2

Relations	Synonymy L_s	Contrast L_c	Implication L_i
Reading-time (c/s)	363,9	375,7	375,4

Table 3 presents the mean time spent to verify the relation between the first and the seond sentences. An analysis of variance reveals a significant effect of the type of semantic relation ($p < 0.01$): t_i is significantly higher than t_s ($p < 0.01$).

Tab. 3

Relations	→	Synonymy	Contrast	Implication
Verification time (c/s)	→	295,6	329,8	387,7

The tab. 4 shows the proportion of "reference verbs" recalled as a function of the type of the semantic relation.

Tab. 4

Relations	→	Synonymy	Contrast	Implication
% of "reference verbs" recalled	→	42,4	37,9	53,0

χ^2 gives these differences as significant ($p < 0.03$)

If we compare response-times with % "reference-verbs" recalled, we observe that a significant lengthening of response-time corresponds with a significantly higher performance. In the case of "contrast relation", we consider that there are two possible explanatory hypotheses or conjunction of them for the discrepancy between response time and recall percentage:

a) The negative aspect of contrast relation has prevented from the construction of an integrated unit for all the information and decreased the accessibility to the mnemonic trace at recall time.

b) The lengthening of response-time is not sufficient to produce any effect on the mnemonic performance.

The tab. 5 presents the percentage of correct recognition scores as a function of the type of relation. It also appears that the type of relation is a factor, which, in this experiment, does not have a significant effect on recognition performance.

Tab. 5

Relations	→	Synonymy	Contrast	Implication
% of correct recognition	→	58,3	56,8	62,9

6. Conclusion

The most interesting result of this experiment is the correlation between the response-times and the recall performances for synonymy and implication relations. If we assume that processing times are additive we may consider that a longer response-time will correspond to a more extensive information processing. We don't obtain the same correlation with the contrast relation. The congruity principle, as defined by CRAIK and TULVING (1975), doesn't seem sufficient to explain this discrepancy. It's difficult to admit that this principle would differently influence the synonymy and implication relations and the contrast one. In the case of contrast relation, we suggest that the inversion of an attribute ("better" or "worst") on the modality "change" may interfere with the effect of breadth of analysis. Therefore, from our point of view, a componential theory would offer a more compatible explanation of those results. Further experiments will be devoted to test this last hypothesis.

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Organizational Effects of Semantic Relations

J. HOFFMANN and M. TRETTIN

The concept of semantic relation has become a central concept of the recent memory research in psychology. Similar as the classical concept of association, the term semantic relation stands for assumed connections between memory units. But semantic relations cover more than only connections between single memory units. They are, we assume, the result of abstraction processes and they reflect classes of real relations between classes of objects in memory. Semantic relations are differentiable memory contents. The relation between SKY and BLUE retrievable from memory is qualitatively different from the relation between PLAYING and BALL, the connection between TREE and PLANT is different from the one between HUNTER and SHOOTING. These qualitative differences of semantic relations are the cognitive basis of their classification. In literature there are various proposals for the classification of semantic relations ranging from the assumption of four basic binary relations (ANDERSON and BOWER, 1974) up to a list of more than 20 relations for determining the structure of semantic memory (RUMELHART et al., 1972) but very seldom these classifications have been validated by empirical data.

KLIX et al. (1976) had proposed a differentiation between intraconceptual and interconceptual relations on the basis of the different effects of these relations in analogical reasoning. This differentiation has been explained in detail in the study of KLIX and VAN DER MEER (this volume). Thus it is hardl ynecessary to give further explanations. We just want to emphasize our methodological approach: Any classification of semantic relations has to be confirmed by different effects of the different relations in mastering cognitive tasks. From the differentiation of cognitive effects of semantic relations we derive a psychologically based classification of semantic relations. Only if we are able to isolate such different effects we can speak of qualitatively different classes of semantic relations in human memory.

We have followed this methodological approach in our experiments. As a cognitive task we choose the free recall of word lists. Many experimenters have argued that different memory functions are included in mastering such an easy recall task. Figure 1 reveals by an heuristic schema the memory functions presumably involved.

Three important functional units are differentiated: a sensoric information store, an operative short term memory (STM) and a long term memory (LTM) storing episodic and semantic information as well as knowledge about techniques of integration and organization of information. One can assume that during reception of a word list each word will be subjected to a sensoric pattern analysis, the result of which will be immediately linked to the stored knowledge about the given sensoric pattern (1). Simultaneously the given unit will be transferred to the STM (2). We assume that the simultaneous representation of sequentially received information units in STM serves the integration and organization of given information sequences.

These organizational processes are influenced by the stored strategies and techniques of organization (5), by episodic information (4) e.g. by remembering similar experiments and last but not least by the stored knowledge about the given information

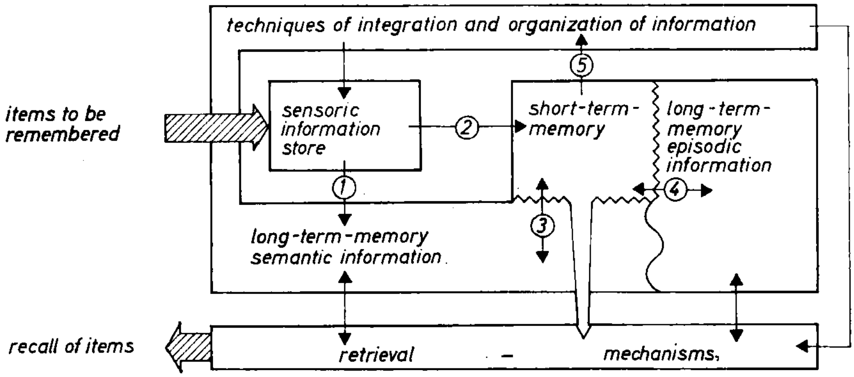

Fig. 1: A heuristic schema, differentiating functional units in memory performances, for a detailed explanation see HOFFMANN (1979).

units (3). By this way (3), we assume, the semantic relations between the presented units stored in memory win an influence on the actual organization of the list in memory.

Thus we conclude: If there are indeed psychologically relevant differences between intra- and interconceptual relations we would expect differences in their effects on the organization of word lists in free recall tasks. This expectation is to be verified.

The first experiment we want to discuss is a transfer experiment with a simple design. In the first part of the experiment the subjects are presented a word list which is clearly organized by intra- or interconceptual relations. One group learns a categorially blocked list (members of four categories were presented adjacently) the other one learns a situationally blocked list (words such as TEACHER, TEACHING, PUPIL, CLASSROOM describing situationally connected concepts were presented adjacently). Each list contained 16 words. The words were presented sequentially on a screen in front of the subjects. The presentation time per item was 1000 ms, the ISI was 1500 ms. After the presentation of the list and an additional filled retention interval of about 20 s the subjects were ordered to recall the list items in any order of their choice. Each list was presented three times with the same procedure except a variation of the presentation order within the limits of the chosen organizational principles. The same procedure was used for all further experiments too.

After the third presentation and recall of the first list the subjects were presented a second list of words chosen in a way allowing both an intra- and an interconceptual organization of the list. Figure 2 reveals the principle.

If read horizontally fig. 2 contains interconceptually related concepts (AGENT, ACTION, OBJECT, INSTRUMENT), read vertically an intraconceptual organization of the same concepts becomes obvious, their belonging to different categories such as professions, plants, gardening tools and actions. Needless to say that the list was presented in a mixed order without emphasizing any of the two organizations. The crucial question was: Does the organizational structure, aquired by learning the first list effect the organization of the second list? Figure 3 summarizes the results. The relative frequency of semantically interpretable neighborhoods in the recall order, i.e. situational pairs and categorial pairs, are plotted against the trials. The centre

Bauer farmer	*mähen* cut	*Gras* gras	*Sense* scythe	- *situation*
Förster forester	*pflanzen* plant	*Baum* tree	*Spaten* spade	
Gärtner gardener	*gießen* water	*Blume* flower	*Kanne* can	
Landwirt agriculturist	*jäten* heel	*Unkraut* weed	*Hacke* hoe	
category				

Fig. 2: A set of words, organizable both by interconceptual relations into situational units (lines) and by intraconceptual relations into categories (columns).

shows the results of a control group learning the second list only. Categorial and situational pairs are observed with rather the same frequency. The left side of the fig. shows that the prelearning of an interconceptually structured list leads to an increase in the frequency of interconceptually determined pairs (sit. pairs) and to an

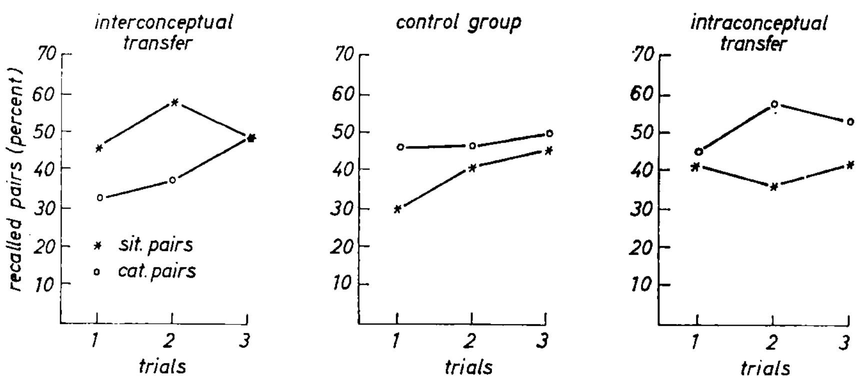

Fig. 3: Relative frequency of semantically connected pairs in the recall of an unordered list in dependence of the semantic organization of a list presented before. On the left you see the effect of an interconceptually organized first list (in comparison to the control group the frequency of situational pairs is enhanced, $p < 0.10$ for the 1st and 2nd presentation). On the right the effect of an intraconceptually organized first list (in comparison to the control group the frequency of categorial pairs is enhanced, $p < 0.125$ for the second presentation).

decrease in the frequency of intraconceptually determined pairs (cat. pairs). The reverse applies when the subjects first learn an intraconceptually organized list (on the right). The semantic organization built up during learning the first list in a specific way effects the semantic organization of the second list. This general statement has been supported by the results of a second experiment.

The subjects were again presented a word list which can be organized by intra- as well as by interconceptual relations between the labeled concepts. We only varied the presentation order (see fig. 4).

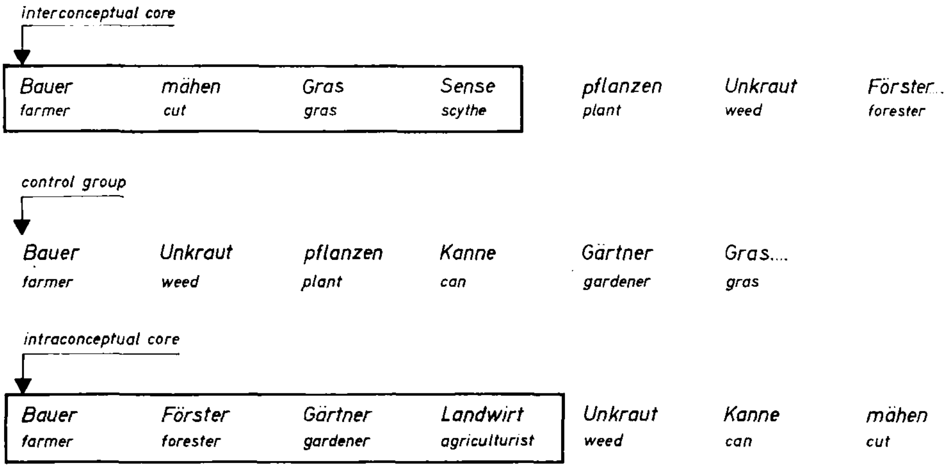

Fig. 4: Variation of the presentation order of one and the same set of concepts.

The items were presented to the control group in mixed order. One experimental group is given at first an intraconceptually organized block, while the remaining part of the list was casually arranged. For a second experimental group the intraconceptual block was replaced by an interconceptual block. Our aim was to establish the in-

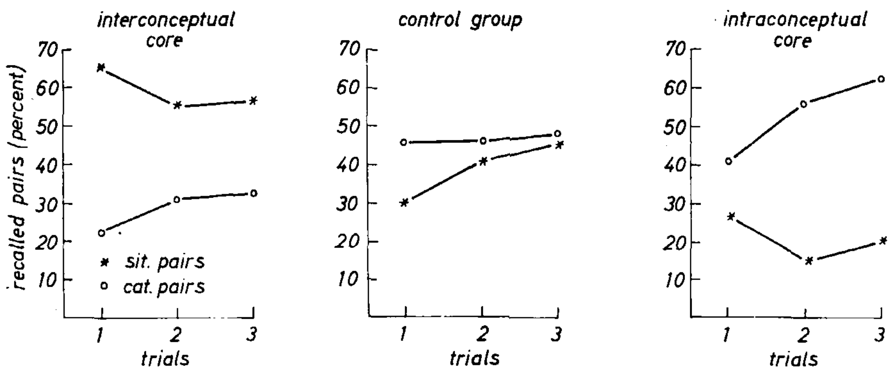

Fig. 5: Relative frequency of semantically connected pairs in the recall order in dependence of the presentation order of the list (see fig. 4). In comparison to the control group you see on the left the effect of an interconceptual core (transfer effect is significant for the first presentation, $p < 0.05$. On the right you see the effect of an intraconceptual core, the frequency of categorial pairs is enhanced $p < 0.125$ for the 3rd presentation.

fluence of these different "list-cores" on the semantic organization of the remaining part of the list. Figure 5 presents the relative frequency of situational and categorial pairs in the corresponding recall orders. The recall of the blocked "list-cores" of course is not included in the counting. However, apparently these have a strong influence on the semantic organization of the remaining unarranged part of the list. A situational core enhances the frequency of situational pairs and decreases the occurrence of categorial pairs. The reverse is true for a categorial core. Both experiments reveal, first of all, that the semantic organization of actually received information is not limited to the presented concrete material, but can be generalized. If specific semantic relations are stimulated by actual material, this semantic organization can be transferred to new materials. This supports our notion that semantic relations are not single memory units but internal representations of classes of relations.

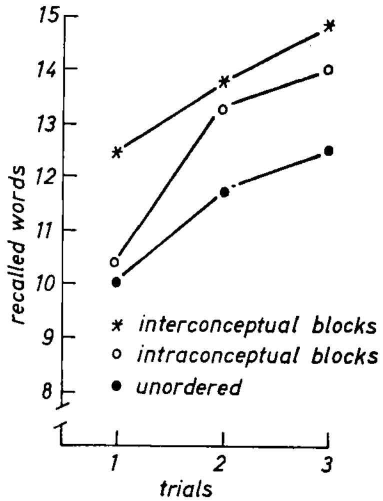

Fig. 6: Mean number of correctly recalled words plotted against trials for three different presentation orders of one and the same set of concepts. The blocked orders lead to significantly higher recall ($p < 0.05$) except for intraconceptual blocks at the first trial.

Secondly the transfer is specific. Intraconceptual organizations in transfer enhance the effect of intraconceptual relations only, while interconceptual organizations solely enhance the effect of interconceptual relations. This speaks in favour of the proposed differentiation between intra- and interconceptual memory organizations.

This poses the question for the effect of these two memory organizations on recall. Does an intra- or an interconceptual organization of one and the same set of concepts result in a better recall? For the experimental treatment of this question we again used lists which could be organized intra—as well as interconceptually (see fig. 2). We only varied the order of presentation of the words. A control group was presented the list in an unarranged fashion. For a first experimental group we chose a categorial block order (fig. 2 read vertically), emphasizing an intraconceptual organization. In a second group we emphasized the interconceptual organization by using a situational block order (fig. 2 read horizontally). Figure 6 reveals the frequency of correctly recalled words in dependence on the said conditions. As expected the number of correctly recalled words is higher for the two ordered lists than for the unordered list. But it is interesting to note that the enhancement of recall for the categorial block presentation arises not before the second recall, whereas the situational order works at once during first recall.

This result can be compared with an observation made with the transfer results discussed before. Figure 7 summarizes the results of our both transfer experiments (compare fig. 3 and 5). The mere amount of transfer, calculated as the difference

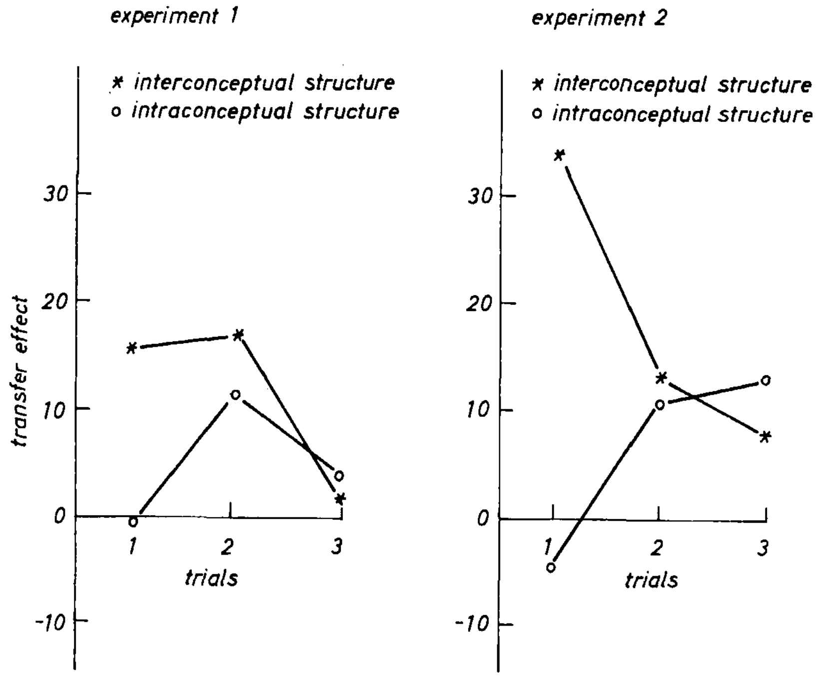

Fig. 7: Pure amount of transfer, calculated by the specific differences between experimental and control group—summarizing the results of the first two experiments, compare fig. 3 and 5.

between the corresponding control and experimental groups, is plotted against the trials. A positive difference stands for positive transfer, a negative one for negative transfer, respectively. The data of both experiments reveal the same trend. The transfer of an interconceptual organization works at once with the first presentation of the second list; with further presentations the transfer effect decreases. Rather the opposite is true for the transfer of an intraconceptual organization. There is no transfer after the first presentation, and only with further presentations of the second list a transfer effect appears.

Altogether, the results suggest, that concepts can be integrated into semantic units more immediately and quickly on the basis of interconceptual relations than on the basis of intraconceptual ones. Following this interpretation the detection and application of intraconceptual relations takes more time than with interconceptual relations. Our last experiment is designed to prove this assumption. Under otherwise identical conditions we varied the time of presentation. We proceeded from the following consideration: Should our assumption of the time dependence of semantic organizational processes be correct, we can expect, among other things, that the relative advantage of interconceptual organization will vanish under pressure of time with presentation times sufficing whether for intra—or interconceptual organizations. The results are shown by fig. 8.

The mean number of correctly recalled words after the first list presentation is plotted against the time conditions in dependence on the three presentation orders. The upper line refers to the presentation time per word, the lower line to ISI's respec-

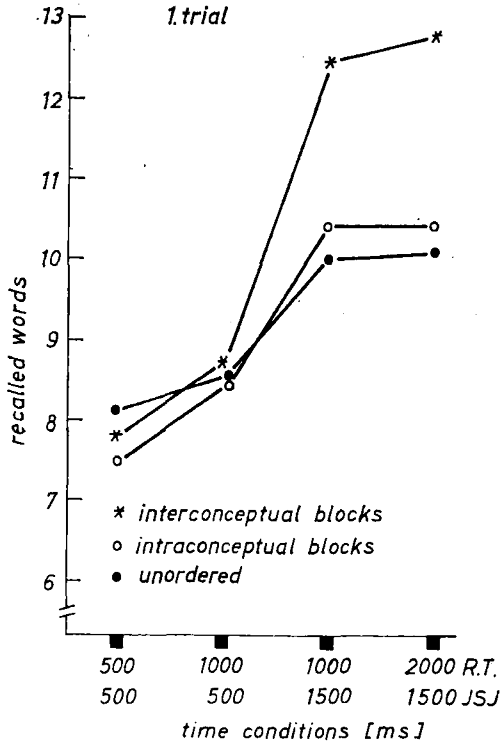

Fig. 8: Mean number of correctly recalled words after the first presentation of the list in dependence of the presentation order and the time conditions (presentation time Pt, inter-stimulus-interval ISI). Only the interconceptually blocked lists with an ISI of 1500 ms are significantly different from the other conditions, $p < 0.05$.

tively. The conditions 1000/1500 ms corresponds to the third experiment with better recall for the interconceptual organization (compare fig. 6). As expected this relative advantage for the recall of interconceptually organized concepts vanishes with the shortening of the time conditions. Obviously the semantic integration and organization of successively presented units takes time. The time necessary to built up a semantic organization depends on the type of the semantic structure. Interconceptual organizations will be build up quicker than intraconceptual organizations.

Hence both classes of semantic relations are differentiable by their effects on the memory organization of actually presented information. It remains to be explained what types of long-term representation of semantic relations underly these different effects of intra- and interconceptual relations. From the different effects in actual memory organization we can only draw indirect conclusions for long-term-memory structures. At least, two alternatives appear to be worth discussing. First: Our data might base on different compatibilities between the given information structure and preexperimentally elaborated LTM-structures, i.e. our interconceptual units of actors, actions, recipients and instruments may be more compatible to LTM-structures than the used categorial clusters. The better imaginability of situational units may play an additional role for the organizational power of interconceptual relations.

The second alternative takes into account different storing principles for intra- and interconceptual relations in LTM, as proposed by KLIX et al. (1976, see also KLIX, in this volume). Interconceptual relations may be stationary stored as ordered relations between concepts within fixed semantic cores or frames whereas intraconceptual relations are stored rather as cognitive procedures for the identification of relations between concepts than as explicitly stored relations. Following this interpretation our data base on the assumption that the operational identification of intraconceptual relations is more time consuming than the attachement of interconceptual units to already elaborated LTM-structures. Whether this differentiation in storing principles is true for all examples of the two classes of relations is of course questionable. However the differentiation between stationary and operationally stored information may be of general importance for theorizing about LTM-structures and cognitive operations in memory. Further experiments are to be done for a deeper elucidating of this issue.

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Memory of Verbal Messages and the Abstract Versus Concrete Organization of the Knowledge About the World

J. Bobryk and I. Kurcz

1. Introduction

In line with the literature (Clark and Clark, 1977) we assume that knowledge about the world (referred to by the Clarks as the mental encyclopedia) is the basic structure of the mind and that knowledge about language (mental dictionary) "is somehow grafted onto it", as phrased by the Clarks. The mental encyclopedia is organized by the categories of the classificational system of experience. Words that enter the mental dictionary denote only some of the categories that make up the mental encyclopedia. In the search for categories that order knowledge about the world, we cannot, therefore, stop at an analysis of the words of the language.

Many questions can be posed. As to the list of these categories, this is still an open question—perhaps the list is infinite? The problem of the nature of these categories—innate or acquired—also remains controversal. In what form is knowledge stored in long term memory—abstract and/or imaginal?—this is one of the most discussed problem in the last ten years. Semantic memory theorists (like Kintsch for ex.) assume that the building material of this knowledge is the proposition, which establish relations between different categorial elements. But still numerous other conceptions of semantic memory (Paivio for ex.) accentuate the role of concrete images in this process. (Semantic memory is what we called here the knowledge about the world.)

An interesting attempt to analyze the categories of perceptual experience and their relation to language is the work by Miller and Johnson-Laird, 'Language and Perception'.

Apart from psychology we also find interesting work in this domain with theoreticians of literature who are developing the so-called text grammars (Greimas 1970, van Dijk 1977). Continuing the research by Propp on text structure, Greimas is concerned with the structure of narration as such (reporting action). His view is that at its deepest level this structure belongs to the universal species-specific categories of cognition (in Kant's sense). In each story there are 3 pairs of "actants" or actors who are embodied in surface structure in the form of:

sender – receiver
subject – object
helper – opponent

Usually both receiver and subject are represented by the hero of the tale. The sender is the character reporting the problem. In folk tales analyzed by Propp this was the character who sent the hero on his way. The object is the figure who represents value for the hero. In folk tales this is the princess whom the hero generally marries at the end of the story. The helper is the collaborating figure and in fairy tales often takes the form of the 'magic helper'. The opponent is the person that stands as obstacle, or the anti-hero. The sequence of the action in its most abstract aspect might be presented as follows:

- the hero learns about an adverse situation or one that inspires action (main role or only role is played by the sender)
- the hero undertakes to attempt a resolution (helper and opponent)
- successful termination (saving the object, etc.).

On the basis of this kind of theory another question arises concerning the role of the word (its material carrier) in memory coding processes. What penetrates primarily and most lastingly into the memory of the text receiver? When we use different texts with the same deep—structure is this structure responsible for that what is really coded in memory, or does this coding depend also on the accidental information belonging to the surface structure? This constitutes the main question posed in the reported experiments.

There is another group of theories, this time from psychology, inspiring our research on the relation between knowledge about the world and knowledge about language (the relation of the mental encyclopedia to the mental dictionary). These are the cognitive theories concerning the mechanisms that regulate human cognitive processes (e.g. KELLY, 1955, BIERY, 1971). These theories introduce an important concept of personal construct which is a dimension or the criterion by which information is coded from the surrounding world. This concept may be useful in resolving our main question concerning the role of surface structure in the memory coding processes. Applying this concept to the lexical entries in the mental dictionary—it is not so, that the psychological correspondent of the material carrier of a word plays its role in different ways depending on what dimensions and what position along these dimensions the given cognitive category takes. For instance, a dimension could be abstractness-concreteness. Does the vehicle of the word or of the whole sentence not function differently, for instance taking up more or less place in memory, depending on what type of category—abstract or concrete—it denotes? Could not the deepest structure of the text, in GREIMAS's terminology—which corresponds to universal cognitive categories—be deformed (for example, stored in memory in different ways) if we manipulate this or any other dimension in the construction of a narrative?

I will describe three of our experiments which are somehow related to this problem. The first two on word memory and on sentence memory are directly related to the main question, the third one on text memory has an exploratory character. They are part of a larger research program started this year by the Psycholinguistic Unit of the U. W. entitled "Cognitive properties and the structure of language knowledge".

2. Method and results

2.1. Memory for words

2.1.1. Experimental design

Memory was studied by the recognition method, as follows: Material consisted of 40 nouns selected from the Polish language dictionary (we will call them input words) and 40 their synonyms, 40 non-synonyms but similar in meaning, 40 words similar in sound, and 40 words dissimilar both in meaning and sound. The non-synonyms were, for example, logically related as coordinates or subordinates, part-whole, etc. These 160 test words and 40 input words made up the experimental material used for recognition.

Each subject heard 40 input words which they were to remember, and in the recognition test, heard only 40 words, which included 8 input words, 8 synonyms of 8 more input words, 8 words similar in meaning to another 8 input words, etc. The recognition lists differed for each subject, and covered the entire list.

100 secondary school students aged 16 to 18 took part in the experiment. The following outcomes could be expected in the recognition test:
- to recognize the word correctly (this type will be marked by the symbol I)
- to confuse the word with a synonym (symbol S)
- to confuse the word with a word similar in meaning (symbol Z)
- to confuse the word with a word similar in sound (symbol D)
- to confuse the word with some dissimilar control word (symbol C)

The following three variables were introduced here. Some input words had clearly abstract content, and the others clearly concrete content. The recognition took place either at once after the presentation, or after a delay of 60 minutes. For half of the subjects, the 40 input words were presented with their definition, for the remainder without definition.

2.1.2. Results

Figures 1 and 2 illustrate the effect of the variable concreteness-abstractness.

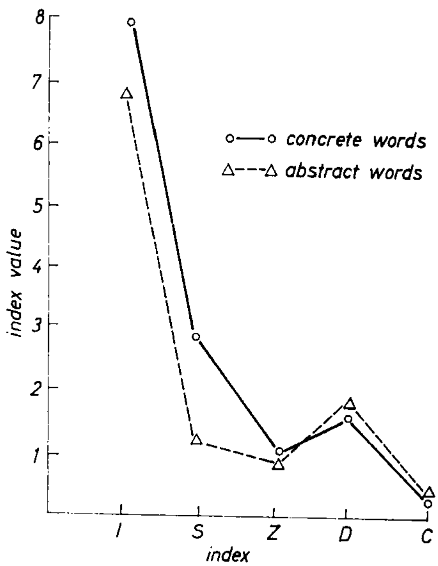

Fig. 1: Variable concreteness—abstractness in general.

I identical words; S synonymous Words; Z words similar in meaning; D words similar in sound; C control Words.

On the horizontal axis are marked the classes of recognized words (I, S, Z, D, C) and on the vertical axis the numbers of recognitions per class. Differences in the indices S mean that the words with abstract content are much less frequently confused with their synonyms than words with concrete content. This shows that for abstract words the connection between the word content and the word vehicle is very strong.

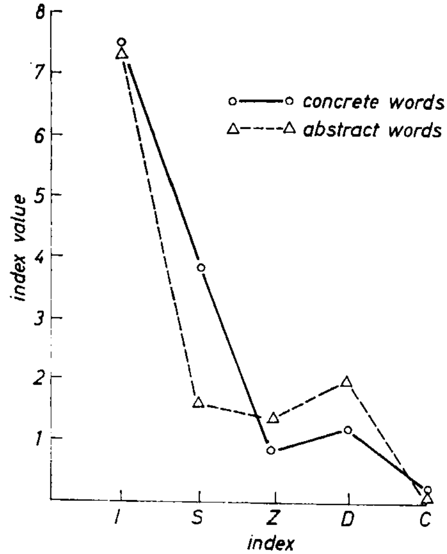

Fig. 2: Variable concreteness—abstractness with definition.

This effect is only due to the abstractness of the word and not to its unfamiliarity. When we give a definition of an input word we observe not only the higher effect for S indices, but a new significant difference between D indices in both conditions, which shows again that the abstract words are more strongly connected with their material carrier than are concrete words.

2.2. Memory for sentences

2.2.1. Experimental design

The design of this experiment is similar to the previous one. 100 secondary shool students aged 16 to 18 took part. 15 declarative sentences were constructed, in past tense with a simple and banal type of content. These were input sentences. 15 sentences were constructed to correspond to these, having the same content but expressed in a different grammatical or stylistic form. Another 15 sentences had a similar content but which was slightly changed in the particular aspect that was easy to imagine. Still another 15 sentences had a content which was changed in the abstract aspect, more difficult to imagine.[1] Finally there were 15 sentences quite dissimilar (control ones). The subjects were divided into five groups, each having an equivalent list of 15 sentences for the recognition test. Each list contained 3 sentences identical with the input sentences (I), 3 semantically equivalent, or synonymous in meaning

[1] Examples of sentence changes according to type IM and type A in relation to the input sentence are as follows: "Mary gave a book to her friend"—type IM: "Mary gave a doll to her friend", and type A: "Mary got a book from her friend".

(S): 3 sentences with semantic change of imaginal type (IM): 3 sentences with abstract modifications of the arguments (A)—and 3 dissimilar, control sentences (C).

The following could happen in the recognition test: The sentence could be recognized correctly (type I) as

identical with the input sentence,

or

the sentence could be recognized in some modified form of the input sentence (Type S),

or

the sentence could be recognized with content changed in some imagined aspect (Type IM),

or

the sentence could be recognized with content changed in an aspect that could not be imagined (Type A),

or a totally dissimilar sentence could be recognized (Type C).

Only one variable was introduced here—immediate recognition and recognition after a delay of 60 minutes.

2.2.2. Results

The results are shown on fig. 3. Correct recognitions (I) differ significantly from incorrect recognitions of all three sentence categories (S, IM, A). The control sentences

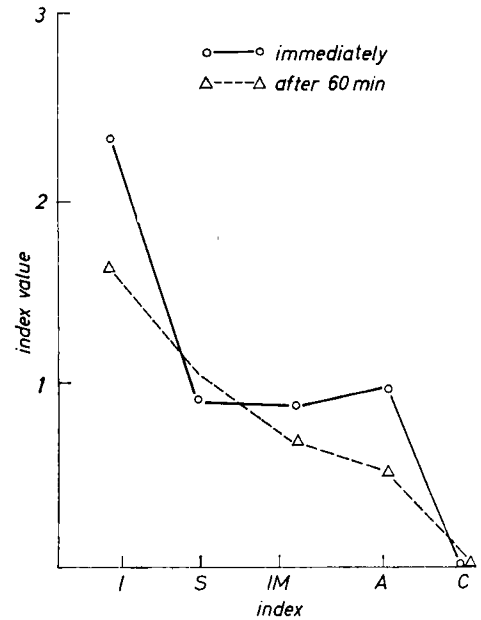

Fig. 3: I identical sentences; S synonymous sentences; IM semantic change of imaginal type; A semantic change of abstract type; C control sentences.

(C) evoke practically no errors. There are no significant differences between the different types of errors. The only significant difference found in our analysis is the difference in the proportion of abstract errors after delay compared to all other types of errors. That is—there are fewer errors of the abstract type after delay than any other errors.

This shows that the memory is shorter lived for both the imaginal aspect of the message content and for the message form. The longest storage in human memory is for the abstract aspect of a message and that this is a time-consuming consolidation.

2.3. Memory for texts

2.3.1. Experimental design

4 short stories (6 typed pages) were used. These stories were specially constructed for the experiment in the following aspects:
- They were a popular type of story for the widest readership (one detective story, one science fiction and two love stories).
- They shared the same deep structure—which means that they contained the same abstract elements (characters of the story), relations between the characters and the same sequence of events.

In more detail:

Each story had a principle hero who in the following order:
- learns about an adverse or a threatening state of affairs—and is motivated to undertake some action (to achieve some goal-object which constitutes another character of the story);
- undertakes a series of attempts to resolve the situation;
- achieves success in attaining his goal.

In addition to the hero, there were 4 other characters:
- the sender—the person reporting (informing about) the adverse situation and inspiring the action,
- the helper—the person who aids the hero's action;
- the opponent—the person who hinders the action;
- the goal-object—the figure who embodies a certain value for the hero, who is to be saved, whose favours are to be won, etc. The story was read to the subjects and then they were required to answer a number of questions about what they remembered. For instance they were asked:
- to name and itemize in order the sequence of events, the situations in the order of which the hero appears and acts, and in which he undertakes his action.
- to recall and name in order of recall all the characters appearing in the story
- to classify by self-chosen criterion the characters of the story, that is, to divide them into any number of groups. (This is G. MILLER's technique).

2.3.2. Results

- Table 1 shows the semantic proximity between the main hero and the other characters. Row K is based on the classification of the characters appearing in the story, while row O is based on the order in which they were recalled. The figures marking the columns of the table refer to the rank of proximity. Generally one can say that despite the same deepest structure of the texts the semantic relations between the characters differ; they are more in accord within the framework of a single story, which is probably due to surface structure effect of the text. There is a high correlation between the two indices within the story but not across stories.

Tab. 1: *Semantic proximity between the main hero and the other story characters (ordinal scale) Kranking based on classification; O ranking based on free recall*

Rank of the character

Story numbers					
1	K	helper	sender	object	opponent
	O	sender	helper	object	opponent
2	K	object	helper	sender	opponent
	O	object	helper	opponent	sender
3	K	sender	helper	opponent	object
	O	sender	object	opponent	helper
4	K	object	sender	helper	opponent
	O	sender	object	helper	opponent

Tab. 2: *Percent of persons who recalled the given sequence of the hero's actions*

Story numbers	a	b	c
1	21%	100%	30%
2	80%	90%	80%
3	6%	64%	48%
4	88%	81%	37%

a hero is informed about the situation,
b hero's attempts to resolve the situation,
c hero's success in resolving the situation.

– Table 2 presents the data for actions identified by the subjects. It shows the percentage of persons who mentioned actions of a given class of undertakings by the hero.
Column a—the hero learns about the unfavourable state of affairs,
Column b—the hero undertakes action in order to resolve this situation,
Column c—the hero achieves success.

Almost all the subjects gave preference to the 'b' type of actions. Despite a common deepest structure e.g., for the story 3, only six percent remembered the action of informing the hero.

Experiments on memory for texts are now being conducted in our laboratory. We plan some further analyses of these results and further experimentation.

3. Conclusion

At the present stage of our work our results do not confirm the universality assumed by the text grammarians (principally by GREIMAS) of the "deepest structure of text".

Although this structure was imposed on the subjects, they attended mainly to other elements. For instance they classified according to such criteria as "man and wife", "went to school together", "like each other", "man and woman", etc.

As concerns the main problem we have posed, we can say that the abstract information is much more dependent on, and is much more tied to its material carrier than concrete information is. This has been verified on both word and sentence memory experiments.

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On the Acquisition of Relational Concepts in Ontogenesis

F. Klix and L. Ahnert

Comprehension of words refers to combination of phonemic structures and conceptual feature characteristics. The acquisition of the semantics of words is a process which takes place in ontogenesis depending on the complexity of the conceptual feature structure, characteristic of a word.

We are going to show this with regard to the acquisition of prepositions.

Prepositions are words that label local relations between an object and its reference object, so-called locations, and whose conceptual feature structures are of different complexity. That is illustrated in fig. 1.

PREPOSITION (in Englisch sense)	general position		coordinates		relativ position on the vertical		contact	
	external	internal	vertical	horizontal	away from earth	close to earth	with	without
IN (working in the garden)		O						
AM (sitting at the table)	O						O	
BEI (situating near town A...)	O							
ÜBER (a lamp is over the table)	O		O		O			O
AUF (something lies on the table)	O		O		O		O	
UNTER (something lies under the table)	O		O			O		
NEBEN (beside the window)	O			O				

Fig. 1: Description of selected locations by various conceptual features.

For our experiments certain locations were selected. Each of them can be described by various conceptual features.

The general position criterion distinguishes between internal and external locations.

Furthermore, there is a number of other features that specify the external locations in more detail, by a particular coordinate axis, by the position on the vertical relative to earth and by a criterion describing the remoteness of two located objects.

These conceptual feature sets do not only represent the different degrees of complexity of locations. They also show which features the various locations have in common and in which they differ. Thus ÜBER (over) – AUF (on) – UNTER (under), on the one hand, and NEBEN (beside), on the other hand, are described by a vertical or horizontal portion of coordinates. ÜBER (over) – AUF (on) differ from UNTER (under) by their relative position on the vertical.

A method was required allowing to identify, if these features of the concept structures concerned have already been acquired in a certain age group or not.

We decided to utilize an essential implication of this internal feature representation.

It consists in the fact that the lack of certain features in an age group must lead to characteristic confusions in language comprehension and usage.

Such confusions can be accounted for by referring to the relationships between certain locations.

There are two basic types of relationship, *symmetry* and *asymmetry*.

For *symmetry* the following applies:

$$L(X, Y) \rightarrow L(Y, X).$$

If there is a local relation between two objects X and Y, then the same relation holds between Y and X. To give an example, from X *beside* Y follows Y *beside* X.

This means both locations are interchangeable and identical in meaning.

In German this symmetry rule is only applied to the locations NEBEN (beside), BEI (near), AM (at). In the following they will be called symmetric locations. Regarding their feature sets it is assumed that the symmetry rule is based on the general positions criterion.

Asymmetry, on the other hand, is characteristic of the relationship between ÜBER (over) and UNTER (under) as well as that between vertically oriented locations (asymmetric locations). So asymmetry seems to be based on the features vertical and relative position of objects on it.

It can be expressed in the following way:

$$L(X, Y) \rightarrow \sim L(Y, X).$$

If such a location exists between X and Y it does not hold for Y and X. For the second location one must find a related new label whose conceptual and relational features express an equivalent meaning. It is only then that the same meaning is conveyed. For example, from X *on* Y follows Y *under* X.

We are starting from the assumption that with the formation of conceptual features for words also the above mentioned relationships can be constructed and the distinction between the two types of relationships is guaranteed. In other words, for as long as these features are not available for word comprehension locations have to be identified separately without any interrelations.

Thus the equivalence of certain locations cannot be recognized. Children that do have acquired conceptual features should be able to detect these equivalences from the feature structures themselves. Our approach to examine this assumption was the study of inference performances, which allows to make statements about how verbal information is cognitively represented.

1. Method

As method we used a recognition paradigm. 3-to 5-year olds were chosen as Ss.

The procedure consisted of two parts, an acquisition phase and a recognition test phase.

The acquisition task was a story read out to each child. The child was asked to keep in mind its content.

The story consisted of three sentences in the order of their presentation:

1. an irrelevant sentence introducing the scene,
2. a premise containing the location to be checked,
3. a filler sentence describing more closely the reference object.

For these sentences see fig. 2.

Presentation was followed by an interval during which the child was allowed to play. In the subsequent test phase each subject was presented four successive sentences and asked to decide whether they contained in the acquisition phase or not.

The four test sentences were:

1. the premise of the acquisition phase (true premise),
2. a simple inference following from this premise. It was obtained by applying the symmetry rule to symmetric locations and the asymmetry rule to asymmetric locations (true inference),
3. and
4. two control sentences derived either from 1, or 2.

PROCEDURE	SYMMETRY L (X, Y) → L (X, Y)	ASYMMETRY L (X, Y) → ~L (Y, X)
aquisition phase:		
1. irrelevant sentence	The boy sleeps already.	We want to play.
2. premise	The doll lies *beside* the boy.	The ball lies *under* the teddy.
3. filler sentence	The boy is a heavy sleeper.	The teddy has got a soft cloth.
interim phase:		
recognition test phase:		
1. true premise	The doll lies *beside* the boy.	The ball lies *under* the teddy.
2. true inference	The boy lies *beside* the doll.	The teddy lies *on* the ball.
3. false premise	The doll lies *under* the boy.	The ball lies *beside* the teddy.
4. false inference	The boy lies *on* the doll.	The teddy lies *beside* the ball.

Fig. 2: Fundamental procedure of the experimental tasks used.

These simple inference sentences will now be considered in terms of the results, bearing always in mind the question of whether they were accepted as equivalent in meaning to the sentence presented in the acquisition phase or not.

2. Results

It is evident (see fig. 3) that sentences derived by the symmetry rule (SYM) are recognized in all age groups as having equivalent meaning.

With asymmetrically generated sentences (ASY (V)) it is different. There is an obvious failure to accept them in the youngest age group.

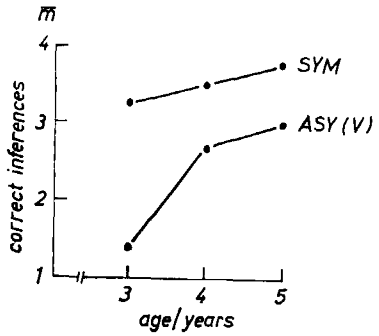

Fig. 3: Relationships between age and mean correct responses to true inferences, correctly generated by symmetry and asymmetry rules.

How can this difference be accounted for? In the first test series the symmetry rule was applied to symmetric locations and the asymmetry rule to asymmetric locations. As has already been stated the symmetry rule is realized by the general position criterion whereas the asymmetry rule is tied up to further features. We now assume that the 3-year old child does not accept asymmetrically generated sentences because he lacks the necessary conceptual features. What follows is that for this age groups the feature structures of asymmetric and symmetric locations are identical.

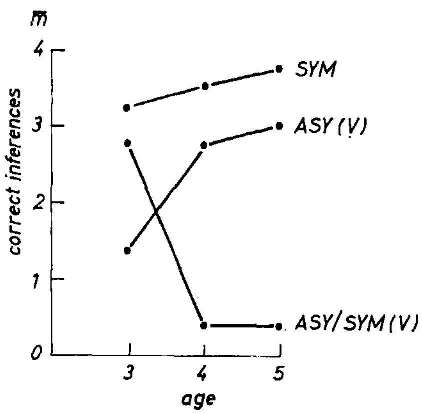

Fig. 4: Relationships between age and mean correct responses to true inferences, generated by symmetry and asymmetry rules applied to asymmetric vertically oriented locations.

For this reason we used an experimental variant in which the symmetry rule was also applied to asymmetric locations (ASY/SYM (V), to give an example, from X *under* Y follows Y *under* X). The hypothesis now reads as follows: Such sentences ought to be accepted by 3-year old children as bearing the same meaning, although this is wrong.

Our assumption has been confirmed (fig. 4).

In fact 3-year old children accept these falsely generated sentences as having the same meaning.

Simultaneously it was shown that in older age groups there is good discrimination between rules wrongly and correctly applied to asymmetric, vertically oriented locations.

From this it is concluded that the feature 'vertical' becomes relevant to decisions in the older age groups.

Analogous to the previous experiments two experimental series were designed to analyse the horizontally oriented location. For this purpose the relative position on the horizontal had to be introduced, namely the right-left position. The symmetry (ASY/SYM (H)) and asymmetry (ASY (H)) rules were applied as well.

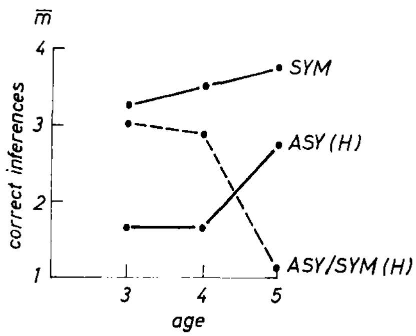

Fig. 5: Relationships between age and mean correct responses to true inferences, generated by symmetry and asymmetry rules applied to asymmetric horizontally oriented locations.

Figure 5 illustrates the discrimination between wrongly and correctly derived sentences containing asymmetric, horizontally oriented locations.

In this case the 3- and 4-year olds failed whereas the 5-year olds were successful.

location and its feature set	symmetry rule	asymmetry rule
symmetric locations AM (at): *external* BEI (near): *external* NEBEN (beside): *external* ∧ horizontal	SYM *X* neben *Y* → *Y* neben *X*	
asymmetric locations ÜBER (over): external ∧ *vertical* ∧ ... AUF (on): external ∧ *vertical* ∧ ... UNTER (under): external ∧ *vertical* ∧ ...	ASY/SYM (*V*) *X* unter *Y* → *Y* unter *X*	ASY (*V*) *X* unter *Y* → *Y* auf *X*
rechts neben: external ∧ *horizontal* ∧ ... (to the right hand) links neben: external ∧ *horizontal* ∧ ... (to the left hand)	ASY/SYM (*H*) *X* rechts neben *Y* → *Y* rechts neben *X*	ASY (*H*) *X* rechts neben *Y* → *Y* links neben *X*

Fig. 6: Scheme for the construction of experimental series employed.

3. Conclusions

We started from the fundamental assumption that the ability of linguistic differentiation depends on the acquired feature characteristics of labeled concepts.

To distinguish a class of locations feature sets were determined. The experiments indicate that in the oldest age groups, the 5-year olds, such feature sets or equivalent ones are completely represented. The 4-year olds prove a deficit in concept comprehension with horizontal conceptual features. The youngest age groups fail with horizontal and vertical dependent features.

This gradual growth of feature acquisition has also been confirmed in other experiments.

In the present report we have shown by way of an example how word comprehension develops in ontogenesis with the growing refinement of conceptual feature structures.

Words are available at an early age. But conformity with adult language comprehension emerges only with the formation of their conceptual feature structures.

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The Development of Semantic Relations in Childhood

A. PRZYBILSKI, H.-D. SCHMIDT and H. SYDOW

1. Introduction

Our report starts from upon experimental studies concerning the development of verbally labeled semantic relations in childhood. The samples included are located within the age span between 5 and 8 years, a developmental stage of forced structural changes in cognition (WHITE, 1965, SCHMIDT, 1970). The comprehension of our data is bound to some suppositions:

Semantic relations indicate a special organization of mnestic material stressing the moment of meaning in sensumotoric and iconic memory as well as in verbal memory. The comprehension of meaning is a process of identification carried out by a memory structure on the basis of sensory stimulation and leading to an output of motivational evaluation (KLIX, 1976). Semantic relations accentuate "perceivable and predictable relations between things, human beings, and actions" (GIBSON and LEVIN, 1975, p. 77). This fact illustrates that subjective meaning reflects the objective value in use of objects and persons to the benefit of life insurance and control, this in a wide sense, directly or indirectly (HOLZKAMP, 1973).

There are many possibilities of classifying semantic relations. We start from the classification of KLIX, KUKLA and KLEIN (1976), a division founded and validated by means of research data of experimental psychology of memory. These authors differentiate interconceptual and intraconceptual semantic relations. Intraconceptual relations are bound to marks, attributes, features; they stress relations between properties of objects as a basis of semantic order. Interconceptual relations describe situational, spatial, and temporal constellations of meaning, "semantic kernels" (KLIX) of memory structuring experienced events. The elements actor, action, instrument, and object are basic entities constituting semantic organization.

The relevant literature tells us where to seek the emphasis of research on semantic relations in childhood. Let us characterize it in an interrogative form:

(i) Which concatenations are to be found between preverbal, actional structures of meaning in infancy and verbally labeled semantic configurations in later age stages (BRUNER, 1975)?

(ii) Which rules control the sequences of origin of semantic relations in childhood? Are these rules more precisely formulated in action theories or in feature theories (CLARK, 1973, NELSON, 1974)?

(iii) Which connections are to be detected between the development of semantic relations on one hand, the development of speech reception and production on the other?

(iv) How to evaluate different methodical alternatives of identifying semantic relations as cognitive available abilities of ordering, how to objectivate them? Above all this question means the problem of selecting appropriate indicators, the influence of simultaneous or serial exposition of items, the effect of illustrative material, the influence of permitting definite quantities of material and groups of ordering as a consequence of instruction (DENNY and MOUTON, 1976). Within this context a very important question arises: How consistent is the use of semantic relations by the child of different age stages? The answer is decisive for the psychological value of a definite classification of semantic relations too, at least in the area of cognitive developmental psychology.

(v) Are we obliged to look at interindividual differences in addition to general trends of development? They could justify the search for cognitive styles (KAGAN and KOGAN, 1970), actually for styles of preferring specific semantic relations.

Our experimental studies are connected with the 2nd and 4th question mentioned above. We start from the following hypothesis: Interconceptual semantic relations are forming the ontogenetic zero point, intraconceptual ones should be regarded as secondary, derived phenomena. Hence the later a vailability of both relation types (as a metalinguistic ability) should differ. Inquiry studies in the past have shown us that this hypothesis might be fruitful for further investigation (SCHMIDT, 1978).

The word "secondary" must be explained. Interconceptual and intraconceptual relations are not standing in a sharp opposition. We must take into consideration—from a developmental point of view—a parallel origin of both relation types in all those cases of stressing special features of objects in explorative and manipulative actions of the child. If this does not happen within the child's actional relations, then the corresponding intraconceptual relations are a more or less late product of cognitive development. In other words: The origin of intraconceptual semantic relations must be explained on the basis of the child's actional relations in his world of manipulation, the latter being reflected in the semantic kernels of memory.

2. Problems, methods, procedures

The following problems are focussed as objectives of our experimental investigation:

(i) Differences between children of different ages, referring to the prevalence of interconceptual or intraconceptual semantic relations in the internal organization of verbal material.—Such a prevalence could be evident if the children are obliged to choose one relation among competing ones. We suppose that interconceptual relations are generally dominating in the period from 5 to 8 years. This dominance, however, should have a varying intensity as a function of other competing relations. We suppose the question of prevalence to be answered in a relative sense only. Moreover, the answer is bound to an important supposition:

(ii) The consistency of children's decisions between special semantic relations.—Only this condition coming true we are able to prove prevalent, predominant relations in the conceptual structures.

The experimental paradigm and the procedures derived from it exhibit the following characteristics:

(i) In connection with KAGAN's (1964) technique of his Conceptual Style Test (CST) we presented triples of nouns stemming from the children's age-specific vocabulary. Each triple included 2 semantic relations thus constituting a conflictual decision structure. We investigated the instrumental relation (ISR) as a substitute of interconceptual relations, and the subordination (SBO), the superordination (SPO, cover-concepts), and the part-whole-relation (PWR) as substitutes of intraconceptual relations.

Figure 1 illustrates the conditions of competition. On the left side the principle has been demonstrated in a schematic manner, on the right side 3 triples of our experimental design are listed.

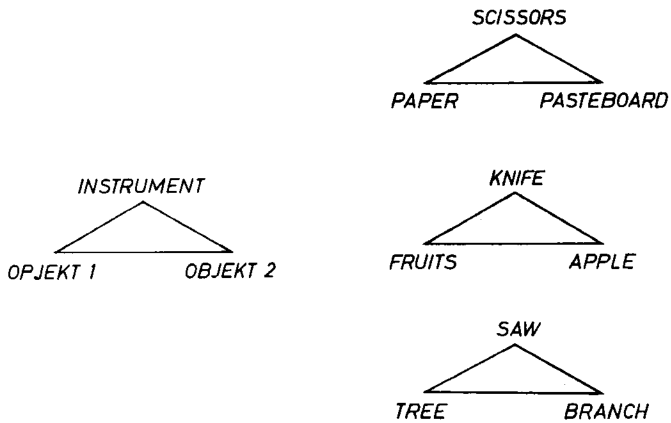

Fig. 1: General experimental conditions (three choice alternatives) and three concrete examples.

(ii) The objective conditions of competition were transformed in subjective ones by instruction. The children had to decide which 2 words of the triple were belonging together, fitting together, which were best matched. These decisions served as experimental parameters indicating which internal semantic memory structure had been activated by the exposition of a special triple. Of course this conclusion presupposes that the children performed a semantic analysis and did not answer mechanically (e.g., preferred pairs in a special position). In order to make the decisions more unambigous, within a second experimental series the children had to choose one of two pairs of words, the number of decision alternatives thus being reduced from 3 to 2. Each pair of words represented one of the competing semantic relations (fig. 2).

object 1 — instrument
object 1 — object 2

paper — scissors
paper — pasteboard

Fig. 2: General experimental conditions (two choice alternatives) and a concrete example.

(iii) Available samples from Berlin kindergartens and schools were included, 120 normal children totally. According to an appropriate design each child had to decide on the relation preference in 25 triples. Inter- and intra-item permutations were arranged to exclude the known effects of interference. A long period of "warming up" was arranged at the beginning of the experiment in order to ensure the best motivational conditions. The experimenter read to the child and repeated the item more than once; the child had to repeat it too. The experiments were carried out from

November 1977 to July 1978, partly in connection with a diploma thesis, partly within methodical exercises of students in a junior course.[1]

3. Results

The results referring to the first problem are depending on the degree of consistent answering. So it is better to report the consistency data first.

(i) In both methodical variants the children did not decide randomly. About 63 per cent of the total sample insofar reacted consistently as preferring a definite semantic relation in triples with homogeneous semantic relations (significant deviation from chance). Those children answering consistently moreover exhibited a lower degree of dependence on the position of a word in the triples. Half of the oldest consistent children preferred ISR/PWR to SBO/SPO, the other half exhibited the opposite trend. The children at the age of 5 and 6 years did not show this effect; they generally favoured ISR and PWR. Hence it is conceivable that cognitive attitudes of different directions of semantic analysis arise from conditions in school responsible for stressing different directions of semantic analysis more than in preschool life space.

(ii) In connection with the problem of age-specific decisions on definite semantic relations under the condition of competing relations the following results might be important:

(a) The children at the age of 5 years already are capable of identifying semantic relations by applying an appropriate cognitive analysis. They do it if a specific relation is confronted to a "zero relation" (random, meaningless sequence of 2 words) within a triple (e.g. saw—tree/saw—cloud). In this case the identification of homogenity extends from totally correct decisions to more than 80 per cent (for the SPO-items). Table 1 demonstrates the results.

Tab. 1: *Identification of semantic relations*

Semantic relation	Correct identification
ISR	100%
PWR	97%
SBO	92%
SPO	85%

(b) At the age of 5 to 6 years ISR is obviously predominant (tab. 2). This prevalence decreases with age. Both samples are reacting specifically to the competition conditions in each case. Moreover a methodical effect is to be registered: The decision on two relation alternatives has another effect than that on three alternatives (investigated only in the younger age group).

[1] The authors express their thanks to the students S. Hoppe, B. Schemmel and K. Weihmann for collecting and computing data with the second experimental method mentioned above.

Tab. 2: *Reaction to competing semantic relations (including the instrumental relation). Relative frequencies of ISR*

Age groups	Competing semantic relation		
	ISR/SBO	ISR/SPO	ISR/PWR
5/6 years (3 altern.)	0.73	0.71	0.64
(2 altern.)	0.67	0.67	0.41
8 years	0.60	0.54	0.41

(c) The data of tab. 3 are expressing the relative prevalence of definite intraconceptual relations within the context of this relation class. The low convincingness of SPO is evident for both age groups. The changing stress of PWR as a function of age is evident too, moreover being superimposed by a methodical effect.

Tab. 3: *Reaction to competing intraconceptual relations (relative frequencies of the relation named first)*

Age groups	Competing semantic relation		
	SPO/SBO	SPO/PWR	SBO/PWR
5/6 years (3 altern.)	0.33	0.23	0.64
(2 altern.)	0.45	0.37	0.41
8 years	0.28	0.31	0.42

(d) An integrative summary of all data scheduled gives an impression on the rank order of prevalence of all semantic relations. In the age group of 5/6 years we find the following sequence: ISR > SBO > PWR > SPO. The second graders prefer: (ISR > PWR) > SBO > SPO.

4. Discussion

(i) Our investigation is a proof of possible mutual validation of experiments in general and developmental psychology frequently having been tested in the past (TRABASSO, 1972, KLIX, 1976). The problem of low or high cognitive effort in solving analogy problems with systematically varied semantic relations (KLIX, KUKLA and KLEIN, 1976, KLIX and VAN DER MEER, 1978)—in this case with adult Ss—converts into the problem of ontogenetic stages of availability of semantic relations. This is an example of fruitful cooperative relations between the two subdisciplines.

Let us mention a sentence of W. STERN from the preface of his "Psychologie der frühen Kindheit" (1914): "Die allgemeine Psychologie ... muß in engere Wechselwirkung zur Kindeskunde treten; sie empfängt von ihr den Einblick in die Genesis der seelischen Funktionen, deren Struktur und Gesetzlichkeit sie selbst untersucht; sie gibt ihr andererseits die wissenschaftlichen Gesichtspunkte, Theorien und Termini, ohne welche die Kinderpsychologie nichts als billiger Dilettantismus wäre."

(ii) Our data concerning the rank order of preferring semantic relations are supported by well known results on stages of ordering abilities of children in classification experiments. The succession of prevalent perceptive, then functional, and at last abstract-logical attributes very often has been found (experiments of OBERER, REICHARD and AL-ISSA, SWARTZ and HALL, quoted from NICKEL, 1974; data from KAGAN, MOSS and SIGEL, 1963, OLVER and HORNSBY, 1966, DENNY and MOUTON, 1976). Comparing these data with ours one should, however, take into consideration the differences resulting from unique or additional application of illustrative means of representation. We only offered verbal material; hence perceptive properties made no difference (at the most as a phonetic resemblance).

(iii) Apparantly, H. WERNER's (1953) characterization of preschool children's view of life in the sense of being a world of "actional things" is simplifying reality by typification. The fixation of semantic kernels in long term memory—these kernels being action centred explicitly—immediatly and narrowly is connected with cognitive differentiation of intraconceptual relations. This quasi-parallel development of both relation types seems to be a function of the fact that action relations between child and objects lift out definite properties of objects, those which are accentuated by action and action consequences. Considering this state of affairs it may be useful to differentiate near-action and far-action intraconceptual semantic relations. With regard to our data we suppose that PWR and SBO are near-action intraconceptual relations. It may be reminded of the fact that activities of dismantling and putting together toys are alreadly apparent in preverbal explorative play. The pars-pro-toto function of objects in illusion and role play must be considered too. At last we must pay attention to subordered objects being working points of identical sensumotoric schemes. Moreover it could be useful to ask the question whether it is important that some intraconceptual relations are to be detected by handling one object only, and others (SPO) only and solely by comparing several objects.

Do we reject our fundamental hypothesis on the primacy of interconceptual semantic relations?—No and yes. No, because there are strong evidences for ontogenetic primarily founded semantic kernels in actional, iconic, and verbal memory, and because our own data exhibit the prevalence of instrumental relation under the condition of competition with other semantic relations. Yes, because intraconceptual relations are to be identified in preverbal ordering and in two-word utterances too (SLOBIN, 1972), and because our data verify the availability of both relation types in both age groups. The dialectical solution of this "as well as" could be found by means of the "action principle" (ANZYFEROWA, 1974): The actional relations of the child not only constitute semantic kernels but attributes of objects too, in this way generating a quasi-parallel development of both relation types. Our interpretation should be located within the context of action theories of cognitive development (PIAGET, 1975, GALPERIN, 1967, NELSON, 1974, LOCK, 1978). It is an advantage of the KLIX-classification of semantic relations to connect the actional and cognitive development of child on all levels of representation, preverbal and verbal ones.

(iv) From a methodical aspect it seems to be important to consider the degree of complexity of the material which has to be analysed semantically. The experiments of DENNY and MOUTON (1976) already demonstrate this effect. Their Ss (children at the age of 3, 4, 5, and 9 years) had to collect pairs of similar pictures only, and hence the results concerning the ontogenetic stages of ordering principles were differing from those of OLVER and HORNSBY (1966) who began with pairs and then continously increased the quantity to 8 objects. In our experiments the reduction of competing semantic relations from 3 alternatives to 2 obviously generates an optimal semantic analysis and a better availability of semantic relations. The younger children deciding on 2 alternatives partly reached the same level as the elder ones on 3 alternatives.

(v) A comparison of these methodical variants raises the question of three important factors mediating the availability of semantic relations. What does happen if we offer word triples? Does the first word generate a gradient thus founding a directional dependence of semantic relations? The relation between knife and bread is easier to be noticed than between bread and knife, the first facilitating the identification of instrumental relation. Does the sequence of words more or less favor the construction of a sentence? Does it more or less favor the origin of an episodic representation? We are not able to answer these questions; further experiments must be arranged in order to see more clearly in this matter.

5. Summary

Our experimental studies concern rules of early ontogenetic development governing the availability of inter- and intraconceptual semantic relations in verbal memory. The data, gained with methods comparable to KAGAN's CST, support the assumption of a quasi-parallel development of either semantic relation type as well as a prevalence of interconceptual relations in the age from 5 to 8 years if the child must decide between competing semantic relations. This result could be explained within an action theory of cognitive development, in this case connected with the hypothesis that there are interconceptual relations on the one hand, being essentially action centred, and near-action and far-action intraconceptual relations on the other hand, the first ones being an early product of development, the latter being a late one.

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Some Memory Tests for Instrument and Beneficiary as Propositional Arguments

J. Engelkamp

Recent research in the psychology of language has strengthened the notion that propositions, or predicate-argument structures, constitute the units of linguistic information processing as well as the building blocks of semantic memory (e.g. Engelkamp 1973, 1976a, Hörmann 1976, 1977, Kintsch 1972, 1974, Kosslyn and Pomerantz 1977, Manelis and Yekovich 1976, Norman and Rumelhart 1975, Perfetti 1972, Raue and Engelkamp 1977, and others).

Taking this commonly accepted view as a point of departure, the present study pursues the question of the memory processes underlying the different types of argument, i.e., semantic relations. In doing so we come to realize how vague and imprecise the term proposition itself is.

A proposition consists of a predicate and one or more arguments. Zero-place (ambient) verbs are left out from consideration. The connection between an argument of a particular type and the predicate is called semantic relation. In spite of a variety of attempts to list all possible arguments, and hence semantic relations (e.g., Fillmore 1968, Chafe 1970), authors tend to disagree as to what exactly is covered by the term argument. There is a particularly sharp controversy around the semantic relations obtaining between the concepts of instrument and beneficiary and that of predicate.

Fillmore (1968) views both instrument and beneficiary (for which he uses a different term) as arguments; Chafe (1970) excludes instrument from this category. Halliday (1970) concides that both instrument and beneficiary are arguments, but he distinguishes between obligatory and optional beneficiary, which raises the question whether both of them may be regarded as arguments.

It should be further noted that instrument-specified predicates *admit* also a beneficiary, whereas predicates that *dictate* a beneficiary do not admit an instrument. Obviously, such inconsistencies in the definition of individual arguments add to the ambiguity of the concept of proposition.

As stated at the outset, it may be legitimately assumed that propositions constitute the units of semantic memory. On this assumption we would be justified in using the processing of linguistic information in memory as evidence for the propositional nature of such information. Accordingly, we shall study the memory processing of predicates accompanied by instrument and beneficiary in the hope of obtaining clues as to whether both instrument and beneficiary may be treated as arguments.

The experiments reported below are based on the following considerations. The commonly held view that propositions are the natural units demands that concepts which function as arguments in a predicate-argument structure should be processed in memory differently than concepts that are not arguments of a proposition (see also Engelkamp 1973).

Experiments were devised to test the following hypothesis on the cognitive processing and storing of arguments:

A proposition being the natural unit of memory, recall should be superior for those sentences that form complete propositions. If a proposition is incompletely reflected in a sentence, its recall should be as much affected as in the case of a sentence containing some additional concepts.

In application to the concepts under discussion, this would mean that the absence of instrument and beneficiary in a sentence where both are required as arguments (i.e., belong to the relevant proposition), should worsen recall while their presence should improve recall of the sentence; in case of a sentence where neither instrument nor beneficiary function as arguments, their absence should benefit recall while their presence should impair recall.

Experiment I

To test this hypothesis, three groups or verbs were used in the experiment, in accordance with the distinctions made by CHAFE (1970).

S Verbs, or simple verbs for which the underlying predicate dictates but two arguments: an agent and a patient. An example of such "simple" predicates would be the following proposition:

(1) swallow (Agent: child; Patient: pill)

C Verbs, or complex verbs for which the underlying predicate dictates (according to CHAFE) three arguments: an agent, a patient, and a beneficiary.

These verbs can be further subdivided into those which admit an additional instrument and those which do not admit it. By the same token we take note of HALLIDAY's distinction between optional and obligatory beneficiaries, a distinction parallel to the one adopted here. The two subgroups are thus:

CIB Verbs, i.e., complex verbs that admit an Instrument and a Beneficiary. An example is offered with proposition (2).

(2) knit (Agent: girl; Patient: sweater; Beneficiary: friend; ⟨Instrument: knitting machine⟩)

Instrument has been put in brackets to indicate that it is not an argument according to CHAFE.

CB Verbs form the other subgroup. These are complex verbs which dictate a Beneficiary, next to Agent and Patient of course, but which do not admit an Instrument. The following is an example.

(3) lease (Agent: businessman; Patient: house; Beneficiary: tenant)

The three verb groups S, CIB, and CB will be used to test the relevance of the concepts Instrument and Beneficiary in the realm of memory processes.

The first experiment was based on the assumption that linguistically incomplete propositions are less easily remembered and recalled than linguistically complete propositions.

Take for instance a sentence with but two arguments, that of agent and that of patient: if it is built around an S verb, whereby the underlying proposition is fully realized, such a sentence should be easier to remember and recall than a sentence built around a CIB or CB verb, where the underlying proposition would not be fully realized (the assumption being that both instrument and beneficiary are arguments).

Experiment I is thus meant to test recall for S, CIB, and CB sentences when these have a similar surface structure. For reasons not relevant here, S sentences have been further subdivided into S_1 and S_2 sentences.

Method

Material: Twelve sentences were constructed for use in a recall test. In each, two identical concepts (an agent and a patient) were tied up with S_1, S_2, CIB, or CB predicates.

The following example illustrates this principle.

(4a) The man ate the cucumber (S_1 sentence)
(4b) The man missed the cucumber (S_2 sentence)
(4c) The man peeled the cucumber (CIB sentence)
(4d) The man preserved the cucumber (CB sentence)

In effect, in any set of sentences the only surface difference was in the predicate.

Design: These sentences were entered on four lists so that each list comprised three S_1 sentences, three S_2 sentences, three CIB sentences, and three CB sentences placed in different argument context. That is to say, arguments used for the construction of S_1 sentences on one list were used for S_2 sentences on the second list, for CIB sentences on the third list, and for CB sentences on the fourth list. In this way, each list contained the same argument contexts, but the arguments were combined in each with a different predicate.

Each list was administered to a group of ten subjects, which provided for a design with repeated measurements for the effect of the four sentence conditions.

Procedure: The sentences were presented on slides in a free recall experiment. Each slide was shown for 3 s. There were altogether five trial runs. The order of the slides was varied from person to person and from trial to trial. The subjects were asked to reproduce the sentences during each intertrial interval in arbitrary sequence. The time taken by subjects to reproduce the recalled sentences used to grow from trial to trial, and the duration of the intervals was extended accordingly.

Subjects: The 40 subjects were paid volunteers from among undergraduates of Saarland University.

Results

Analysis of variance performed on the recall scores for the four sentence conditions produced a significant effect ($F_{3/39} = 9.2$; $p < 0.01$). Subsequent pair-wise comparisons on the t test for dependent samples showed a significantly lower recall score (subject mean of 6.37) for CB sentences than for all other sentence conditions. No differences were recorded between the recall scores for S_1, S_2, and CIB sentences (8.30, 8.02, and 7.72).

A comparison of the recall scores for the verbs yielded the same result: there were likewise no differences between S_1, S_2, and CIB sentences (8.57, 8.08, and 7.85), whereas the recall score for CB sentences was much lower (6.82).

Discussion

Only the obligatory beneficiary has proved effective in the sphere of memory. Its absence was found to lower the recall score for the entire sentence as well as for the verb alone. Both instrument and optional beneficiary failed to reveal any effect on recall in the present experiment. The absence of instrument and optional beneficiary did not lower the recall score for the respective sentences and verbs.

Whereas Experiment I was designed to reveal the detrimental effect of the absence of certain arguments, Experiment II was meant to demonstrate the beneficial effect of the presence of arguments in the sentence.

Experiment II

Once again the experiment was addressed to the now familiar concepts of instrument and beneficiary. This time the test sentences were based on two-place and three-place verbs as defined by HELBIG and SCHENKEL (1973). In their differentiation of verb valence these authors took recourse to the method of deletion (Abstrichmethode), which led them to the distinction between *syntactically* obligatory and optional concepts. This procedure has enabled us to distinguish not only between optional and obligatory beneficiaries, as with HALLIDAY (1970), but also between optional and obligatory instruments. Accordingly, CIB sentences could be further subdivided into those with obligatory and those with optional instrument.

The hypothetical structure of the propositions which underlie sentences with instrument or with beneficiary may be described—in terms of predicate complexity—in the following way (obligatory arguments being marked by the suffix$_{obl}$ and optional arguments by the suffix$_{opt}$):

Sentences with Instrument

Complex predicate: Predicate (Agent$_{obl}$; Patient$_{obl}$; Instrument$_{obl}$)

Simple predicate: Predicate (Agent$_{obl}$; Patient$_{obl}$; Instrument$_{opt}$)

Sentences with Beneficiary

Complex predicate: Predicate (Agent$_{obl}$; Patient$_{obl}$; Beneficiary$_{obl}$)

Simple predicate: Predicate (Agent$_{obl}$; Patient$_{obl}$; Beneficiary$_{opt}$)

Considering now the sentences in which these structures are realized, we would expect superior recall for sentences with complex predicates than for those with simple predicates, provided the obligatory concepts link up with the predicate into a natural memory unit, or else, if only the distinction between obligatory and optional arguments is justified in terms of memory. In these conditions, the sentences with complex predicates amount to integral memory units; so do the sentences with simple predicates, except that these may be optionally enriched with one argument. Consequently, the latter should prove more difficult to integrate in memory.

Should we find superior recall for the sentences with complex predicates, the distinction between obligatory and optional arguments would gain additional relevance.

Method[1]

Material: As in the previous experiment, parallel sentences were constructed by putting verbs in identical sentence contexts, with the difference that in the case of complex verbs all three obligatory arguments were included while in the case of simple verbs the sentence contained the two obligatory arguments as well as the optional argument.

[1] The data reported in this section were collected and processed by Mr. BURKHARDT RAUE, in partial fulfilment of the requirements for his diploma thesis.

There were eight sentences with instrument and eight with beneficiary, in each case one half with simple and the other half with complex predicates. The sentences with the simple and those with the complex predicates differed only in the verb. Hence the "critical" sentence component was represented by the same word, except that for some verbs it amounted to an obligatory, and for other verbs to an optional argument. The following examples illustrate the difference between sentence types, the complex verb appearing in the first sentence of each pair.

Sentences with Instrument

(5a) The drunkard belaboured the traveller with his fists.

(5b) The drunkard knocked down the traveller with his fists.

Sentences with Beneficiary

(6a) The merchant procured the tourist the watch.

(6b) The merchant sold the tourist the watch.

Design: The 16 sentences were divided into two complementary halves, each set containing the same number of sentences with instrument and beneficiary and the same number of sentences with two-place and three-place verbs. The two experimental conditions occurred in the two sets in alternation. The total number of sentences in each set (list) was increased to 22 by adding some neutral sentences and a number of sentences with locative and modal arguments, which are not considered here.

Procedure: Each of the two lists was administered to 18 subjects in four trial runs. The order of sentences was rotated across subjects and trials. The sentences were entered into a booklet, one per page. Subjects were allowed to look at each sentence for 7 s and were asked to remember them. After each trial run subjects had to reproduce the sentences they could recall.

Subjects: The 36 subjects were male and female pupils of senior classes in a secondary school at Rheine; they were not paid for participating in the experiment.

Results

The recall scores for instrumental sentences revealed no significant differences between the two predicate conditions in the recall of either sentences or verbs. Of the complex sentences 3.9 were recalled on the average, of the simple sentences 3.7. The scores for the verbs were comparable.

Significant differences were found however in the recall of the sentences with beneficiary. Sentences with complex predicate were better recalled ($\bar{x} = 3.7$) than sentences with simple predicate ($\bar{x} = 2.6$, Wilcoxon matched-pairs signed-ranks test, $p < 0.01$). The results for the verbs were comparable.

Discussion

As in the case of the previous experiment, the present evidence confirms the distinction between optional and obligatory beneficiary. Only the obligatory beneficiary appears to be a component part of the natural memory unit addressed to by the respective predicate. Only the missing obligatory beneficiary lowers the recall score of the proposition.

The results fail to support the distinction between optional and obligatory instrument adopted here after HELBIG and SCHENKEL (1973). Optional and obligatory instruments had produced similar recall scores.

General discussion

It was proposed at the outset to decide the question as to whether a particular concept is an argument or not, or the question as to whether the concepts of instrument and beneficiary ought to be viewed as arguments, by submitting these concepts to a memory test. A concept was to be regarded as argument if its presence or absence in the sentence would either raise or lower the recall score compared with the effect of other concepts.

On the evidence of these criteria, the experiments have revealed such an effect only for the obligatory beneficiary, which may be therefore regarded as an argument in the adopted sense of the term. In contrast, both instrument and optional beneficiary have not revealed the kind of memory effect that is understood to be typical of arguments.

But before we draw the final conclusion that both instrument and optional beneficiary have a very small memory effect, small enough to be neglected in the framework of the theoretical discussion of propositions, we would be well advised to conduct additional experiments.

I have, for instance, shown elsewhere (ENGELKAMP, 1973) that sentences with instrument ensure superior recall compared with the same sentences in which the instrument is replaced by some other concept that cannot be regarded as argument in the pertinent proposition.

The present study has shown that the two distinctions between optional and obligatory concepts (HALLIDAY, 1970, HELBIG and SCHENKEL, 1973) possess different relevance in the context of memory processes. This alone should prompt the cognitive psychologist to test such linguistically motivated distinctions (classifications) in suitable memory experiments.

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The Activation of Sentences in Semantic Networks

U. GLOWALLA, H. H. SCHULZE and K. F. WENDER

Several of the current theories of human long-term memory use propositional networks as a means for the representation of knowledge. One way to test some aspects of the theories is to examine the time course of search processes in long-term memory. Typically this is done by having subjects learn sentences and afterwards asking them questions about these sentences. The interesting variable is the time subjects need for their answers.

In an experiment by THORNDYKE and BOWER (1974) subjects learned sentences of the form agent-verb-object and were tested for recognition of complete sentences. The authors concluded that a parallel search model with simultaneous access best fitted their data. They also introduced one experimental variable which has been found to be effective in several later studies. Some of the words they used appeared in more than one sentence. In terms of the network models the corresponding concept nodes are connected by a link to each of these sentences. With respect to the memory search this has as a consequence a slowing down of the search *process*.

DOSHER (1976) tested her subjects by showing pairs or triplets of words. The subjects had to decide whether these words came from the same sentence or not.

DOSHER found support for the THORNDYKE and BOWER search model and also she concluded that a memory structure corresponding to the HAM model (ANDERSON and BOWER 1973) gathered more support than the model of NORMAN, RUMELHART and the LNR research group (1975).

KING and ANDERSON (1976) used only one type of probe pair namely verb-object probes. However they varied the number of sentences in which each of their verbs and each of their objects *appeared.* Both fans varied from one to three and had a significant effect on reaction time.

In the present study we used four different pairs of words as probes. Furthermore verb fan and agent fan varied in two steps. As an additional variable we introduced a delay between the first and the second word of each probe pair. The order of presentation within each pair was also varied systematically. The interaction between fan, length of delay, and order of presentation is the main concern of this study.

1. Method

Materials and procedure: Fiftytwo sentences of the form "An agent verbed an object in a location" were prepared for each subject. The agents were names of professions, the transitive verbs described common activities, the objects were concrete nouns, and the locations were everyday places. A typical example would be "The policeman investigated the knife in the hotel".

The experiment was controlled by an HP-computer. Material was presented on an alpha-numeric display. Subjects answered by typing into a keybord or by pressing one of two response buttons. During the learning phase of the experiment sentences were shown one by one on the screen. Subjects were instructed to read each sentence and to memorize it. To enhance learning subjects copied each sentence on to a sheet of paper. When they were finished with one sentence the subjects could get the next one by pressing a pedal.

Following the first learning phase, subjects went through a drop-out procedure. Each sentence was presented at least four times, each time with one of the content words missing. Subjects had to complete the sentence by typing the missing word into the keybord. Presentation of sentences followed a random procedure. If the answer to a particular probe was correct, this probe dropped out from the pool of probes. If the answer was false the probe remained in the pool and was presented again at a later point.

In the main test phase on each trial subjects were presented with two words and had to decide whether these two words came from the same sentence or not. Subjects responded by pressing one of two buttons. Half the subjects had the "no" button and half the subjects had the "yes" button at their dominant hand.

The two probe words of a trial appeared in succession with a slight pause in between. This delay was varied systematically. After pressing one response button subjects learned as a feedback how many points they had earned on the trial. The number of points was determined by two payoff conditions as detailed below.

Subjects could initiate the next trial by stepping on a pedal. This caused a fixation point to appear in the middle of the screen for 500 ms. Thereafter the fixation point vanished and the first probe was shown on the left. Following a certain delay the second probe was presented to the right of the first one. Reaction time was measured from the onset of the second probe.

2. Design

The experiment followed a 4 × 3 × 2 × 2 × 2 × 2 × 2 design. These factors were: Type of probe, length of delay, verb fan, agent fan, presentation order, speed vs accuracy, and positive vs. negative probes. Each of these factors will be described in turn.

Type of probe: From the set of four content words namely (Agent (A), Verb (V), Object (O), and Location (L)) the following four pairs of probes were used in the experiment: AV, VO, OL, and LA. We did not use all six possible pairs in order to keep the experimental efforts within limits. However, in the probes that were used each type of content word appeared equally often. The factor *type of probe* is of special interest with respect to the internal structure of the within proposition representation. The probes were randomly distributed over trials.

Length of delay: The pause between the two probes of one trial was varied in three steps: 200 ms, 400 ms and 800 ms. These were also randomly distributed over trials. The idea of varying length of delay was to trigger the search process at three different points in time.

Verb fan: The verbs used in the sentences came from a pool of 32 verbs. Each verb appeared either exactly in one sentence or exactly in three different sentences. This is called a verb fan of one or a verb fan of three. This is illustrated in fig. 1.

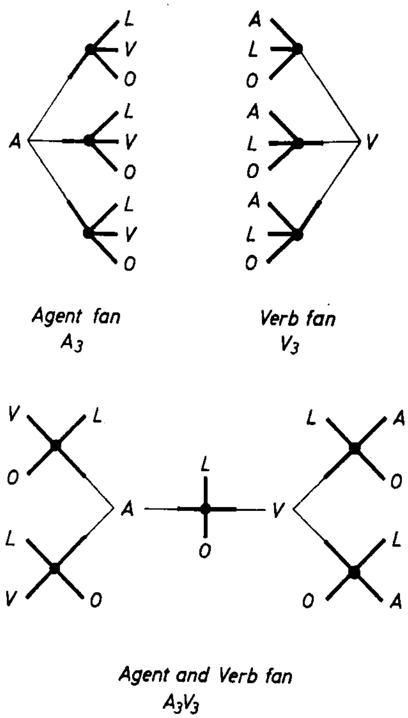

Fig. 1: Illustration of the different fan conditions.

Like the other conditions the verb fan was randomly distributed.
Agent fan: Agent fan also varied in two steps. Like the verbs the agents appeared either in one or in exactly three sentences. Verb fan and agent fan were orthogonally combined.
Presentation order: Within one pair of probes the one probe was presented first fifty percent and in the remaining cases the other probe appeared first. For example from an LO pair half the time L was first and O was second and half the time the sequence was the other way around. This factor was introduced to investigate the interaction with fan conditions and length of delay.
Speed vs. accuracy: In order to get our hands on the speed-accuracy tradeoff two payoff conditions were introduced. Under the speed conditions subjects got a bonus of 40 points for each correct response and were punished with −40 points for a false one. Furthermore for every 100 ms of reactiontime 2 points were deducted.

Under the accuracy condition the bonus for a correct answer was again 40 points, however the penalty for a false one was −120 points and the cost for every 100 ms was 1 point.

The total experiment was divided into two blocks one under speed and one under accuracy instruction. The sequence of speed and accuracy was counterbalanced over subjects.

Positive vs. negative probes: Half of the pairs of probes were positive that is the words came from the same sentence. In the other fifty percent of the pairs the words came from different sentences. These are called the negative probes.

For each subject the sentences in the experiment were constructed anew. There were 32 words serving as agents, 32 serving as verbs, and 48 words for objects as well as 48 for locations. The number of words for agents and verbs was smaller because under verb fan 3 and agent fan 3 the same word appeared in three sentences.

Each sentence was used with only one delay condition and with only one type of probe pair. This made 48 sentences in total: 4 (type of probes) × 3 (delays) × 2 (verb fan) × 2 (agent fan). For the speed and the accuracy condition exactly the same sentences were used. This was also true for presentation order. For example an OL probe from one sentence appeared once in the sequence OL and once in the sequence LO.

For each subject a new set of 52 sentences was created by randomly combining agents, verbs, objects and locations. Four of these sentences were used for warming up trials. These had no words in common with the test sentences. One session consisted of the learning phase, the drop out procedure, followed by the test phase. In the test phase each subject got 224 probes under speed and 224 probes under accuracy instruction. The first 32 probes of the speed and also of the accuracy block were warming up trials and were not included in the data analysis. One complete *session* with appropriate brakes in between lasted for about three hours.

Subject: Subjects were 35 students *who* were paid for their participation.

3. Results and discussion

Under each condition the data were averaged over subjects. With these scores a seven factor complete analysis of variance was performed. We will not give the details of this analysis here. Some results are reported in tab. 1. From the seven main factors six were significant at the 1 % level. The remaining factor (presentation order) reached

Tab. 1: *Mean reaction times for correct answers and error rates*

	Mean RT	% Error
Accuracy	1043	8.9
Speed	936	11.4
Positive Probes	912	10.2
Negative Probes	1067	10.1
Delay 200 ms	1095	12.1
400 ms	975	10.0
800 ms	898	8.4
Probe pair AV	919	8.5
VO	880	9.3
OL	888	6.7
LA	793	6.8

the 5% level. From the 21 two factor interactions 6 were significant. Every one of these could be interpreted as a result of the fan effect. None of the higher order interactions was significant. Thus the data look pretty additive.

Table 1 also gives the mean reaction times of hits for the different probes. As may be seen the LA probes have the shortest and the AV probes have the longest reaction times. This result is at variance with the network models and also with the data of DOSHER. On the other hand we do not think that we have got a chance result because our data show a lot of regularities as will be seen in the following figures. However, we have no interpretation to offer for our probe effect.

Figure 2 shows the mean reaction times for hits under the different fan conditions as a function of length of delay.

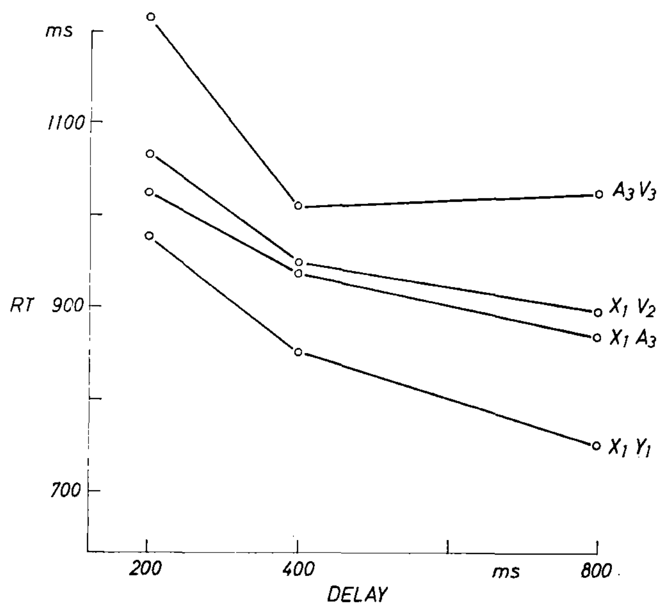

Fig. 2: Reaction times for hits as a function of delay for different fan conditions.

Figure 3 gives the corresponding data for correct rejections.

As may be seen reaction time decreases in a regular fashion with increasing length of delay. This supports the assumption that subjects already start the first search process when the first probe is presented.

There is a considerable fan effect at all delays. The verb fan effect looks to be a little stronger then the agent fan. The correct rejections also show a large fan effect. Furthermore, it appears that the fan effect for negative probes is non additive, that is, the fan effect under the A_3V_3 condition is larger than the sum of the simple fan effects.

Figure 4 contains the mean reaction times of hits and correct rejections for different presentation orders of fan. The high-low condition represents those trials where the first word had a fan of three and the second word had a fan of one. With respect to the search process the model described below assumes that under this conditions the first search process is slower than the second one. Under the low-high condition things are the other way around. For the positive probes presentation order of fan has a strong effect of nearly 100 ms for the longer delays. Reaction time is shorter

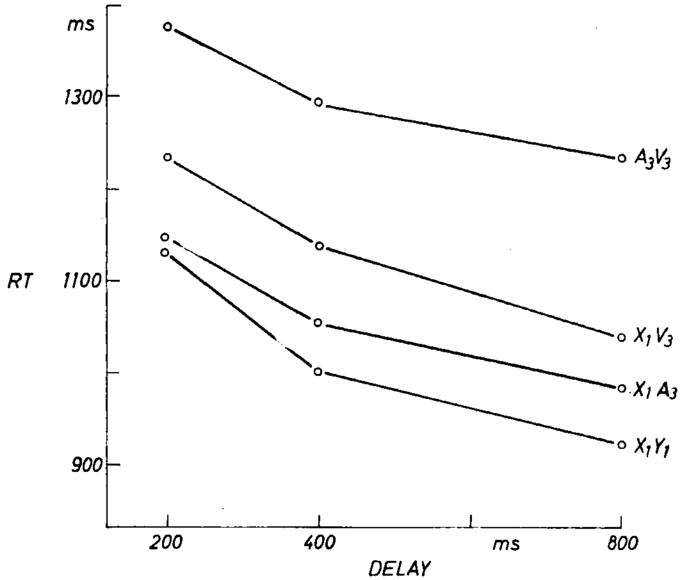

Fig. 3: Reaction times for correct rejections as a function of delay for different fan conditions.

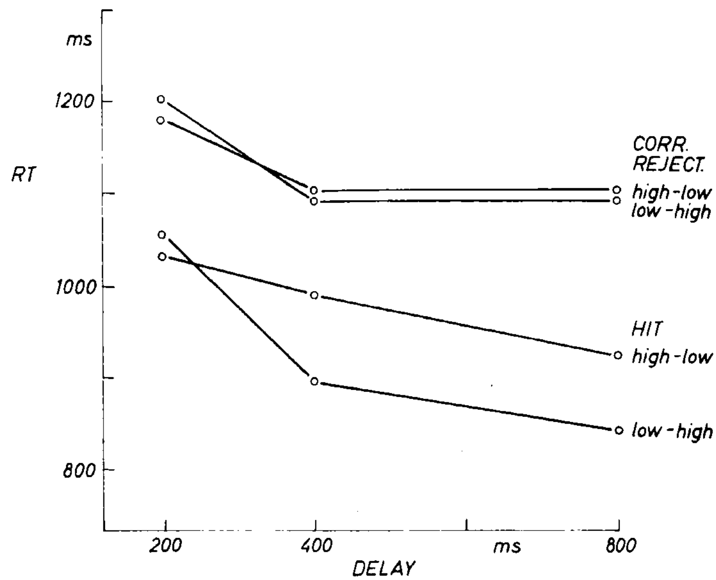

Fig. 4: Reaction times for different orders of presentation as a function of delay.

when the first process is the faster one. Leaving aside that this corresponds to common sense the result contradicts what King and Anderson conclude from the ACT model (Anderson 1976). The model described below predicts in the correct direction. For the correct rejection, however, there is apparently no effect of presentation order. This poses a problem for the KING and ANDERSON model as well as for ours.

The model

The model that we use to analyse the data is similar in spirit to the models used by THORNDYKE and BOWER (1974) and KING and ANDERSON (1976). The assumptions can be divided in two parts: (1.) Assumptions about the search process (2.) Assumptions about the mechanism of speed accuracy trade off. With respect to the first part we make the following assumptions: When probes p_1 and p_2 are presented, the search process tries to find a link between the token nodes corresponding to the two probes. This search process starts from the token nodes as soon as the probes are encoded. The search processes that start from the two probes are assumed to be independent and in parallel, but since the two probes are not presented at the same time the second search process starts with a delay. For simplicity we assume that the encoding time is a constant and the same for both probes. Then the search processes from the two token nodes have the same delay as the probes. We assume that the search time is determined by the fastest of the two search processes. There is one exception however: When the search from the first probe is terminated before the second probe has been encoded, then the subject cannot yet make a decision and has to wait until the second probe has been encoded. To simplify the mathematical analysis we assume that the search times from the token nodes are exponentially distributed random variables with rates depending upon the probe type and the propositional fan.

We assume that the speed-accuracy tradeoff is governed by a deadline mechanism, that means, depending upon the speed instruction the subject is setting a deadline. When the search has been terminated before the deadline expires the subject makes a correct response with probability one (assuming perfect memory). If the search time exceeds the deadline, then the subject responds before the search is finished and guesses with probability g that the two probes are from the same sentence. We assume that the deadline is an exponentially distributed random variable with a rate depending upon the speed instruction. The deadline process starts when the second probe has been encoded.

With these assumptions we can derive the probabilities of correct responses and the expected latencies.

The expected latency can be expressed as the sum of two components: The minimum of search time S and deadline Z plus an unspecified residual time R that is uncorrelated with the search time and contains processing time for encoding, decision and motor program. R is the same in all experimental conditions. We define the search time from the encoding of the second probe. This has the consequence that if the search from the first probe is terminated before the encoding of the second probe then the search time is zero.

Let a, b, c be the rates of the exponential distributions for the search from the first probe, from the second probe and for the deadline respectively. Then the expected latencies for correct responses are given by. (We omit the residual time R in the formulas.)

$$(1) \quad E(RT/C)\,P(C) = ((a + b)/(a + b + c)^2 + cg/(a + b + c)^2) \exp -aD$$

where D is the delay between the probes. The equation has the following intuitive interpretation: With probability $(1 - \exp -aD)$ the search process for the first probe is finished before the encoding of the second probe. Then the expected search time is zero. With probability $\exp -aD$ the search from the first probe is not finished before the encoding of the second probe. Then a correct response is given when either the two search processes are faster than the deadline with probability $(a + b)/(a + b + c)$ or the deadline is faster with probability $c/(a + b + c)$ and the subject makes a correct guess. In both cases the expected time is $(1/a + b + c))$ which is the expectation of the minimum of three exponentials.

The expected latency for incorrect responses is

$$(2) \qquad E(RT/\bar{C})\,P(\bar{C}) = (c(1 - g)/(a + b + c)^2) \exp -aD$$

The probability of a correct response C is

$$(3) \qquad P(C) = 1 - (c(1 - g)/(a + b + c)) \exp -aD; \qquad P(\bar{C}) = 1 - P(C)$$

For the data analysis it is more convenient to work with the conditional expectations $E(RT/C)$ and $E(RT/\bar{C})$. When these are computed from (1) (2) and (3) it can be shown that $E(RT/\bar{C}) = 1/(a + b + c)$ is independent of D and $E(RT/C) < E(RT/\bar{C})$.

It is our aim to predict the reaction time for correct answers to positive and negative probes as well as the frequencies of correct and false responses simultaneously. Our first results of the parameter estimations look quite promising. However, the model fitting is not yet finished. But a qualitative evaluation can already be made: The salient qualitative features of the model are:

1. It predicts the change of latency and probability correct with the delay between the probes rather well.
2. The effect of the order of probe presentation (high-low fan versus low-high fan) is accounted for.

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Information Processing in the Verification of Sentences and Pictures

J.-C. VERSTIGGEL

1. Introduction

In this paper we report the main lines of research that are currently explored in our laboratory by the method known under the name of sentence-picture verification.

This method was first initiated in the sixties by GOUGH (1965) and SLOBIN (1966), in early psycholinguistic studies about the psychological reality of grammatical transformations. Subjects were presented with a sentence, and then asked to verify if it was true or false in regard to an accompanying picture; they were to decide, as quickly as possible, if the picture was correctly described by the sentence.

A great number of models have been generated to account for the resulting latency data. Generally, they include a chronometric stage analysis (DONDERS, 1969, STERNBERG, 1969): The total time taken to reach a decision about the truth of a sentence is decomposable into a series of successive, independent and presumably additive mental operations.

However, it seems possible to distinguish between two directions in current research:

(a) One direction uses the sentence-picture verification task in order to deal with the nature and the functional properties of the cognitive representations of linguistic and pictorial information. It is assumed that the sentence-picture comparison involves:

– Either one common abstract cognitive representation of sentences and pictures, to which these two kinds of information can be reduced (ANDERSON and BOWER, 1973, CLARK, 1974);

– Either an "interface" system, which translates the two specific representations of the linguistic and pictorial information (PAIVIO, 1971, SEYMOUR, 1974, TVERSKY, 1969, 1975).

(b) The other direction uses the sentence-picture verification task in order to deal with the comprehension of language. Here the goal is to provide a description of models for linguistic information processing. This linguistic information, therefore, will be emphasized, whereas the pictorial information will serve as a mere decision criterion (CARPENTER and JUST, 1975, CHASE and CLARK, 1972, TANENHAUS, CARROLL and BEVER, 1976, TRABASSO, 1972).

2. Sentence-picture verification task as a method of studying the nature of cognitive representations

What do people do when comparing linguistic and pictorial information? Sentence-picture verification tasks can provide us with clues. In the model proposed by CHASE and CLARK, coding processes lead to an isomorphic representation that sentences and pictures share in common, under the form of linguistic descriptors. This model was relevant in situations in which the two terms to be compared were presented simultaneously; however, with a successive presentation paradigm, it has been shown (TVERSKY, 1975) that subjects use a rather figurative representation of sentences, in order to compare them with the pictures.

The possibility of a dual coding is a problem in itself. Abstract sentences don't lend themselves easily to figurative representations. Even with concrete sentences, figurative representations are not always easily constructed, as it is the case with negative constructions (see HOFFMANN and KLIX' 1977). Therefore experimental research mainly deals with sentences that people can easily relate to an unambiguous representation, e.g., "The door is open", "The door is not closed", "The star is above the circle", and so on... This being so, subjects presumably begin by encoding sentences on the basis of their linguistic structures, constructing an abstract, conceptual representation. The comparison with a pictorial referent leads subjects to translate this abstract representation under the form of a pictorial encoding.

If two modes of encoding of sentences and pictures are possible, the problem arises to know which factors will be responsible for the choice of the prevailing mode of representation.

This problem has been recently studied in an experiment conducted by DUBOIS and WEILL (1977). "Uncertainty" was manipulated in order to answer the following question: To what extent will the processing of linguistic and pictorial informations depend on the subject's knowledge of the modality of the second term of the comparison? In other words, is it possible that the constraints of the experimental situation (possibility or impossibility of anticipating the modality of the second term of the comparison) affect the nature of the cognitive representation of sentences and pictures?

In this experiment, subjects were presented with (a) sentence-sentence, (b) sentence-picture and (c) picture-sentence conditions. These conditions were crossed with two modes of presentation of the second term: It was always a sentence or a picture, or it was either a sentence or a picture, with equal probability. These two conditions of presentation were referred to as Homogeneity condition and Heterogeneity condition, respectively.

The experimental material was similar to CHASE and CLARK'S (1972). Eight sentences were constructed by crossing the four following binary descriptors:

(a) Syntactic function: Positive vs. negative sentences;
(b) Preposition: Above vs. below;
(c) Order of appearance of the elements: Star-circle vs. circle-star;
(d) Veracity: True vs. false.

The subjects were presented with a first stimulus in a tachistoscopic channel for a 2-second period. At the end of this period, the first stimulus disappeared, and the second stimulus was shown. The onset of the second stimulus triggered a millisecond timer which stopped when the subject pressed either a "true" or a "false" button.

The main results of this experiment were as follows:

(1) *The second term is a sentence.* RT's in the Homogeneity situation were similar in the picture-sentence and the sentence-sentence conditions. The knowledge of the linguistic nature of the second term of the comparison seems to have led subjects to

Tab. 1: *Mean verification times (cs) as a function of the uncertainty of the materials (Homogeneity vs. Heterogeneity situations) and the nature of the terms to be compared (from Dubois and Weill, 1977)*

Condition	Situation	
	Homogeneity	Heterogeneity
First sentence, then picture	126	149
First picture, then sentence	250	///
First sentence, then sentence	247	238

emphasize a linguistic encoding of the first term, irrespective of its nature (linguistic or pictorial). Moreover, RT's in the Heterogeneity condition (sentence-sentence only) were not increased. On the contrary, they were slightly shorter, but this difference did not reach significance.

(2) *The second term is a picture.* RT's were considerably shorter in this condition than under the conditions under which the second term was a sentence: They were reduced by half or so. This tends to prove that subjects emphasized a pictorial encoding of the sentence; nevertheless, the fact that RT's were significantly shorter in the Homogeneity condition than in the Heterogeneity condition tends to prove that this pictorial encoding prevailed in the Homogeneity situation only: When the subjects remained in a state of uncertainty regarding the nature of the second term of the comparison, a linguistic encoding of the sentence prevailed over a pictorial one.

3. Sentence-picture verification task a method of studying language comprehension

The measuring of the amount of time people take to decide whether a sentence is true or false of an accompanying picture is a technique which can allow us to draw inferences about the internal representation of that sentence. More precisely, it enables us to draw inferences about hypothetical transformative operations that subjects are supposed to perform on the basis of their representation. From this point of view, the comprehension of a sentence is defined here as a complex, multiple process, in which (at least) two successive stages may be distinguished:

(a) *Stage 1*: The first stage in the processing of a sentence corresponds to the elaboration of an internal, abstract cognitive representation of the meaning of that sentence. This representation will be called the "signification" of the sentence. One of the most powerful descriptions of the signification is a propositional one (Predicate/Arguments). It is quite plausible that people directly represent and access linguistic information in a complex form, presumably by performing the minimal operations that are necessary for understanding the sentence. Under these conditions, the representation of the predication of the sentence will reflect its grammatical complexity. For instance, a sentence like "The door is not open" could be internally represented as (False [Open (Door)]).

(b) *Stage 2*: The second stage in the processing of a sentence corresponds to the subsequent operative transformations that people may be led to perform over the initial minimal representation. When given sufficient time people will presumably convert the initial representation into a simpler one; if such mapping is possible, the transformation of the initial representation will be used because it simplifies the representation and therefore reduces the number of operations if this information is to be manipulated again. In the example chosen, the sentence "The door is not open" will be represented (1) in a complex form like (False [Open (Door)]), and (2) subsequently reduced to a simpler representation, presumably on a form like [Closed (Door)].

The goal of several research projects conducted in our laboratory is to discover under what conditions such a conversion is possible. To illustrate this problem, let me tell you about an experiment which DUBOIS and I have conducted recently (DUBOIS and VERSTIGGEL, 1978).

It was hypothesized that different kinds of "emphasis" would lead subjects to perform different kinds of transformations, on the basis of a common abstract, cognitive representation of the linguistic information. The basic semantic frame took the following form:

"(L'étoile X le rond) (est X n'est pas) (au dessus X au-dessous) (du rond X de l'étoile".

Two kinds of cleft-sentences were constructed:

(*1*) *Argument-emphasizing sentences*:
This corresponds to the French construction:
(C'est X ce n'est pas) (l'étoide X le rond) qui est (au dessus X au—dessous) (du rond X de l'étoile).

(2) *Predicate-emphasizing sentences*:
The corresponding French construction was:
(C'est X ce n'est pas) (au dessus X au dessous) (du rond X de l'étoile) qu'est (l'étoile X le rond)

It was hypothesized that, in the first stage, these two kinds of cleft-sentences would be internally represented in the same propositional way, such as:

(Truth value [Preposition (Argument$_1$, argument$_2$)]), for instance: (False [Above (Star, circle)]) for the two sentences "Ce n'èst pas l'étoile qui est au-dessus du rond" and "Ce n'est pas au-dessus du rond qu'est l'étoile".

However, in the second stage, the locus of the emphasis (argument or predicate), together with the constraints of the experimental situation, might lead subjects to convert that cognitive representation into a simpler one, before comparing it with the picture. Therefore, we assumed that, when given sufficient time, people perform a simplifying convertive transformation over the negative sentences.

(a) *Argument-emphasizing negative cleft-sentences.*
It was assumed that negative sentences like "Ce n'est pas l'étoile qui est au-dessus du rond" would be converted into positive sentences like "C'est le rond qui est au-dessus de l'étoile". At the end of this conversion, the preposition remains unchanged. Therefore we predicted that the effect of the lexical marking of the preposition would be a simple, constant one: Indeed, it is an established fact (see CHASE and CLARK' 1972) that, in this type of experiments, sentences containing a marked prepositional form (below) take longer to be verified than sentences in which an unmarked form

(above) appears. Therefore we predicted that, irrespective of the grammatical form of the sentence (positive or negative), the subjects would take longer to verify sentences containing "below" than sentences containing "above".

(b) *Predicate-emphasizing negative cleft-sentences.*
It was assumed that negative sentences like "Ce n'est pas au-dessus du rond qu'est l'étoile" would be simplified into positive sentences like "C'est au-dessous du rond qu'est l'étoile". At the end of this conversion, the preposition has changed. Therefore we predicted that the effect of the lexical marking of the preposition would be a complex one: The fundamental effect will remain unchanged for the positive sentences; on the contrary, it will be reversed for the negative sentences; indeed, negative "above-sentences" are internally represented as positive "below-sentences"; in the same way, negative "below-sentences" are internally represented as positive "above-sentences". Therefore the prediction concerning RT's was: Negative "above-sentences" will take longer to be verified than negative "below-sentences".

The results (see fig. 1) were in total agreement with these predictions. They tended to prove that people perform different operative transformations over the basic

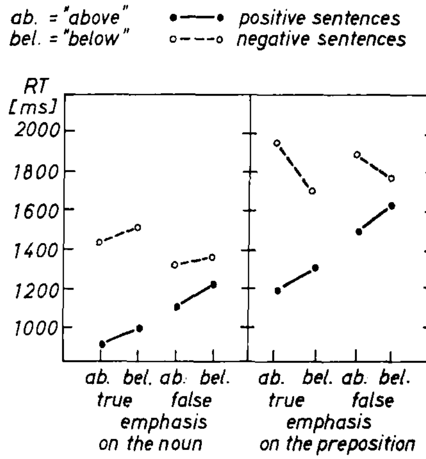

Fig. 1: Mean verification times (in ms) in the two conditions of emphasis, for the positive and negative sentences, as a function of the nature of the preposition (above/below) and the nature of the response (true/false) (from DUBOIS and VERSTIGGEL, 1978).

representations of linguistic informations, according to the functional properties of the elements to be transformed. We are conducting further experiments, in order to make a more detailed study of the relevant factors in this type of experimental situation.

4. Conclusion

In summary, the sentence-picture comparison is a technique which enables us to study *the nature of the linguistic representation*, together with the *transformative operations* that people are able to apply to this representation when performing comparative tasks. These transformations are related to the temporal evolution and the corresponding modifications of the representation in memory. However, nothing has been said in this paper about the processes involved in the comparison itself. What do people do *in order to compare* a sentence against a picture? This is another problem, that will be studied by constructing comparison models.

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The Method of Analogy Recognition for the Determination of Semantic Relations in Long-Term Memory

F. KLIX and E. VAN DER MEER

1. In present psychological research, the question is increasingly investigated as to how our knowledge, especially the linguistically imparted one, is organized in Semantic Long-Term Memory (LTM). It is known that informations stored in memory do not exist independently but that they enter into various different relations—a reflection of really existing connections between objects, events, scenes, etc.

These relations between units in semantic LTM, i.e. the concepts, are referred to as semantic relations. In literature, however, we find different approaches to the classification of these semantic relations.

As established in the KLIX paper, we in our work distinguish between presumably stationary stored, property-alien interconcept relations and the property-related intra-concept relations which have to be generated operationally.

The existence of two distinguishable classes of semantic relations in LTM can be verified in psychological experiment.

This becomes evident also in the change of orientation region, i.e. when experience-dependent interconnection of space-time correlations are weakened. We investigated this aspect with the help of analogy-demands.

2. It is the purpose of this paper to further differentiate this sub-division of semantic relations into inter- and intra-concept relations. For this purpose we employ the method of analogy recognition.

The first figure illustrates the general version of an analogy. It reads:

$$\mathfrak{A} : \mathfrak{A}' \sim \mathfrak{B} : \mathfrak{B}'$$

$$\begin{array}{ccc} \mathfrak{A} = [A, (R_i)_{i \in I_1}] & \xrightarrow{R_i^*} & \mathfrak{A}' = [A', (R_i)_{i \in I_2}] \\ \downarrow S & & \downarrow S' \\ \mathfrak{B} = [B, (R_i)_{i \in I_3}] & \xrightarrow{R_j^*} & \mathfrak{B}' = [B', (R_i)_{i \in I_4}] \end{array}$$

Fig. 1: General version of an analogy.
We have structures $\mathfrak{A}$, $\mathfrak{A}'$ as the original domain. They contain states A and A′ and relationships between them. The same is in the derived (or picture) domain $\mathfrak{B}$, $\mathfrak{B}'$. R_i^* determines the differences of the relationship between both structures.
Restrictions with regard to mappings S and S′ are omitted here (see KLIX and PÖTSCHKE, 1977).

The structures $\mathfrak{A}$ and $\mathfrak{A}'$ form the original domain, the structures $\mathfrak{B}$ and $\mathfrak{B}'$ the derived domain of the analogy. Each structure consists of a number of states and a number of relations.

An analogy is present when there is at least one identical relation between original and derived (or picture) domain.

The next figure (fig. 2) shows what we intend to understand by a *semantic* analogy: It exists between concepts of natural language which can be defined by word marks. The property sets and connections existing between these properties, form the basis

$$\begin{array}{ccccl} \mathfrak{A} = (WM_1, M_1) & \xrightarrow{R_1} & \mathfrak{A}' = (WM_2, M_2) & & \text{original domain} \\ \downarrow S & & \downarrow S' & & \\ \mathfrak{B} = (WM_3, M_3) & \xrightarrow{R_2} & \mathfrak{B}' = (WM_4, M_4) & & \text{derived (or picture) domain} \end{array}$$

with:

$\mathfrak{A}, \mathfrak{A}', \mathfrak{B}, \mathfrak{B}'$ = struktures (concepts)
WM = word mark
M = property set
S, S' = mappings
R_1, R_2 = relations

Fig. 2: General version of a semantic analogy.
It exists between concepts of natural language (defined by word marks). The property sets and connections existing between these properties form the basis for semantic analogy formation.

for semantic analogy formation. For the time being we have considered the properties belonging to the property set of a concept as being equal.

We assume that a semantic analogy can be decided when the following applies:

The concepts of the original domain have in their set of properties identical or comparable properties. Therefore a specific relation can be generated between both concepts. The same holds for the picture domain.

Thus, if at least one identical relation exists in the original and in the picture domain, we are faced with a semantic analogy.

3. From the above said, consequences can be derived which the next figure (fig. 3a) is to elucidate:

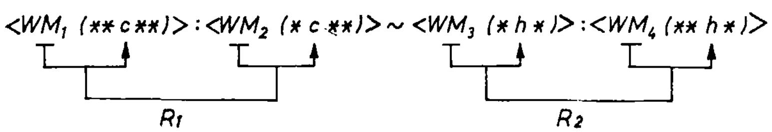

Fig. 3: a) Scheme on property sets of concepts (WM = word marks; a, b.. = properties). The identification of a property as element of a concept structure is an elementary recognition performance. We call this relation attribute relation.

(+)-examples

Encoding
$\text{Ex}(R_1) \rightarrow R'_1$
$\text{Ex}(R_2) \rightarrow R'_2$
$\sim(R'_1, R'_2) \rightarrow +$

(−)-examples

Encoding	
$\text{Ex}(R_1) \rightarrow$	R'_1
$\neg\text{Ex}(R_2) \rightarrow$	$\neg R'_2$
$a_i[+] \rightarrow$	$a_i[-]$

b) The hypothetical decision algorithm for the attribute relation. Left side: positive examples, right side: negative examples, rejections are necessary (a_i means the reaction disposition).

We have presented here the identification of a property as element of a concept structure as an elementary recognition performance. We call this relation attribute relation. Examples are grass: green or fire: hot.

From this scheme on property sets of concepts we shall now derive our assumptions as to the cognitive effort required for the recognition of attribute relations.

Figure 3b shows the hypothetical decision algorithm for the attribute relation.

In case of a positive example (e.g. blackboard : black ~ blood : red). identification takes place after the activation of the four concepts, i.e. their property sets. Comparisons between them are establishing the specific relation R_1. This means that an identical property is recognized in the property sets of the concepts in the first concept pair. Then identification of the corresponding relation R_2 takes place between the second concept pair of the analogy. This is followed by an equivalence test for both relations. If this equivalence exists, the analogy is accepted.

In the negative examples we have used (e.g. grass: green ≁ ice: warm) no common relation R_2 can be found in the second pair of the analogy. Thus the equivalence test of the relation is not necessary. Instead the positive reaction disposition of the subject changes. Evidence for the existence of a general positive reaction disposition of the subject were found by CARPENTER and JUST (1975), as well as HOFFMANN and KLIX (1978) in investigations of sentence-picture comparison.

The revision of this positive reaction disposition is then followed by rejection of the analogy.

Compared to the attribute relation, according to the same fundamental assumption, the intra-concept relation of opposite or contrast requires a higher cognitive effort for recognition. The next figures are to illustrate this (fig. 4a, b):

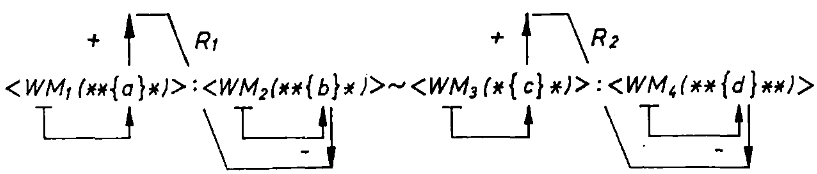

Fig. 4: a) The contrast relation between concept pairs.
The common property dimension has to be established. This distinguishes the demand from all the other requirements.

(+)-examples	(−)-examples
Encoding	Encoding
Identification of property dimension (2×)	Identification of property dimension (2×)
Ex $(R_1) \rightarrow R_1'$	Ex $(R_1) \rightarrow R_1'$
Ex $(R_2) \rightarrow R_2'$	$\ulcorner$Ex $(R_2) \rightarrow \ulcorner R_2'$
$\sim(R_1', R_2') \rightarrow +$	$a_i[+] \rightarrow a_i[-]$

b) The hypothetical decision algorithm for the contrast relation.

In the contrast relation (e.g. light: dark ~ big: small), the common property dimension has to be established before the detectability of R_i. This distinguishes the demand from all the other requirements. It constitutes the basis for relation formation between both concepts of a pair. In case of our example (light : dark ~ big : small), we are concerned with the dimension of brightness in the first concept pair and with the dimension of size in the second concept pair. The relational property R_1 then is the contrary manifestation on the respective dimension.

The intra-concept relation of comparative involves even more effort. An example for this is bright : brilliant ~ big : giant. This can be seen from the next figure (fig. 5a).

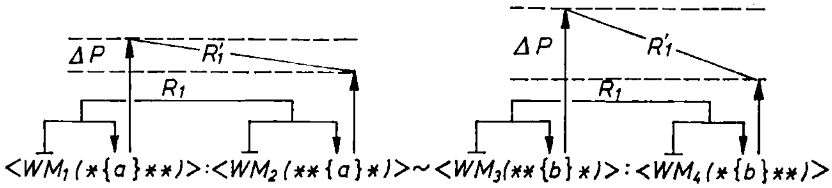

Fig. 5: a) The comparative relation between concept pairs. The properties and the property dimensions are given with the concepts. The properties relevant between one concept pair are located along the same manifestation direction of this dimension, however, at different positions.

(+)-examples

Encoding
Ex (R_1)
$\Delta p(R_1) \rightarrow R'_1$
Ex (R_2)
$\Delta p(R_2) \rightarrow R'_2$
$\sim(R'_1, R'_2) \rightarrow +$

(−)-examples

Encoding
Ex (R_1)
$\Delta p(R_1) \rightarrow R'_1$
$\neg$Ex $(R_2) \rightarrow \neg R'_2$
$a_i[+] \rightarrow a_i[-]$

b) The hypothetical decision algorithm for the comparative relation.

In this type of relation, the properties and the property dimensions are given with the concepts. The properties relevant between one concept pair are located along the same manifestation direction of this dimension, however, at different positions. Let us now turn to the hypothetical recognition procedure (fig. 5b): The scheme given for positive examples shows that the relevant properties and property dimensions of the first concept pair are first to be identified in the analogy (ergo R_1).

Then the manifestation difference of properties in one direction of the common property dimension has to be established. This difference $\Delta p(R_1)$ is introduced as new relation R'_1.

It constitutes the second step in complying with the demand. These two steps are repeated in the second concept pair of the analogy. Subsequently, equivalence test takes place.

In the negative examples we used (such as lean : thin ~ wise : blue) no common property dimension exists in the second concept pair and thus no specific relation R'_2. Therefore, the test procedure of the self-terminating comparison process can stop here earlier. We summarize:

According to our deliberation, attribute relation should require less cognitive effort for recognition than contrast relation, and contrast relation in turn should require less effort than comparative relation. Here again, negative examples of comparative relation should be recognized more readily than the positive ones. Our deliberations for these algorithmic procedures have been derived from analogy experiments (KLIX and VAN DER MEER, 1978). There we were also able to measure the time required for processing one figural property. If we now go one step further, assuming that the activation of one elementary concept property requires the same cognitive effort as the recognition of a perceptive property, then the necessary recognition times can be calculated from the algorithmic procedures.

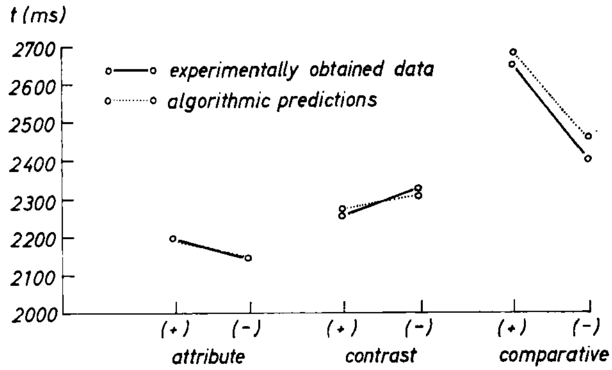

Fig. 6: Comparison between algorithmic predictions and the experimentally obtained data for the attribute, contrast and comparative relation; (+) positive examples, (−) negative examples.

The next figure (fig. 6) shows a comparison between these algorithmic predictions and the experimentally obtained data: we see that the recognition times predicted by the algorithm do not significantly differ from the empirical data. Hence it follows (1) that there is good qualitative concurrence between our assumptions on the recognition effort for the considered intra-concept relation type and the data obtained by experiment.

Furthermore we find (2) a high degree of quantitative concurrence in the time constants which we have adopted from the analysis of analogy recognition experiments with geometric structures. This points to the assumption that semantic properties indeed influence information processing in the same manner as figural properties.

What is the summarized conclusion from our results?

They support the assumption that the defined class of intraconcept relations can be further differentiated, namely according to the cognitive effort involved in property comparison processes and thus in decision procedures.

In this context, the question arises for a differentiation within the class of inter-concept relations.

The KLIX paper in this volume already mentions the connection between the valence and the propositional attributes of interconcept relations. This result leads to assume that inter-concept relations apparently cannot be distinguished by the cognitive effort of comparison processes but according to the degree of complexity of their integration in memory as expressed in the quantity of attached attributes.

4. It is now our purpose to continue this sub-division of both classes of semantic relations, to continue it by variation of the typicality of relations. Typicality in our

definition is the degree to which connections between concepts are characteristic. It could be objected to what has been said so far that the results on the distinguishability of intra- and inter-concept relations are conditioned by the typicalit yof the relations considered.

At the same time it is a very critical test condition to establish how the variation of typicality effects intra- and inter-concept relations.

If our assumptions stated so far as to the memory-distinguishable representation of intra- and inter-concept relations are correct, then a decreased typicality should influence both classes of semantic relations in an entirely different way. The cognitive effort for intra-concept relations should not be influenced by the variation of typicality of relations, while this should have a strong impact on the cognitive effort for inter-concept relations (the reasons are given later on). In order to test our expectations, we have conducted the following experiment:

We construct concept pairs which are connected by intra- and inter-concept relations. Now we vary (1) the substance homogenity or the semantic distance of the concept pairs (i.e. whether they belong to one or two orientation regions) and (2) the typicality of relations between the concepts of each concept pair.

The determination of degrees of typicality and orientation regions is effected empirically in the framework of rating experiments. The subject is now expected to decide as quickly as possible whether the relations existing between two concepts are analogous to those existing between two other concepts.

The results obtained in these experiments can be seen from the following figure (fig. 7):

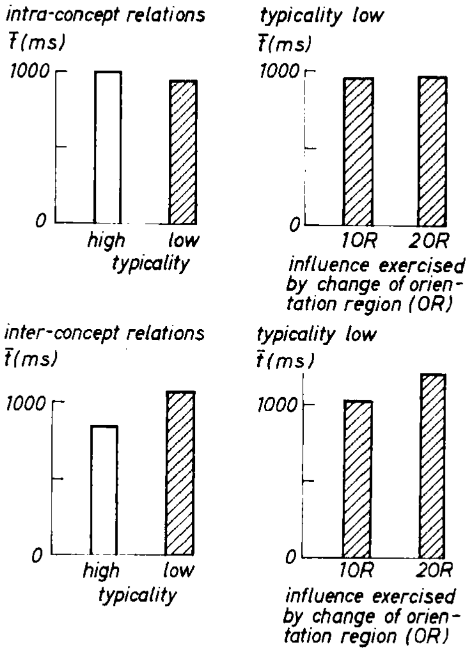

Fig. 7: The cognitive recognition effort for intra- and inter-concept relations, depending on typicality and orientation region. The variation of typicality has a different influence on both classes of semantic relations.

It shows the cognitive recognition effort for intra- and interconcept relations, depending on typicality.

Intra-concept relations are not significantly influenced by variation of typicality. Neither does reduction of typicality increase the recognition effort as a whole, nor is the change of orientation region noticeable. On the other hand, inter-concept relations require a significantly higher recognition effort when the typicality is reduced and the influence exercised by change of orientation region remains. Thus, variation of typicality has an entirely different influence on both classes of semantic relations. How is this to be understood?

Intra-concept relations are not significantly influenced by variation of typicality. This is also natural according to our previous hypothesis, because concept properties belonging to the property set are activated with the word marks. Thus, they are available for comparison. Comparison processes thus should *not* depend on how typical the activated properties are and in which orientation region the respective word marks are interconnected.

How is the situation in case of inter-concept relations?

Less typical inter-concept relations presumably have to be verified by searching processes in memory. Their memory integration as expresses in the quantity of attached attributes is more complex than in case of typical inter-concept relations. It is now necessary to suppress the irrelevant propositional attributes and to identify the relevant relation. Thus the total recognition effort for less typical inter-concept relations increases.

The change of orientation region necessarily has to continue to have an effect, because, if the immediate interrelations of the inter-concept relations are fixed in the orientation regions then to exceed this limit must yield strong in effects in terms of time.

Thus our results support the distinction between two classes of semantic relations in Semantic Long-Term Memory which are differently represented.

Two methodical conditions—change of orientation region and variation of typicality—yield different time effects in both classes of semantic relations.

Our results let it seem probable that intra-concept relations are generated irrespective of the degree of typicality by property comparison. The cognitive effort here depends on the degree of complexity of the comparison processes and thus on the decision procedures. Inter-concept relations, on the other hand, constitute stationary memory entries. The recognition effort required for them depends on the quantity of attached propositional attributes.

The immediate interconnection of inter-concept relation is fixed in the orientation regions. If these are transgressed, the recognition effort increases.

It will be left for further investigations to determine empirically whether or not our interpretation of the nature of semantic relations as presented here is correct.

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The Effect of Semantic Relations in Search Processes within Well-Trained Memory Structures

W. Krause, H. Lohmann and G. Teschke

1. The Problem

Problem solving processes may be conceived of as search processes within memory structures. To elucidate them presupposes knowledge of memory structure properties. Such knowledge, however, can only be gained if these properties are at least to some degree shown to be independent of the cognitive task involved.

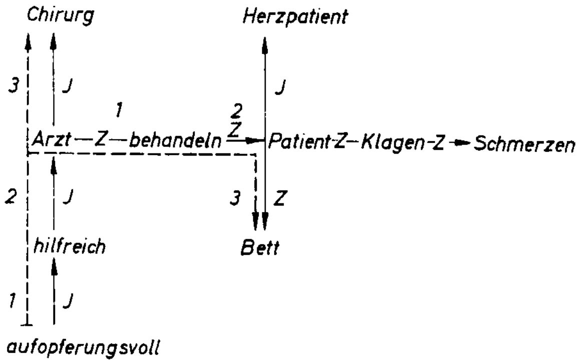
The present paper intends to present further experimental evidence of invariant properties of memory structures. We will examine whether the two classes of semantic relations found in the analogy formation paradigm (Klix, Kukla and Klein, 1976, Hoffmann and Trettin, Klix and van der Meer in this volume) also prove effective in more complex problem solving processes. We start from two well-known findings in order to integrate them within the present approach.

(I) Hayes (1966) has shown the effect of structural components in searching well-trained asemantic memory structures (tracing a path in a maze); Mayer (1976) has demonstrated the influence of semantic memory in such experimentation.

(II) Klix, Kukla and Klein (1976) have identified two distinct classes of semantic relations in human memory. Both of them have been established in analogical reasoning situations.

Combining these two results our question is, whether the two classes of semantic relations are also effective in problem situations more complex than the ones used in these studies. If so, they should prove to be invariant properties of memory. We decided to use a situation similar to the "spy" problem of Hayes (1966). In analogy to the complex maze in Hayes' experiments a graph was constructed with different semantic realizations along its edges. Certain nodes of the problem graph were, so to say, linked by means of intraconceptual relations (J) (COMPARATIVE, QUALITY, SUBORDINATION relations) and others by means of interconceptual relations (Z) (AGENT, OBJECTIVE, LOCATION relations). In the control situation nodes were connected by neutral relations. Figure 1 shows the two problem graphs used in the experiment (a) semantic fields, analogous to the material from Klix, Kukla and Klein (1976), b) neutral fields, the nodes of the problem graph labelled with male first names).

Our main hypothesis is as follows. If the temporal differences discovered for inter- and intraconceptual relations in analogical reasoning experiments reflect, in fact, a task-independent, invariant property of human memory, a similar pattern of differences should emerge in more complex problem solving situations. In our experiment Ss had to produce sequences of words by finding paths through a problem graph. We assume for this process that the time reduction in comparison to a neutral situation is larger in the case of interconceptual relations than in the case of intraconceptual relations. Confirmation of the assumption is supposed to be evidence of the invariance of the proposed property of human memory structures. Its falsification, on the other hand, would call in question the invariance of memory structures.



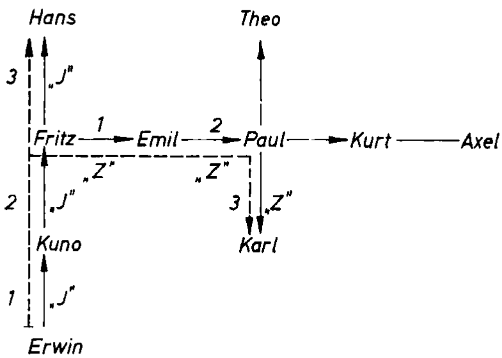


Fig. 1: Two problem graphs used in the experiment.
a) semantic field, the edges of the graph being marked by semantic relations, for instance "Arzt — behandeln" in the AGENT relation;

b) neutral field showing the same graph structure as a) expect for the asemantic marking of edges, e.g. by "Fritz — Emil".
Different reductions of search time for neutral and semantic fields are expected.

2. Procedure

The experiment consisted of three parts: a learning series, a search series (se) and a delayed search series (dse). In the learning experiment Ss were instructed to learn pairs of words connected by different (neutral or semantic) relations from the problem graph.

For instance:

Arzt	→ Chirurg
hilfreich	→ Arzt

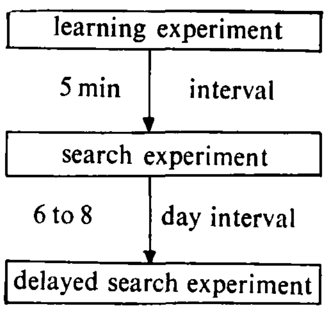
aufopferungsvoll → hilfreich
Arzt → behandeln
behandeln → Patient
klagen → Schmerzen

The learning experiment was stopped following the third error-free reproduction of second element of each pair of words. In such a way we hoped to generate a controllable human memory structure. In the search experiment (se) Ss were asked to produce word sequences after being given the first and the terminal elements of the sequences.

For example: Using the trained word pairs produce a sequence of words from:

"Arzt" $\xrightarrow{to}$ "Bett" or from
"aufopferungsvoll" $\xrightarrow{to}$ "Chirurg".

The two sequences in the graph are distinguishable in terms of the two classes of semantic relations (fig. 1). In the first case there are only interconceptual relations, whereas in the second there are only intraconceptual relations. Errors and search time (time for activation of single concepts) were recorded. In the second search experiment (dse) the same task was presented after an interval of 6 to 8 days. We thought such a delayed replication necessary because of the possibility that the time difference between inter- and intraconceptual relations might disappear due to an artefactual training effect of the learning series. This would imply for two semantic relations that they might both become activated as readily. To minimize this procedural influence the delayed search experiment was introduced, assuming that after a six to eight day interval the memory structure would be fairly similar to the natural structure.
The experimental pattern was as follows:



In order to exclude any influence of the problem graph structure we compared search times and errors obtained for semantic and neutral fields only for identical structures.

3. Results

3.1. Reduction of search time as influenced by semantic relations

The reduction of search time during activation of single concepts in word sequences completion, which is caused by the effect of semantic relations, has been reported in the literature (MAYER 1976). Our data support this finding. Figure 2 demonstrates average search times along some edges of the problem graph in the delayed search experiment for a neutral and a semantic field.

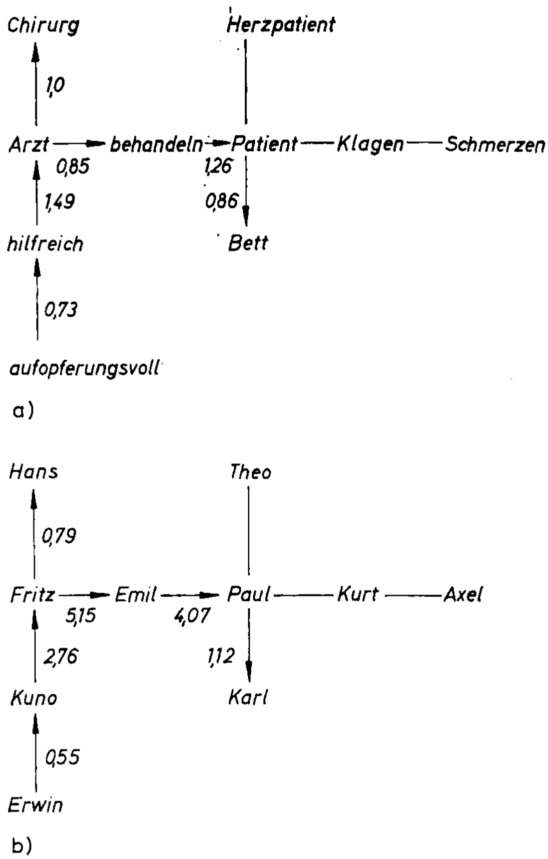


Fig. 2: Average search time (s) along several edges in the delayed search experiment for a) the semantic field and b) a neutral situation.

The data for case a) were obtained from three different fields, differences between fields being not significant. In case a) the search time was shorter than in case b).

The search experiment (se) reveals a similar trend. The notion of time reduction can be illustrated by way of distance differences in the specific memory structures. Figures 3 and 4 demonstrate the differing search times along the edges for the semantic and the neutral fields, obtained in the search and the delayed search series.

Figure 5 shows average search times and errors of the semantic and neutral fields, independent of problem graph structure.

Adding the results of the search experiment and the delayed repetition we get a reduction of search times and errors by nearly 50 per cent.

In the following section we turn to the basic question of the present paper, the influence of classes of semantic relations.

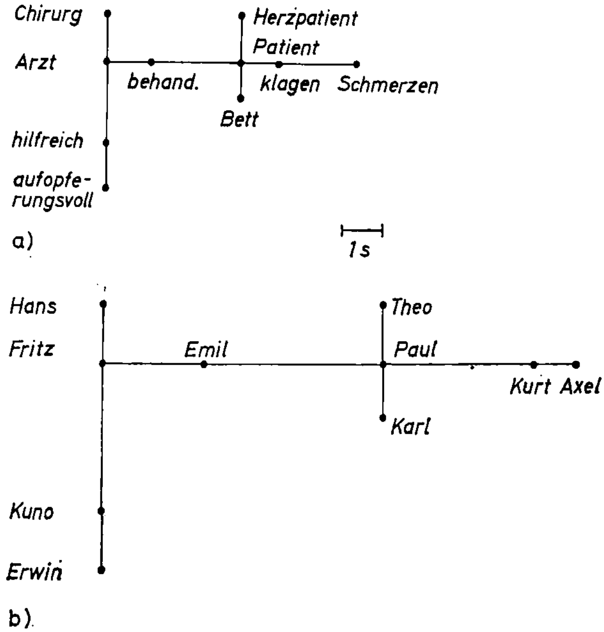


Fig. 3: Distances in the graph proportional to the search times.

a) semantic field,
b) neutral field.

Results obtained in the search experiment.

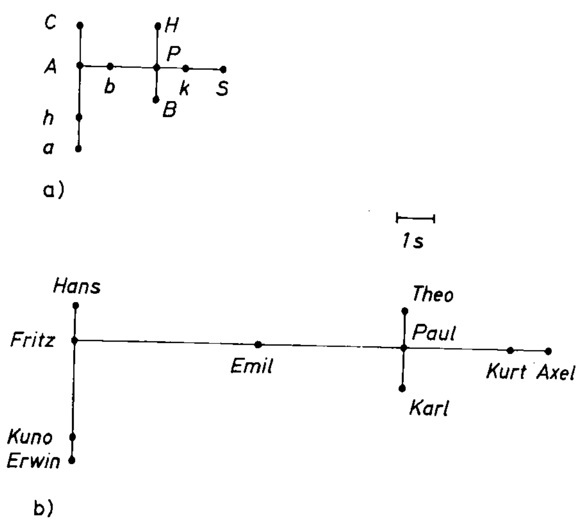


Fig. 4: Distances in the graph proportional to the search times (see fig. 3).
Results from the delayed search experiment.

The reduction of time in the semantic field as compared to the neutral field is obvious.

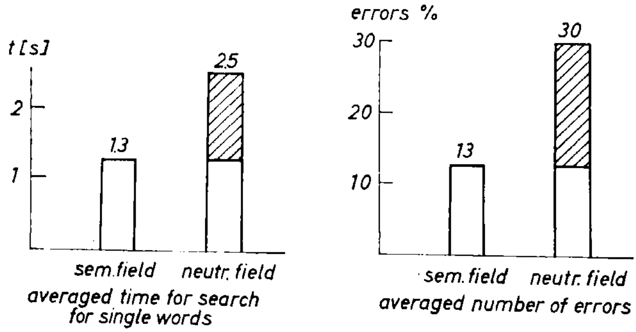


Fig. 5: Average search time for a single step and the average number of errors for both semantic and neutral fields.

3.2. Reduction of time and errors as a criterion for distinguishing between classes of semantic relations

The graphs in fig. 1 were constructed in the following way: one set of words was connected by intraconceptual relations and the other by interconceptual relations.

The two classes of semantic relations cannot directly be compared within the same graph because of the different structures of the subgraphs. Therefore, in each case we consider the differences of times and errors between neutral and semantic field for

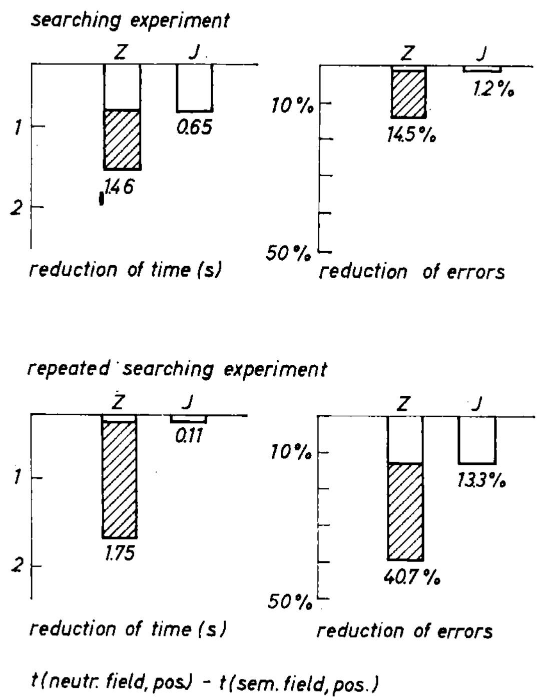


Fig. 6: Reduction of time and errors caused by interconceptual (Z) and intraconceptual (I) relations in search and delayed search experiment.
On an average search time is reduced by 0,8 s and, after a 6 to 8 day interval, even by 1,6 s, when the marking is interconceptual rather than intraconceptual.

identical subgraphs. Due to less cognitive effort a larger reduction of time in the case of interconceptual relations as compared to that of intraconceptual relations is expected. An appropriate outcome would fit in with the KLIX, KUKLA and KLEIN data. Figure 6 confirms our expectations.

Activation of concepts connected by interconceptual relations is 0.8 s faster than of those connected by intraconceptual relations. Within a period of 6 to 8 days this reduction of time increases to 1.6 s

$$(t\ (88) = 3.77; p < 0.001).$$

Accordingly, a greater reduction of errors is observed for interconceptual relations than for intraconceptual ones

$$(u\ (20) = 7.0;\ \ p < 0.05).$$

In other words, compared with the neutral concept field the error rate decreases more markedly in the case of interconceptual relations than for intraconceptual relations.

The following table demonstrates the experimentally obtained time measurements for search and delayed search experiments.

The symbols are:

$t_{\text{I neut.}}$ = the search time (s) (time for activating the next word in a sequence of words) for a relation in the neutral field in a position where within the semantic field an intraconceptual relation is found.

$t_{\text{I sem.}}$ = the search time for an intraconceptual relation in the semantic field.

$t_{\text{Z neut.}}$ = the search time (s) (time for activation of the next word in a sequence of words) for a relation in the neutral field in a position where within the semantic field an interconceptual relation is found.

$$\Delta I = t_{\text{I neut.}} - t_{\text{I sem.}}$$
$$\Delta Z = t_{\text{Z neut.}} - t_{\text{Z sem.}}$$
$$\Delta = \Delta Z - \Delta I$$
$$m = \text{average search time}$$
$$v = \text{variance}$$

ab. 1: *Search time (s) of the intra- and interconceptual relations in the neutral and the semantic field for fferent positions in the graph (cf. fig. 1)*

:arch experiment:

Positions in the graph	Search time										
	$t_{I_{\text{neut.}}}$	$t_{I_{\text{sem.}}}$*	$t_{Z_{\text{neut.}}}$	$t_{Z_{\text{sem.}}}$*	ΔI m	ΔI s	ΔZ m	ΔZ s	Δ	Sign.	number of subjects
1	0.99	1.21	2.37	1.21	−0.22	1.46	1.16	2.68	1.38	s	60
2	4.08	2.30	5.32	2.52	1.78	2.59	2.80	2.87	1.02	s	60
3	1.61	1.21	1.48	1.04	0.40	1.36	0.44	1.50	0.04	ns	60
Mean values					0.65	2.05	1.46	2.65	0.81	s	180

Delayed search experiment:

Positions in the graph	Search time										
	$t_{I_{neut.}}$	$t_{I_{sem.}}$*	$t_{Z_{neut.}}$	$t_{Z_{sem.}}$	ΔI		ΔZ		Δ	Sign. number of subjects	
					m	s	m	s			
1	0.55	0.73	5.16	0.85	−0.18	0.30	4.31	4.26	4.49	s	24
2	2.76	1.49	4.07	1.24	1.27	1.69	2.83	2.29	1.56	ns	18
3	0.79	1.00	1.01	0.86	−0.21	0.63	0.15	0.53	0.36	s	46
Mean values					0.11 **	1.08	1.75 **	2.87	1.64 **	s	88

* averaged over 3 different semantic fields
** determined from the total of 88 subjects

The relatively high variances gave rise to an analysis of the data of each single subject. From the average value of time differences followed that interconceptual relations cause a larger time reduction than intraconceptual relations in comparison with a neutral situation. We wanted to see whether this applied to all subjects or was just due to the averaging process.

We checked a total of 268 answers and in 175 cases found for search plus delayed search series a time reduction and in 93 answers an increase in the time required. So 65 per cent of responses came up to our expectations. The difference between this outcome and a random distribution, 134 answers showing a time reduction and 134 the opposite, is significant. Thus, our assumption has been confirmed. We are in fact justified in distinguishing between the two classes of semantic relations also in a more complex problem solving task, although in this task for intraconceptual relations a derivational procedure in the sense of KLIX, KUKLA and KLEIN (1976) does not seem necessary.

Let us, finally, consider the effect of each of the single relations and, in particular, examine, if their class membership is reflected in our data.

3.3. Reduction of time through specific relations

The following table demonstrates the reduction of time for each single relation in the search and delayed search experiment. The first three relations are marked as interconceptual and the final three as intraconceptual.

Tab. 2: *Reduction of time (s) for single semantic relations in the search (se) and delayed search experiments (dse)*

	se	dse
Z AG	1.11	4.09
Z OBJ	2.80	2.75
Z LOC	0.44	0.14
I QUAL	1.78	1.30
I KOMP	−0.22	−0.17
I SUB	0.41	−0.21

Proceeding on the basis of the delayed search data table 2 points to the possibility of an alternative classification in terms of time differences, viz. AGENT, OBJECT and QUALITY, on the one hand, and LOCATION, COMPARATIVE and SUBORDINATE, on the other. This agrees fairly well with results in recent analogy formation experiments which suggest a separate treatment of the QUALITY relation.[1]

4. Conclusion

In the present investigation we were able to show the task-independent action of two classes of semantic relations in human memory. Interconceptual relations obviously effect faster and less faulty activation of concepts than intraconceptual relations. This is in agreement with results of HOFFMANN and TRETTIN (this volume), suggesting that situational rather than categorial structures are more readily reproducible.

The different degrees of reduction of time needed for differently mediated activation are interpreted as reductions of different distances in the memory structure. Further studies will be required to gain an insight into how, irrespective of the cognitive task, semantic relations separate into the two general classes.

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[1] Despite the fact that we treated this problem as a combinatorical one we can't found more than two classes of semantic relations differ in the search time. As we have already stated the assignment of the single semantic relations of the two classes are not stable.

Characterizing of Cognitive Processes by Means of Event Related Potentials

E. REBENTISCH, F. KLIX and R. SINZ

The present paper deals with the application of psycho-physiological methods to the analysis of cognitive processes. In this connection it should be noted that basic research for the creation of methodical suppositions for experiments in this field are essential at present. There are many results for the modification of certain components of evoked potentials (EP) to sensory stimuli in dependence by parameters of processing information or the central nervous state of the subjects (Ss). In all these experiments besides a general activation dimension an additional one is only used in the interpretation. It is circumscribed as content meaning, level of security regarding the occurrence of certain events or also the complexity of underlying processes. A further approach is represented by the experiments of WEINBERG (1970), who investigated the reflection of an expected but not applied stimulus in the EP. The potentials, that he found and called emitted potentials in form and amplitude relations correspond very much to the direct sensory evoked ones. It cannot be dicided positively at the time, whether the potentials, according to the author's suspicion, reflect the memory realization of the omitted stimulus or whether there is only conditioning related to the potential.

As a whole one can conclude, that the differentiation capacity of EP must be assessed as relatively limited because of their unspecific character. That will be seen especially in the context of the conventional methodics of the consideration of modification of direct sensory evoked potentials through central nervous state changes in connection with processes under investigation. The question arises, whether also cognitive operations simular to sensory stimuli, are reflected in reproducible EEG-potentials i.e. whether certain components are differentiatable, which are exclusively ascribed to cognitive operations. Then such potentials should also be found independent from a sensory stimulus. This presupposes for that is an sufficient synchronicity of the central nervous excitations as is the case under sensory stimulation. This poses the problem of the elimination of sensory stimuli in psycho-physiological experiments for the investigation of cognitive processes. That is not only required because of the higher level of synchronization in the case of sensory stimuli, but also because the EEG cannot be considered as a linear sum of potentials made up of to different partial processes.

A first experimental approach to stimulus independent representation of cognitive operations in event related potentials was the use of a stimulus of small intensity with additional habituation, which triggered the cognitive process as to time.

The requirement for the Ss was to retrieve one item out of a given set. This task seemed to be simple enough under repetition to be synchronously realized in time.

The condition variables were different complexities and modalities (regarding the item property conceptual/pictorial). Figure 1 represents the experimental arrangement. The S. learns 4 items, there are opened and closed doors as words or pictures. In experiment 1 the complexity was varied by using affirmative and negative items: the item set consisted in the words 'closed', 'opened', 'not closed' and 'not opened'.

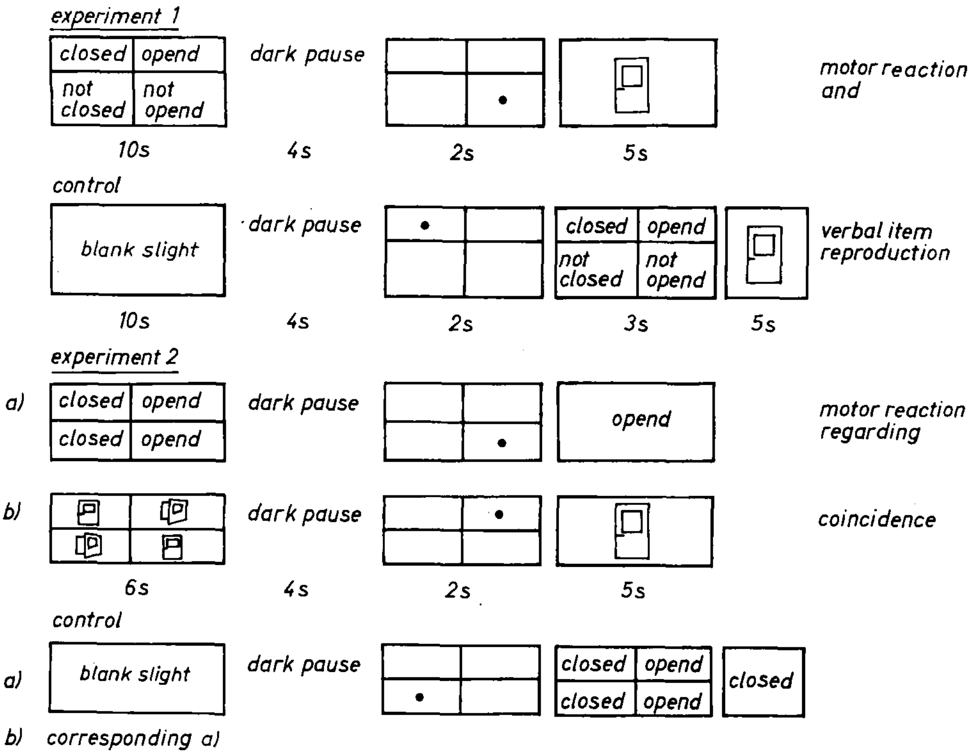

Fig. 1: Schematic representation of the experimental arrangement of experiments 1 and 2 (erratum—slight: slide).

In experiment 2 the modality was varied: the item set consisted in the words 'closed' and 'opened' and in the pictures of closed and opened doors.

After the learning phase a point in the respective quadrant of a coordinate system indicated the item to be remembered. The beginning of the exposition of this slide is used as the triggering point for the averaging of the EEG. In all reported experiments a single item is exposed directly after the retrieval stimulus—again an opened or closed door—for the comparison with the remembering item exclusively to create a time stress to warrant comparability of the process in repetitions of this experiment. The item to be compared always had the modality of the learning phase to favour retrieval in the modality of the learning phase.

In the control experiment the S. had to perceive only the position of the point during the 2-s-interval of the exposition of retrieval stimulus, in order to be able to choose the corresponding item of the item arrangement. In this case there was no memory process connected with the spatial information of the retrieval stimulus.

In all experiments the EEG was recorded temporally and occipitally unipolarly on both sides and vertically unipolarly. 50 single potentials were averaged in each case. The data of 10 Ss were used.

The results of experiments 1 and 2 are summarized as follows:

1. The form of averaged potentials was similar to direct sensorily evoked ones: They consisted in the main of a negative component with 120 ms peak latency and a following positive component with 220–250 ms peak latency.

2. The amplitude of the potential was lower in the control condition than in the retrieval condition. The amplitude reduction was most violent left temporally.

3. The amplitudes of the potentials were significantly bigger in the event of negative items than in the event of affirmative items (experiment 1, fig. 2 and tab. 1).

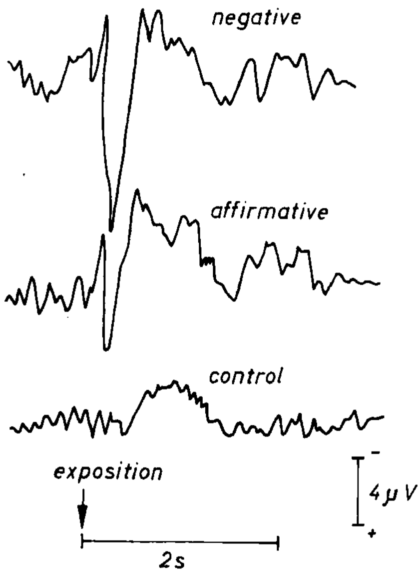

Fig. 2: Example of the recording of an averaged potential in temporal left recording in experiment 1.

Tab. 1

	Affirmative	Negative	Control
N	2,3	3,3	1,2
P	8,1	10,9	4,0

Averaged potential amplitudes (negative and positive component) of 10 Ss in experiment 1, recording temporal left, values in μV, the values are differing according to conditions by $p < 0.05$.

4. The difference in the retrieval of pictorial and verbal items, showing itself, inter alia, in a difference between the two temporal sides, with significantly greater amplitudes on the left in the case of word retrieval. There were no significant differences in the case of picture retrieval. A constant result furthermore was the extension of the duration of the positive potential component in picture retrieval compared to word retrieval (fig. 3 and tab. 2). The examination of amplitude values of the single Ss in experiment 2 leads to differentiation of two groups: the one with bigger and the other with less differences between word and picture retrieval. Those Ss, who according their own statement realized a strong separation between verbal and pictorial memory in retrieval process, belonged to the group with the larger differences.

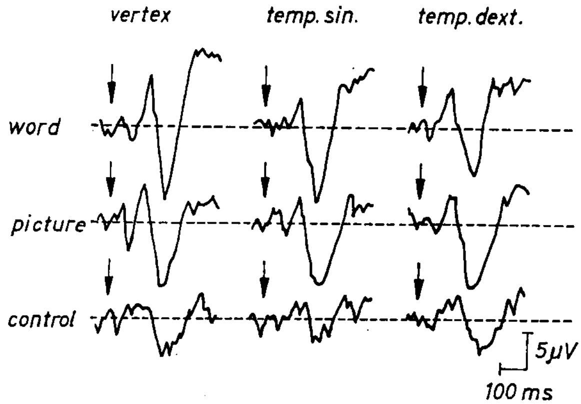

Fig. 3: Recording example in the experiment 2.

Tab. 2

		Temp. left	Temp. right	Vertex
Word	N	6,5	4,8	8,2
	P	14,6	12,6	8,4
Picture	N	4,5	4,1	7,6
	P	9,4	10,6	8,0
Control	N	2,0	2,6	3,5
	P	3,2	2,7	4,7

Averaged potential amplitudes (negative and positive component) of 10 Ss in experiment 2. The values of the retrieval conditions are significantly different as compared to the values of control condition in all recordings ($p < 0.01$) and in the same way the values of the word condition differ from those of the picture condition in the temporal left recording ($p < 0.05$).

The large differences between control and retrieval conditions suggest, that the requirement is directly reflected in the potential of the retrieval condition. This is supported by the condition dependence of the potential parameters.

HOFFMANN and KLIX (1977) showed, that the negation is separatively coded in an elementary step. Data of EP received during information reception also support this (KLIX and REBENTISCH, 1976). Thus a higher complexity of the remembering items is indicated by an enlargement of potential amplitudes. The results of experiment 2 prove the electrophysiological differentiability of both modalities in the retrieval process. The scale of modality specification depends on the subjectively reflected separability of both modalities. The left temporal area has therefore also especial signification for the retrieval process in using verbal material. The results support the assumption regarding a differentiable word and picture representation in the memory.

How can one decide the question of the direct reflection of retrieval process in the potential in view of the similarity of the found potentials to sensory potentials. The following alternatives can be discussed:

1. Since the retrieval stimulus represents a sensory stimulus, it is possible, that its central processing will only be modified by its meaning content, in our case by the

absence or presence of coding function. Because of the large differences between control and retrieval condition we do not want to content ourselves with this explanation.

2. Since the coding of remembering item is effected by the sensory stimulus, a part of these special attributive processes can be represented in the form of sensory potentials. In the light of this consideration the occurrence of the potentials reflects the participation of the optical analyzer in the retrieval process. The time interval of the potentials should be identified as a first phase of the analysis of coding stimulus.

3. Different elementary proceeding steps could be represented in the EEG as potentials, which are similar to one another. This hypothesis could be in accord with results of ELUL (1972). That implies an electrical generator, triggered by elementary events. Such events could be either sensory stimuli or cognitive elementary operations.

Because the results of experiment 1 and 2 do not permit a decision between these alternatives, the sensory stimulus will be eliminated completely in a third experiment. This experiment is based on the following principles:

1. A cognitive operation must be determined in the result of another one, because a sensory stimulus should be avoided.

2. The S. indicates the moment of the solution of this first task by a motoric reaction. But the moment of the beginning of investigating cognitive operation must be sharply determined. If the instruction of Ss. is to start the operation only after their reaction, this supposition is not necessary fulfilled. Therefore the information about the solving task should be determined by the result of the preceding one only up to one missing binary information. Then this binary information will be given simultaneously with the reaction of S. It consists in the application or nonapplication of a visual stimulus. Thus the S gets the complete information about solving of the task not before only to the moment of his reaction. In the case of nonapplication of the visual simulus we have an experimental condition that avoids a sensory stimulus.

The reaction of the S. will be used for the triggering in the EEG averaging.

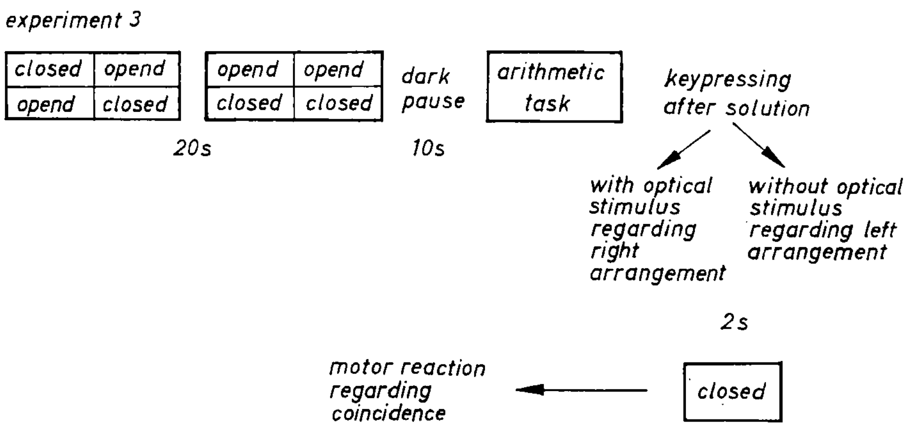

Fig. 4: Schematic representation of the experimental arrangement of experiment 3.

The requirement was again a retrieval task (fig. 4). The S learns two arrangements of 4 items, according to those in experiment 2. Then the S has to solve an arithmetical problem the results of which are in the set of the numbers 1, 2, 3 and 4, corresponding to the 4 quadrants of the item arrangement.

After solution of the arithmetical problem the S pressed a key. Simultaneously an optical stimulus was applied in 50% of the trials. The appearance or non-appearance of the optical stimulus refers to the right or left item arrangement.

The EEG of the 2-s-interval after the reaction is again the basis for the analysis of the experiment.

The condition variable of experiment 3 is again the modality as to conceptual/picturial. Control condition is the solution of an arithmetical problem and the indication of the solution moment by key pressing. It was made sure that the motoric reaction, the nonappearance of the optical stimulus as to emitted potentials and also eye movements were not effective as additional potential sources.

The essential feature of the averaged EEG (2 s) varying according to the conditions is the occurrence of certain rhythms.

Under control conditions no rhythm was found, which was stable within the 2 s.

An adequate analysis including methods of spectral analysis will be carried out later, therefore in the present paper we only mention the frequency of the occurrence of rhythmic potentials.

All in all we can say that in word retrieval, compared to picture retrieval, rhythms are not only more stable, but are also of longer period duration. Temporally on the left, word retrieval is found linked with a duration of periods of approximately 500 ms, and at other loci of recording—most frequently at the vertex—the duration is in the area of 220–250 ms. In the event of picture retrieval, about 50% of the Ss showed rhythms of periods of between 150 and 185 ms in vertical and occipital recording; the others lacked regular rhythms. A typical example is given in fig. 5.

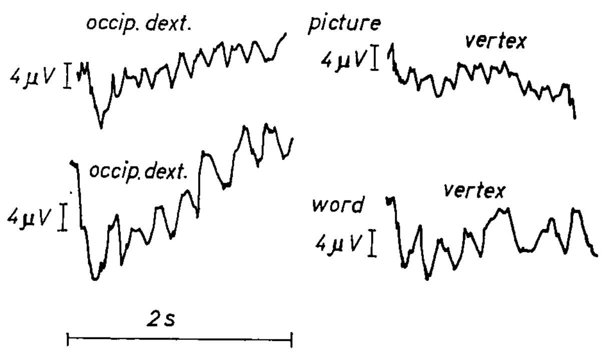

Fig. 5: Example of the recordings in experiment 3 with occipital and vertical recording.

Easily isolated initial complexes of potentials like those under the conditions of experiment 1 and 2 could not be detected. Consequently it is improbable, that these are correlated to an essential part of retrieval process. It can be assumed, as already mentioned, that the potentials reflected an initial process of attribution between the sensory retrieval stimulus and the item stored.

Considering the rhythms, we first of all face the question whether they are generated in the course of the cognitive operations or whether the requirement merely leads to a synchronization of the phases of existing rhythms. Spectral and correlation analysis procedures will provide an answer at a later point. Are the waves related to individual operations, or is a rhythm of this kind only some unspecific attendant phenomenon of processes in the central nervous system?

Discussing this very important matter, we can rely on results obtained by KLIX and HOFFMANN (1978) in their analysis of the time required in different cognitive processes. There elementary times of between 200 and 260 ms were detected for elementary cognitive operations in the context of verbal-conceptual requirements, and of about 55 ms in the context of visual-pictorial requirements.

The elementary times between 200 and 260 ms correspond to our rhythms in word retrieval, with recordings made vertically and occipitally. The double period duration of potentials temporally left cannot for the time being be explained in this connection. Period durations of 55 ms do not occur and, strictly speaking, their occurrence cannot be expected because even small unregular temporal shifts in relation to the required beginning of the retrieval would eliminate such a rhythm by the averaging. That rhythms occured with periods between 55 and 250 ms can be seen in connection with the fact, that the retrieval of pictorial items in form of visual structures could not be realized by all Ss and not continuously. A hypothesis, that in this case both function systems are cooperative and the found rhythms with mean period duration have process triggering properties, however, is at present still speculative in nature.

It is not possible, to attribute single different operations to individual periods of rhythms. But possibly the retrieval process is realized in a time rhythm, where the single steps of a search algorithm need about equal times.

To sum up: the results of all three experiments suggest—also from the viewpoint of psychophysiology—that the storing of verbal and pictorial information is of a distinguishable processual nature. Conditions are differentiated in terms of both a spatial cortical dimension (experiments 1 and 2) and time parameters (experiment 3).

The results of the investigations reveal that the method of obtaining event-related potentials can be extended and that, if certain specifications are made, results can be obtained that relate to cognitive information processing.

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Componential Analysis of the Recognition of Semantic Relations Between Concepts

F. KUKLA

The recognition of semantic relations between concepts is an essential condition for many cognitive processes. It is part, for instance, of processes of language understanding, conceptual classification and differentiation.

Semantic relations between concepts can themselves be part of individual memory structure and as such can be recalled and identified in a cognitive process. But if they are not explicitly stored and recallable, then they must be derived in the process of recognition from the representations of the concepts. We shall examine this process here.

The forms of representation of concepts in memory are an important condition for procedures of obtaining semantic relations between concepts. We proceed from the assumption that concepts are represented in memory on the basis of features which make it possible to recognize the objects assignable to them in a multitude of situations requiring such recognition. Which particular features are then actualized and become operative depends on the specific requirements (= tasks) and on the conditions of situation and context. Thus, the relation between concepts which is derived from the features is usually specified by the requirement situation.

Therefore, the present inquiry is focused on the process of recognizing semantic relations between concepts, which relations are not explicitly stored. Its aim is to identify individual components of this process in order to render understandable the complex operations of which these components are a part. We particularly wanted to know if component processes (components) of recognition can be traced to the features of concept representation. The underlying hypothesis is that recognition takes place through individual comparisons of conceptual features that are actualized.

As to the *method*, in view of the foregoing, the material and requirements had to be selected in such a manner that the same set of features of concepts is actualized in the subjects and that the operations involved in relation recognition are then linked to that set. In one case we selected 12 in another case 8 concepts for this purpose, which can be subordinated to a common generic term (the category "waters") (cf. fig. 1). It encompasses a set of features common to all these concepts. The features specifying the individual concepts had been determined in an analysis carried out by HUNDSNURCHER (1970) in such a manner that they made it possible fully to differentiate between the concepts (cf. fig. 1). In the first case there were eight and in the second case 6 features that are classifiable as values of three attributes: F (flowing/stagnant), N (natural/artificial), G (very large/large / small/very small).

The object was to test the utilization of the features by the subjects through three successive requirements: definition, classification and discrimination of the concepts prior to the critical experimental requirement (analogy solution) and to have them actualize a uniform set of features of the quantity of concepts (cf. fig. 2). Nineteen different features were used by the subjects the first time the concepts were presented for definition. Only 58 per cent of the definition features corresponded to the features of the three attributes F, N, G. The agreement between the test persons' use of the

	features \ concepts	II. (8 concepts) Fluß (river)	Bach (brook)	Kanal (canal)	Graben (ditch)	See (lake)	Tümpel (pool)	Teich (pond)	Becken (basin)	I. (12 concepts) Strom (stream)	Rinnsal (rill)	Meer (sea)	Pfütze (puddle)
F	flowing	+	+	+	+	−	−	−	−	+	+	−	−
	standing	−	−	−	−	+	+	+	+	−	−	+	+
N	natural.	+	+	−	−	+	+	−	−	+	+	+	+
	artifical	−	−	+	+	−	−	+	+	−	−	−	−
G	large	+	−	+	−	+	−	−	+	−	−	−	−
	small	−	+	−	+	−	+	+	−	−	−	−	−
	very large	−	−	−	−	−	−	−	−	+	−	+	−
	very small	−	−	−	−	−	−	−	−	−	+	−	+

Pair combinations of concepts with number of features changed between them (MD):

1 MD in:	G, F, N	river: brook	(G)
2 MD in:	N/G, F/N, F/G	brook: canal	(N/G)
3 MD in:	F/N/G	canal: pool	(F/N/G)

Fig. 1: Experimental material: Concepts, attributes and features.

features increased in the subsequent free classification of the concepts: 83 per cent of the classification criteria mentioned corresponded to the six features of the attributes F, N, G. In the subsequent differentiation between the concepts of all pair combinations, only the six features of the three attributes (F, N, G) were named almost exclusively (92 per cent). It was to be ensured in this manner that representations of the concepts by means of the features of the attributes F, N, G became operative (for all subjects) in the subsequent task of relation recognition. It is now assumed that the semantic relations between the concepts of all combinations of pairs are determined through concurrent and differing features. They can be classified according to the number of features and to the features by which they differ. According to this classification there exist relations with 1, 2 or 3 feature differences (MD) (cf. fig. 1 with examples).

The recognition of semantic relations between the concepts was examined on the basis of the solution of conceptual analogy tasks in the form of a : b = c : ? Here the subjects had to recognize the relation existing between the concepts a, b and being given the third concept c, to establish the relation c : d analogonsly by selecting a 4th concept from the set (d_i), which had been learned. The analysis of the process of recognition was based on the times required for solving the analogy problem and for recognizing the relation a : b contained therein, given different types of relation.

The presentation of c was delayed by from 1 to 5 and 7 s after a : b in order to isolate the relation recognition a : b from the complete analogy solution process. The

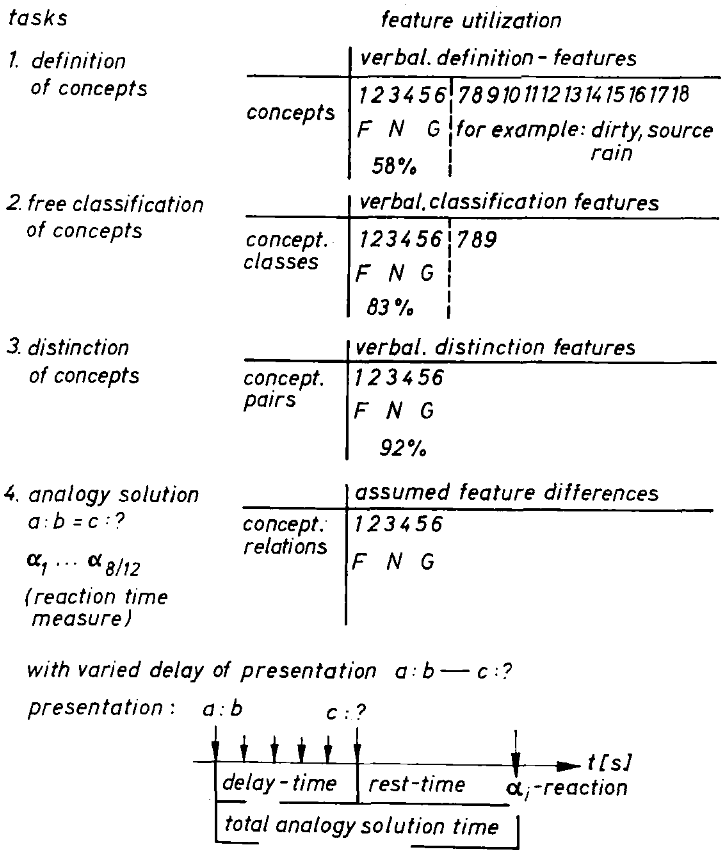

Fig. 2: Experimental procedure.

delay (VT) between the presentation of a : b and the presentation of c : ? and the time that elapsed between the presentation of c and the answer of the test person (cf. fig. 2) were measured. The object was to determine precisely that time of delay in the presentation of c which it takes to complete the recognition of the relation a : b (optimum time of delay). If the relation a : b has not been recognized by the time c is presented, the time spent for recognizing the relation is still contained in the time it takes to answer, thereby increasing it in relation to the optimum delay time. The rest time reaches its minimum when relation recognition is completed in the time of delay. Any additional delay in the presentation of c was not to have any influence on the measured time.

The experiment was carried out with 12 concepts and with simultaneous presentation of both parts of the task. The effect of the delay in presentation was examined only in analogy tasks involving eight concepts.[1] Having gone through tasks 1 (definition), 2 (classification) and 3 (differentiation), the subjects were acquainted with the paradigm of analogy formation with the aid of other spheres of concepts (family relations, geometric forms). They were then asked to solve the analogy tasks that

[1] Considerable burdening of the memory and difficulties in differentiation of 4 features of attribute G encountered with the 12 concepts prompted us to reduce the number to 8.

could be formed from all combinations of pairs of concepts, the time being measured with the aid of a microphone. The times of delay were realized in experimental blocks which were permutated and distributed over two days. Twenty-three test persons took part in the experiment.

We shall first consider the *results* obtained with the simultaneous presentation of the complete analogy task, i.a., without delay between a : b and c : ? (cf. fig. 3). They show that the time it took to find the analogy solution is dependent on the specific

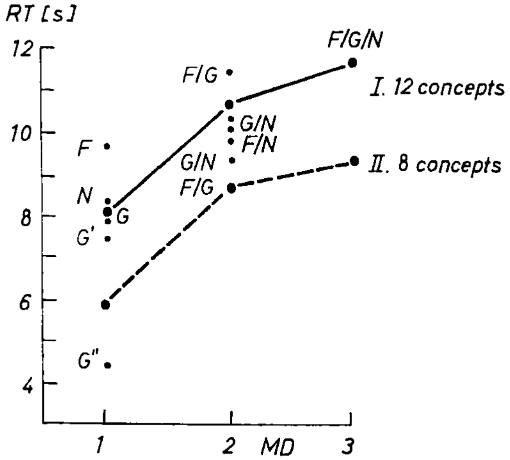

Fig. 3: Relation between number of features changed between the concepts of a pair a : b (MD) and time (RT) for solution of the analogy a : b = c : d.

type of relation involved. The time it takes to work out the analogy solution increases with increasing number of features distinguishing concepts of each pair. This is observed in tests with both 12 and 8 concepts. But the time increase in relation to the feature differences is not a linear one. Individual evaluations and opinions expressed by the subjects suggested the assumption that part of the subjects did not solve the analogy in the form specified. Instead, they reduced the number of feature differences that were to be rendered analogous by transposing the concepts. Instead of solving an analogy a : b = c : d with three feature differences between a and b and c and d, they solved the analogy a : c = b : d with one feature difference between a and c and b and d, thereby reducing the time it took to work out the solution. In addition the time required for the analogy solution within one relation class differs for individual feature differences and their combinations (cf. fig. 3). The question that remains of interest is whether the times spent for solving the entire analogy problem, which are dependent on the relation type (feature differences), can themselves be determined already for the process of relation recognition a : b.[2] Information is to be obtained,

[2] Under the present conditions, the times required for solving analogy problems do not make it possible as yet to say something about the process of relation recognition itself, because in addition to the time required for recognizing the relation a : b, they include times for search, comparison and decision processes involved in establishing analogies. Thus, the fact that the time increases as the feature differences grow must not be due to more time being spent for relation recognition, but can be due, for instance, to differences in difficulty of the search processes involved in establishing the 2nd relation c : d or to differences in the number of individual comparisons between the 1st and the 2nd pair of concepts formed.

by way of relation recognition, through experiments with successive presentation of both analogy parts — a : b and c : ? First of all, fig. 4 shows that the time still required for solving the analogy problem decreases as the delay between the presentation of a : b and the presentation of c increases. This was to be expected, because the relation must be recognized more and more completely during the delay time. Figure 4 also

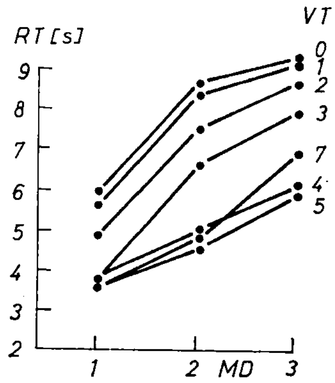

Fig. 4: Rest-time for analogy solution (RT) for concept pairs with different number of feature differences (MD) after delay-time (VT) between presentation of a : b and presentation of c:?

shows that there is a linear relationship between the remaining time (= rest time) for establishing the analogy in the case of a long delay in the presentation of c on the one hand and the number of feature differences on the other. This supports the aforementioned explanation of the non-linear increase in the solution time with the increasing number of feature differences if both parts of the analogy are presented simultaneously, because if the presentation of c after a : b is delayed, then the possibility of rearranging the set analogy task a : b = c : d into a : c = b : d and thus of reducing the time required for the solution is forfeited.

The time for relation recognition can be determined indirectly in two independent ways: Firstly, it can be calculated using the difference between the total time for solving the analogy problem and the remaining time used for establishing the analogy. Secondly, it should be determined as an optimum delay time, which is just enough to conclude the relation recognition before c is presented. Figure 5 shows that the remaining time (rest time) that is still needed for solving the analogy problem diminishes as the delay in the presentation of c increases until the relation recognition a : b can be performed entirely before the presentation of c. From this optimum time of delay on, the time for establishing the relation b : d remains nearly constant. It is clear that a maximum saving in the time required for solving the analogy problem if the number of feature differences between the concepts a, b increases can be achieved only by increasing the delay in presenting c. The optimum delay, after which only negligible changes are measured in the rest time, increases with the number of differences in the features of the concepts of a relation. 3, 4 and 5 s limit the ceilings of intervals in which lie the optimum times of delay for relations with 1, 2 and 3 feature differences and represent the approximate time spent for recognizing these relations. The approximate equidistance of the position of the optimum times of delay shown in

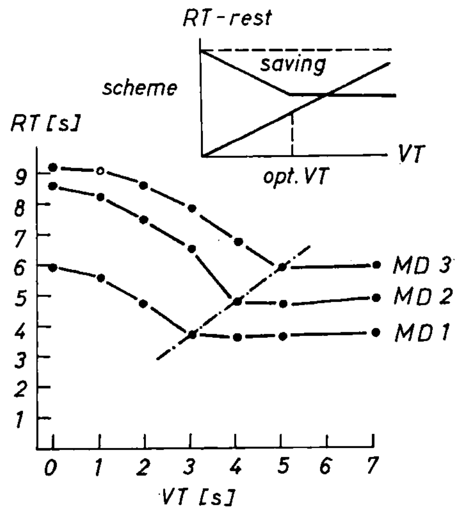

Fig. 5: Rest-time for analogy solution (RT) after a delay-time (VT) between presentation of a : b and presentation of c:? for concept-pairs with different feature differences (MD).

	analogy solution time (measured)		*recognition of the relation a : b*		*opt. delay-time measured*
	total a:b=c:d	*rest after opt. VT c:d*	*(computed as difference total-rest)*		
1 MD	*5,90*	*3,68*	*2,22*		*2...3*
				1,48	
2 MD	*8,59*	*4,89*	*3,70*		*3...4*
				1,36	
3 MD	*11,03*	*5,97*	*5,06*		*4...5*

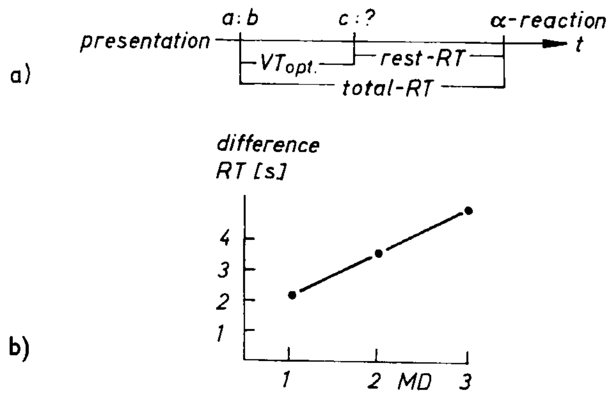

Fig. 6:

a) Decomposition of total solution time;

b) Relation between time of relation recognition a : b (RT) (determined as difference) and number of features changed between the concepts of the pair a : b (MD).

fig. 5 suggests that the corresponding times of relation recognition are in a linear relationship with the quantity of feature differences.

The second way of determining the time required for recognizing the relation a : b as a saving in the time required for solving the problem is determined when a : b is given and when the presentation of c is optimally delayed. Here the additivity of the two distinguished parts of the entire analogy solution (relation recognition a : b + relation establishment c : d = analogy solution) is assumed and the unknown relation recognition is calculated on the basis of the times measured for the entire analogy solution and for the establishment of the relation (cf. fig. 6). There is a linear relation between the differences between the measured total time for solving the analogies and the rest time that is still required for establishing the analogy after an optimum delay (and hence after relation recognition) on the one hand and the number of feature differences between the concepts of a relation on the other hand.[3] As expected, they lie in (or in the case of 3 MD, very close to) the intervals, which have been assumed in accordance with the rest time changes with varying delay time as an approximation of the optimum delay time (cf. Table in fig. 6). The times of recognition of the relations determined by the two independent methods are in an almost linear relation to the number of feature differences constituting the relations.

What do these results mean with reference to our inquiries and hypotheses?

We have assumed that relations not explicitly entered in the memory must be derived from the representations of concepts in the process of recognition. The differences in time spent for recognizing conceptual types of relation are attributed, i.a., to the differences in the degree of difficulty of the processes of relation derivation involved. The close relationship that has been proved to exist between the time of recognition of relation and the feature differences of conceptual representation confirms the expectation that processes of relation recognition can be attributed to actualized concept features. The aim of the inquiry was to identify components of relation recognition. This means that answers must be found to questions concerning what the time for recognizing the conceptual relations examined is made up of.

We assume that relation recognition is based on feature comparisons of concepts that have been related. The features of all three attributes of the two concepts of a relation must always be compared in order to arrive at the correct solution of the analogies, for it is after all the purpose of the relation recognition. Thus, the different amounts of time spent for recognizing relations with different numbers of feature differences cannot be attributed to the differences in the number of necessary feature comparisons. Owing to the fact that the amount of time required increases with increasing feature differences, the result suggests that processes of recognizing differences between features (as opposed to feature concurrences) have a decisive bearing on relation recognition. This is understandable in view of the significance of feature differences between concepts for solving analogies: Two relations are analogous only if they differ in the same features and in the same direction. For instance, if a : b decreases from "large" to "small", then c : d must also decrease from "large" to "small" and not from "small" to "large". Knowing only the concurring features

[3] The mean value for the total time needed for solving an analogy problem involving 3 feature differences was determined only for those subjects here who arrived at the solution without transposing the analogy.

between the two concepts is not enough to arrive at correct relation recognition and analogy solution. Concurring features can be forgotten again in relation recognition, but each of the different features involved in feature comparison must be identified with the direction of differentiation and retained. This requires more time than in the case of recognition of concurring features. For the time being nothing can be said about the additional operations connected with this. The fact that the time required for relation recognition varies linearly with the number of feature differences means that a nearly constant amount of time is added to the amount of time spent for recognition with each feature difference, i.e., the additional time required varies additively. This suggests that the comparisons of concept features take place successively. Owing to the fact that all (actualized) features of related concepts must always be compared for each relation recognition, no inferences can be made from the recognition times concerning the sequence of feature comparisons.

However, the nearly constant 1.42 s by which the recognition time increases with each additional feature difference cannot be attributed solely to the recognition of this difference. The determination of each additional feature difference means that there is one agreement less each time. Thus there are at least two different components involved in the time increment.[4] An estimate of the shares of time involved (the additivity of these components being assumed) based on the times measured in experimental relation recognition shows that 0.26 s are required for determining feature identity and 1.69 s for recognizing a feature difference.

Additional time for encoding the concepts cannot be determined. It is to be assumed that no separate and uniform encoding of the concepts takes place as an independent process prior to relation recognition, but that their features are recalled only within the comparison. And this takes place—just as the comparisons themselves—successively for the features of attributes. Thus the encoding of concepts into their feature representations takes place in a broken down form as part of the successive attribute-by-attribute feature comparisons. According to this, the time spent on encoding the two concepts of a relation would already be part of the time required for the recognition of this relation.

Summing up, it can be said that the results mentioned in the foregoing support the following view of the components of recognition of conceptual relations: Relations between concepts not entered in memory, which concepts are represented on the basis of similar feature attributes, are recognized by means of successive attribute comparisons of features of conceptual representations. The feature comparisons are made successively and comprehensively with regard to the conceptual features actualized through the requirement and context. They require more time in the case of a feature difference than in the case of identical features. Results of comparisons are retained (for a short while) as an attribute-by-attribute listing of the feature differences and are then available for other cognitive operations (e.g., for establishing analogies between such relations).

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[4] Each time the number of feature differences increases there is one feature difference more and one concurrence less for the three necessary feature comparisons. Relations with 1 feature difference require the determination of 2 concurrences and the recognition of 1 difference, while relations with 2 feature differences require 1 concurrence and 2 differences, etc.

Strategies of Serial Comparison and Decision in Memory: Invariant and Task-Dependent Components

H.-G. GEISSLER, U. SCHEIDEREITER and W. STERN

1. Introduction

It is today becoming increasingly clear that performance in different recognition tasks involves common cognitive procedures (cf. SHEPARD and PODGORNY, 1977, KLIX and VAN DER MEER, 1978, KLIX this volume). What remains a matter of debate, however, is whether parallel (holistic), serial (analytic) or mixed models of information processing provide an appropriate account of the data. The present report intends to tackle this issue within the domain of visual recognition, where it is comparably easy to get stimulus features and relations under experimental control.

We start from the assumption that it is basically the possibilities of stimulus organisation in memory which determine the way in which a small number of procedural components are combined to meet a given task in a given situation. From this view the ability of parallel processing does not exclude the general need for serial processing.

It is proposed as one major assumption along this line that there exist general strategies of serial comparison and decision and that only the units of processing vary depending on task and stimulus organisation. Consider, for illustration, the memory-search task of STERNBERG (e.g. STERNBERG, 1966). For making the decision on whether a probe item presented belongs to the memory-set or not Ss may rely on different strategies depending on memory-set structure. One first possibility which has been assumed in most of the studies is an item-by-item search with the item serving as comparison unit. Assuming a constant comparison time per item a linear increase of RT with number s of items in the memory-set is predicted as indeed has often been observed in such experiments. An alternative strategy would be to decompose the items into subunits or separable item features and at this level proceed by comparison.

If the structure of the entire stimulus set is sufficiently rich one may think about other strategies which test information on a category rather than on the item level. If, for instance, the memory-set is strictly separated from its complement by distinctive features, a decision by a one-step comparison is possible.

Referring to reaction time studies a considerable body of evidence has been compiled in support of the view that both (holistic and analytic) strategies have their counterparts in reality (cf. TAYLOR, 1976a, SHECHTER, 1968, DE ROSA and MORIN, 1970, DE ROSA and TKACZ, 1976, PRINZ and SCHEERER-NEUMANN, 1974, VELICHKOVSKY and SCHMIDT, 1978, DEUTSCH and CLAUSING, 1978).

For the purpose of the present paper three possible implications of the above considerations will be pointed out which do not yet seem to have been elaborated:

(1) In the first and second strategy both items and item features are concrete

patterns and the strategies should hold in general, but in particular also in cases where exactly those patterns are features which serve as items in others; it follows that the principles of comparison should be the same, independent of the comparison level. If, then, the distinction of holistic and analytic comparison processes makes any sense, analytic comparisons are nothing but a sequence of holistic comparisons. This conclusion can hypothetically be extended to the comparison of items and sets of items. Features in this case do not represent parts of patterns but subsets of given sets of patterns. If an integral representation of a probe and a subset relevant for decision exists, a holistic comparison can be executed at that level. Otherwise, analytic processes are necessary.

(2) A holistic comparison is, then, by definition, a parallel comparison process between probe stimuli and targets (sets, single items) with reference to a feature space which both are embedded in. The result of the comparison can be conceived of as a function of distance (similarity) measures. Empirical results and simple considerations indicate that these distance measures should include discrete as well as continuous variables (analogue information).

(3) Decisions are based on the outcome of comparison and adjustable decision criteria. To account for differences between positive and negative decisions in "memory-search" and in "same-different" paradigms (BAMBER, 1969, 1972, NICKERSON, 1972, TAYLOR, 1976b) it is suggested that comparison can proceed in parallel at different representation levels. In cases where effects of speed-accuracy trade-off can be neglected the fastest procedure is regarded to determine the decision.

2. Distance-based decision in multiple classification tasks

The experimental demonstrations will be opened with a brief summary of multiple classification experiments which concerns the perhaps most doubtful points of the above conclusions:

a) May categorizations be truly considered as based on element-set distances? b) Does the relevant distance measure actually refer to a compound representation including continuous variables?

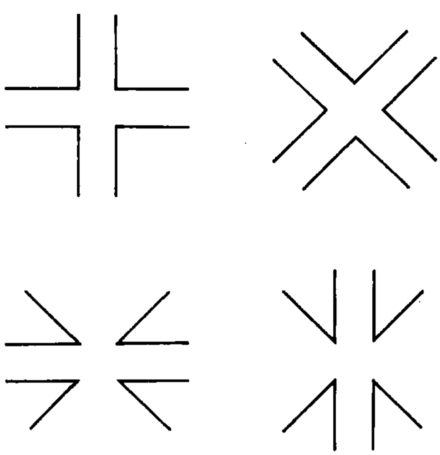

Fig. 1: Prototype patterns used during training.

Figure 1 shows the prototype patterns used in the training series of the experiments, where Ss learned to respond to each particular pattern with a letter. Figure 2 displays a hypothetical decision tree which derives from clustering the stimulus set and is supported by *RT*-data. According to the tree the first decision is between rectangular

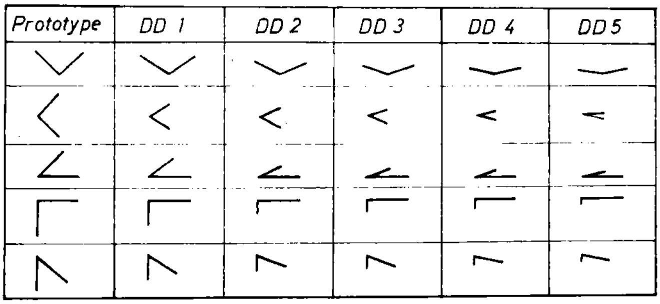

Fig. 2: Hypothetical decision tree of recognition performance (cf. the text).

and acute-angled patterns. A second decision is made on the basis of leg orientation and is shared by groups of patterns containing four elements each. Identification of the particular element follows as a last step of decision.

A lot of evidence for decisions relying on element-set distance including analogue information stems from several test series following the described training series, in which gradual distortions (shrinking) in geometrical progression were introduced (fig. 3). Figure 4 contrasts some predictions drawn from an element-set distance model

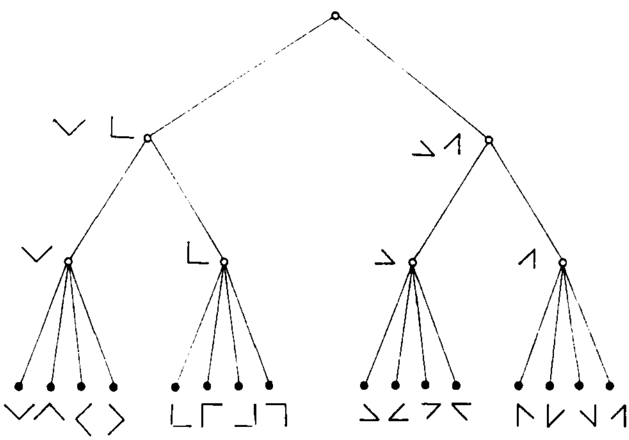

Fig. 3: A representative sample of distorted patterns. Distortions, denoted by DD, are geometrically spaced.

and typical patterns of experimental results. Theoretical calculations were based on differences of mean Euclidian distances from representations of two alternative pattern categories, assuming a logarithmic scale for distortion and a linear relation to reaction time. The figure exhibits diagrammes as well as calculations for suitably selected parameter values and orthogonal vs. non-orthogonal dimensions. The rightmost panel shows corresponding experimental data (GÜNTHER, 1974). Essential to

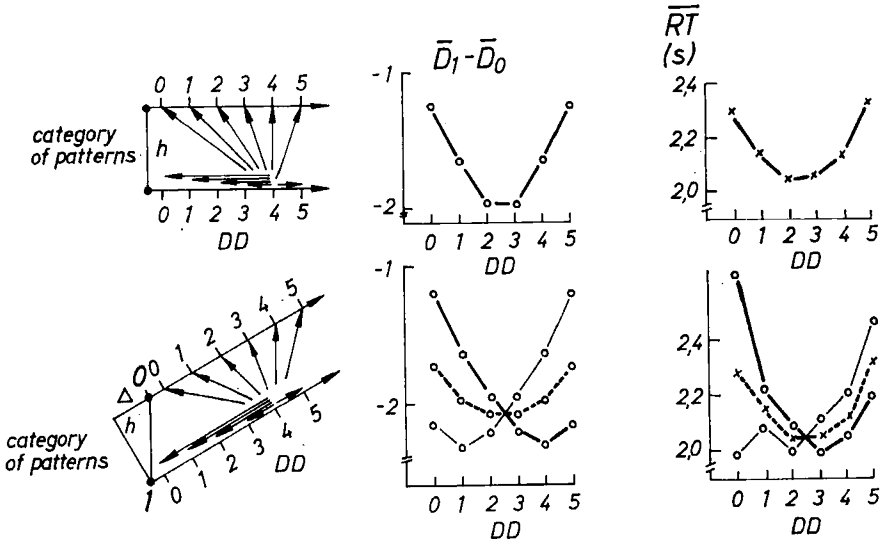

Fig. 4: Euclidean distance model of distortion effects (cf. the text, dashed lines represent means for both categories). The formula is

$$\bar{D}_c(P) = \frac{1}{N} \sum_{DD=1}^{N} \sqrt{h_c^2 + (DD_c - \Delta_c - DD_P)^2}.$$

$\bar{D}_c(P)$ – mean distance of probe item P from all patterns of the category c. $c = 1$ for the probe item category, $c = 0$ for the alternative.

DD – degrees of distortion used in the experiment, DD_c for patterns of category c, DD_P for the probe item.

h_c – distance between categories: $h_1 = 0$, $h_0 \geqq 0$.

Δ_c – $\Delta_c = 0$ for orthogonal dimensions

$\left.\begin{array}{l}\Delta_1 = 0 \\ \Delta_0 = \Delta\end{array}\right\}$ for non-orthogonal dimensions.

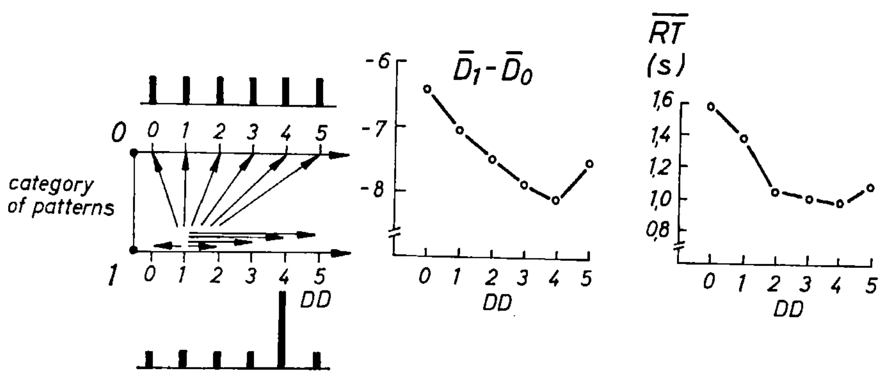

Fig. 5: The Euclidean distance model applied to effects of local changes of presentation rate at $DD = 4$ for one out of a category of patterns (cf. the text). The formula is

$$\bar{D}_c(P) = \sum_{DD=1}^{N} p_{DD,c} \sqrt{h_c^2 + (DD_c - \Delta_c - DD_P)^2}$$

$p_{DD,c}$ – presentation rate.

our present purpose is the mirror symmetry of the functions predicted, which in the experiments was approximately obtained for complementary categories. As mirror symmetry has been found only for a decomposition of the entire stimulus set corresponding to the second decision in the hypothetical tree, it can be concluded that the analogue information is being integrated at that level. Crucial to this assumption is the impact of local changes of the presentation rate at a given degree of distortion. Figure 5 delineates the *RT*-shift predicted for a substantial increase at the fourth degree of distortion. This agrees with the general pattern of results obtained for each of the four subcategories, although presentation rate had been locally increased for one pattern category only (fig. 5, right panel, SCHUMANN, 1972). This strongly supports the assumption. Whilst the formal model was specified under more or less arbitrary constraints which remain open to correction, it seems difficult to account for the above facts in a way fundamentally different from the one suggested by the element-set distance hypothesis.

3. Decision strategies in modified memory-search tasks

The general suggestions (1)–(3) involve recognition strategies flexibly changing depending on specific conditions even within one single task. This shall be demonstrated using data from a modified version of the STERNBERG task (STERN, 1978). Figure 6

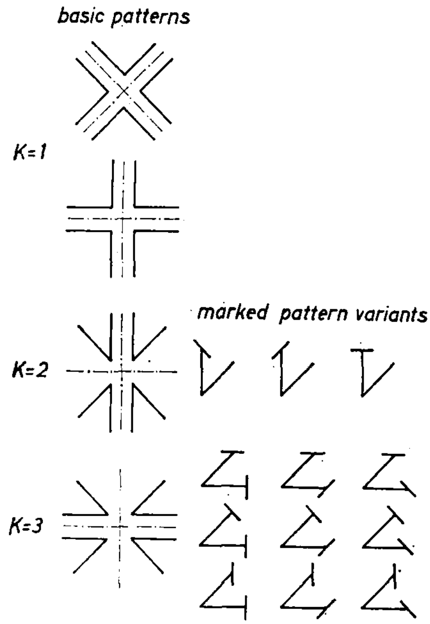

Fig. 6: A representative sample of patterns used by STERN (1978).

shows a subset of the patterns used in the experiment. Unmarked angles correspond to the first level of complexity indicated by $K = 1$. The patterns containing one and two marks define the second and third levels indicated by $K = 2$ and $K = 3$, respectively. Marks could have three possible orientations relative to the marked legs. A fixed set-procedure was adopted with memory-sets containing 1, 2 or 3 patterns belonging to the same level of complexity. With reference to the experimental conditions the general strategy components to be inferred from (1)–(3) are specified as follows[1]:

1) Holistic comparisons are asserted if memory-set and probe items come from subsets of different complexity. Two possibilities should be considered:

(a) holistic item-set comparison by direct access to category information relying on element-set distances;

(b) holistic item-by-item comparison.

2) Analytic comparisons are assumed if memory-set and probe items are taken from subsets of equal complexity.

Figure 7 presents mean *RT*s for the three levels of complexity $K = 1, 2, 3$ as a function of the number of memory-set items s and with complexity of the probe items $T = 1, 2, 3$ as a parameter. $\overline{RT}$s for $K \neq T$ qualitatively follow the pattern predictable from 1(a) and 1(b).

$\overline{RT}$s vary inversely with some reasonable measure of distance between memory-set and test items. Significant linear trends suggesting item-by-item comparison have been found for $K = 1$ only.

For $K = T$, $\overline{RT}$ is highest and dependence on s approximately linear. The increase of slope with K points to an analytical comparison process.

To demonstrate serial feature comparison we here confine ourselves to negative responses and $K = 2, 3$. A self-terminating feature comparison procedure is illustrated

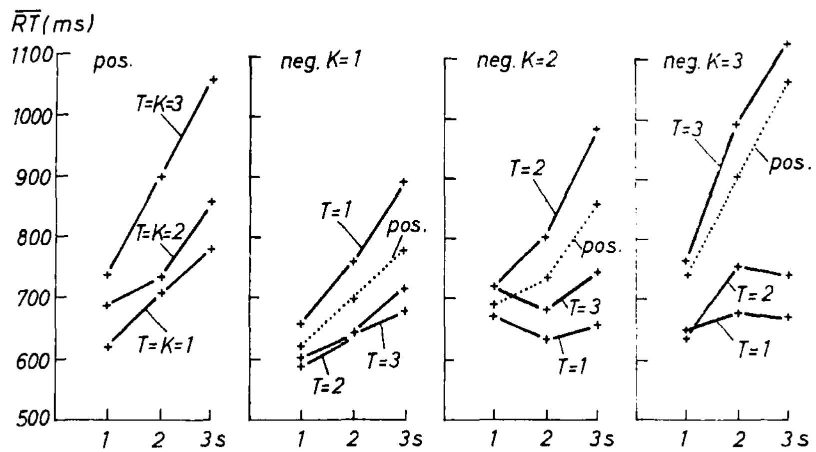

Fig. 7: $\overline{RT}$s for three levels of complexity $K = 1, 2, 3$ of memory-set items as a function of number of memory-set items and with complexity $T = 1, 2, 3$ of probe items as parameter.

in fig. 8. For purposes of further analysis $\overline{RT}$-data have been arranged according to number i of parts shared by memory and test items which are conceived of as the relevant comparison units. The result is shown in the left panel of fig. 9. The middle panel displays the predictions of the self-terminating model obtained by a regression

[1] A striking formal analogy to models suggested by Atkinson and Juola (1974) and Rips, Shoben and Smith (1973) should be pointed out.

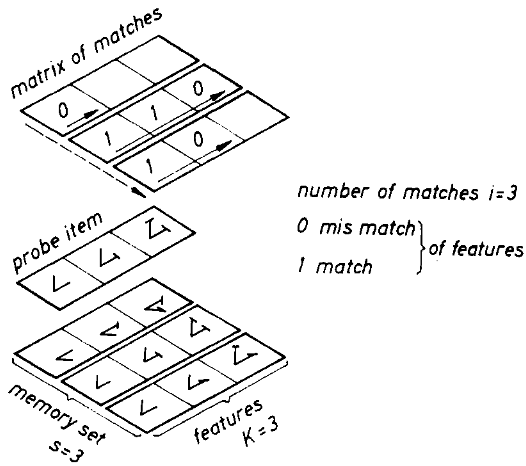

Fig. 8: Self-terminating search explained.

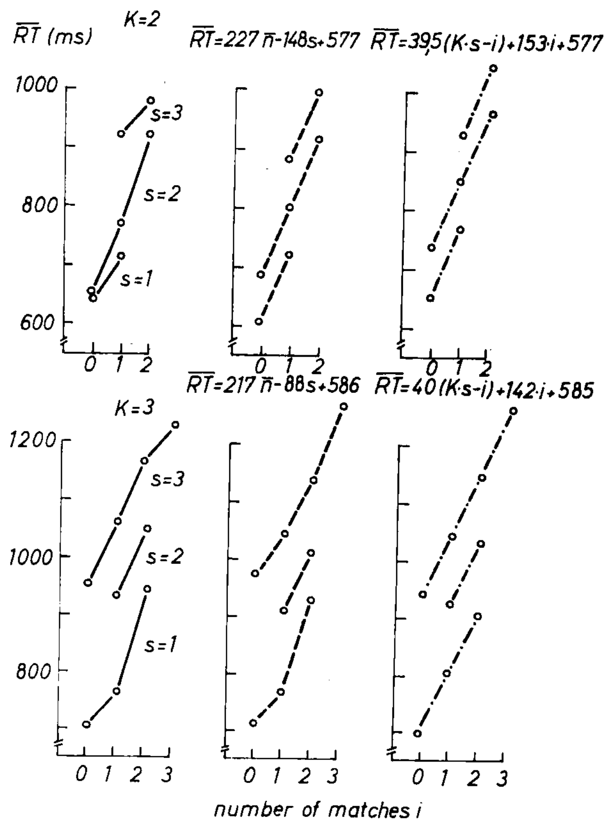

Fig. 9: $\overline{RT}$s for $T = K$ and negative responses as a function of features shared by memory-set items and probe items (left). Fitted prediction of self-terminating (middle) and exhaustive search models (right).

analysis. Regression was based on expected number of serial comparisons allowing for different comparison times T_+ and T_- for feature matches and mismatches and free variation intercepts (tab. 1). T_+ turns out to be approximately invariant across com-

Tab. 1

	T_+ (ms)	T_- (ms)	I (ms)
$K = 2$	217	79	577
$K = 3$	227	129	586

plexity (217, 227 ms for $K = 2, 3$), estimates coming very near the values found by Klix and van der Meer (1978) for analogical reasoning. A draw-back of the solution is the dependence of T_- on complexity. The right panel of fig. 9 shows corresponding prediction as obtained from an exhaustive comparison model. Though quality of fit is about the same, the exhaustive model stands out by the approximate invariance of all its three parameters:

Tab. 2

	T_+ (ms)	T_- (ms)	I (ms)
$K = 2$	153	40	585
$K = 3$	142	40	577

At present, therefore, it seems fair to assume comparison processes at a feature level. The available data, however, do not yet allow a unique identification of the particular strategy at least by an analysis which includes only negative responses.

In conclusion, the presented evidence appears to support the view that the same basic principles of comparison and decision apply at different levels of representation, viz. those at which the processing units are defined. Among the major unsolved problems of the approach is the question of how sequences of appropriate processing units are formed in dependence upon task. Some issues arising in this connection have been treated within the paradigm of "recognition of structure" by Scheidereiter. We must refer here to a report of the chief results in Geissler, Klix and Scheidereiter (1978).

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Text Comprehension and Memory for Inferences

M.-F. EHRLICH

1. Introductory remarks

During the last few years, the work dealing with the memorization of texts and of stories has been considerably developed (cf. EHRLICH, 1976, 1978). After numerous experimental investigations carried out from a psychopedagogical prospect, theoretical statements appeared (FRÉDERIKSEN, 1972, KINTSCH, 1974, RUMELHART, 1975, THORNDYKE, 1977, MANDLER and JOHNSON 1977) which focus on several important questions of great complexity: the semantic analysis of texts, the nature of their representation in memory, the relations between memorization and comprehension.

Whatever their specific features, all of the models take into account, not only the information explicitly presented in the text, but also, the information which can be inferred from it. Here, the notion of inference is a very general notion; it is defined as an intellectual operation implying some inductive or deductive reasoning that is based on logical, semantic or pragmatic relations.

Now regarding the subject who is reading a text, to what extend does he generate inferences and remember them? Very few experimental studies were devoted to this question. The purpose of this paper was to study the relationship between the level of comprehension of a text and the memorization of the various sorts of information which it conveys. Certainly, text comprehension is a very complex problem; here, only one aspect will be dealt with. My general hypothesis is as follows: when a subject is reading a text, he builds up a representation of this text which includes a major or minor number of concepts and of relations depending on the reader's intentions and the objectives he wants to reach, be it consciously or not. In others words, I consider that the representation elaborated by the subject reflects his comprehension of the text. In the experiments, two levels of comprehension were considered: the first level, which might be called superficial level, refers to the processing of the explicit information; the second level, which might be considered a deeper level than the first one, refers to the processing of not only the explicit information but also the information that can be inferred from the former.

The text, half-a-page long, presented the subject with new information relative to astronomy. It consisted of four basic propositions which expressed inclusion relations between five concepts according to the following model: A are B, B are C, C are D, D are E. Because of the transitive character of these basic propositions, inferential propositions of increasing levels of complexity can be derived.

The experiment, which had two phases, had the characteristics of an incidental memory test. Firstly, the subjects read the text. Secondly, the retention of the inferences was tested by means of a verification task regarding the propositions derived from the text. The variable, level of text comprehension (superficial or deep), was made operational by having vary the operations carried out by the subject during his reading of the text. Certain subjects had to judge whether a proposition precisely stated in the text (D are E) is true or false and were asked only to consider the explicit information. Other subjects had to judge an inferred proposition (B are E), and, in order to do so, needed to re-establish the inclusive structure of all of the text's propositions. This corresponds to a deeper understanding. After having read the text, all of the subjects were submitted, under identical conditions to a verification task regarding the explicit propositions and the increasingly inferential propositions. The general hypothesis is that the observed performance on this verification task is dependent on the type of operations carried out in the course of reading.

2. Experiment I

2.1. Method

2.1.1. Material

An 115-word text dealing with astronomy, a field that the subjects knew little of, was constructed. The text consisted of four basic propositions as well as of additional statements whose function was that of masking the inclusive structure of the basic propositions. Among the additional statements, some were at the beginning and some were at the end of the text in order to cancel the classical effects of primacy and of recency, while others constituted complementary information inserted between the basic propositions. The text is the following:

"Telescopes and astronomical field-glasses permit the study of the stars, the science which is called astronomy. Novae are irregular galaxies; they are distinguished from those which have a spiral, an elliptical, or a spirally-crossed configuration. Irregular galaxies are nebulae; they come in various sizes and are measured in tens of thousands of light years. Nebulae are constellations; their name is of Greek origin calling to mind, more or less, their configuration. Constellations are asterisms; the latter are composed of gas clouds and dust which stagnate between the stars. In order to determine the stars' position, astronomers depict the sky as a sphere surrounding the earth".

The four basic propositions express the relations which unite the five concepts: nova (A), irregular galaxy (B), nebula (C), constellation (D), and asterism (E);

- novae are irregular galaxies: $A \subset B$
- irregular galaxies are nebulae: $B \subset C$
- nebulae are constellations: $C \subset D$
- constellations are asterisms: $D \subset E$

From these four propositions[1], one can derive inferential propositions of increasing complexity according to the number of intermediate concepts necessary in order to establish the new relationships:

- inference level 1: $A \subset C$, $B \subset D$, $C \subset E$
- inference level 2: $A \subset D$, $B \subset E$
- inference level 3: $A \subset E$

[1] It has to be noted that, in French, these propositions are written with definite and indefinite articles in the following way: "*Les* novae sont *des* galaxies irrégulières".

From now on, the four basic propositions explicitly presented in the text will be designated level 0 inferences. Thus, in all, there are ten propositions.

2.1.2. Subjects and experimental procedure
Two groups of 20 subjects, 3rd year psychology students, in individual sessions, participated in the experiment. There were two successive phases:
- the reading of the text during which the subjects of the two groups were asked to carry out different operations.
- the verification task regarding the propositions derived from the text, some being true, others being false.

a) *The reading of the text*
The text was typed on paper. The subjects were asked to read it and to judge, "taking into account all of the information given by it", whether a proposition written in the top margin of the paper, above the text is *true* or *false*. The experimental variable is the inference level of the proposition judged by the subjects of the two groups:
- the subjects of group A verified the level 0 proposition: "*constellations are asterisms*" ($D \subset E$). The last of the basic propositions was chosen thus that the subject would be obliged to process the whole text.
- the subjects of group B verified the level 2 inferential proposition: "*irregular galaxies are asterisms*" ($B \subset E$).

The subjects had as much time as desired at their disposition in order to perform this task. The time was recorded.

The two groups of subjects were differentiated by the type of operations that the subjects carried out on the text's information:
- In group A, a simple comparison between the text's statements and the proposition to be judged was sufficient in order to decide whether the proposition was true or false. In order to fulfil the requirements of the task, it is possible for the subject to deal only with the information explicitly contained in the text. On the contrary, in group B, confrontation between the explicit statements doesn't suffice and the subjects necessarily need to connect the statements and to apply an inferential reasoning; it's only by correctly using the logical rules of inclusion and of transitivity that the subject can decide whether the proposition "irregular galaxies are asterisms" is true or false.

In this sense, the required level of comprehension is deeper for the subjects of group B than it is for the subjects of group A. It implies not only the taking into account of the explicit information but also that which can be validly inferred from the text's statements.

b) *The verification task*
Immediately after reading the text, the subjects were submitted to a verification task. Not having been forewarned about this phase of the experiment, the subjects are in an incidental memory situation. The characteristics of this task were identical for both groups of subjects. The propositions were presented successively. For each one of them, the subject had to "decide whether it was true or false, taking into account all of the text's information and everything that could be deduced from it". The subjects were asked to respond rapidly but without hurrying.

The propositions were projected on a screen and the subject responded by pressing one of two answer buttons labelled TRUE and FALSE. An automatic device recorded the response as well as its latency in hundreths of seconds.

The subjects of each group were presented:

. propositions of different inferential levels: $N\,0$, $N\,1$, $N\,2$, $N\,3$.

. true and false propositions. True propositions were considered to be false when its' two terms were permuted.

It is important to specify that, for a given subject, a proposition is presented either in its true form or in its false form, with the exception of the proposition identical to that judged at the time of the reading of the text, $D \subset E$ for group A and $B \subset E$ for group B, presented in its two forms to all of the subjects in the concerned group. In order to respect this constraint and so that the totality of the ten propositions were presented in this verification task under their two forms, true and false, for each of the groups A and B, two sub-groups of subjects were distinguished: those of subgroup 1 judged 6 true and 5 false propositions, those of sub-group 2 judged 5 true and 6 false propositions. Four aleatory orders for the presentation of the propositions were used.

2.2. Results

2.2.1. Reading time

The median reading times are 55 seconds for group A and 76 seconds for group B.

These results indicate that the time necessary to read a text is a function of the type of operations carried out by the subject: a deep processing implying the putting into relation of the statements of the text and the establishment of the rules of inclusion and transitivity requires more time than a more superficial processing which is limited to the explicit statements. This result should be accepted as true with several reservations; although the observed difference was relatively large, the MANN-WHITNEY U-test indicates that is doesn't altogether attain a satisfying statistical threshold.

In order to analyze the verification task, the responses for the true and for the false propositions were separated.

2.2.2. Verification of true propositions

a) Firstly, it's necessary to consider separately the data gathered at the time of the presentation of the proposition (P.id.) identical to that verified during the text's reading. The proportions of correct responses are as follows:

Group A: verification of $D \subset E = 75\%$

Group B: verification of $B \subset E = 80\%$

One thus ascertains that, as far as the recognition of the previously verified proposition is concerned, the performances of the subjects in both groups are similar.

b) *The mean proportions of correct responses* for the whole of the true propositions, excluding (P.id.), are 43.50% for group A and 64.70% for group B. Students' ‚t' indicates that this difference is statistically significant: $t = 2.98$, $\alpha < 0.005$.

In fig. 1, graph (a) shows the proportion of correct responses as a function of the inferential level of the propositions for both groups A and B. Two points should be noted:

– for the $N\,0$ propositions, when it is a question of recognition, in the classical sense

of the term, of statements explicitly formulated in the text, the performances of the subjects of both groups are identical.
- for the inferential propositions $N1$, $N2$ and $N3$, the rate of correct responses drastically decreases for group A, while it remains stable for group B.[2]

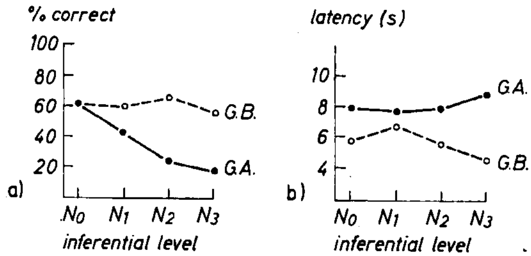

Fig. 1: Proportions of correct responses (graph a) and latencies of correct responses (graph b) for *true* propositions.

c) Study of the *latencies of correct responses* furnishes interesting indications:
The latency of the response at the time of the presentation of the proposition identical to that verified during the reading (P.id.) is longer in group B than it is in group A: the median values are 6.99 seconds and 3.99 seconds respectively.

An examination of graph (b) of fig. 1 indicates that the response times are shorter in group B than they are in group A. In the latter, they don't seem to be affected by the inferential level of the tested propositions. By contrast, in group B, if one leaves aside $N0$ which has a particular status, the latency of the answers tends to decrease when the inferential level increases from $N1$ to $N3$.

2.2.3. Verification of false propositions

a) The proportions of correct responses for proposition (P.id.) are 30% for group A and 40% for group B. This indicates that, in a good number of cases, the subjects tended to consider the propositions as being symmetrical. We will return to this point.

b) *The mean proportions of correct responses* for the whole of the false propositions, excluding (P.id.) are 67% in A and 56% in B. The difference between these two values isn't significant: $t = 1.65$.

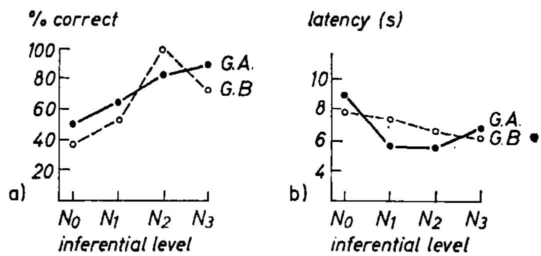

Fig. 2: Proportions of correct responses (graph a) and latencies of correct responses (graph b) for *false* propositions.

[2] The particular characteristics of the experimental material, the fact that the number of observations per subject differs from one modality to the next for the inferential level factor doesn't allow an analysis of variance.

An examination of graph (a) of fig. 2 indicates that the subject's behaviour in both groups is very similar: the correct responses increased as a function of the inferential level of the tested propositions. For all subjects, it was easier to judge as "false" a proposition whose inference level is high than a proposition whose inference level is low.

c) *The latencies of the correct responses* are the following:
- For the inverse proposition of that verified during the rading: "E are D" in group A, "E are B" in group B, the response time is longer in the first group than it is in the second: 7.55 seconds and 4.74 seconds respectively.
- The data presented in graph (b) of fig. 2 seems to indicate that, in both groups, the latency of the responses is longer for *N* 0 propositions, which, it should be remembered, are the inverse propositions of the four basic propositions explicitly formulated in the text, than it is for inferences of level 1, 2 and 3. However, it is only a tendency which should be confirmed by further experimental research.

2.2.4. One can wonder whether the better performances by the subjects of group B are due to the nature of the operations carried out during the reading or to the fact that these operations take more time. In order to attempt to answer this question, the correlations between the reading time and the total number of correct responses (variable from 0 to 11 considering all of the propositions verified by the subjects) were computed. The correlation coefficients (BRAVAIS-PEARSON) are $r = -0.20$ for group A and $r = 0.10$ for group B. They are statistically nonsignificant.

The whole of the data makes clearly conspicuous the decisive role of the cognitive operations carried out by the subject while reading the text on the observed performances in the task of verifying the propositions. Nevertheless, the particular character of the four basic propositions makes the interpretation of the gathered data difficult, notably in the case of false propositions, obtained by permutation of the concepts of true propositions: A are B (true), B are A (false). It is by placing ourselves in the perspective of traditional logic that we have constructed the four basic propositions, giving the relations of inclusion an interpretation said to be "by extension", that which is found in the classical syllogism illustrated by EULER's circles. But it is well known that certain statements of this configuration allow an equivalent extension for the subject and for the predicate. This is the case, for example, when the statements express a definition. One is thus confronted with the problem of the double interpretation of this type of proposition: interpretation "by extension" (belonging to a class) or interpretation "by comprehension" (attribution of a feature or of a property) (cf. OLÉRON 1964, REVLIS, 1975). More scrupulous examination of the subjects' responses shows that some of them adopted the second interpretation by considering the propositions to be symmetric: both A are B and B are A are judged to be true. This strategy is favoured by the fact that the subjects couldn't rely on pre-experimental knowledge of the concepts in order to determine the correct direction of the relations.

Here we have a bias which is suspectible of affecting the experimental data. In order to eliminate this difficulty, we carried out a second experiment, identical with the previous one but preceded by a series of logical exercises essentially aiming at privileging the interpretation "by extension" and at reinforcing the use of the rules of inclusion and of transitivity.

3. Experiment II

3.1. General principles

In the second experiment, we used the as same text in the first. Two groups of 30 subjects were constituted; they were, as before, 3rd year psychology students who had never participated in similar research. At the beginning of this experiment, which took place in individual sessions, all the subjects did exercises in logic according to the following plan:

A first exercise, on nonsense verbal stimuli leads to know the subject's spontaneous interpretation of propositions of the type: X are Y.

After, the subject is trained to systematically privilege "by extension" interpretations. This is done by means of exercises illustrating the notion of class and inclusion, disjunction, intersection, implication and transitivity relations. These exercises are carried out using figurative material composed of stimuli characterized by their shape (square, circle, triangle), and by their colour (green, blue, red).

Lastly, as a control test, the subjects were given the two following premises: X are Y and Y are Z and were asked to judge whether the three following relations were true: Z are Y, X are Z, and Y are X.

This last exercise was carried out using verbal stimuli which designated shapes (quadrilaterals, polygones, geometric figures), animals (tree-frogs, batrachians, vertebrates), and nonsense verbal stimuli identical to those used during the first exercise (stucs, brets, tars).

The two phases, the text's reading and the verification of the propositions took place in the same way as they did in experiment I. The three tasks followed each other without the subjects being informed at the beginning of the session as to their characteristics and as to their objectives.

3.2. Results

The responses given in the logic exercises indicate that, at the beginning, 41 out of 60 subjects adopted an interpretation "by comprehension" of propositions of the type "X are Y" and considered this relationship to be symmetrical. On the contrary, after the special training which they underwent, only 8 subjects persisted in making this error and 52 interpreted this relationship as translating to belong to a class. The analysis of the results deals only with those subjects: 27 in group A, 25 in group B.

3.2.1. Reading times

The comparison of the two median values: 89 seconds for A and 104 seconds for B, shows that there is a difference of 15 seconds in favour of group B. The statistical test (MANN-WHITNEY *U*) shows that it is significant only at the threshold of 0.08.

3.2.2. Verification of true propositions

– If one firstly considers the responses given at the time of the presentation of the proposition identical to the one verified during the reading of the text (P.id.), it can be noted that the performances of both groups of subjects are identical: 85.18% for A and 84% for B.

– *The mean proportions of correct responses* for all of the true propositions, excluding (P.id.) are 57.85% for group A and 82.14% for group B. The difference is statistically significant: $t = 4.25$, $\alpha < 0.001$.

Inspection of graph (a) of fig. 3 indicates that for level *N* 0 propositions, the subjects of both groups performed identically and well (about 85%). On the contrary, for the inferential propositions, the response profile is very different. In A, the proportion of correct responses very rapidly decreases and doesn't attain more than 23% for the *N* 3 propositions. In B, the proportions of correct responses remains stable and close to 80%.

– *Study of the correct response latencies* leads to the following observation: the latency of the response corresponding to the proposition already presented during the reading is identical in both groups. The median value is 5.19 seconds for group A, 5.76 seconds for group B.

Inspection of graph (b) of fig. 3 reveals that the response times tend to increase with the inferential level of the proposition tested in group A although it remains stable in group B.

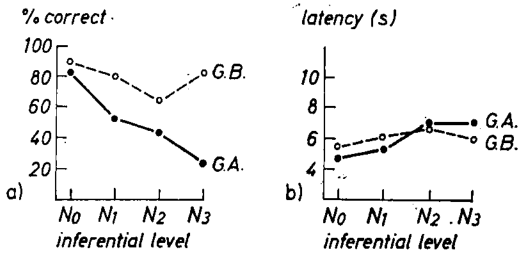

Fig. 3: Proportions of correct responses (graph a) and latencies of correct responses (graph b) for *true* propositions.

3.2.3. Verification of false propositions

– The proportions of correct responses for proposition (P.id.) are high for both groups: 81.48% in A, 72% in B.

– *The mean proportions of correct responses* for all of the false propositions, excluding (P.id.) is higher in B (71.68%) than it is in A (56.55%). This difference is statistically significant: $t = 2.58$, $\alpha < 0.02$.

Graph (a) of fig. 4 shows response profiles similar to those observed in the case of the true propositions. It is only for propositions *N* 1, *N* 2 and *N* 3 that the groups

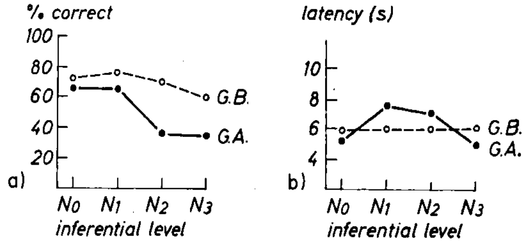

Fig. 4: Proportions of correct responses (graph a) and latencies of correct responses (graph b) for *false* propositions.

differ, the number of correct responses decreases in A while it tends to remain stable in B.

– *The latencies of correct responses* are as follows:

For the proposition inverse to that verified during the reading ("E are D" in group A, "E are B" in group B), the latencies are very close, 5.65 seconds and 5.49 seconds respectively.

Figure 4, graph (b) shows, for group B, a great stability of correct response latencies as a function of the inferential level of the propositions. On the contrary, the results of group A are less clear: the latencies increase from *N* 0 to *N* 1 and *N* 2 but sensibly decrease for *N* 3. These data should be considered with prudence, because it is necessary to take into account the small number of responses (5) from which the median was calculated.

3.2.4. The correlation coefficients between the reading time and the total number of correct responses produced by the subjects are negative and non-significant: $r = -0.23$ for group A and $r = -0.34$ for group B.

4. Discussion

The main results of these two experiments are the following:

The reading time of a text is a function of the nature of the operations carried out by the subject on the statements which make it up: the use of inferential reasoning requires more time than does only taking into account the explicit statements. In any case, it isn't the time itself which determines the subject's performance on the further memorization task but how the subject used his time.

The subjects' performances were identical when it was a question of remembering the explicit statements in the text (propositions *N* 0), but very different in the case of the statements which could be derived from the first by using the rule of inference (propositions *N* 1, *N* 2, *N* 3): only those subjects who were asked to construct and to use this rule during the reading of the text (group B) were capable of remembering and of generating inferential propositions.

These data show the close relationship which exists between memory said to be inferential and the level of comprehension of a text. It clearly appears that the knowledge structure built up by the subjects while reading the text presents variable characteristics which are dependent on the objectives which were assigned to them (in one group or the other). It is only when the reading is accompanied by the use of pertinent cognitive processes leading to a deep level of comprehension of the text that the subject's constructed conceptual structure integrates some inferred relations and that the existence of an inferential memory occurs. The data for the latency of correct responses seem to indicate that the links that subjects created between the diverse concepts of the structure are of the same strength no matter what the inferential level of the relations which they hold together may be.

Certainly, these conclusions should be judged with the particular characteristics of the experiments in mind. Here, the inferential memory is studied with a text whose statements provide precise, logical relations. The results can't directly be generalized to texts whose inferences are based on semantic or pragmatic-type relations. Moreover, the text's retention was tested by means of a verification task which, as one knows, involved complex response mechanisms and only concerned a part of the text's information, eliminating all possibility of estimating the retention of the additional statements which were inserted between the basic propositions. It is clear that further research has to be carried out in order to better understand the relations between reading, comprehension and text memorization.

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Processing of Comparative Sentences

J. SEGUI

In this report, I hope to be able to show that sentence comprehension can profitably be studied by considering a single type of structure from several different perspectives. In the following series of experiments, the comparative sentence is examined from a structural, functional, and referential point of view.

In a first experiment (SEGUI and BERTONCINI, 1978) we studied the comprehension of positive and negative comparative sentences (sentences with "less" (moins) and "more" (plus)) by using a picture-sentence verification procedure. Two linguistic variables, the positive and negative form of the comparison term, and the marked and unmarked forms of the adjectives were used. By combining these two variables, the following four types of comparative sentences were constructed:

a) Le carré rouge est plus grand que le carré bleu.
(The red square is larger than the blue square).
b) Le carré bleu est plus petit que le carré rouge.
(The blue square is smaller than the red square).
c) Le carré rouge est moins petit que le carré bleu.
(The red square is less small than the blue square).
d) Le carré bleu est moins grand que le carré rouge.
(The blue square is less large than the red square).

All the sentences used in this experiment expressed a comparison between two geometrical figures. In this way the subjects would have no reference norm for size for the two stimuli, for instance, a red square and a blue one.

In this experiment, we wanted to determine whether or not the time necessary to verify the relation expressed in the sentence was a function of its structural and/or cognitive complexity.

From the results, it appeared that the linguistic variables under consideration introduced highly significant differences: sentences with a positive form (more) were more quickly verified than sentences with a negative form (less) and sentences with the unmarked adjective (long) are more quickly verified than sentences with a marked adjective (short). These results are analogous to the results obtained by FLORES d'ARCAIS (1974) who worked on Italian.

However, contrary to the results of FLORES d'ARCAIS, a clear interaction between the two variables was found for true sentences, as can be seen in fig. 1.

The discrepancy between these two results could perhaps be attributed to a difference in the type of adjectives used in the sentences. In my study, all the adjectives are relative adjectives which belong to the set of size adjectives like long-short, large-small, high-low, etc. The distinction between marked and unmarked adjectives seems to be clear for this type of adjectives (BIERWISCH, 1967, 1970, HUTTENLOCHER and HIGGINS, 1971).

The interaction obtained was interpreted as reflecting a transformation of the double negative comparative sentence into a positive form; that is to say, the transformation of the sentences with "less plus a marked adjective" into a sentence with "more plus an unmarked adjective" (for example, "A is less short than B" is converted into "A is more long than B"). In other words, it is suggested that the comprehension of the double negative sentence requires that the subjects transform it into a

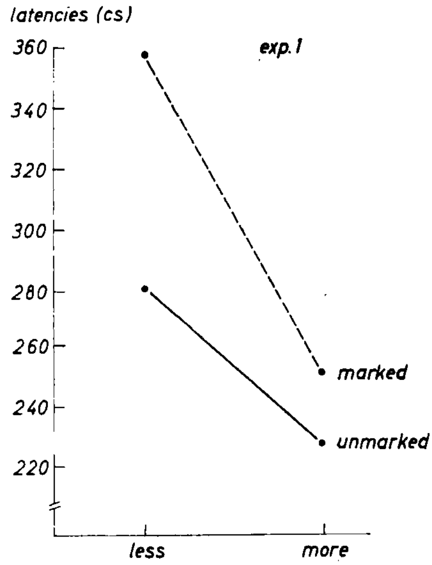

Fig. 1: Mean latences to verify comparative sentences as a function of comparative form (more/less) and the character of the adjective (unmarked/marked).

positive sentence, and that the verification process would then be applied to the derived positive sentence. This hypothesis about a "reformulation" of the double negative comparative sentence during comprehension has been explicitly formulated by HUTTENLOCHER and HIGGINS (1971). Furthermore, SHERMAN (1976) has shown the relevance of the transformation hypothesis for multiple negative sentences, using a large range of syntactic structures.

It is clear that in our experiment the comprehension of sentences was studied without taking into account their real function in language. It thus seemed important to know in which conditions of communication, double negative sentences, complex from the structural and cognitive points of view, are used.

On the basis of the previous experiments, it was hypothesized that the double negative comporative sentence would be employed only when its comprehension by the hearer would not require a transformation into a positive sentence. Such a condition is fulfilled when the terms compared in the sentence have previously been categorized as being close to the marked pole of the underlying semantic dimension.

Thus, on the basis of our intuition, it seems evident that the sentence "The bee is less small than the ant" is more acceptable than the sentences "The elephant is less small than the rhinoceros" even though these two sentences are equally true. Consequently, the claim is that the use of double negative comparative sentences presupposes that the terms being compared are located on the marked side of the underlying semantic dimension.

If this hypothesis is correct, it should be possible to show that double negative comparative sentences convey some implicit information concerning the absolute position of the terms being compared on the underlying semantic dimension.

In order to test this hypothesis, we devised (SEGUI et FOURMENT, in press) an experiment in which subjects were asked to make inferences about the "referents" of the noun phrases of comparative sentences. The subjects were presented with three possibilities and asked to choose the appropriate one. Thus, for example, after having read the sentence: "Peter's house is less large than Paul's", the subjects received the three following assertions:

1. The houses are rather large.
2. The houses are rather small.
3. One can not say anything about the size of the houses.

Choosing the first assertion implies the possibility of making an inference according to the directionality indicated by the adjective of the sentence, choosing the second assertion reflects the possibility of making an inference against the directionality of the adjective, and finally choosing the third assertion corresponds to the impossibility of making an inference.

Tab. 1: *Percentage of Response "Inference" According to the Directionality of the Adjective of the Sentence*

	Plus (more)	Moins (less)	Aussi (as)
Unmarked	26	49,3	78,7
Marked	39,3	76	89,2

The results obtained show that the possibility of making inferences based on the directionality indicated by the adjective varies with the form of the comparative sentence (less, more, and as) and with the character of the adjective (marked or unmarked).

As can be seen, in accordance with the hypothesis, double negative comparative sentences seem to involve some very strict presuppositions concerning the absolute position of the compared terms. In other words the subject considered that the sentence "A is less small than B" would only be used when the two objects being compared were categorized as smaller than the reference norm.

These results indicate that the conditions in which the subject uses comparative sentences correspond to rather strict presuppositions concerning the absolute position on the underlying semantic dimension of the terms being compared.

It is the existence of these restrictions on the use of comparative sentences that enables the subject to make inferences on sentence referents based only on the type of syntactic structure used to express the relation. It is important to observe the high correlation between the degree of structural and cognitive complexity of the relation expressed in the sentence and its presuppositional nature. The more complex the comparative sentence is from a linguistic point of view, the more accentuated its presuppositional character will be.

The high frequency of positive comparative sentences with unmarked adjectives could be attributed not only to the fact that they are the simplest one from the linguistic and cognitive points of view, but also to the fact that their use is not submitted to precise constraints. In other words, the more natural and neutral way to express a relation between two objects consists probably in formulating the comparison with a positive comparative sentence with an unmarked adjective.

However, the majority of the subjects in this experiment found it impossible to make inferences about the referents of the compared terms when the comparative is positive, independently of the character (marked or unmarked) of the adjective. This result suggests that the positive sentence with unmarked adjectives will not always necessarily be used to express a comparison between two familiar objects. In those cases where the objects are categorized as being close to the marked pole of the underlying dimension, it is probably more natural to make comparisons with respect to this pole.

In a recent experiment (Segui, Léveillé and Gilis, in press) on the verification time for positive comparative sentences expressing a relation between two animals (working with a set of eight animals ordered according to their size), a clear effect of semantic congruity is found. When the two animals being compared are categorized as small, the verification time for sentences with the adjective "small" (A is smaller than B) is shorter than for sentences with the adjective "large" (B is larger than A). The opposite result is obtained when the animals are categorized as large.

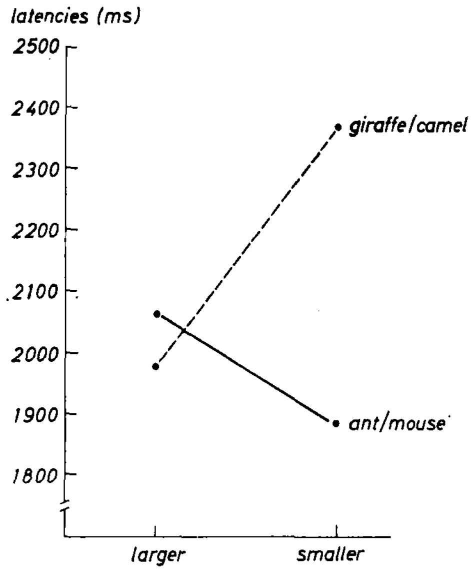

Fig. 2: Mean latencies to verify comparative sentences as a function of the absolute position of the terms on the underlying semantic dimension.

Our hypothesis is that the congruity effect is a consequence of the absence of correspondence between the characteristic properties of the terms being compared (properties coded in memory) and the polarity of the semantic dimension specified by the adjective in the sentence. Thus, for example, to decide the truth value of the sentence "The camel is smaller than the giraffe", involves certain difficulties due to the fact that both of these animals are categorized in memory as being larger than the reference norm (cf. BANKS, CLARK, and LUCY, 1975, BANKS, FUJII, and KAYRA-STUART, 1976, BANKS and FLORA, 1977).

Of course, the way in which a term is coded in memory with respect to a given semantic dimension can be more or less strict. The closer a term is to the pole of a dimension of comparison (the pole could be represented by a term which serves as the extreme of the comparison) the more probable it is that this term is coded with respect to this polarity.

This hypothesis about a differential probability of coding of terms of a conceptual category allows us to account for the regular decrease in the congruity effect as the terms being compared are at greater distances from the extremes of the underlying semantic dimension.

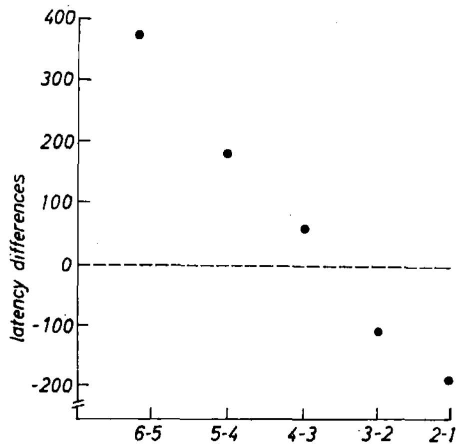

Fig. 3: The difference (time to verify "smaller" comparative sentence—"larger" comparative sentence) for the adjacent pairs of terms. 1: ant, 2: mouse... 6: giraffe.

The demonstration of a congruity effect in the verification of comparative sentences goes against the predictions of the "principle of lexical marking" proposed by CLARK (1969). Indeed, according to this theory, the comparative sentence with an unmarked adjective is psychologically simpler than the complementary sentence with a marked adjective.

Our results show that this is not necessarily so when the sentences used include terms familiar to the subject; that is to say, terms likely to be categorized in memory with respect to the semantic dimensions of the comparisons.

There is still, nevertheless, the cases where the terms in the sentence are distant or not strictly categorized along the semantic dimension. In this case the verification times are always shorter when the relation is expressed by an unmarked adjective. This is shown in fig. 4 in which there is also a clear effect of the symbolic distance for the two types of sentences (cf. MEYER, 1973, PAIVIO, 1975, KERST and HOWARD, 1977, FRIEDMAN, 1978).

This result supports the hypothesis that the comparison between two terms would be expressed with an unmarked adjective in the comparative sentence, except when the compared terms are categorized by the subjects as being close to the marked pole of the underlying semantic dimension of comparison (or when one of the terms serves as the focus of comparison or the topic of the discourse).

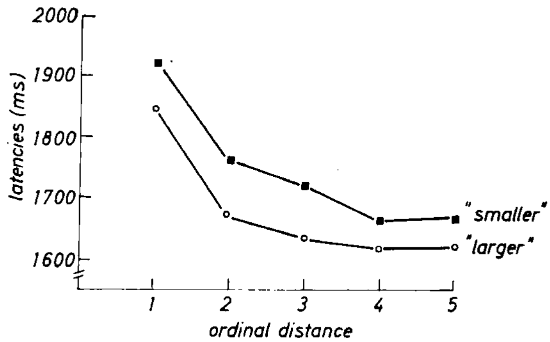

Fig. 4: Mean latencies to verify comparative sentences as a function of the ordinal distance between the terms of the sentence and the character of the adjective (smaller/larger).

The experiments on comparative sentences show that in sentence comprehension studies, one should take not only a structural point of view but also a functional and referential one. Only with a deeper knowledge of the structure and function of sentences we will be able to make inferences about the psychological operations that underlie their processing.

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Anticipation Activities and Semantic Decisions in a Sentence Word Comparison Task

J. P. GAILLARD

1. On the problem state

Some years ago one would have considered verbal events as a Markovian process, but in the probabilistic analyses of the discourse some experiences revealed that the listener must take into consideration the post verbal events and the future verbal events (MILLER and FRIEDMAN, 1957, GOLMAN-EISLER, 1964). Then we can suppose that language production the same as language comprehension activities do not include a finite stochastic process but more an anticipation activity based partly on post verbal events.

In the present work we have developed the anticipation hypothesis when reading in a semantic decision task. We visually presented first, a full sentence and then, a word to the subjects and instructed them to respond as quickly and accurately as possible if the meaning of the word was consistent with the meaning of the sentence. Ex.: Sentence: The surgeon operated on the patient in the hospital. Test word: scalpel.

In this kind of experiment the latency time recorded could be theoretically considered as the sum of multiple fractions of time.

1. The grapho-phonic identification of the test word and its semantic treatment.
2. The comparison and decision activity in memory.
3. The effectuation of the motor response.

This latter mean fraction of time is then considered as a constant when the subjects are randomly chosen. The two other components of the total reaction time (RT) can vary with different independent factors. Anyway, we consider the first component, as a parallel or serial process between the perceptual identification and the semantic treatment. If the other RT components are kept constant, the RT will vary, in part, with the degree of readability on the semantic compound of the test word. In this work we will not present specific predictions depending on the readability of the test word even if some results suggest such an interpretation. The second time component referring to a comparison and decision process will vary according to a congruence relation between the sentence and the test word. We can represent the congruence relation by the semantic distance separating the two terms of the comparison in memory. The bigger the semantic distance between the two terms the lower the congruence will be.

In both experiments we varied the congruence of the sentence/word couple and observed the RT in a semantic decision task according to an estimated semantic distance. More precisely, in these experiments we set forth the hypothesis of a comparison between the test word and a list of anticipated words in memory. The list of expected words might be generated when the reading of the sentence occurs and be hierarchically ordered in a pile. The comparison process might be a successive binary micro-comparison between each word in the pile and the test word. Each micro-comparison will take a time -t- and the more the micro-comparisons, the longer will be the total time of comparison. Another hypothesis supposes that each word in the sentence is compared with the test word. If the meaning of one word in the sentence is compatible with the meaning of the test word, the 2 terms of the comparison will be congruent and the more the number of words in the sentence compatible with the test word, the more congruent the sentence/word couple will be. We then suppose that the total comparison time will vary inversely with the number of compatible words in the sentence. We suggest here that the first hypothesis, or anticipated word-list hypothesis, could be an extension of the second hypothesis if we consider that the length of the word list depends on the semantic compatibility of the different words within the sentence. A strong compatibility within the sentence will initiate a strong selection restriction in the lexical memory, and the anticipated list length will be short. Then the number of micro-comparisons will decrease as the compatibility within the sentence increases.

2. Experiment I

To test this hypothesis, we first standardized 24 sentence/word couples with 20 subjects. We orally presented each sentence and after it, we presented a word. The subjects had to evaluate on a scale from 0 to 5 if they estimated that the meaning of the sentence was congruent with the meaning of the test word. Zero would mean: "I estimate that there is no relation between the meaning of the sentence and the test word" and 5 would mean: "There is a very close relation between them".

The results we obtained by standardizing the 24 couples show that the rating of the 12 expected congruent couples is between the mean values of 2,80 for the lowest and 4,47 for the highest. The values for each sentence/word couple were calculated by the mean of the values given by 20 judges, and we called this mean value the "Congruence rating" (CR). The 12 expected non-congruent couples had a CR between 0,44 for the lowest and 1,66 for the highest.

The first reason why we expected higher ratings for the 12 sentence/word couples has to do with the fact that the test word was a possible "instrument" in the sentence, but we will discuss this question later. A second reason was that one word in the sentence at most was a priori compatible with the test word. We made the prediction that the CR for these 12 couples will vary according to the number of compatible words in the sentence and will be ordered as following.

$$CR_1 < CR_2 < CR_3 < CR_4$$

(The integers 1, 2, 3, 4 refers to the number of compatible words.)

This prediction was realized.

Tab. 1: *Congruence rating obtained when standardizing the material*

Number of compatible words in the sentence	1	2	3	4
"Congruence" rating	3.42	4.04	4.05	4.22

Then the first experiment was a look at the variation of the RT as a function of the CR we obtained when standardizing the material. The main prediction was that the RT for the congruent couples would decrease when the number of compatible words in the sentence increased. We also predicted a positive response for the 12 higher CR couples and a negative response for the 12 lower CR couples.

2.1. Method

2.1.1. Material and design

We used the same 24 sentence/word couples and each subject saw the 24 couples: 12 couples for which we expected a positive response, and 12, with a negative response. Each of the sentences had the following grammatical structure:

an agent
an action
an object
a locative

Therefore, the 24 sentences had the same grammatical structure and the 12 compatible test words were an "instrument" for the preceding sentences. The 12 incompatible words were nouns which were not semantically and directly connected to any word in the sentence.

The 24 couples were randomly ordered in four different orders each forming a block of 24 trials. Consequently, the four blocks were made up of the same 24 couples but presented in 4 different orders.

2.1.2. Subjects

19 subjects of both sexes and different ages were recruited from the University of Paris VIII. All were students in the University but in different departments. The session lasted about 1 hr.

2.1.3. Apparatus and procedure

Subjects were run individually. The sentence/word couples were tachistoscopically presented, the first sentence for five seconds, then the sentence disappeared and a word was presented for another 5 seconds. Subjects were instructed to respond as quickly and precisely as possible "... if the meaning of the word was connected to the meaning of the sentence". If they judged that there was a connection, they pushed a button labeled "yes"; in the opposite case, they had to push a button labeled "no". We instructed the subjects to maintain their fingers on the buttons ready to respond. For half the subjects "yes" was on the left and for the other half, "yes" was on the right. We did not ask the subjects if they were right or left-handed. An electronic clock connected to a photo-electric cell in the tachistoscope and to the reaction panel to recorded the RT. It started when the test word appeared and stopped when the subject pushed one of the 2 buttons facing him. The type of response, "yes" or "no", and the RT were recorded automatically. The RT was recorded to the hundredth of a second.

2.2. Results

The total percentage of errors was 6,74%, but there were more errors for expected positive responses than for the negative ones. 10,74% and 2,74% respectively. To compute the RT we eliminated the response errors. The main prediction was tested by calculating the mean RT corresponding to sentences with o (neg. responses), 1, 2, 3 or 4 words (pos. responses) compatible in the sentences with the test word.

Tab. 2: *Mean reaction time in cs for block 1*

Number of compatible words in the sentence	0	1	2	3	4
Mean RT	207	215	175	170	161

As predicted, we obtained a decrease in the RT when the number of compatible words increased.

Tab. 3: *Mean reaction time in cs for the four blocks*

CR classes	<0.5	0.5 to 1.0	>1.0	<3.5	3.5 to 4.0	>4.0
Mean CR	0.4	0.7	1.2	2.9	3.7	4.2
Mean RT						
Block 1	206	195	219	209	191	168
Block 2	175	168	185	149	136	140
Block 3	170	166	174	167	169	163
Block 4	141	143	135	110	126	118

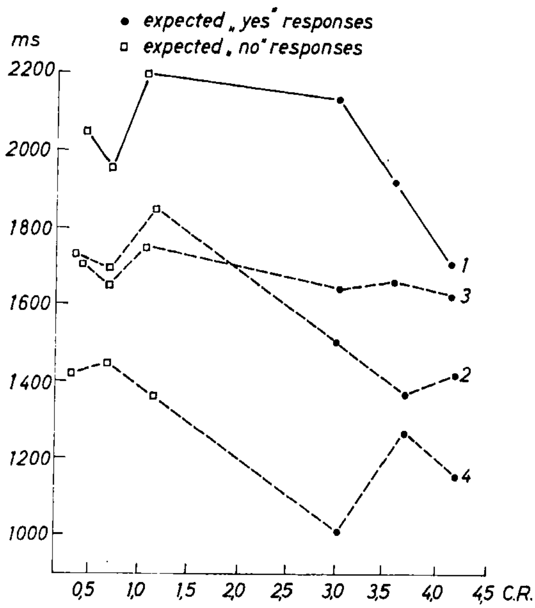

Fig. 1: Mean RT in ms for the four blocks as a function of the CR.

We calculated the mean RT for 2 × 3 classes of CR. The "yes" RT corresponding to the CR < 3,50, between 3,50 and 4,00 and >4,00. The "no" RT corresponding to the CR < 0,50, between 0,50 and 1,00 and >1,00. We reproduced the mean RT corresponding to each class of CR in tab. 3 for the four blocks.

Blocks 2, 3 and 4 represent the learning of the sentence/word couples and we notice a decrease in RT except for block 3 compared to block 2 where pos. RT's are no longer than pos. RT's for block 3 (fig. 1). The reason for this is not clear. However, we can see that the pos. RT for the class superior to 4,00 for block 1 is not different from the corresponding RT for block 3. But the main assumption on the learning effect is that the predicted relation between the CR value and the RT is eliminated. We then concentrate on the analysis of the results in block 1.

There was a negative correlation between CR and pos. RT ($r = -0.54, p < 0.01$), and a positive correlation between CR and neg. RT ($r = 0.38, p < 0.01$).

The percentage of errors for the first block is reproduced for each class of CR in tab. 4.

Tab. 4: *Percentage of error as a function of CR*

CR classes	<0.5	0.5 to 1.0	>1.0	<3.5	3.5 to 4.0	>4.0
% errors	0	7.46	14.89	17.24	10.48	16.0

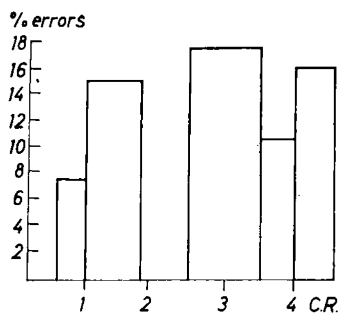

Fig. 2: Distribution of percentage errors.

The false neg. responses tend to increase with the CR, while the false positives tend to decrease with the increase of CR except for the values of CR above 4.00.

2.3. Discussion

These preliminary results support the main hypothesis of a correlation between the number of semantically-connected words in the sentence with the test word and the RT. Furthermore, the results are largely compatible with the signal detection theory, if we admit the CR is an estimate of the semantic distance between the meanings of the sentence and the test word. The CR is a good index of the RT in a semantic decision task. However, the rank of the compatible word in the sentence was not controled. One may object that there is a recency effect when a compatible word is at or near the end of the sentence. It was the case in the 4-compatible-words sentence where the last word was always a compatible word to the test word. On the other hand, in the one-compatible-word sentence, this word was at or near the beginning of the sentence.

3. Experiment II

Experiment II was conducted to test an eventual recency effect. A new set of 24 couples was standardized to this effect. To determine the CR for each couple we used the same method, scale and instruction as in experiment I, but in two different ways. First, we determined a CR for each word in the sentence with the test word and then, we controlled the number of compatible words in the sentence. The mean CR calculated by the formula

$$CR_1 = \frac{\text{Total CR}}{\text{Number of words in the sentence}}$$

Tab. 5: *Congruence rating for the 24 sentence/word couples*

Number of compatible words in the sentence	CR_1	CR_2	Mean CR_1	Mean CR_2
4	4.32	4.88		
4	4.24	4.85	4.34	4.86
4	4.46	4.85		
3	3.63	4.25		
3	3.22	4.66	3.39	4.43
3	3.32	4.38		
2	2.76	3.58		
2	2.73	4.83	2.79	3.97
2	2.90	3.50		
1 b	1.85	4.58		
1 m	1.60	3.33	1.67	4.30
1 e	1.56	5.00		
0	0.13	0.05		
	0.00	0.07	0.08	0.08
	0.13	0.12		
	0.49	0.22		
	1.35	0.29	0.65	0.26
	0.11	0.29		
	0.55	0.40		
	0.72	0.59	0.46	0.58
	0.13	0.77		
	0.69	1.59		
	0.77	1.59	0.57	1.88
	0.27	2.48		

was the CR_1 of the sentence/word couple in the first method. In the second method we proceeded as in experiment 1 to determine the sentence/word couples CR_2.

In the first method we tested the material with 20 judges and in the second method with 20 other judges.

Predictions were the same as for experiment 1, but we further predicted a recency effect when the compatible word was at the end of the sentence.

3.1. Method

3.1.1. Material and design

We used the 24 couples which were standardized for experiment 2. The expected compatible test word maintained an "instrument" case relation with the sentence for the 12 expected congruent couples. The grammatical structure of the sentence/word couple was the same as that described in the first experiment. The material tested was composed of 12 expected congruent couples and 12 non congruent ones. In the 12 congruent couples, 3 sentences had 4 words compatible with the test word, 3 sentences had 3 words compatible; 3 sentences 2 words, and 3 sentences 1 word. For these last 3 sentences, the rank of the compatible word in the sentence could be at the beginning (1 b), the middle (1 m), or at the end (1 e) of it. We obtained a within-subject design with the number of compatible words, and the rank of the word in the sentences (1).

3.1.2. Apparatus and procedure

Subjects were run individually. The sentence/word couples were presented on a screen in front of the subject with a kodak carousel system. The experimenter presented a sentence, and when the subject indicated he had read it, the experimenter presented the test word.

Instructions were the same as in the preceding experiment. An electronic clock started when the sentence appeared and stopped when it disappeared; then a second electronic clock started when the test word appeared and stopped when the subject pushed one of the two buttons labeled "yes" or "no". The experimenter recorded the type of response, the RT and the time required to read the sentence (SRT). RT and SRT were recorded to the nearest cs. Unlike with experiment 1 subjects were presented the 24 sentences only once.

3.2. Results

The percentage of errors was 3,47% and the distribution of the number of errors shows that there is an increase of false positive responses and a decrease of false neg. when the CR increases.

Tab. 6: *Percentage errors for experiment II*

Number of compatible words in the sentence	0	1	2	3	4
% errors	2.22	7.77	5.55	4.44	1.11

RT plotted against the number of compatible words in the sentence shows a decrease of positive RT. The variance analysis revealed there was no statistically significant difference between pos. and neg. RT $F\ (6.174) = 0.28$, $p > 0.10$. The

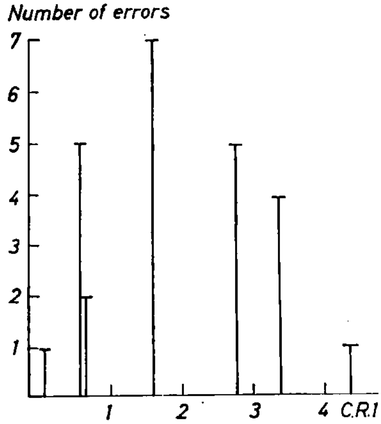

Fig. 3: Histogram of errors for each of the 8 CR classes.

difference in RT between conditions with 1, 2 and 3 compatible words as compared to the condition with 4 compatible words was statistically significant: $F\ (6.174) = 2.86$, $p < 0.05$. With conditions 1 and 2 words compared to 3 words it was significant: $F(6.174) = 2.60$, $p < 0.05$. But with condition 1 word compared to condition 2 words it was not significant: $F(6.174) = 0.03$, $p > 0.10$. For the positive RT the negative correlation with the CR_2 was significant $r = -0.75$; $p < 0.01$. But for the neg. RT the correlation with the CR_2 failed to show a significant level: $r = -0.15$; $p > 0.10$. The RT/CR_1 correlation was $r = -0.65$; $p < 0.02$ and $r = 0.16$; $p > 0.10$ respectively.

To test the effect of the rank of the compatible word in the sentence, we compared the RT obtained in conditions 1 b, 1 m with condition 1 e. The RT difference was not significant: $F\ (6.174) = 1.24$; $p > 0.10$. The RT for conditions 1 b and 1 m were significantly different: $F(6.174) = 2.94$; $p < 0.05$.

Tab. 7: *Mean reaction time in cs and standard deviation for experiment II block 1*

Number of compatible words	Mean RT	ST	
Ie	110.9	42.0	
Ib	112.3	42.5	128.2
Im	161.3	85.8	
2	125.0	52.2	
3	104.4	46.6	
4	98.7	35.6	
0	122.6	46.4	

In this experiment we recorded the time required for reading the sentences (SRT). Results show that the SRT decreases as the number of compatible words in the sentence increases.

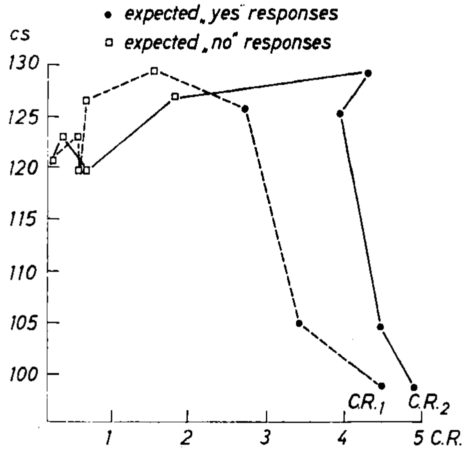

Fig. 4: Mean RT for experiment II as a function of CR 1 and CR 2.

Tab. 8: *Mean reading time in experiment II for sentences*

Number of compatible words	Mean reading time
1	356
2	297
3	292
4	251
0	310

3.3. Discussion

Experiment II reproduces the results we obtained in experiment I except for the neg. RT which was not significantly different from the pos. RT and was not correlated to the CR. However, the main prediction on the pos. RT was consistent with the hypothesis of a semantic anticipation when reading. This hypothesis is supported by the reading time results. We can explain a decrease of reading time with the number of compatible words in the sentence by assuming the subjects anticipate the next word in the sentence when reading. Once the next word is anticipated, it should facilitate identification and the semantic treatment of the information. On the other hand, there was no recency effect but a difference between the sentences with the compatible word at the middle (1 m) and the beginning (1 b). The mean RTs corresponding to such sentences were 112.5 cs and 161 cs respectively: (F (6.174) = 2.94, $p < 0.05$). This particular result is accounted for by a high CR for sentence 1 b (CR = 4.58) and a comparatively low CR for sentence 1 m (CR = 3.33).[1] If the semantic congru-

[1] A third experiment to control the effect of the CR value on the RT with a one-compatible-word sentence was performed and confirms this interpretation.

ence between sentences and test words can explain the main results, we can draw no conclusion as to whether or not there is a recency effect on RT in such a decision task. Indeed, the apparatus shows an inertia which causes a delay of 1 s maximum between the presentation of the sentence and the presentation of the test word. This inertia is responsible for a crucial delay in testing an eventual recency effect. Another argument consists in admitting that the subjects may read the sentence more than once and may go back to read the first or middle words at the moment internal understanding decision is made. The same process might occur during the blank and initiate a rehearsal of the sentence. In these cases the last reading word might be at the beginning or the middle of the sentence and a recency effect could occur wherever the compatible word is. Finally one could argue the compatible word in conditions (1) was the verb according to the grammatical structure whereas the test word was an "instrument" of the sentence. Recent results (LE NY' 1978) showed a recency effect for nouns but failed with the verbs. Some theoretical arguments could explain these results if we admit the verb (as an action) has a different status compared to other lexemes in a semantic structure.

4. General discussion

With the main results we obtained we can now turn to a model of semantic decision derived from the signal detection theory. When a semantic comparison occurs between 2 terms some authors (ATKINSON and JUOLA, 1973) pointed out a cognitive activity founded on a trace strength of the stimulus memorized. One issue of the comparison could be interpreted as a familiarity value between the two terms; thus, the familiarity increases with the number of presentations of the stimulus. Another explanation in such comparison tasks is founded on a semantic feature model (SMITH, RIPS and SHOBEN, 1974) and then the subjects are supposed to check an overlap between the 2 terms calculated from the number of features in common. Anyhow whatever the model one have to suppose criteria for decisions (JUOLA and ATKINSON, 1974, SMITH, RIPS and SHOBEN, 1974, HUESMANN and WOOCHER, 1976). In addition to the main characteristics of classical decision models, a more complete semantic decision model should include an anticipation activity which allows the subject to have the list to-be-compared in memory.

Semantic anticipation activities could be integrated in a grammatical case theory and, in particular, be related to semantic sentence structure theories. When reading, anticipations will be made as semantic hypotheses on the next words to come. Such anticipations could be established partly on semantic cases which have not been seen by the subject but which compose the typical frame of a sentence. Then the semantic material anticipated would be compared to what is printed or said and this kind of activity could have a great influence on what is memorized when reading.

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Effect of Context on RT in a Semantic Decision Task

M. M. Hupet

Since Quillian proposed his basic theory of human semantic memory, there has been a strong revival of interest among psychologists for what is involved in the process of "knowledge actualization". As you may have noticed from the sessions of this symposium, the basic questions have not changed very much: How do people retrieve information? What is the process by which an individual can search his memory and produce a response that is appropriate to a given question? There is much evidence that people are very good at this. Up to present, however, relatively little is known about how they do it. Even if we were agreeing for restricting the knowledge actualization problem to the question of how people deal with information like *A car is a vehicle*, *The robin is a bird*, or *A tree is a tree*, it would not be easy to escape the controversies arising from various ad hoc explanations.

Actually, since Quillian's theory was proposed, there have been an impressive number of experiments concerned with storage, retrieval and priming in semantic memory. In recent years, a large variety of tasks have been used to assess the organizational and processing properties of memory. However, among the problems with the models that have been proposed, it must be noted that they are based on experimental work which, most of the time, concentrated upon taxonomic relations of nouns, and more particularly upon superset relationships, and this, as pointed out by Kintsch "to such an extent that other problems have been lost sight of". Indeed, much has been said and written about how people are supposed to process sentences like *The robin is a bird,* or *Lion and Zebra are both animals* etc. The crucial problem, however, is that it is not easy to see how the theoretical elaborations that have been proposed for such materials could be extended to account for how people deal with sentences like *The car-dealer suggested me to buy a new car*, or *It smells good in the new car.*

In order to widen the approach, several experiments have been conducted, using an original experimental paradigm which, it was hoped, would allow to get further information about the processing of such complex sentences. The experiments I want to talk about are of the sentence evaluation type in a paradigm allowing the investigation of semantic-facilitation effects on the evaluation process. Actually, I wanted to examine how long it takes to decide whether a word can be used to complete an unfinished sentence given as prior context, and to delineate the implications of such RT data for the manner in which expectancies develop and for how people use expectancies to modulate their performance.

The basic paradigm used in this series of experiments is as follows. The Subject is first presented with an unfinished sentence, i.e. a sentence the last word of which is missing, to which he makes no overt response. The subject is then presented with a word and asked to decide whether this word can be used as ending word of the preceding sentence, i.e. whether this word makes the whole sentence a semantically acceptable sentence.

Experiment I
Materials: As regards the collecting of sentences to be used in this series of experiments, a preliminary study was conducted in which 50 Ss were given 100 unfinished sentences and simply asked to complete each sentence with a single word. At the end of this preliminary phase, it was decided to eliminate all the too easy sentences, i.e. the sentences for which all or nearly all the subjects had given the same ending word. Actually, 43 different sentences were retained, for which the number of ending words ranged from 3 to 18.

For experiment I, 10 sentences were selected from the initial set of 43 sentences. The number of different ending words that had been proposed for these sentences ranged from 6 to 17.

For each of these 10 sentences, two test ending words were selected, according to the number of Subjects who had proposed these words. One word was a low frequency ending word, i.e. a word that had been proposed by a few Subjects only (the actual propability of these low frequency words ranged from 0.02 to 0.06). The other test word was a high frequency ending word, i.e. a word that had been proposed by a majority of Subjects (the actual probability of these words ranged from 0.24 to 0.54)[1]. Trick sentences like *The ants in the kitchen at the noise* were added to the experimental sentences.

Procedure: The experimental and trick sentences were randomly presented. Each unfinished sentence was projected for 2.5 s, after which it disappeared. Then, the test word appeared on the screen, and response latency was measured from the onset of this test word.

Results:
1. As regards the feasibility of the task, this experiment showed that the Subjects had no trouble at all in dealing with the instructions. They easily understood what they were expected to do, and all of them were very good at this.
2. A strong frequency effect was observed. The mean RT for the low frequency test words was 185 ms longer than the mean RT for the high frequency words ($t = 2.81$, $p < 0.01$).
3. An interesting point to be noted, however, is that the frequency variable does not seem sufficient to fully account for the data. Indeed, the dispersion of RTs for low frequency words was nearly twice as great as the dispersion for high frequency words, with RTs for some low frequency words being nearly as short as RTs for high frequency words. This observation leads to the following hypothesis which will be tested in another experiment. This hypothesis assumes that during his reading of the un-

[1] This frequency variable might better be called the dominance of the possible responses. This is defined as the likelihood that a particular response will be given when the Subject is asked to name words that fit a particular unfinished sentence. That is, rather than the frequency in the French language in general, it is the frequency with which it is given as an ending word for a particular unfinished sentence. Dominance, as defined here, is closely related to the conjoint frequency as defined by WILKINS (1971).

finished sentence, the Subject is actually anticipating a possible item. If the test word is of low frequency, two cases are still to be considered: the actual test item, indeed, can be more or less semantically related to the anticipated item, and this might result in RT differences. In other words, the frequency effect would be modulated by a semantic distance effect.

4. As regards the number of different ending words that had been proposed in the preliminary study, it had a significant effect on RTs for low frequency test words ($\varrho = 0.66$, $p < 0.01$), but no significant effect on RTs for high frequency words ($\varrho = 0.16$). This effect, which might be called a size effect, can be explained as follows: if the test item is a high frequency or dominant item, it is most likely anticipated, and therefore it has no longer to be "chosen" when presented. On the contrary, if the test ending word is a low frequency one, it is most likely unexpected, not anticipated, and thus it has still to be "chosen" among N possible words when presented.

Experiment II

In order to get further information about the postulated modulating effect of the semantic distance on the frequency effect, further experiments were conducted to highlight the role of semantic relatedness in the evaluation of complex sentences of the sort used in Experiment I.

For each sentence used in this series of experiments, we not only found differences in the dominance of the ending words that had been proposed by the Subjects, but we also intuitively expected differences in the semantic similarity between all these ending words. For example, the sentence *That girl has a nice ...* was completed by *hair* (9), *head* (1), *set of teeth* (1), *breast* (4), *voice* (2), *gait* (2), *skirt* (1), *gown* (28), *dress* (1) and *doll* (1). *Gown* is the dominant response to that sentence, while *skirt* or *head* were given by only one Subject. *Gown* and *skirt*, however, are presumably closer

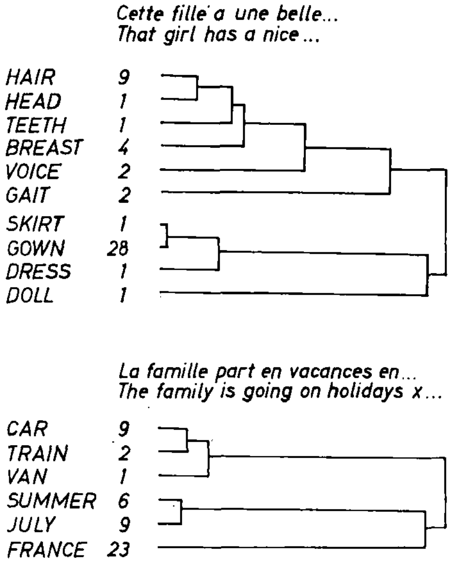

Fig. 1: Subjective groupings of the ending words that have been proposed by the Subjects for two of the experimental context sentences.

to each other than *gown* and *head.* As noted above, this semantic distance variable may have modulated the frequency effect observed in Experiment I.

It was thus decided to get a representation of the semantic relations holding between the ending words given for each sentence. This was achieved through a sorting task conducted with another group of 50 Subjects. The JOHNSON's clustering technique was then applied to the matrices of distances, and this allowed the drawing of tree-diagrams showing the subjective groupings of sentences differing only in their final word. Tree-diagrams corresponding to two context sentences are given as examples in fig. 1.

With this material, another experiment was set up to test directly whether the well known semantic distance effect holds in the present experimental situation. The basic paradigm was slightly modified as follows: the Subject was presented with an unfinished sentence that he was required to read covertly. He was further instructed to depress a key when he felt he had understood the sentence, and he was told that his response would at once make appear two words on the screen in the prolongation of the sentence which remained exposed. The Subject was asked to respond Yes whenever he thought that these two words *and both of them* could be used as acceptable ending words for the sentence; in every other case, he was told to respond No.

Two synchronized projectors were used for this experiment, one of them projecting the sentence, and the other projecting the test words. They were operated by a microprocessor which further allowed the recording for each trial of both the sentence reading time and the response latency to the test words.

Materials: 10 experimental sentences were used. For each of these sentences, two pairs of words were selected among all the possible ending words that had been proposed in the preliminary study. The selection of these pairs was based on the distance ratings obtained from the free-classification task. In one pair, the two test words were very close in meaning (i.e. they had been put together by the majority of Subjects), while in the other pair, the two test words were distant in meaning (i.e. they had never been put together). This experimental material is reported in tab. 1 Warm-up sentences as well as trick sentences were added to these experimental sentences.

Subjects: 46 Subjects participated in this experiment, divided into two equal groups, each group receiving the 10 experimental sentences with 5 pairs of words which were close in meaning and 5 pairs of distant words.

Results: Mean RTs for the two types of pairs are illustrated in fig. 2. The latency data reported here are based upon correct responses only. As in various RT situations, semantic distance has a strong effect on response latency in the present paradigm. When the two test ending words had been judged very close in meaning, the response latency as to their acceptability was on the average 259 ms faster than when the two words had been judged distantly.

There is another observation illustrated in fig. 2 where the number of different "semantic categories" to which belonged the ending words that the Subjects had proposed is reported in brackets. As it appears from fig. 2, response latencies in both conditions (close or distant in meaning) were affected by another variable that it is difficult to specify in the framework of the present experiment. This difficulty is due to the fact that there is a very strong relationship between the number of possible

Tab. 1: *Experimental context sentences and pairs of cloase or distant test words*

Context sentences	CLOSE		DISTANT	
(1) The rider is mounting without	SADDLE	STIRRUP	SADDLE	DIFFICULTY
(2) For my birthday he offered me	PRALIN	SWEETS	PRALIN	RECORDS
(3) In her case, she always has a	COMB	MIRROR	COMB	PEN
(4) That girl has a nice	GOWN	SKIRT	GOWN	VOICE
(5) The fam. is going on holidays x	TRAIN	CAR	TRAIN	JULY
(6) He likes walking with his	BROTHER	FATHER	BROTHER	HORSE
(7) For her wedding, she got a	RING	WED. RING	RING	FLOWER BASK.
(8) This evening, I shall eat a	MELON	PINEAPPLE	MELON	STEW
(9) The worker was searching his	LUNCH	THERMOS	LUNCH	WORKING SITE
(10) For the meal there is only one	CUTLET	SAUSAGE	CUTLET	SPOON

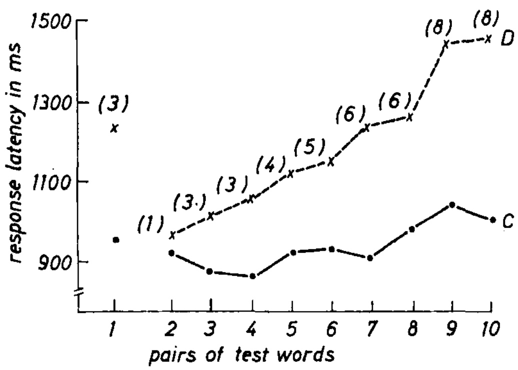

Fig. 2: Mean response latency for each pair of close or distant test words (cf. tab. 1 for identification of each pair). Number of semantic categories (see text) are reported into brackets.

ending words that had been proposed for each context sentence and the number of semantic categories to which these words belong. Therefore, it is not clear whether it is the number of words, the number of semantic categories or both which are responsible for the differences in RT within each type of pairs. Let us suppose that if the number of different words increases, the number of different semantic categories that they represent will be increasing too. Granting this, it would not be unreasonable to assume that the probability of a correct anticipation will decrease as the number of possible semantic categories increases. This would fairly account for the data reported in fig. 2, but further research will be needed to test these assumptions.

We have not talked very much about syntax in this symposium. Maybe it would be fair to reintroduce it now by paying some attention to the RT data reported on the far left of fig. 2. These RTs have been observed for the sentence *The rider is mounting without* ... As it appears from fig. 2, mean RT to the pair of words which were close in meaning (*saddle*, *stirrup*) are compatible with RTs observed for other similar pairs, i.e. pairs given after a context sentence inducing items which may be regarded as belonging to a comparable number of semantic categories. On the contrary, mean response latency to the pair of words which were distant in meaning (*saddle*, *difficulty*) is much higher than RT observed for other similar pairs. This might be due to the fact that the two test words of this pair had two different grammatical statuses as ending words of the context sentence, and that the shifting from one grammatical status to another required an extra step in the decision process, resulting in an increase of response latency. Yet, this pair was the only one in the series where the two test words had a different grammatical status, and since these two words in that pair actually differed in concreteness, further experimental work will be needed to highlight the impact of syntactic factors on the semantic decision process.

Closing remarks

Several questions arise from this series of experiments, and I would like to make a few closing remarks about two of these questions.

The first question concerns the precise determination of the various semantic categories which are actually represented by the ending words that have been proposed for each context sentence. The data obtained in the present series of experiments showed that such a determination is highly hazardous if it is only based on tree-diagrams derived from the products of a sorting task a la MILLER. It is tempting to determine the various semantic categories by applying a criterion like the strength of the different clusters, and to consider for instance that above a critical value of strength, all the words are instances of the same category. However, this simple procedure is questionable, mainly because the Subject's strategy in the sorting task much depends on the actual set of words he is presented with, and may thus vary from one context sentence to another. Better data in this matter would be obtained if all the context sentences with all their respective ending words were randomly presented in pairs that the Subject would have to judge on a similarity scale. Such a procedure, although less economic in the case of a large number of context sentences, would be less sensitive to differences between set of words that would have been proposed for each context sentence.

Another problem of some theoretical importance arises from what is involved in what I have called an anticipation process. From a theoretical point of view, it might be useful to discuss the present data in terms, for example, of the two-stage model as proposed by KINTSCH. It might be useful indeed to examine the connection between the concept of "anticipation" and the concept of "inferential processing" as defined by Kintsch. Before doing this, however, it would be very helpful to get a better insight into the anticipation behavior itself. The trouble, indeed, with the experiments I have talked about is that the Subject is supposed to anticipate something during his reading of the sentence, but I do not know whether every Subject was anticipating something, and even if I knew this, I would not know what the Subject was anticipating. Is he anticipating a single word, or several words? Does this anticipation consists of entering a particular semantic category or several semantic categories, the Subject waiting for the actual test item before starting any kind of further processing? Or does this anticipation consist of the whole processing leading to the selection of one particular suitable lexical item? Related to the structure of the tree-diagrams, as illustrated in fig. 2, which might be regarded as an indicator of what remains to be done when the context sentence has been processed, the question simply is: where is the Subject at the time he is presented with the test item? Differences in response latency are to be expected depending on what the Subject has actually anticipated, since the result of such an anticipation is likely to determine the relative complexity of the further processing which would be needed to go from what has been anticipated to what is actually presented as test ending word.

There are several ways to tackle this problem. One of them, originally proposed by Costermans who is now using it in experiments concerned with retrieval processes, only requires a slight modification of the basic paradigm as used in the above experiments. The Subject would be presented with an unfinished sentence for which he would be asked to produce as quickly as possible an appropriate ending word. His response would make appear a test word on the screen, and he would be asked to decide whether this word can *also* be used as an appropriate ending word for the sentence. The first response would let us know what the subject has anticipated and how long it took him to produce his response. Response latency to the test word would give us an insight into the further processing that might be needed, depending for instance on the distance between the Subject's first response and the test word.

Short-Term Memory During Discourse Processing

R. J. JARVELLA

This paper is largely a brief review of some work on short-term memory for on-going discourse. The work to be summarized is mainly from my own research program in this area, but will also include some recent studies by my present colleagues, WILLIAM MARSLEN-WILSON and LORRAINE K. TYLER. A fuller treatment of all of the work reported on here with the exception of the studies mentioned on speaking can be found in the forthcoming volume of *The Psychology of Learning and Motivation* (JARVELLA, 1979).

The main problem area of interest here is very short-term memory, even immediate memory, for a running language message. This is in fact a problem of representation. What we remember is linguistic form and content, and possibly other abstractions on or from the physical signal. It is only these short-term representations that I will try to clarify. I will start by giving them a name. The concept I will try to elaborate I will call a *processing structure*. A processing structure will be looked at as a short-lived representation of some stretch of speech which is formed as language is processed.

Discourse processing is intrinsically dynamic. It is the process which divide and integrate speech over time, not memory incidental to them, which should concern us. The representations we have after therefore should be functional ones. In the current state of psycholinguistics, this is largely a matter of guesswork. However, before considering the research to be reviewed, I wish to make two points about processing structures in this regard. One is that they themselves are an outcome of some processing, but perhaps also still the basis of work not yet done. The other is that, once begun, they can guide processing of further speech within the structure, and then may serve to bridge what has been said with what is still to come. Both points, I think, hold plausibly for both the perception and production of language.

It is a major theoretical question how such processing structures would get built up, be sustained, and at some critical point start to break down. In actual practice, we are forced to ask when, or under what conditions, speech seems to be integrated into a largely unified structure in processing, and what linguistic devices foster or help supercede this tendency. The kind of evidence for these phenomena I have tried to bring together here is fairly direct; it is based primarily on immediate recall of superficial linguistic form. The general view on memory in this context is that the language sequence or sequences entering into a processing structure are temporarily stored in an accessible fashion.

The experimental paradigm for studying listening (or reading) in this way has been to present a discourse message for the subject to understand, and only occassionally interrupt it to test his memory for what he just heard (or read). At that point, he might be asked to recall as much as he can verbalize of just the very end of the passage, cued to recall one of the final two sentences, or asked to judge whether a presented sentence is repeated exactly. His responses are then scored for accuracy-number of words correct, clauses and sentences recalled or recognized, and so forth. Usually, the experiment is designed that different subjects will receive the same test material in different contexts. The contexts define the linguistic factors being studied: in one case, a critical clause falls in the same sentence as the clause following it, in another, the same two clauses fall in successive sentences, for example.

1. Sentence and clause recency effects

Research of this kind has generally found that the final sentence heard from discourse is recalled far better than the one heard just before it. This is true when clause position is controlled and only the syntax varied (e.g., (clause 1 clause 2) (clause 3) TEST vs. (clause 1) (clause 2 clause 3) TEST). Averaged across four studies of this kind (JARVELLA, 1972), the critical middle clause was fully recalled 54% of the time when it was part of the final sentence, 22% of the time when it was not.

Like an immediately heard sentence, the clause heard last in spoken discourse is generally recalled best. Often perfect verbatim recall is limited to the final clause alone. In the experiments referred to above, for example, fully 82% of the final clauses in the longer sentences were recalled.

Each of these findings also applies to recognition memory. The experiment was repeated replacing the recall requirement with one in which subjects immediately had to judge whether a printed sentence matched exactly one of the two just heard. The printed sentences usually contained small differences. About 90% of these changes were noticed in final clauses, 60% in previous clauses from the same sentence, and 40% in final clauses from the earlier sentence.

By the time a full constituent of these kinds is heard in discourse, the clause or sentence preceding it is not only relatively quite difficult to remember. The recall function over serial positions is qualitatively different as well. In both cases, the previous segment tends to be worse recalled in its middle; the function is bow-shaped. Apparently, the processing structure has already started to but not yet fully lost its integrity. This kind of finding implies that the primary analysis of the constituent is complete; in some way, it has already been understood. I will return to its later use in the second section, where I will suggest that memory is organized by the processes of segmenting and building interpretations of discourse on different levels.

How fast does forgetting occur? One way of looking for the "breaking point" is to see what happens to memory for clause and sentence constituents just heard as slightly greater bits of speech follow them. In one experiment (JARVELLA, SNODGRASS and ADLER, 1978, Exp. I) we followed full sentences or clauses with 2, 4, or 7 words of another sentence or clause. For example,

> "To stack the meeting for MCDONALD,
> the union had even brought in outsiders."
>
> ....
>
> ....
>
> ....

The item ended in the three forms underlined. In a parallel item, a sentence boundary fell between "McDONALD" and "the". In both cases, recall of the completed segment dropped significantly, and the serial position function became severely bow-shaped after just two words of further speech.

The division of spoken discourse by the perceiver into sentences appears to be enhanced by prosodic cues. When these are removed, the between-sentence effect is largely cancelled, while the clause effect is at the same time strengthened. In a comparable study where pauses, natural rhythm, and variation in pitch were removed, *both* between- and within-sentences, about 90% of the words in final clauses were recalled vs. 50% of those in the non-final clauses. With pauses between sentences, recall of the non-final clause was better, whichever sentence it was part of. In silent reading, where passages are presented on a video display such that there is phenomenally an effect of a window sweeping across each line of text in succession, the strongest clause segmentation effect of all has been found. About 90% of immediate clause words were orally recalled, less than 40% of previous clause words from the same sentence. More than half of all responses had a running memory span precisely equal to the length of the last clause read.

The above studies all used adult subjects. When similar techniques are used with children of beginning school age (JARVELLA, 1976, TYLER and MARSLEN-WILSON, 1978a, b), there is a tendency for the younger subjects to recall only the final clause heard, omitting the previous one no matter which sentence it was part of, or to recall the beginning and end of a two-clause sentence better than its middle, much as adults would remember a *previous* sentence. For older children, recalling the first clause of such longer sentences seems to depress recall for the second one, or both clauses may be remembered about equally well and both display *U*-shaped serial position functions.

2. Processing dependencies between clauses and sentences

At one level, the results so far considered suggest that heard or read discourse is processed one clause at a time. Such clause by clause processing may be quite characteristic of language use in this kind of context. However, the clauses within a sentence, and often those in two adjoining sentences, are also related. Process dependencies are needed on a higher level as well. The multiple-clause sentences referred to above are probably but one example.

Thus, it seems clear that processing structures—short-term representation—are needed to handle such cases as the interpretation of anaphors (as in assigning antecedents to pronouns), of elipsis, of subordination, and other grammatical dependencies. One advantage of having a clausal (or larger) constituent as a processing outcome is that, where appropriate, it might be used to support a linguistic or conceptual bridge to what follows it, as when this appendage is abbreviated. And vice versa, there are other cases where, as in cataphora, backwards pronominalization, and other right-to-left grammatical phenomena, having the superficial form of a segment in memory may secure its interpretation *from* what follows it. There appears to be some empirical support for both these hypotheses.

First, consider the case of support *for* the following structure. Two experiments on coreference seem relevant here. In one (JARVELLA, 1973), critical phrases in discourse were followed by anaphors and elipses, were repeated in the following speech, or were followed by novel content. The tests made were both within a sentence and between sentences. The antecedent phrases were better recalled and recognized when reimplied than when followed by novel content; the rest of the sentence containing them was better recalled when they were reimplied than repeated. In a second study (JARVELLA, 1976), coreference between noun phrases in the last pair of clauses heard from discourse also led to better recall of the clauses by children.

Second, consider how one clause may "wait" on another. It was stated above that a previous clause was better remembered when it began a final sentence than when it ended a non-final one (see JARVELLA, 1971). However, this effect was especially strong for *subordinate* clauses, which at the beginning of sentences—the better recalled condition—may depend on further information. In a largely independent study, where the same clauses were used to form sentences with both main-subordinate and subordinate-main clause order, recall was superior when the subordinations came first (JARVELLA and HERMAN, 1972). Results obtained for child subjects show the same general trend.

Thus, both the nature of a speech segment and its *following* context seem to affect whether they are partly processed together or not, or form a single representation. If the context is completely irrelevant, for example, a clause or sentence instruction to recall, the discourse segment may be remembered in about the same form as if nothing had followed it (JARVELLA, SNODGRASS and ADLER, 1977, Exp. II).

3. Segmentation and integration in speech production

Much of what I have said about language perception I think may hold equally well for language production. The process of speaking is also organized in such a way that a little can be said at a time, and yet control is maintained so that what is said follows reasonably well with what has preceded it, and is grammatically well-formed. We have begun to try to look experimentally at these phenomena in Dutch—the organization of fluent speech, the processing structures which bind it on different levels, and (again largely by conjecture) the functions of knowing what you have just said or are about to say next. I will briefly mention two kinds of approach which offer promising results.

One kind of experiment we have tried attempts to isolate natural speech segments in spontaneous monologues. The subject is asked a series of open-ended interview questions, which he answers as fully as he can. However, as he talks, he is trained to place a fixed syllable between parts of his utterance. Subjects are able to do this with little interference if any observable in their speech output. The resulting sequence of now explicitly marked segments is highly suggestive both of canonical size of speech units and their organization into larger structures.

The other kind of experiment is aimed at locating the speech boundaries, and therefore the units they circumscribe, in attention during fluent production. Both the subject's verbatim memory for what (as in the listening-reading experiments) was just uttered and his saying what he had planned at the time of interruption are called for. It is extremely rare in this situation for subjects to retreat beyond the major constituent boundary previous to the general location of the test signal, or to go beyond the major boundary following it. Responses are also repeated in such a way to suggest that the boundaries between the processing structures involved include linguistic material used in making transitions but without real content. As such, it varies from the structures themselves.

4. Final remarks

The concept of *processing structure* is introduced here to help characterize the systematic nature of fragmentary, transient representations formed of on-going discourse as it is heard or uttered by language users. It is in opposition to "higher" forms of representation, which are often taken to be *non*-linguistic. The role of processing structures in language production and understanding is not transparent and deserves further study.

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Narrative Recall and Recognition by Children

G. DENHIERE

> To read (to listen to) a narrative, this is not only a word to word follow up, but also a level to level progress.
>
> ROLAND BARTHÈS

From several experiments of recall and recognition—immediate and delayed—of various narratives by different groups of children we shall try to answer the following questions:

1. Which kind of information is the most frequently recalled by children?
2. How do the performances change with age?
3. How can we explain those changes?

1. Theoretical background

1.1. Narrative analysis

Three levels can be distinguished in narrative semantic analysis: lexical, propositional and macro-structures. Only the latter two have been considered here.

1.1.1. Propositional analysis

Sentences are analysed in predicate-arguments propositions and, at this level, a text is represented as a sequence of propositions named "text-basis" (v. KINTSCH, 1974, VAN DIJK, 1975).

A verb, an adjective, an adverb, a preposition can be used as predicates; a proposition can be employed as an argument of a complex proposition, and the nature of semantic relations between predicates and arguments can be identified by case grammar relationships (FILLMORE, 1968).

Table 1 shows the propositional analysis of the episodes A and B of the narrative "$Giant_{A-B}$" used in the first recall experiment.

1.1.2. The macro-structure

A narrative cannot be reduced to the series of sentences it contains. Following structuralist linguists (BARTHÈS, 1966, BREMOND, 1966, 1973, TODOROV, 1966), we consider that the macro-structure refers to "an autonomous level of meaning with a structure which can be extracted from the narrative message: the story ... We read words, we see pictures, but through them, we follow a story" (BREMOND, 1973, p. 11f.).

The descriptive units of the macro-structure level are actions or events and they are expressed by predicate-arguments macro-propositions. Consequently the macro-propositions sequence which defines the macro-structure of a narrative corresponds to a summary of this narrative.

Schematically we consider that a minimal macro-structure includes the following categories:

a) an initial situation which introduces the description of agent(s) location, time, historical and cultural conditions, etc...;

b) a complication: in relation to initial situation, describes one or several specific major events or actions;

c) a resolution: which states the agent's subsequent actions to the complication events or actions;

d) an evaluation: the whole episode (complication + resolution) can be followed by an evaluation giving the agent's mental reactions;

e) a moral: this category, as the previous one, is optional.

Figure 1 and fig. 2 show the (simplified) macro-structure of the episodes A and B of the "Giant$_{A-B}$" narrative.

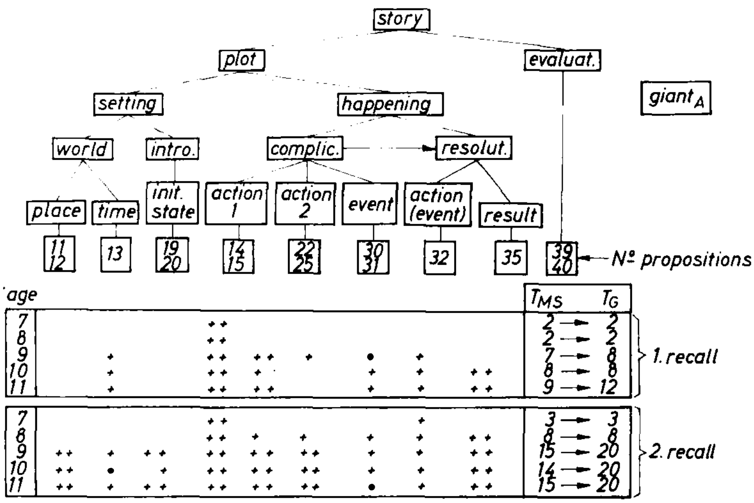

Fig. 1

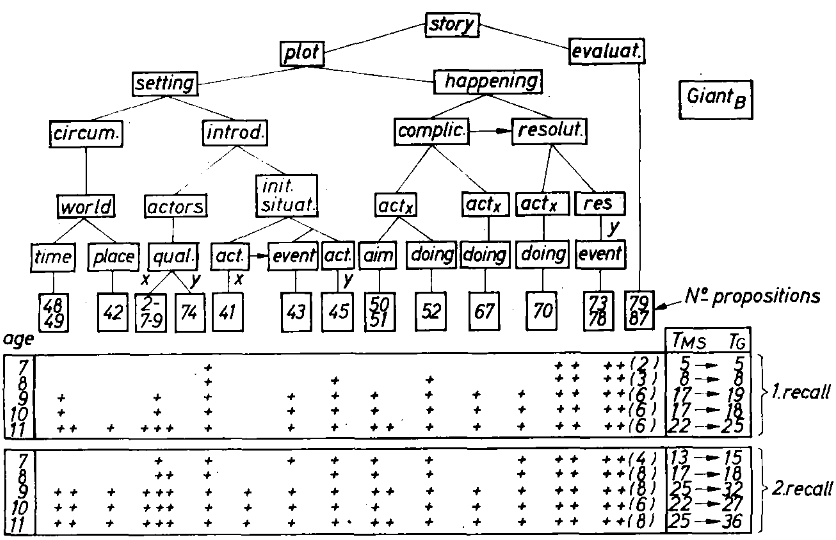

Fig. 2

1.2. Psychological hypotheses

Referring to this structural analysis we will now consider the hypothetical psychological activities involved in recall of narratives.

– During the presentation (hearing or reading) of a narrative, the subject analyses the semantic information into units corresponding to propositions. The subject's activity consists on:

– segmenting the text into propositions and,

– identifying (explicit and implicit) relations between those propositions.

– This re-composition activity leads to subject's interpretation of the text, thus assigning a meaning to the encoded information. It results in an ordered sequence of propositions which is then transferred in memory.

– Along with their cognitive growth, children elaborate a cognitive schema corresponding to the major categories of the narrative macro-structure. This cognitive schema helps and guides the semantic information analysis and its memory storage.

– However, all the propositional information which is subordinate to those major narrative categories can't be directly stored in memory. It must be condensed and summarized. The S must select among the propositions of a sequence the most important one(s), the one(s) that can express and summarize the semantic contents of each category.

– These macro-propositions are stored in long-term memory. When he she recalls a narrative, the subject must first retrieve those stored macro-propositions and then recover the subordinate propositional information attached to each one.

2. Experimental research

2.1. Recall experiments

2.1.1. Developmental study (6 to 12 yearold children)

The main goals of this research were the following:

a) Do the most frequently recalled propositions belong to the macro-structure?

b) At what mean age the macro-structure is present in the recall protocols? Or, in other words, at what mean age the narrative macro-structure becomes a cognitive schema for storing and retrieving semantic information?

c) Does a second presentation help those children who have not been able to recall the macro-structure at the first trial?

Material: The narrative, headed "Giant_{A-B}", was composed of two distinct episodes with the same major agent "Gargantua". The first episode (A) included 30 propositions and the second (B) 47. The propositional analysis has been presented in tab. 1 and the macro-structures in fig. 1 and fig. 2.

Procedure: E read the narrative and S had to recall "all he could remember" and a 2nd recall followed a second E's reading.

Subjects: Five 25 children groups participated in this experiment. Their mean age was 7, 8, 9, 10 and 11 years. With 7 and 8 yearolds, the experiment was individually administered and oral recall was used. With the 3 elder groups, the experiment was administered to small groups of 3 to 5 Ss and children wrote their recall.

Tab. 1: *Analyse propositionnelle du rócit utilisé. Cette analyse correspond à la base du texte incompléte du récit. La nature des relations entre le prédicat et les arguments des propositions (agent, patient, etc...) sont omises ici. Los abréviations utilisées pour indiquer les relations interpropositionnelles correspondent aux relations suivantos: lieu, temps, manière, quantité, nombre, partie de, possossion, Instrument, simultanéité, succession, but, cause, conséquence*

Récit

Il y a bien longtemps vivait un bon géant appelé Gargantua. Il était bon et aimait rendre service aux pauvres gens.

Un jour, assis sur une falaise, il trempait ses pieds dans l'eau pour les laver. Le soleil brillait et il avait chaud. Dans ses deux main réunies, il prit un peu d'eau pour se désaltérer. Au même moment passait une barque qu'il saisit aussi. Quand le géant but, les mâts du bateau lui chatouillérent le gosier. Il se dit qu'il avait avalé une poussiére.

Une autre fois, alors qu'il se promenait dans la forêt, il vit une pauvre vieille qui ramassait du bois mort. Il décida de l'aider. En un instant il arracha quelques uns des plus beaux chênes et les attacha avec des lianes. Il saisit le fagot et l'equilibra sur son èpaule. La route était longue et le géant fut bien content de déposer son fardeau contre le mur de la chaumiére de la vieille dame. Ilélas 1 la maison s'effondra. La pauvre vieille avait maintenant du bois pour se chauffer mais elle n'avait plus de maison pur s'abriter.

Analyse propositionnelle:

1. VIVRE, géant
2. BON, géant
3. *Temps*: LONGTEMPS, 1
4. *Quant.*: BIEN, 3
5. S'APPELER, géant. Gargantua
6. BON, géant (= Gargantua)
7. RENDRE SERVICE, géant, gens
8. PAUVRES, gens
9. AIMER, géant, 7
10. ET, 6, 7
11. ETRE ASSIS, géant
12. *Lieu*: SUR, 11, falaise
13. *Temps*: UN JOUR, 11
14. SE TREMPER, géant, pieds
15. *Partie de*, pieds, géant
16. *Lieu*: DANS, 14, eau
17. LAVER, géant, pieds (= 15)
18. *But*: POUR, 14, 17
19. BRILLER, soleil
20. AVOIR CHAUD, géant
21. *Conséq.*: ET, 19, 20
22. PRENDRE, géant, eau
23. *Quant.*: PEU, eau
24. *Instr.*: DANS, 22, mains
25. *Partie de*, mains, géant
26. *Nombre*: DEUX, mains
27. REUNIES, 26
28. SE DESALTERER, géant
29. *But*: POUR, 22, 28
30. PASSER, barque

31. *Simult.*: MEME MOMENT, 22, 30
32. SAISIR, géant, barque
33.   *Man.*: AUSSI, 32
34. BOIRE, géant, eau
35. CHATOUILLER, mats, gosier
36. *Partie de*: DU, mats, bateau (= barque)
37. *Partie de*: LE, gosier, géant
38.   *Simult.*: QUAND, 34, 35
39. AVALER, géant, poussiére
40.   Se DIRE, géant, 39
41. DE PROMENER, géant
42.   *Lieu*: DANS, 41, forêt
43. VOIR, géant, vieille
44.   PAUVRE, vieille
45.   RAMASSER, 44, bois
46.   MORT, bois
47.   *Simult.*: ALORS QUE, 41, 43
48.   *Temps*: UNE FOIS, 41
49.   AUTRE, 48, 13
50. AIDER, géant, 44
51.   DECIDER, géant, 50
52. ARRACHER, géant, chênes
53.   DEAUX, chênes
54.   Superl.: LE PLUS, 53
55.   *Nombre*: QUELQUES, chênes
56.   *Partie de*: 55, 53
57.   *Partie de*, chênes, 42
58.   *Durée*: INSTANT, 52
59.   ATTACHER, géant, chênes
60.   *Instr.*: AVEC, 59, liancs
61.   *Succes.*: ET, 52, 59
62.   SAISIR, géant, fagot (= chênes)
63.   EQUILIBRER, géant, fagot
64.   *Lieu*: SUR, 63, épaule
65. *Partie de*, épaule, géant
66.   *Succes.*: ET, 62, 63
67. LONGUE, route
68. CONTENT, géant
69.   *Quant.*: BIEN, 68
70. DEPOSER, géant, fardeau (= fagot, = chênes)
71.   *Lieu*: CONTRE, 70, mur
72.   *Partie de*: DE, mur, chaumiére
73.   *POSS.*: DE, 44, chaumiére
74.   VIEILLE, dame (= 44)
75.   *Cause*: DE, 68, 70
76. *Conséq.*: ET, 67, 68
77. Hélas
78.   S'EFFONDRER, maison (= chaumiére, = 73)
79.   AVOIR, 44 (= 74), bois
80.   SE CHAUFFER, 44
81.   *But*: POUR, 79, 80

82. *Temps*: MAINTENANT, 79
83. AVOIR, 44, maison
84. *Négat.*: NE PLUS, 83
85. S'ABRITER, 44
86. *But*: POUR, 83, 85
87. *Oppos.*: MAIS, 79, 83

Results: Tab. 2 presents the mean numbers of:

. recalled propositions by subjects,
. accepted propositions by E. and, among these,
. the ones which are identical to text-basis and,
. the ones which are similar to text-basis.

Tab. 2: *Mean numbers of recalled propositions* (R), *accepted ones* (A); *among these latter propositions: those identical to text-basis* (A-I) *and similar* (A-S) *ones at the 1st and 2nd recall for each age-group. The text-basis included 87 propositions. The two lower lines of the table refer to the mean ratio of accepted propositions to recalled ones and to the mean ratio of identical propositions to accepted ones*

Propositions	1st Recall					2nd Recall				
	7	8	9	10	11	7	8	9	10	11
Recalled (R)	24,9	27,3	45,5	44,1	51,0	36,4	43,0	58,5	54,7	62,5
Accepted (A)	17,0	18,9	35,3	35,0	41,6	26,2	31,8	50,1	46,0	54,3
Identical (A-I)	9,8	11,2	23,1	22,6	28,9	16,2	20,8	37,3	35,1	42,6
Similar (A-S)	7,2	7,7	12,2	12,4	12,7	10,0	11,0	12,8	10,9	11,7
$\% \frac{\text{Accepted (A)}}{\text{Recalled (R)}}$	68,4	70,3	77,4	79,8	81,9	71,7	74,9	84,7	84,5	87,2
$\% \frac{\text{Identical (A-I)}}{\text{Accepted (A)}}$	54,7	55,4	64,2	64,4	69,1	59,3	62,4	71,4	76,6	77,6

The statistical analysis shows that:

a) 7 and 8 years groups are significantly inferior to the 3 elder groups which have similar performances. The increase performances (which age and with presentations) results from the increasing number of identical propositions recalled.

Tab. 3: *Correlations (Bravais-Pearson) of accepted (recalled) propositions between age-groups for the two episodes of the narrative "Giant$_{A-B}$". The first episode included 30 propositions and the second 47*

	1st Episode					2nd Episode				
Age	7	8	9	10	11	7	8	9	10	11
7	—	0.90	0.76	0.66	0.55	—	0.93	0.85	0.91	0.91
8	0.81	—	0.70	0.63	0.49	0.90	—	0.86	0.92	0.90
9	0.69	0.71	—	0.81	0.70	0.84	0.73	—	0.89	0.90
10	0.78	0.77	0.79	—	0.77	0.91	0.82	0.90	—	0.95
11	0.55	0.71	0.85	0.65	—	0.91	0.84	0.88	0.94	—

b) Tab. 3 presents the intermediate groups (BRAVAIS-PEARSON) correlations for the recall frequency of each proposition. All computed correlations significantly differ from zero ($p < 0.01$). Their values decrease with age for the episode "A" but not for the episode "B".

c) The macro-structure recall has been evaluated by means of propositions that have been recalled by more than half the Ss of each group. We have plotted on fig. 1 the number and the nature of this half over recalled propositions with regard to the macro-structure of the 1st episode "A" at the 1st and 2nd recall of the 5 groups. We can see that:

– the majority (the totality for younger groups) of those propositions belong to the macro-structure,

– only the 3 older groups recall the (minimal) macro-structure at the first trial. At the 2nd recall, the 4 older groups perform it.

A similar result can be observed in fig. 2 for the episode "B". However, here all the groups recall the (minimal) macro-structure at the 2nd trial.

Conclusions:

(i) After only one presentation, 7 yearold children cannot recall the macro-structure of the two narrative episodes;

(ii) the 8-yearolds' performances vary from one episode to another;

(iii) the 9–10–11-yearolds recall the macro-structure of the two episodes.

2.1.2. The repetition influence of recall tasks on the 7 yearold children's performance

From the previously reported experiment it's difficult to conclude if 7 yearold children are able to recall the narrative macro-structure or not because:

a) the narrative was composed of two episodes and their presentation order was not balanced and,

b) the two episodes did not contain the same number of underlying propositions.

Therefore, in this 2nd experiment, we only used one-episode narratives. We chose 4 different narratives ("$Giant_A$", "$Giant_B$", "Truck", "Bear's cub") with the same number of propositions ($N = 55$). The Ss were asked to immediately recall two different narratives with an 8 days' delay between each trial. The main goals of this experiment were the following:

a) Do 7-yearolds recall the macro-structure of each presented narrative?

b) Will there be a learning-effect from the repetition of recall tasks?

Subjects: Four groups of 15 seven yearold children participated in this experiment.

Procedure: Groups 1 and 2 differed in the presentation order the "$Giant_A$" and "$Giant_B$" narratives with an 8 days' delay. The same procedure was used for groups 3 and 4 who were asked to recall "Truck" and "Bear's cub" narratives.

Results: Table 4 presents the mean number of recalled propositions accepted (Part A) and the number of those propositions that have been recalled by more than half the Ss of each group for the 4 narratives (Part B).

a) The mean number of accepted recalled propositions significantly differ ($p < 0.01$) in each narrative, even though each one contains the same number of underlying propositions.

Tab. 4: *Mean numbers of accepted recalled propositions for the four narratives ("$Giant_A$", "$Giant_B$", "Truck", "Bear's cub") at the first* ($R._1$) *and the second* ($R._2$) *recalls Part* (A) *Part* (B) *presents the number of propositions which are recalled by more than half of the subjects of each group*

	$Giant_A$		$Giant_B$			Truck		Bear's Cub	
(A)	R_1	R_2	R_1	R_2	(A)	R_1	R_2	R_1	R_2
G.1	8,2	16,9	16,8	25,9	G.3	10,5	14,3	15,2	20,8
G.2	11,9	19,2	14,3	23,2	G.4	12,7	15,6	12,9	18,7
(B)					(B)				
G.1	3	13	14	26	G.3	4	10	10	17
G.2	7	16	11	26	G.4	5	16	5	12

b) The repetition of memory tasks leads to a learning effect: for all narratives the number of propositions recalled by Ss of each group is superior when they have previously (8 days before) recalled another narrative.

c) Two readings permit the recall of the macro-structure of the 4 narratives by the majority of the 7 yearolds. After one reading, only two narrative macro-structure ("$Giant_B$" and "Bear's cub") are recalled.

2.1.3. Delayed recall by 8;6 and 11 yearold children

If, as we suppose (1.2.), children above eight store the narrative macro-structure of a narrative in their long-term memory and use it to retrieve propositional information which is subordinated to each category of macro-structure, then this macro-structure must be presented in the delayed recall (8 days).

We tested this hypothesis with 8;6 and 11 yearold children who are able—as we have already seen in the 1st experiment—to recall a narratives macro-structure after one reading. The narrative was composed out of the two previous narratives "$Giant_A$" and "$Giant_B$" containing 55 underlying propositions each.

The two age groups were divided in two subgroups to permit a balanced order presentation of the two "$Giant_{A-B}$" narratives.

Tab. 5: *Mean number of accepted recalled propositions*

		1st Recall		2nd Recall	
		$Giant_A$	$Giant_B$	$Giant_A$	$Giant_B$
G_1	0_1	9,5	16,1	7,2	14,1
	0_2	11,7	15,9	9,5	12,1
	$\overline{m}$	10,6	16,0	8,4	13,1
G_2	0_1	18,3	25,7	15,7	24,3
	0_2	18,5	25,4	17,0	22,6
	$\overline{m}$	18,4	25,5	16,4	23,5

Results: Tab. 5 presents the mean number of accepted recalled propositions of each subgroup.

a) The presentation order of episodes (A–B) doesn't affect immediate and delayed recall by 8;6 and 11 yearolds.

b) After only one reading the two age groups recall the macrostructure of the two "Giant" episodes.

c) After a one week delay the mean decrease is equal to 2 propositions and it's the same for each subgroup for each episode and the narrative macro-structure is again recalled by the majority of Ss of each subgroup.

2.1.4. Conclusions of recall experiments

1. The groups above eight years recall the narrative macro-structure after one reading whatever may be the narrative and the modality—immediate or delayed—of recall.
2. Narratives and experimental procedures modify the 7 and 8 yearsolds' groups performances. How can we explain that fact? We suggest the following hypothesis: the building up of a cognitive schema corresponding to narrative macro-structure hasn't reached completion until the age of 7 to 8 years. So, these subjects cannot store propositional information in an organized, categorized manner in the same way as older children can. Therefore, they can't use this cognitive schema to retrieve the stored propositional information.
3. If this hypothesis is true, we shouldn't find large differences between children (as a function of age) in recognition tasks in which the subject is not obliged to use (as in recall) the narrative macro-structure to achieve the retrieving criterium.

2.2. Narrative recognition by 7, 8 and 11 yearold children

We used 3 of the 4 previous narratives "$Giant_A$". "$Giant_B$" and "Bear's cub" which were decomposed in 20 sentences.
Distractors were:

a) synonymous statements with original sentences (by replacement of predicate: "Giant was happy → lucky");
b) complement-statements of original predicates ("Giant was happy → sad") or arguments ("Giant washed his feet → hair");
c) statements which had no semantic relationship with original sentences ("the doctor attends the patients", "iron is harder than wood").

Tab. 6: ***Experimental design of the recognition tasks***

	Reading		Recognition	
	1st	2nd	Immediate	Delayed
G.1	$Giant_A$	$Giant_B$	$Giant_B$	$Giant_A$
G.2	$Giant_A$	Bear's cub	Bear's cub	$Giant_A$
G.3	$Giant_B$	$Giant_A$	$Giant_A$	$Giant_B$
G.4	$Giant_B$	Bear's cub	Bear's cub	$Giant_B$
G.5	Bear's cub	$Giant_A$	$Giant_A$	Bear's cub
G.6	Bear's cub	$Giant_B$	$Giant_B$	Bear's cub

Subjects: Three 60-children-groups participated in this experiment. Their mean age was respectively equal to 7, 8 and 11 years. Experimental Design: Each group was divided in to six of 10. Each subject was submitted to an immediate and delayed (8 days) recognition task, according to the schema presented on tab. 6.

Procedure: E advised the subject that he would read two narratives: the first one "to teach him the habit of listening attentively" and to show him what kind of narrative would be read later; the second one on which he would have to answer some questions by "yes" or "no" (immediate recognition). The subject wasn't advised that there would be a second recognition task on the first read narrative 8 days later.

For 7 and 8 yearolds the experiment was individually administered. E read the questions and Ss orally answered. With the 11-yearolds small groups of 3 to 5 Ss were used and Ss wrote down their answers.

Each booklet contained 50 statements: 20 original statements (old items), 10 synonymous, 10 complements and 10 "no relation" statements. Ss were asked to answer "yes" to original statements and "no" to the others (new items).

Results: Mean number of correct responses including:
- hits to original statements ("old items") and
- correct rejections of synonymous and complement statements ("new items") are presented on tab. 7.

Tab. 7: ***Mean number of correct responses*: *hits to original statements* ("*old items*") *and correct rejections of synonymous and complement-statements* ("*new items*") *in immediate and delayed recognition***

Age	Recognition					
	Immediate			Delayed		
	Items					
	old	new	total	old	new	total
7	14,3	13,0	27,3	12,5	12,9	25,4
8	14,9	14,0	28,9	13,5	12,8	26,3
10	14,5	15,7	30,2	13,3	14,4	27,7

We neglected "no relation statements" for which there are only very few mistakes.

Immediate and delayed recognition doesn't make such a difference as recall does: mean differences for hits and correct rejections are small and there is no interaction between age and delay.

3. General conclusions

1. Propositional analysis effectively permits to study recall protocols and to confront it with the narrative text-basis.

2. The most frequently propositions recalled by 6 to 12 yearold children belong to the narrative macro-structure which can be "a priori" extracted by the E.

3. For the 8 to 12 yearolds the results support the hypothesis that those subjects use a cognitive schema which corresponds to the main categories of the narrative macro-structure. Macro-structure is recalled by those Ss whatever are the narratives and the experimental procedures.
4. 7 and 8 yearold children's performances vary with narratives. According to our data children of 7 are able to recall the macro-structure of narratives which describe actions and events in a logical and chronological order ("Giant_B", "Bear's cub") but are not able to manage it with narratives based on temporal simultaneity actions and events ("Giant_A", "Truck"). Those children need two readings to recall the macro-structure of the latter two narratives.

Therefore we conclude that building up of a cognitive schema corresponding to narrative macro-structure is not completely elaborate at the age of 7. The learning-effect we obtained with the repetition of memory tasks supports this hypothesis.
5. The recognition task results lead to attribute the differences between age groups to their particular way of encoding information. When younger Ss haven't to search stored information in memory (as is the case in recall), their performances aren't significantly poorer than those of older children. It seems that the younger ones are able to store information but they can't retrieve it.
6. Further experiments are needed to confirm this interpretation. We should be able to show that major differences between various age groups come from processing and storing of information. Besides, procedures of recall with different kinds of cues would reduce differences in performances between children.

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Positivity Bias in Perception and Organization of Cognitive Field

M. LEWICKA and J. SUCHECKI

1. Introduction

In numerous studies on human cognition (particularly social cognition) it has been observed that people tend to perceive the surrounding world through some kind of "pink glasses" that is, that they tend to ascribe to the perceived objects those attributes which are positive rather than negative. The phenomenon has been stated in social perception mostly where it was described as positive halo effect and leniency effect, but semanticists also have been turning our attention to the prevalence of positive over negative words in human vocabularies as well as to the primordiality of positive over negative linguistic categories (cf. WARR, 1971). The phenomenon has been termed "positivity bias" in perception (PEETERS, 1971) and due to its frequency it has drawn attention of psychologists from different theoretical fields. Chronologically, one of the first hypotheses set up to account for the phenomenon was OSGOOD's "Polyanna's hypothesis" (cf. BOUCHER and OSGOOD, 1969) which relates it to the specific organization of human cognitive field. According to OSGOOD, "positivity" signifies a cognitive representation of "normal" states of objects whereas "negativity" means a state which deviates from the norm. In perception people naturally would tend to ascribe to unknown objects those attributes rather which they consider "normal" (positive) and would restrain from attribution of the "abnormal" (negative) traits. The hypothesis further implies that "positive evaluation" is some kind of a human aprioristic attitude and hence that positive attributes are taken for granted by the perceiving subject. Negative evaluation, however, should be preceded by a prior scrutiny of the perceived object and thus constitutes an "aposterioristic" attitude.

OSGOOD's hypothesis does not necessarily imply that people would tend to have a generally positive *emotional* attitude towards the world and would avoid negative emotions. It rather points out that what is "semantically positive" may in fact constitute an emotionally neutral and frame of reference in perception of little informational value. The more distant is the attribute from the positive norm (the more negative it is) the more highly it is weighted by a subject, the greater is its anticipated influence upon final impression, and—hence—the more rigorous should be the criteria of validity applied to the process of its attribution to other objects.

Similar interpretation was provided by BENJAFELD and GREEN (1978). According to them, people tend to attribute greater weight to negative than to positive semantic categories and hence they ascribe to other objects much less negative than positive traits. The negative phenomena form thus an isolated cognitive "figure" on the general positive "background", and the ratio of negative to positive features of objects, as represented phenomenologically, is best described by the "golden section coefficient": $\frac{a}{a+b} = \frac{a}{b}$, where $a \approx 0.618b$, and "a" is the number of negative traits, while "b" that of positive traits.

There is also a theory of trait inference by Peabody (1967, 1970) which seems to account fairly well for the more frequent inference of positive than of negative traits when other attributes of objects are already given. According to the hypothesis, any personality related trait can be located along a descriptive dimension on which it has its "descriptive meaning", this being its distance from the poles of the dimension. Independently, each trait has its evaluative meaning which is related to some extent to its descriptive position, as extreme traits are usually valued negatively while those which are moderate intensities of the poles are valued positively. Let us take as an example a dimension of "self-control" with four traits ordered along it, according to their descriptive value: "vehement"—"spontaneous"—"self-controlled"—"inhibited", out of which two extreme traits are evaluated negatively and two intermediate are positive. It can also be noted that those traits which belong to the left half of the dimension descriptively oppose the other two which belong to its right half, while traits which belong to the same half of the dimension are descriptively consistent. When provided with some information on another person (eg. "spontaneous") a subject would tend to complete its image by ascription of other attributes from the dimension. When deciding which attributes of the three left to choose he must decide between two inference rules: that of evaluative and descriptive consistency. When ascribing the trait "self-controlled", the subject would form an image which is evaluatively consistent (+ +) but descriptively inconsistent, when the choice is "vehement", the image will be descriptively consistent (both traits signify lack of emotional control) but evaluatively inconsistent (+ –). A similar situation arises when the subject is to infer from a negative attribute (e.g., vehement). When ascribing "spontaneity" he would form a descriptively consistent but evaluatively inconsistent image (– +), while the ascription of "inhibition" would result in the evaluatively consistent (– –) but highly descriptively inconsistent image. The degree of descriptive inconsistency of two traits however, is, a function of the traits' distance on the descriptive dimension and, as it easily can be seen, it is much higher for two negative traits (two poles of the dimension) than for two positive ones (its two intermediate values). This may account for the subjects' higher tendency to form evaluatively univalent images of positive persons than of negative ones, and—thus—would explain the prevalence of positive categories over negative ones in person perception.

One should mention here a purely linguistic interpretation, which views the positivity bias phenomenon as an example of a more universal linguistic rule. According to it, meanings of the words which oppose each other are not independent. One of the words from the pair is basic and it is formed in early stages of ontogenesis, while the other is secondary and it develops later. The primary words, called the "unmarked categories" are in fact more general names of the whole dimension of which the secondary categories ("marked") are specific examples only. When the information included in the marked category is given, the inference of the more general, unmarked traits is almost tautological, while such is not the case with inference from unmarked categories. It can easily be shown that positive words are usually unmarked while negative ones are marked, and thus inference is much easier from "negativity" to "positivity" than in the reverse situation.

The last interpretation, however, is the narrowest from the above given as it refers only to inferences in clearly semantically opposite pairs of words, whereas PEABODY'S theory accounts for inferences along whole dimensions, and OSGOOD'S may be applied to any inference process, independently of the information's descriptive or semantic position. OSGOOD'S "Polyanna's hypothesis" thus formed the basis in our studies.

2. Empirical studies

All the studies that we shall refer to were concerned with the positivity bias phenomenon as revealed in person perception, and they dealt with perception of both known and unknown persons. As in most of the studies the positivity bias phenomenon was not their direct purpose, we shall refrain from relating all particulars of the procedure and underlying theoretical framework, and shall restrict ourselves to those procedural details and obtained data which directly pertain to the object of this paper.

First of all it should be emphasized that the positivity bias phenomenon has clearly been found in all the studies. In Study I subjects ($N = 240$) were presented with short characteristics of unknown persons of which one was univalently positive and the other negative. Each subject received only one characteristic. Next, the subjects were asked to complete their image of the described person by sorting 80 provided adjective-traits into nine categories, signifying the degree of certainty with which the person was probably endowed with the given trait. Half of the trait-adjectives were positive and the other half negative. There was calculated the number of ascribed positive and negative adjectives for both stimulus persons jointly, and the difference was found to be highly significant ($z = 16.01$, $p < 0.0001$). Also a general halo effect was calculated for positively and negatively valued persons separately, and the halo effect was found to be significantly higher for the positively characterized person than for the negative one ($F = 458.6$, $p < 0.001$).

In Study II subjects were given the matrix form of Rep Test with 10 roles (half were the liked and the other half—disliked persons), to be replaced by well known persons, and with constructs they generated themselves. Having generated the constructs the subjects were to fill in the matrix by rating each person on each construct along a 6-step scale (+3, +2, +1, −1, −2, −3). Positivity of the ratings was calculated from the subjects' ratings of their ideal-selves on the constructs (as positive those poles were rated which the subjects would like to be characterized by). It was found that the general number of positive ratings ascribed equalled 66%, even though there were equal numbers of liked and disliked persons judged. A similar result was obtained by WOJCISZKE (1979) with almost identical procedure, and the percentage of positive ratings he obtained amounted to 62%. The numbers correspond satisfactorily to the BENJAFELD'S and GREEN'S equation, and the figures obtained are almost identical with their predictions.

Apart from this obvious evaluative positivity bias several studies established a strong affective positivity bias revealed in a generally positive emotional attitude towards close acquaintances. In Study I subjects ($N = 240$) were given the Rep Test with provided constructs of which one was a clearly affective dimension (I like—I dislike the person) and were asked to rate 10 acquaintances (5 liked and 5 disliked) along it, on the 6-point scale. It was found that the mean value for the "liking-disliking" dimension equalled 1, even though the numbers of the supposed liked and disliked persons were equal. In Study II subjects ($N = 60$) were provided with the matrix form of Rep Test with generated constructs and with added affective construct of "like—dislike". It was again found that out of 10 persons judged (5 liked and 5 disliked) the mean number of persons judged a "liked" amounted to 6.8. All these data seem to point to the possibility that the sources for evaluative positivity bias should be looked for in emotional and not cognitive factors as, obviously, the generally positive emotional attitude should result in the overall higher ratio of positive evaluations given. There exist, however, strong empirical arguments that this is not the case. First, no any significant correlation between the number of the persons liked and the amount of the evaluative positivity bias ($r = 0.178$, n.s.) was found. Second, in Study I, the subjects who were provided with univalent positive and negative characteristics of an unknown stimulus person, were asked to rate along the 9-step scale their emotional attitude towards the described person (its index being the expressed willingness to cooperate with the person). There was found a highly significant difference in the emotional attitudes towards the positive and negative person ($\chi^2 = 90.13$, df $= 2$, $p < 0.001$), and the evoked emotional attitudes were equally polarized ($\chi^2 = 1.20$, df $= 2$, n.s.). Despite that, the positivity bias clearly appeared and the disliked person was ascribed significantly more positive traits than positive person—negative ones (see: above).

With the most obvious and commonsense interpretation of positivity bias determinants eliminated, we have focused in further explorations on the role of cognitive factors.

Starting from OSGOOD's assumption that "negativity" is more meaningful for an individual than "positivity" and that—hence—stricter criteria of validity should be imposed upon attribution of negative than positive traits, two studies (I, III) were devised in order to go more deeply into the dynamics of impressions formed out of positive and negative information. Both studies dealt with the process of modification of the initial impression under the impact of new and inconsistent information. Additionally, in order to avoid the usual confusion between evaluative and descriptive inconsistency (see LEWICKA, 1977), in Study I the stimulus material was selected so as to provide the subject with one type of inconsistency only, that is either evaluative (with accompanying descriptive consistency) or descriptive (with accompanying evaluative consistency).

In Study I each subject ($N = 240$) was presented with one short univalent characteristic of a stimulus person, either positive or negative. After the measurements of the impressions formed were collected from Ss and the positivity bias effect was clearly stated (see: above), each subject was presented an additional characteristic of the same stimulus person which was either evaluatively or descriptively inconsistent with the previous one. Four kinds of conditions were thus created: $++$, $+-$, $-+$, $--$. Both characteristics were presented as two different opinions coming from two different sources. Next, measurements were taken of the following indices of impressions formed: amount of impression change, amount of rejected new information, number of the ascribed positive and negative traits, and amount of halo effect (consistency of the evaluative tone of the impression with initial information).

It was found that the initially positive impressions were more difficult to change than impressions which were initially negative ($F = 8.133$, $p < 0.005$). As for the amount of rejected new information, there was found a highly significant effect of interaction between initial valence of the impression and type of evoked inconsistency

($F = 46.826$, $p < 0.001$). New evaluatively inconsistent information was rejected significantly more often in the "+ −" conditions than in the "− +" ones. For the descriptive inconsistency, the negative information was rejected to larger extent ("− −" conditions) than the positive information ("+ +" conditions). According to our expectations then the criteria of validity imposed upon incoming information proved to be much stronger for negative than for positive information.

It was also found that, independently of the type of evoked inconsistency, impressions of the initially positive objects after the second characteristic, proved to be significantly more univalent (positive) than those of the initially negative objects ($F = 228.9$, $p < 0.001$). As a result, it was found that the number of positive traits ascribed to both stimulus persons jointly was significantly higher after the second characteristic than the number of negative traits ($z = 14.10$, $p < 0.0001$).

All the results presented in Study I referred to the positivity bias effect as revealed in the process of impression formation whose target was an unknown person. Additionally, the evaluatively inconsistent information was presented as coming from two different sources. Both conditions facilitated employment of some techniques of dealing with the created inconsistency, as negative information did not carry any serious consequences for the subject's future interactions with the stimulus person, and existence of two sources of information enabled the subjects to handle the negative information as relatively invalid and hence to preserve the previously well established positive attitude towards people in general. One should suspect, however, that if negative information referred to a real person with whom the subject was intimately acquainted, and if there existed no possibility of rejecting the information on the basis of its invalidity, the impression would have changed more in the direction of the more meaningful negative information than in that of the less significant positive one. To check this hypothesis, Study III was devised, and carried out by Janusz Czapinski from our Institute.

The study consisted of two phases. In phase I measurements were taken of the subject's ($N = 61$) emotional attitudes towards 12 persons with whom he was intimately acquainted. The subject's task consisted in ranking all persons according to the intensity of positive attitudes towards them. Phase II took place after 5–6 days and each subject was asked to describe two out of the twelve persons from the list. One of the persons was to be characterized with eight negative attributes, the other with eight positive attributes. The persons to be characterized were chosen by E according to their rank places, and they differed by one rank. For positive characteristics those persons were chosen which were ranked as slightly negative, for negative characterization—those which were slightly positive. Having completed the univalent descriptions of the two chosen persons, the subjects for the second time ranked all the persons from the list according to the intensity of their emotional attitudes towards them. Measure of the attitude change was the difference in rank positions between the first and the second ranking for each of the characterized persons, provided with the "minus" sign (decrease in rank position) or "plus" sign (increase in rank position respectively. It was found that attitude change in the positive direction following the positive characterization amounted to $+0.443$ ($t = 2.58$, $p < 0.02$), while that in the negative direction following the negative characterization was -1.459 ($t = 5.443$, $p < 0.00001$). Comparison of the mean attitude changes for the positively and negatively characterized person contradicts the positivity bias phenomenon. In line with the expectations, what was obtained was the negativity bias effect ($t = 3.746, p < 0.001$) that is, the self-generated univalent positive information influenced the previously established attitude to a lesser extent than the self-generated univalent negative information. The result is highly consistent with the implications of OSGOOD's hypothesis. As negative information is more highly weighted than the positive one, and as any subject is for himself the most credible source of information, the impact of the self-generated negative information on the overall judgment was found to be much stronger than the impact of little meaningful, although equally credible positive information.

Further data which seem to support the hypothesis on the overall higher significance of negative than positive evaluations, come from the studies by WOJCISZKE (1979), which show that negative persons are perceived as more difficult to understand than positive persons (they deviate more from the subject's idea of "normality"), and they are perceived in the more complex way than positive persons. What's more, it was found in his study that the stronger is the positivity bias in a subject (the more positive is his image of normality), the more complexly he construes the negative persons he comes across.

We have also obtained some additional data which seem to point to the higher significance of negative than positive information, and to higher cognitive effort put into integration of the former than of the latter. In Study II subjects ($N = 60$) were to freely describe four persons whom they intimately knew. Two of the persons were liked by the subject, the other two were disliked. Next the free spontaneously written characteristics were rated as to their stylistic properties, and there was rated the general expressivity of the utterances. It was found that disliked persons were characterized with a significantly more expressive style than those who were liked ($t = 2.60$, $p < 0.02$). An identical result was obtained in study I, in which the free characterizations of the stimulus person after second information set were rated as to the amount of stylistic expressivity. It was found again that the least expressive were descriptions of the person who was characterized by two univalently positive sets of information, while the most expressive were descriptions of the person characterized by two equally negative sets of information (both sets although evaluatively consistent were descriptively inconsistent).

It seems that the expressive style (as contrasted with the descriptive one) plays probably two important psychological functions, first it reveals the level of the subject's emotional involvement and serves the emotional expression, second—it constitutes a way to cognitively elaborate the material at hand. Irony, metaphorical expressions etc. clearly play the cognitive function, too, and they reveal the subject's effort to cognitively master what is difficult to master by logical, descriptive and commonsense criteria. With negative objects deviating more from the subject's idea of typicality, one should not wonder why more cognitive effort of any kind should be applied to the untypical negative objects than to the typical positive ones.

3. Conclusions

All the data that we have presented seem to lead to the following conclusions:

1. The positivity bias effect is a well proved and common phenomenon in human perception.

2. The effect is clearly of the cognitive rather than emotional nature.
3. Out of several theories, the implications of OSGOOD's "Polyanna's hypothesis" seem to best account for its determinants. As our data show, the negative information is more informative than the positive one, and hence it is more difficult to accept. Once it is accepted, its influence upon the overall judgment is much greater than that of the positive information, and more cognitive effort of any kind is put into its integration into the general impression of the perceived object.

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The Construction and Use of Memory Structures in Controlling Very Complex Systems

D. DÖRNER

1. Problem definition

The aim of the experiment to be described below was to learn something about the cognitive processes activated while solving a very complex problem. In this experiment 49 subjects, students of all departments of the University of Giessen, were given the task of controlling the fate of a small city for over 10 years in the position of mayor (fig. 1 shows the map of LOHHAUSEN). Their aim was to strive for the most satisfying end state and provide for an improvement of living standards. Subjects could decide to take action in many very different ways: they could influence the production and sales policies of the city's factory, take steps to change tax policies, act on the city's medical assistance, etc. Subjects received information about the community and could continue asking questions and making decisions.

The computer simulating LOHHAUSEN was fed subjects' decisions, who in turn received feedback as to the effects of their actions, made new decisions based on this information, etc. (The experiment has been described more detailed elsewhere, cf. DÖRNER, 1978.)

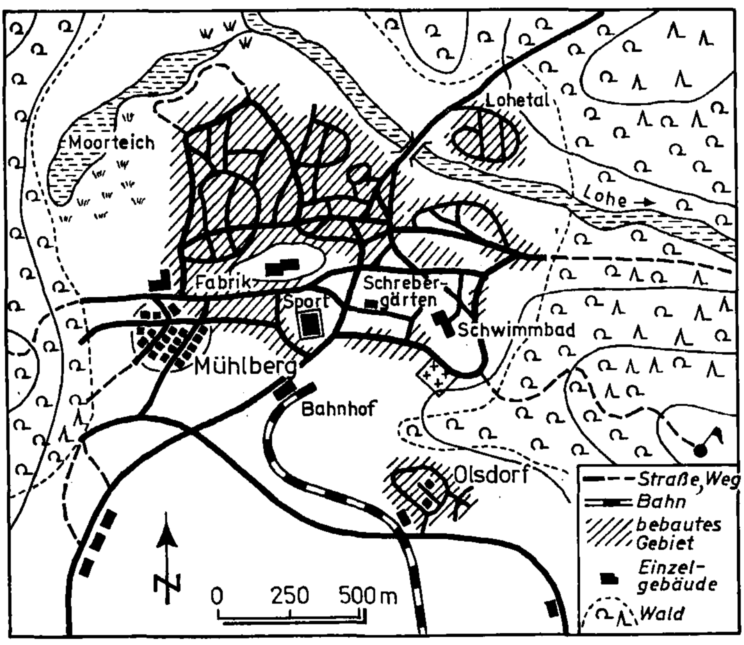

Fig. 1: The city map of LOHHAUSEN.

2. The cognitive demands of complex problems

The task deals formally with changing certain goal variables within a complicated causal network. Figure 2 depicts a network of this type schematically. There are certain goal variables z_i; in our model system such goal variables could be:

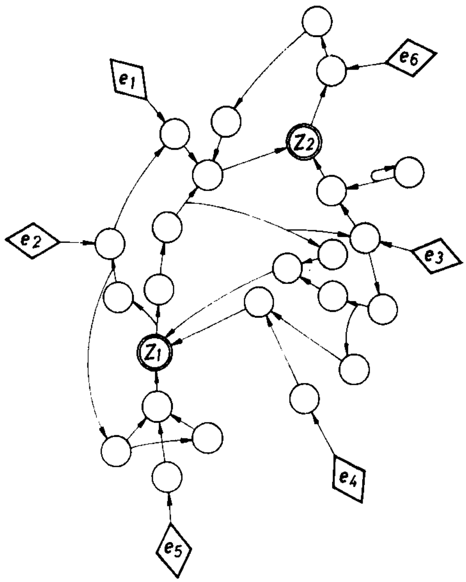

Fig. 2: Schematic representation of a complicated causal network with operator variables (e_i) and goal variables (z_i).

Contentment on the part of the population, amount of production, number of inquiries, quality of the recreational opportunities, etc. In addition, there are certain operator variables e_i which are accessible to an actor's direct manipulation. Such operator variables in this model system could be: housing construction, changing tax rates, qualifying doctor's practices, constructing sport facilities, schools and kindergardens, etc. These variables and others, functioning as transfer links, are connected in the system by certain functions and probability functions (in fig. 2 only the mere existence of the connections is indicated, not the type of connection).

The cognitive demands on a subject arising from such a problem are polymorphic: in order to be able to act the subject must at first find the problems. Only the global end state is given and nothing is pointed out about the present state. Once the subject has found a specific problem, possibilities for taking action must be sought. Formally, a problem always exists when a variable is not in the state it should be in. The variable (e.g. "contentment on the part of the population") is in most cases not directly manipulable, but only indirectly. It is embedded in a network of other variables which are partly controllable. This network should be known in order to find the correct combination of operators. If this knowledge is not at hand, the subject must try to attain it. An additional demand is thus the creation and modification of hypotheses about the system to be controlled, which at first is unknown to the subjects.

The fact that a variable of such a system is usually dependent on many other variables suggests not only one measure, but a combination of measures to be taken. Since goal variables may be connected to one another, it is not unusual to find an antagonism between goals. Two goals or intended states of variables contradict each other and cannot be gained at the same time. They should be weighted against each other and subjects must partly dispense with one or the other goal. Counterbalancing goals is therefore one demand of such a system.

Due to the network characteristics of the system side effects are frequently found. The effects of an operation are seldom restricted to one place but extend over the entire network. It is necessary to take side effects into account and not only consider the main effects of actions.

In most cases it is necessary to decide on focal areas of concentration. Certain problems are more important and pressing than others and must be attended to first. One should not remain fixed to chosen areas of concentration, but should be able to change them if necessary. Correct establishment of crucial areas for attention and well-timed change of the same are further demands of complex problem situations.

3. Results

Our subjects mastered the given task in very different ways. Figure 3 shows the development of some important variables of the system "LOHHAUSEN" for one very good and one very poor subject. Note that there is a very clear difference between subjects with regard to important variables (consider for example the number of unemployed individuals!). "Konrad's" actions led to a continuous improvement in the community, while "Marcus" produced markedly unwelcome conditions.

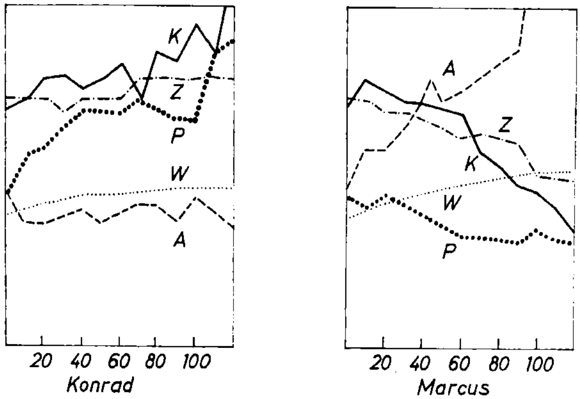

Fig. 3: Development curves of some important system variables form a very good ("Konrad") and a very poor ("Marcus") subject. K means capital, Z = contentness, P = production, W = number of people without housing, A = unemployed people.

The reasons for success and failure are to be found in the clearly obvious differences between their cognitive processes. We examined the transcripts of the communications between subjects and their experimentators exactly. First we chose 12 of the best (⊕-group) and 12 of the worst subjects (⊖-group) from the entire sample group. Then we analyzed tape-records of subjects' statements from the second experimental session precisely by means of a transcription system designed especially for this purpose. This enabled us to transform verbal statements into half-formal standard transcripts. The transcripts acquired by this method are formal in their basic structure and therefore comparable. It is possible to count elements of the recordings and compare the frequencies of similar elements with one another. The analyzed session lasted for 2 hours; the following values were attained during this time.

We discovered two large groups of differences between good and poor subjects:

1. There are strong differences in the way subjects control their own thought processes by critical self-reflection. Corresponding phases of thought processes are found much more frequently in the transcripts of subjects of the ⊕-group than in those of the ⊖-group. However, I do not wish to go into detail about these differences in the course of this article.
2. There are great differences in the use and construction of memory between good and poor subjects and I shall comment about this below in more detail:

Figure 4 illustrates the average frequencies of certain forms of use of memory contents. The following differences appear between the subjects of the ⊕-group and the ⊖-group:

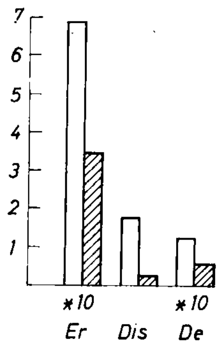

Fig. 4: The average frequencies of recollections (Er), observations of discrepancies (Dis) and deductive judgements (De) by good ⊕-subjects—(blank) and the ⊖-group (cross-hatched). The ordinate values for Er and De are to be multiplied by 10.

a) Subjects of the ⊕-group remember past information, decisions and facts more frequently (Er in fig. 4; the difference is significant).
b) Subjects of the ⊕-group notice discrepancies more frequently between information gained in the past and information recently acquired (Dis in fig. 4; the difference is significant).
c) Subjects of the ⊕-group make more frequent deductive judgements inferred from hypotheses stored in memory (De in fig. 4; the difference is highly significant).

That shows that subjects of the ⊕-group have more access to their memory contents and are able to enrich new situations with stored material in a better fashion than subjects of the ⊖-group. This implies either that subjects of the ⊕-group have more relevant material stored in memory or that this material is more accessible—or—that both statements are valid.

Differences between subjects of the ⊕- and the ⊖-groups are also found with regard to the construction of memory structures, as shown in fig. 5:

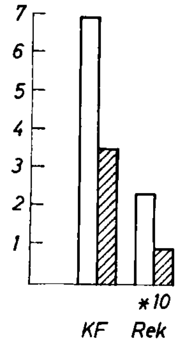

Fig. 5: Frequencies of causal questions and recapitulations of the ⊕—(blank) and the ⊖-groups (cross-hatched).

1. Subjects of the ⊕-group ask more questions relating to the causal dependence of variables or problemize such dependencies. (Example: "What is the reason for the decrease in production during the last months?" Such questions were basically not answered. Subjects had to formulate hypotheses about the inner structure of the system themselves and test these.) (KF in fig. 5; the difference is highly significant.)

In our opinion, this implies that subjects of the ⊕-group assume greater causal dependencies from the very beginning and therefore search for these when they are not readily available.

2. One observation made is interesting, which at first glance may appear to be incidental: subjects of the ⊕-group, compared to those of the ⊖-group, have the highly significant tendency to repeat information directly after acquisition. Such sequences of communication as shown in the following example accumulate for subjects of the ⊕-group: Subject: "What is the unemployment rate of youth at the present time?" Experimentator: "The unemployment rate has increased!" Subject: "Ah yes, has increased." The number of such direct repititions of given information amounts to an average of 22.9 for subjects of the ⊕-group and to an average of 9.5 for subjects of the ⊖-group. The difference using the *U*-test is significant on a 1% level (Rek in fig. 5).

We interpret these recapitulations as indicators of a controlled insertion of the new information in the existing memory structures. Such recapitulations can be interpreted as reinforcement of the given information, which increases the probability of its acceptance into long-term memory. Another interpretation (which does not necessarily exclude the first) would be the following: such recapitulations give subjects a short span of time to integrate new information in the already existing memory structure, establishing a variety of connections possible to other contents.

Consequently, one could characterize the ⊕-group subjects' procedure in contrast to that of the ⊖-group in the following manner: subjects of the ⊕-group construct a mental image of the system to be manipulated more actively than others, correct this image if necessary and control their actions to a greater extent than subjects of the ⊖-group by making use of critical self-reflection.

A large number of other behavioral characteristics differentiating subjects of the ⊕-group from those of the ⊖-group can be deduced from these central features:

The limited ability of the part of subjects of the ⊖-group to clarify the causal embedding of problem variables results in the following apparently behavioral attributes (see fig. 6).

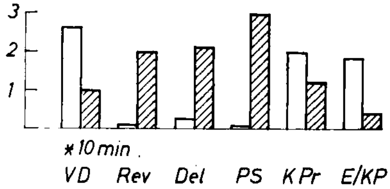

Fig. 6: Frequencies of characteristic behavioral attributes of subjects of the ⊕—(blank) and the ⊖-groups (cross-hatched). Explanations given in the text.

1. Subjects of the ⊖-group switch more quickly from topic to topic during the experimental sessions. The average length of time subjects of the ⊕-group spent on a thematically delineated topic is approximately 26 minutes, for subjects of the ⊖-group, however, 10 minutes (VD in fig. 6; the difference is highly significant).
2. Subjects of the ⊖-group take up topics previously dealt with more frequently than subjects of the ⊕-group, apparently because they have not been able to complete handling the topic (Rev in fig. 6; the difference is highly significant).
3. Subjects of the ⊖-group display a statistically significant tendency to "delegate" tasks ("The head of the financial department should take care of that!"). During the second session subjects of the ⊕-group demonstrated with the average of 0.27 such delegations, whereas subjects of the ⊖-group used these delegations with an average of 2.1 (Del in fig. 6; the difference is highly significant). This "delegation" of tasks indicates in our opinion "flight tendencies" of the subjects and is compatible with the tendency observable with many poor subjects to "shut" themselves in irrelevant although successful nooks of the system.
4. Subjects of the ⊖-group actively search more frequently for problems than subjects of the ⊕-group. In our opinion this is due to the fact that subjects of the ⊕-group are more able to "see" problems based on their better survey of the causal network. Subjects of the ⊖-group, for example, may consider the financial condition of the community unobjectionable as a great deal of money appears in the city's accounts. The fact that this positive cash balance only is a covered credit in reality because the city's main source of income, the community factory, is suffering from a rapid financial decline, does not occur to them, although they are aware of both of these facts. However, they do not relate the two parts of information to each other, contrary to subjects of the ⊕-group (PS in fig. 6; the difference is significant).
5. Subjects of the ⊕-group are not only better in detecting problems, they master them in a more adequate manner right from the very beginning of the experiment. The following results are characteristict Originally there are three main problems in Lohhausen which must be recognized and tackled, i.e. the financial state of the city's factory, the unemployment rate of young individuals, and the housing shortage. An addition of the frequency with which these three problems were recognized by subjects of the ⊕- and ⊖-groups during the first experimental sessions shows an average

of 2 for the ⊕-group and an average of 1.25 for the ⊖-group. This difference is not significant ($z = 1.95$ for the U-test) but the tendency is evident (KPr in fig. 6). If one continues counting how many steps were taken to improve the deplorable state of affairs relative to the number of recognized grievances, the results show an average of 1.85 decisions for each recognized grievance for the ⊕-group; for the ⊖-group the average is 0.36. The difference is highly significant (E/KP in fig. 6).

4. Causes of behavioral differences

The individual tangible elements of behavior harmonize well with each other. The question remains as to the reason for the fact that subjects of the ⊕-group have a better structured mental image of the system to be manipulated from the very beginning of the experiment. In addition to that, they are able to exercise more self-control. Some obvious reasons for the observed differences can be eliminated:

There is no significant correlation between the amount of relevant prior experience subjects reported to have had, e.g. of political or economical nature and the quality of their performance. Furthermore, there are no significant relationships between the subject's major field of study and the quality of performance shown. By the same token, measures of general intelligence (CFT 3 from Weiss, 1971) and of creativity (for details see Kreuzig, 1978a) do not significantly correlate with the level of performance.

There are two possible reasons for the failure of typical psychodiagnostical methods to predict subjects' performance:

1. The performance of our subjects is unique and determined solely by the specific characteristics of the Lohhausen experiment; no prediction is possible.
2. Subjects' performance is for most parts attributable to relatively stable personality traits which were not registered by the indicators mentioned above.

We decided against the (agnostic) first thesis and asked experimentators to supply us with additional information by giving us their impressions of the traits of "good" and "poor" subjects. The inquiry yielded a list of corresponding answers from the different experimentators.

The experimentators shared a rather unanimous opinion of the difference between good and poor subjects with respect to the "basic turnover of information". The good subjects can be distinguished by their endeavors for constant mental activity. When "material" was not available, they attempted to gain it themselves by active pursuit; i.e., they had a strong tendency to exhibit diversive exploration (cf. Berlyne, 1963).

In addition, it was reported that the good subjects showed a relatively high degree of self-confidence.

From these results and other theoretical discussions we drew up a theory, from which the important part for our present purposes is depicted in fig. 7:

An individually varying need for uncertainty exists as a need for information processing. This leads to a high degree of diversive exploration which in turn leads to an accumulation of many quite heterogeneous experiences in memory. The strive for cognitive consonance as an effect of a general need for control leads to a modification of the concrete experiences in abstract comprehensive schemata. These can be applied to the prestructuring of unknown facts and enable an increasingly more efficient

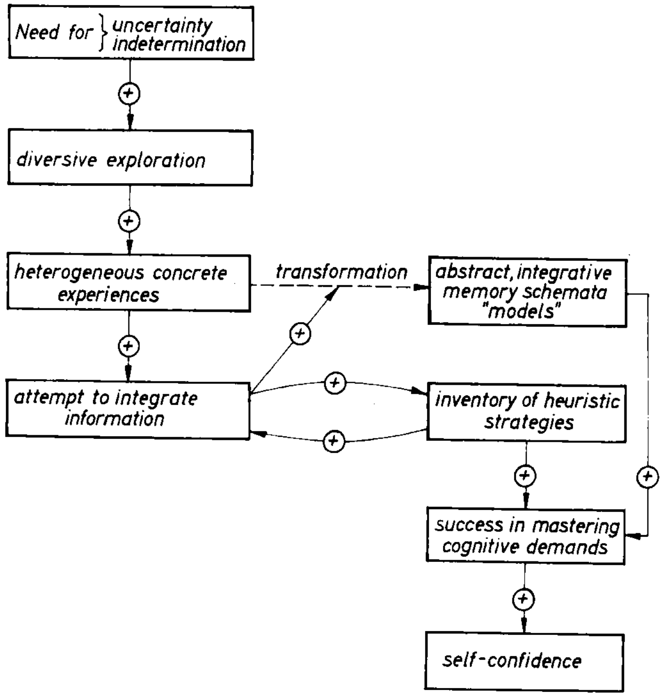

Fig. 7: A theoretical scheme depicting the relations between the need for uncertainty—memory schemata—and self-confidence. Explanations to be found in the text.

mastery even of very new and strange situations. In this way the individual gains self-confidence, as the experience is often made that new situations can be mastered.

A constant acquisition of new information and dealing with dissonant experiences leads to a continuous development of heuristic strategies and thus a greater understanding of the necessity for self-control by means of self-reflection. The result is the accumulation of a large set of comprehensive schemata applicable to many spheres of reality as well as an accumulation of a large number of heuristic strategies. Consequently, this guarantees a high degree of mental flexibility.

This should be sufficient for a rough and incomplete description of our theoretical reflections. We now approached the task of testing these hypotheses. KREUZIG (1978b) constructed a questionnaire to measure the tendency for diversive exploration and some other variables which should register certain aspects of cognitive style. In addition we employed a self-confidence questionnaire and developed a test to measure the ability of structuring spheres of reality by using analogies.

We employed the latter because the pure acquisition of abstract schemata is insufficient for structuring a new sphere of reality. One should also be able to apply the abstract schemata to concrete facts. The transition from abstract schemata to concrete facts is commonly known to be rather difficult at times. We tried to test this ability by requesting subjects to make analogies to rather common everyday "items" like "city", "ship", etc. We rated the number and quality of analogies stated.

After assembling the testbattery we invited our subjects to a post-test. 40 of the 49 subjects accepted the invitation and therefore enabled us to test our hypotheses.

The results of the post-test have been described in detail by KREUZIG (1968b). With regard to the hypotheses just presented we found the following results:

1. The questionnaire scale "controlled diversive exploration" correlated highly significantly with the quality of behavior: $r = 0.47$.
2. The self-confidence questionnaire correlated with the quality of behavior in the same way: $r = 0.47$.
3. The analogy test correlated significantly with the quality of behavior: $r = 0.31$.
4. On the contrary, an intelligence test employed in the post-test (complicated RAVEN-matricen) did not correlate significantly with the quality of behavior.

We believe that these results confirm our theoretical considerations. The quality of behavior displayed while solving very complex problems is dependent on certain measurable personality variables such as those converning "cognitive motives" (the search for uncertainty and control) and those relating to the ability to construct and use abstract memory schemata in certain ways. The traits measured by typical intelligence tests do not have any demonstrable connection to the ability of solving problems in the higher range of intelligence we examined (our subjects were taken from a student population).

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Developmental Stages in Learning to Program

J. A. M. HOWE

1. Introduction

Although recent research in cognition includes attempts to explain complex human processes such as story understanding by studying how information might be represented in memory structures, scant attention has been paid to the problem of explaining how new information is learned. Indeed the term *learning* appears to be missing from the cognitive scientist's vocabulary: he appears to prefer to talk euphemistically about knowledge acquisition, presumably in the fond hope that the problem will be eased by using different terminology. Be that as it may, we take the view that learning and memory are such closely inter-related processes that we cannot understand one without understanding the other. In this paper, we reverse the emphasis by looking at the way in which children learn a complex task, namely computer programming, before we speculate about the long term memory organization implied from our observations.

The work described below was carried out in the context of a project to evaluate the proposition that a 12-year old child's understanding of classroom mathematics can be improved by teaching him computer programming skills as a preliminary to getting him to use these skills to explore mathematical situations. where is grasp is weak (for details of this work, see HOWE and O'SHEA, 1978a, b). The rationale underlying this approach stems directly from research work in Artificial Intelligence which suggests that building computer programs is a particularly good way of understanding a complex *process* such as making a drawing, making a movie, composing poetry or composing a tune since one has to face up squarely to the problem of providing the machine with a set of rules which tell it unambiguously what to do.

2. Programming environment

Viewed against this background, our first task was to teach a group of children to program. For this, we developed our own dialect of the LOGO programming language that was conceived originally in the United States by FEURZEIG and PAPERT. Briefly, LOGO is a simple, but powerful interactive language. The user types commands in LOGO at the teletype console which cause LOGO procedures to be defined, changed or traced. The language has three data types, namely integers, words and lists. There are primitive instructions in the language for integer arithmetic, list processing, input from and output to the console, drawing using a relative geometry, generating musical tunes, conditionals, iterative control, predicates, creating and manipulating user-defined procedures, storing and retrieving user-defined procedures and creating and assigning values to variables.

The usual way of working in LOGO is to systematically extend the language by creating new procedures which the user stores in his own personal section of the computer's file store. User-defined procedures can be re-used in the definition of other procedures, and recursive definitions are permitted. A procedure may be defined with arguments, and may produce a result (i.e. be a function) or a side effect or both. For example, a procedure with arguments for the length and breadth of a rectangle could both draw that rectangle and compute its area and return the value of the area to any procedure that called it. Procedure names may also be passed as arguments, and then executed.

In our laboratory, we set up a programming classroom equipped with teletypes which children use to type in LOGO programs to control a variety of output devices such as a small floor robot (called a turtle), graph plotters and displays (for drawing), a music box (for tunes), a Meccano set (for constructing computer controlled cranes and lifts) and a tape punch (for making paper patterns). Typically, learning to program involved a child working in this programming classroom for one or two hours per week, throughout one school year.

Teaching LOGO

In contrast to those educationists like PAPERT who argue that concepts and relationships are learned by indulging in free problem-solving activities, we believe that they ought to be introduced in a highly structured way. The novice programmer's immediate problem is that he lacks an adequate mental model of the machine. The teaching strategy which we adopted to help novices understand how the machine works is based on the concept of "virtual machine". Technically, a virtual machine is a notional computer which can produce consistently all the behaviour which can be achieved by the statements in the programming language. In other words, the virtual machine is a simplified model of the computer's function which can be used as a basis for program planning and for interpreting the machine's responses.

Tab. 1

Problem	Strategy	Benefit
1. Characterising the virtual machine	Analogies and manipulable models in teaching	Links with novice's existing knowledge
2. Revealing hidden operations	Drawing devices, trace facilities	Hidden actions can be 'seen'
3. Choosing names of instructions	Unambiguous names avoiding concatenation	Reduces chance of misinterpretation
4. Limiting redundancy of function	Simple instruction name for each function	Simplicity reduces cognitive load
5. Improving program readability	Use program layout to indicate program structure additional scope markers on conditionals	Program comprehension improved
6. Minimise user expectations of machine intelligence	Error messages written for clarity and consistency with teaching materials	Reduces expectation that non-syntactic commands will be understood

Some of the problems which arise in teaching programming, together with the strategies for overcoming them, are listed in tab. 1 (adapted from DU BOULAY and O'SHEA, 1978).

Notice that the structure of the virtual machine is designed to minimise the cognitive load on the learner, to provide a basis for interpreting error messages and to establish a small vocabulary for talking about programs and the activity of programming. This vocabulary is employed in the system's error messages, in verbal explanations, and in teaching materials.

The teaching strategy is expressed in our LOGO programming primer (DU BOULAY and O'SHEA, 1976). It comprises 33 ordered worksheets which introduce *computational ideas* such as procedures and sub-procedures, variables and recursion; *problem solving tactics* like decomposing a problem into parts, and the use of *debugging skills* such as running a trace facility to get a commentary on the execution of a procedure. These worksheets are designed for individual, self-paced study. Each starts with an explanation of the worksheet's purpose. Then it typically gives a specimen LOGO procedure which the pupil types in and runs. In turn, this is followed by exercises which involve modifying the specimen procedure in minor ways and finally adapting it to some other problem area.

Notice the emphasis in the worksheets on the use of analogy to illustrate key concepts. Some of the more important examples are given in tab. 2 (from DU BOULAY and O'SHEA, 1978).

Tab. 2

Concept	Analogy
Long term file storage	Tape recording on cassettes
Non-destructive file copying	Photographing
Variable	Named box
Empty list	Pallet
List processing function	Fork-lift truck manoeuvre
Procedure definition	Job description to worker
Procedure	Worker
Procedure call	Imperative verbal command to start work
Sub-procedurisation	Breaking problems into sub-problems
Predicate	Question
Syntax restrictions	Tidiness, discipline
Global/local distinction	Public and private information

Using LOGO

Before a pupil can learn a programming concept, he has to master basic programming skills (for example, to define and edit procedures) and the basic properties of the programming system. In the context of the approach to teaching programming described above, our pupils appear to go through the following stages in learning a LOGO language concept. Initially, the pupil copies and runs a procedure which employs the concept. Next, he may be able to modify the procedure to make an isomorphic procedure, for example by just changing the name of the inputs. At a later time, he may alter the structure of this procedure, for example by extending its range of application by adding another input, or by employing the procedure as sub-procedure in some other problem solution. Subsequently, he may write procedures employing the concept wherever he identifies a need for it. A further indication that a pupil has fully understood a concept is ability to read and understand procedures employing it, and to explain these procedures as descriptions of processes. Instead of describing a procedure line by line, for example, "line 20 says FORWARD 100", the pupil who understands a concept will say, for example, "this procedure has an input to keep track of the changes in polygon side length".

Stages in learning LOGO

Besides analysing our pupils' progress with *individual* LOGO concepts, we are interested in the way that their familiarity with concepts affects their problem solving. In general, our pupils appear to go through three distinct, overlapping stages in the course of learning LOGO programming.

We term the first stage "product oriented" to capture our pupils' desire to produce particular drawings, of effects, without any real concern for the way in which these effects are achieved. Although the early worksheets concentrate on teaching them to plan, build and use procedures, many of them produced their early drawings by issuing commands for immediate execution by the drawing device (N.B. we call this 'direct driving'). This is nicely illustrated by the drawing of a 'snail' shown as fig. 1, where the snail's shell is made up from a sequence of directly executed ARC commands.

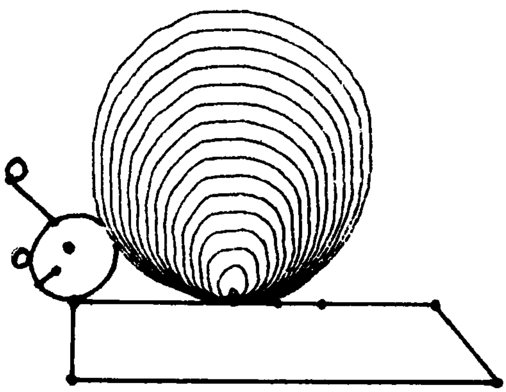


Fig. 1

Notice also that the blobs of ink at the corners of the snail's body illustrate another tactic favoured by the beginner, namely moving the position of the paper on the drawing surface instead of altering the pen's direction of travel. Clearly this pupil rotated the paper after each line had been drawn instead of altering the direction in which the pen travelled.

Another example of product-oriented behaviour illustrates their tendency to copy and run procedures without making any attempt to understand them. One boy had written a procedure to draw a pattern using a set of intersecting ARC commands. The procedure which he wrote is given as fig. 2, together with the pattern drawn.

Notice that the computer will interpret the command EAT in line 30 as a non-terminating recursion instruction. Since the line is parsed from right to left, the

```
DEFINE "EAT
 10 ARC 50 369
 20 LEFT 90
 30 REPEAT 34 EAT
END
```

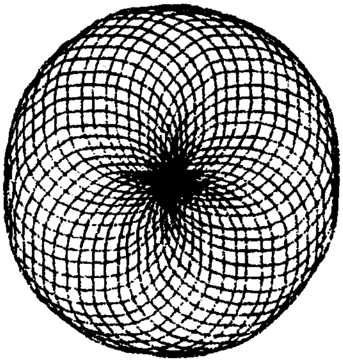


Fig. 2

control command REPEAT 34 will be ignored. However, not only is it redundant, but it is an incorrect use of the command. Now notice that another boy defined and ran the procedure given in fig. 3 to produce an identical effect.

```
DEFINE "FRED
 10 ARC 200 380
 20 LEFT 90
 30 REPEAT 34 FRED
END
```

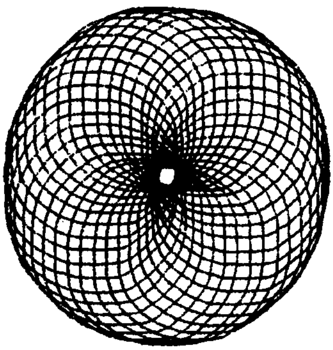


Fig. 3

Although it has a different name and uses different arguments, notice that line 30 contains the error made in the procedure given in fig. 2: this is a clear example of copying another person's procedure without understanding it.

We do not wish to give the impression that all our pupils are exclusively "product-oriented" during the early stages of learning to program. In fig. 4, we reproduce a drawing made by one of our more able pupils during his first weeks in the programming classroom.

A super-procedure named 0000 calls a sub-procedure named 9 POINT which in turn calls a sub-procedure named BEND. The final drawing is executed by means of the control command REPEAT 36 0000.

This procedure is an early illustration of the second stage in learning to program. We call it "style conscious" since a pupil's main concern is to work in what he perceives as correct LOGO programming style. This style seems to be mostly derived from the worksheets which explicitly recommend particular programming, debugging and editing methods. One tactic used by the style conscious pupil is to produce a drawing by direct driving, reworking the sequence of commands until the drawing is acceptable, and only then defining the debugged sequence of commands as a procedure. For example, the procedure SLOB uses a sub-procedure PEAK, repeated three times, to produce the effect shown as fig. 5. However, notice that the command in

```
DEFINE "0000
 1 RT 10
 2 9POINT
END

DEFINE "9POINT
 1 REPEAT 9 BEND
END

DEFINE "BEND
 1 ARC 90 100
 2 ARC -90 100
END
```

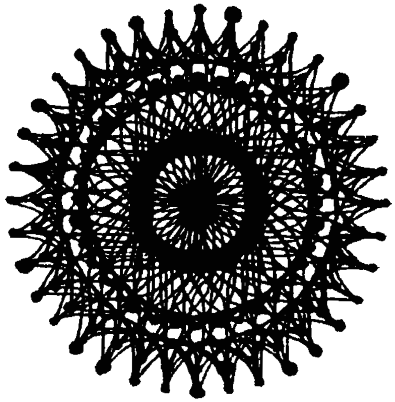


Fig. 4

```
DEFINE "SLOB
  5 PEAK 150
 10 FORWARD 20
 15 PEAK 60
 20 FORWARD 60
 25 PEAK 250
 30 FORWARD 10
 35 PEAK 39
 40 FORWARD 47
 45 BACKWARD 120
 50 PEAK 50
 55 FORWARD 13
 60 PEAK 87
 65 FORWARD 70
 70 RIGHT 120
 75 FORWARD 56
 80 PEAK 300
 85 FORWARD 36
 90 PEAK 25
 95 FORWARD 76
100 PEAK 56
END
```

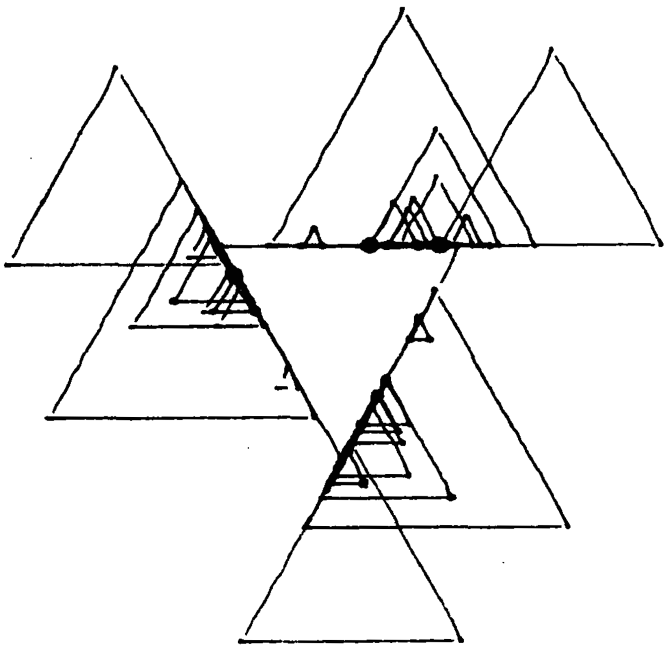


Fig. 5

line 45 to move BACKWARD 120 undoes the effect of the previous command FORWARD 47, yet the latter command is still included in the final procedure—a clear indication that the pupil has used a direct driving tactic.

A style conscious pupil may also slavishly break a problem into sub-problems, or introduce redundant inputs into procedures, or introduce redundant commands because he feels that 'good' LOGO procedures are made up of sub-procedures, or have inputs, or are recursive. We already encountered above the procedure EAT, written by a boy who partially understood iteration but did not understand recursion. Yet he combined both concepts in a single procedure. Unfortunately, owing to the right to left parsing it produced the desired effect so he was not made aware of his error.

Style conscious pupils are also very concerned to learn how to load and run the system and acquire appropriate computer science jargon. We also see an element of ritualistic behaviour: some boys run particular drawing procedures each time they come to the programming classroom, others will run conversational programs which they have written. The following kind of output is typical:

```
    WHAT IS 13 MULTIPLY BY 133          (Computer)
    REPLY: 1629                         (Pupil)
    STUPID HUMAN ASS
    WHAT IS 13 MULTIPLY BY 133
    REPLY: 1729
    PRETTY GOOD YOU SHOULD HAVE GOT IT FIRST TIME
    WHAT IS 14 MULTIPLY BY 144
    REPLY: 2016
CLEVER BOY I SEE YOU HAVE BEEN SWOTTING UP
```

Both "product oriented" and "style conscious" activities are valuable in the course of learning to program. The first enables the pupil to explore the possible results and effects that can be achieved with the computer. The second encourages the child to build up good programming habits such as careful mnemonic naming of procedures, debugging strategies and tidy organization. But the stage we are most interested in is the third stage when pupils use the resources in the programming classroom for analytic and problem solving activities. Now a pupil's work can only be understood by considering the problems he is trying to solve. Besides working at the terminal, he may be using paper and pencil or the blackboard. He may produce a diagram, or a high-level specification of the problem solution written in English. He is quite likely to ransack other people's files for procedures which he can adapt to his purposes. Like the "product oriented" pupil he may stop before he has a really debugged and well organized procedure. In this case, the debugging activity is directed at debugging his understanding of the problem rather than the procedure. While the product oriented pupil copies other people's procedures, the pupil immersed in problem solving activity ransacks other people's files for useful ideas.

An example of creative problem solving is shown in fig. 6.

The boy set out to draw a house by constructing a super-procedure, comprising a sub-procedure to draw a square and a sub-procedure to draw a triangle. When run the procedure drew a shape like an envelope, instead of the house, because the geometrical relationship between square and triangle was not correctly specified. Once he had corrected the bug and drawn a house, he returned to the original procedure and used it in a super-procedure to draw the Maltese cross shape shown above.

Another example was given in Howe and O'Shea (1978a). The procedure ASTERIX, shown in fig. 7, generates Fibonacci series. The boys who wrote it were helped by the suggestion that they ought to try to construct a recursive procedure which generates a doubling of its initial input value. They could then compare the output of this procedure to a known Fibonacci series. That the operation of the program

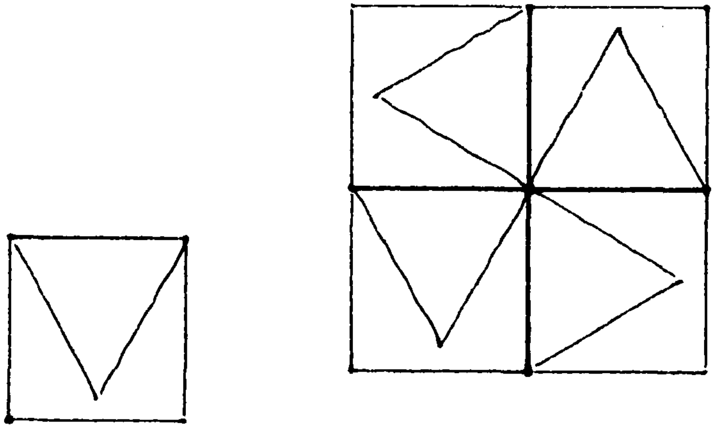
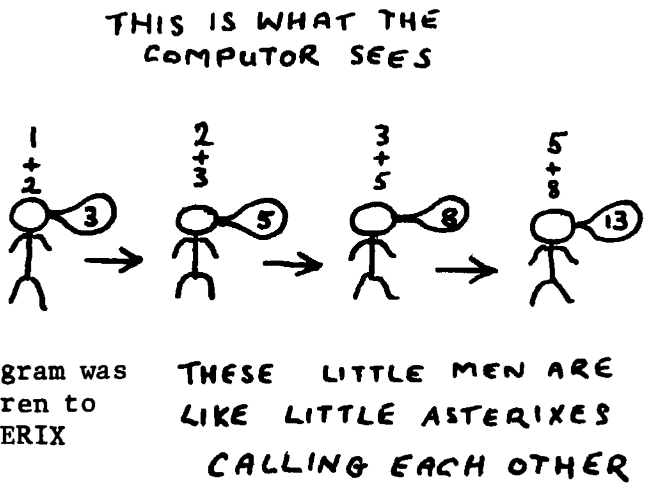


Fig. 6

served as an analogy for the process of series generation was confirmed by the boys subsequently writing several other three and four term series generating procedures.

```
DEFINE "ASTERIX "NUM1 "NUM2
 10 PRINT (ADD VALUE "NUM1 VALUE "NUM2)
 20 ASTERIX (ADD VALUE "NUM1 VALUE "NUM2) VALUE "NUM1
END

ASTERIX 2 1
3
5
8
13
21
34
55
etc.
```



The little man diagram was drawn by the children to illustrate how ASTERIX works.

Fig. 7

3. Relationship to memory

We turn now to discuss the long-term memory organization implied from our analysis of learning to program. Before doing so, let me warn you that the remarks which follow are highly speculative, and serve as little more than a guide for future research since they raise more questions than they answer.

We will begin by making explicit some pre-suppositions. Perhaps the most important ones are those concerning the nature of the information contained in our memory record of past experiences. In common with many previous investigators, we make a distinction between the storage of *particular* information about particular events and particular situations, and the storage of *general* information which has been abstracted from particular situations to represent classes of situations. For example, my recollection that I sat at my table in my room in the University to write this paper is an example of the storage of particular information about an event. In contrast, my memory record that a table provides a useful working surface for tasks like eating or writing is an example of the storage of general information. In cognitive research, there is a long tradition of belief in the notion that general information is organized into some kind of "chunk", extending at least from HEAD's early use of the term "schema" (HEAD, 1920) to denote such an organization to MINSKY's much more recent notion of a "frame" (MINSKY, 1975). Whereas BARTLETT disliked the term schema because it did not capture the active nature of the memory chunk (see BARTLETT, 1932, p. 201), a frame is conceived as an active structure because in addition to representing a stereotyped event or situation it also contains information about how the frame should be used, information about what can be expected to happen next and information about what to do if these expectations are not fulfilled. What this means is that frames are *data driven* in the sense that they are invoked by relevant data, but that once invoked the processing is then *conceptually driven*. As a result, new data will be introduced to a situation, and this new data will invoke further frames, and so on.

How does the concept of frame as an organized chunk of information in longterm memory help us to understand the memory activity underlying learning to program? Here we identify ourselves closely with a view of learning, based on the frame concept, which was put forward recently by RUMELHART and NORMAN (1978). They single out three modes of learning which they call "accretion", "tuning" and "restructuring". Briefly, accretion refers to the accumulation of factual information in memory where the new data structures are no more than copies of existing frame structures except that they represent particular aspects of the current situation. Tuning refers to the process of modifying an existing frame structure to represent new information in situations where the basic relational structure remains unchanged, for example, to represent constraints on the use of a frame to ensure that it will not be invoked inappropriately. Restructuring, as the word suggests, refers to the construction of a new frame structure when existing structures cannot be used.

We turn now to our analysis of learning to program to assess RUMELHART and NORMAN'S suggestion that learning a complex topic involves all three modes of learning, where the first step is the accretion of particular information about the topic, followed by the construction of new frame structures to organize that information appropriately, followed by tuning these frame structures. Looking at the product oriented stage first of all, it would appear that our pupils were engaging in all three modes or learning. They learned by accretion new terminology such as the names of the items of equipment, the names of commands, and so on. They tuned memory structures representing concepts like locomoting about in space to handle the drawing tasks used in the early days of learning to progam. They began to build new memory structures to represent these skills which they had to acquire to solve the problem of getting information into and out of the machine. These ranged from learning how to use the teletype and drawing devices, to learning how to edit and to learning how to build their own procedures. Some minimal proficiency in these skills is necessary before the learner can learn the more advanced programming concepts listed in tab. 2.

As teacher, our task is to help the learner to organize his memory structures by providing a context within which relevant information is provided in a structured way. This is the rationale underlying the choice of the virtual machine as the model of the process, and the use of structured lesson materials. In these materials, we rely heavily on the use of analogies to introduce new programming concepts because we believe that new frame structures are built most easily by generalising from existing structures. But building new frame structures takes effort on the part of the learner, and occupies an appreciable period of time. So we can understand why so much of a novice's behaviour during the early days of learning a complex skill is "product oriented". Clearly, a pupil cannot work creatively until he has built new mental structures to represent the essential concepts. In other words, we cannot expect a novice to do more than blindly execute other people's procedures to get a desired effect.

What the above discussion suggests is that we ought not to think of learning to program as a series of discrete steps. So we can interpret the style conscious stage as emerging through the construction of new, but as yet unrefined, frame structures. The essential point is that these structures are used indiscriminately to begin with, producing the inappropriate but correct behaviour which we observed. However, they are generally refined into new, more specific frame structures which carry more precise information about the situations in which they should be applied, reducing the possibility that any one will be used inappropriately. Notice that this process of tuning a frame structure involves creative activity on the part of the learner, that is to say the information in the structures gets there as a result of successes and failures in applying the frame structures to problems. But notice too that fine tuning these structures is consistent with the growth of problem solving which characterises the third stage. In other words, the problem solving stage also emerges from the earlier style conscious stage as the key concepts are represented in well tuned structures.

As we pointed out earlier, our analysis of the relationship between learning and memory is extremely speculative. For example, the precise form of the underlying long-term memory structures has yet to be clarified. So we must view out work as little more than an incentive and guide for future research into such deep conceptual problems.

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Memory Functions in Language Acquisition

E. RIEDEL

It is now over a year ago that I accepted the invitation to this symposion optimistically and in good spirits. At that time I had in mind to present you with the results of two projects—one dealing with memory problems in language acquisition in the case of deaf and dumb children and another one relating the cognitive variables memory, problem solving ability, logic thinking and faculty of speech to a pictography that I have constructed. The results of the projects will, however, not be available before next year. That is the reason why I would like to introduce you to this pictography at least. I also want to express the secret wish that I might gain support from one or the other among you for research in this field.

Language acquisition is marked—among others—by two important components, i.e. the supply of a lexicon on the one hand and, on the other hand, the supply of rules that help the child insert lexical entries at the right position and inflect or agglutinate them by using morphems according to the given grammatical relations. The lexical entries in their turn are phonemic combinations that can either bear meaning or function. The former are conveyed through given situations, the latter by the correct usage of rules.

Children will not be able to make up an exclamation like

"Die Blume da ist schön!"

before they have encountered situations where they were able to become conscious of features of flowers and sensing their connexion in order to be able to distinguish a flower from other things. Furthermore, they must have an idea of what they themselves would perceive as beautiful, regardless of this be the flower's colour or shape or both.

To put things more precisely: Both words (Blume, schön) have developped from the child's synthetic judgement about past situations. This, however, does not refer in the same way to the article and the predicatively used word "ist" and the word-order. You will not hesitate to say:

Well, this is the little bit of grammar in this sentence.

It is not much, but still.
It is remarkable anyway that the child did not say:

"Schön die Blume ist"

or

"Die Blume schön ist".

Nevertheless, you as father or mother would merely complete the sentence correctly

"Wie schön doch die Blume ist!"

or

"Du magst die Blume, weil sie schön ist".

That means you transform the sentence and doing so you can maintain the already used wordorder.

Even a sentence like

"Schön die ist die Blume!"

you could tolerate silently or vary by slightly correcting it

"Wie schön die ist, die Blume da!"

So you assume implicitly that the child has applied rules, with the restriction, however, that the child would not yet be able to apply all the rules correctly.

But now listen to this sentence:

"Die Wradel ist ganz xil."

Here your tolerance will fail and you will ask angrily: "What's that, do you want to pull my leg?"

In short: your child violated the rules for German twice, but on two different linguistic levels. In the first case an offense occured against the rule of the simple sentence that would tolerate the variations "Schön ist die Blume, nicht?" or "Ist die Blume schön?". In the second example sound combinations were inserted into their designated positions, but you'll dare say that you never agreed with these, let alone drilled them with your child in past situations when he or she pointed to a flower and obviously found it beautiful which was accentuated by the child's fascinated facial expression.

In this connection I would like to draw your attention to two kinds of rules: First the sentence construction and its variation that is subject to certain limitations and then the insertion of lexical units into the terminal node that is subject to restrictions as well.

Now every language disposes of an enormous number of such restrictions or rules and every adult or young person involved in the acquisition of a foreign language has sufficiently been confronted with this fact. But now I am not going to comment on the theoretical aspects for the learnability of a language as P. CULICOVER and K. WEXLER have re cently put themdown in the important book "Formal Syntax". Let me just specify the following: For the learnability of a language three processing stages come into operation:

1) the in-put of information
2) learning method, i.e. the processing of the in-put information
3) the stage of convergence, i.e. the cutting down of a class of grammars to the grammar of the mothertongue in question.

If now the knowledge of the world is based upon the criteria of a feature detection theory the processing stages necessary in regard to the homology of word- and object detection culminate in a convergence criterion likewise, which means that the detection procedures with their dimensions of shape, size, variance and number also induce a condensation of possible worlds to the actual world. These circumstances only seem to account for new born baby's unboundness in regard to his social or ecological surroundings in its central aspects.

In the same sense our long-term memory does not only store information in the order of the arriving data but proceeds according to a standard of evaluation and an organizational plan coordinated to the hierarchical construction of information.

Our question is now: How are the data that are to be worked up incorporated into and stored in a system of rules?

Concerning language acquisition the preliminary answer must be that—essentially—this takes place without intervention of the attentiveness stage by automatic searching and discovering in our memory. This rule processing system is bound to certain structures and operates according to an evaluation scale that is subject to metalinguistic principles which I will mention later on.

I would like to introduce you to my system now, hoping it will find interest with especially those of you that are concerned with the share of memory in verbal reproduction.

With my system I tried to create a synthesis between our knowledge of the classification achievements for objects by metrical discrete feature characteristics and the set-up of a generative grammar by its metalinguistic principles of generalization or simplicity, plausibility or naturalness and learnability.

The first principle is the assumption of a non-linear basis (phrase marker) with the possibility to add structurally dependent transformations; plausibility or naturalness refers to the number of symbols applied in a grammar. With learnability we must theoretically put the claim that the identification of the language from a given number of grammars must be guaranteed for the student within a certain period of time, and that with a given number of pattern sentences, the quantity of which is not to be precisely specified.

I have already pointed out that language acquisition with a child takes place automatically, therefore without consultation of the attentiveness stage, and the child becomes the competent native speaker by employing the criteria just mentioned.

My system now juxtaposes these principles with a visual classification system, on to which the verbal components are projected.

The following three components are combined here:

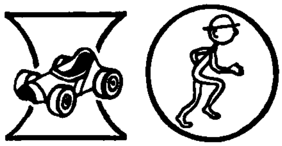
1) grammar with word categories, constituents and phrase embeddings, roughly corresponding to a basis marker;
2) the semantic level to be depicted by pictograms;
3) the situational level that is simply created by the fact that the child is told a story. In our case it will be one of La Fontaine's fables, i.e. the story of the fox, the cock and the raven.

I quote a short sentence from this story:

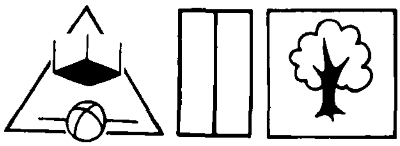
"Die Maus sieht ein großes Tier."

The dimensions become obvious right now: Size differentiates the sentence constituents, that is a nominal and a verbal constituent; colour signifies the constituents and shape the elements within the constituents—the square represents the noun, the circle the verb, the square shape is the tense marker, the rectangle the article and the cut out square the adjective.

What we need now is
the adverb, e.g. "schnell laufen"



the local adverbial phrase, e.g. "unter einem Baum"



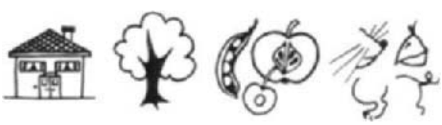
the temporal adverbial phrase, e.g. "heute Nacht"

and for variation of simple sentences the phrase operations (question, negation, command). From this very moment almost every German sentence can be read in this pictography.

The shapes are now covered with pictograms, the lexical entries, whose relational connection defines the semantic level of the sentence.

The pictogram itself represents either the object with its characteristics, as for example

"Haus, Baum, Frucht or Tier"



or it embodies a scene, that is to be symbolized by the corresponding word-proper, such as

"Freund, Hunger, Streit, Ausflug".

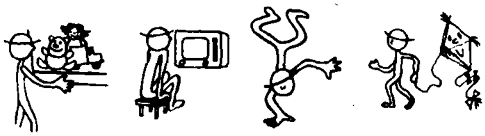
All that functions on conditions that characterize a scene are part of our episodic memory and can therefore be easily recalled.

The verb itself is characterized by a stick-man exerting the activity portrayed by the verb, e.g.

"sich fürchten, sich verstecken, tragen, fliegen"

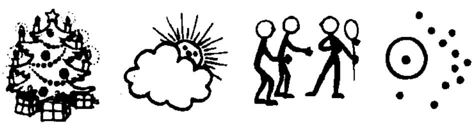
or, on the other hand, embodying a situation that is common knowledge with children, as with

"wollen, dürfen, können or lassen".



But even with words and particles such as

"wieder, bald, auch or nur"



the mnemotechnically best way to render them is also the illustration in scenes, thus ensuring a degree of memorability.

Let me now give you some examples to show how the metalinguistic principles are applied in the construction of a grammar.

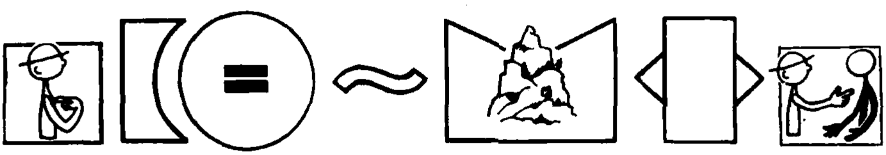
But before that I would like to define my interpretation of the principle of generalization or simplicity.

Generalization is the compilation of rules pertaining to single facts; there needs be a criterion deciding whether and where rules derived from experience can be transformed into general rules of universal grammar or—transcending the process of language acquisition—into general rules of processing and storing information.

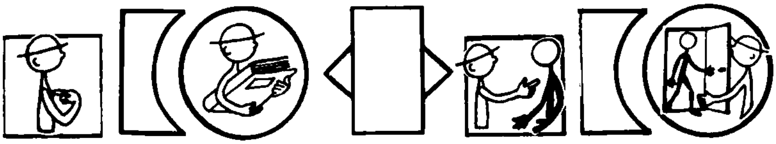
Some illustrating examples here are the complementizers (comp) "als", "wie", "daß" and "zu", in the following types of sentences.

"Ich bin größer als du (groß bist)."

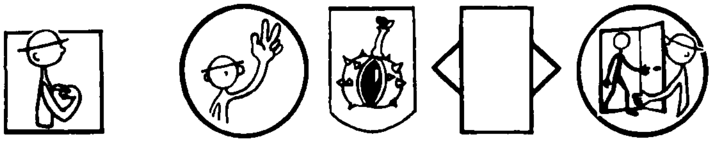
"Ich bin so groß wie du (groß bist.)"



"Ich weiß, daß du kommst."



"Ich verspreche, morgen zu kommen".

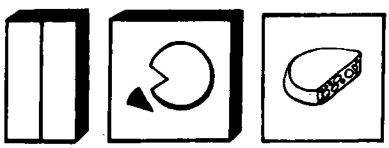


The interdependency of sentences is marked by a visual signal, the width of the symbols.

But constituents also can be directly interdependent and they are signified as determinator and determinandum by the different width as you can see in the following examples:

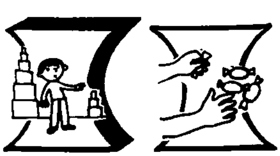
"Ich kann singen."

"Ein Stück Käse."



"Heute Nacht."

"Noch mehr."



The regarding visual rule is:
If two alike symbols—or even better: two alike groups of symbols come to face each other the first must be wide and the second thin, which indicates that the second symbol group lies within the immediate scope of the first.

A complementizer, however, always introduces a whole sentence, even in the example

"Ich verspreche zu kommen."

If we enlarge the sentence by a time adverb, such as

"Ich verspreche morgen zu kommen,"

this adverb may one relate to the promise, or, another time, to the embedded sentences. This must be visually marked by width and position of the time adverb.

But let's now take the sentence

"Ich will morgen kommen",

which could just as well derive from the deep structure

"Ich will (ich komme morgen)".

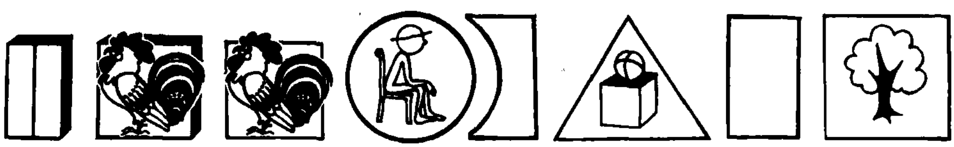
But now the semantic structure shows the scope of "morgen" incorporates both "will" and "kommen".
Therefore

"Morgen (ich will kommen)".

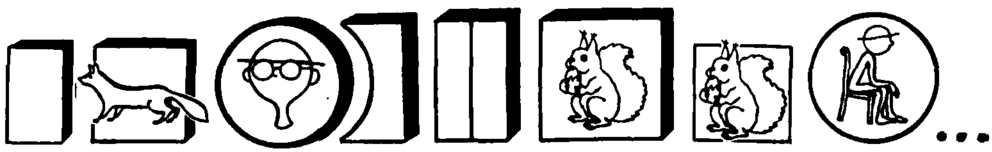
A combination of visual rule indicating dependency but rendering a whole clause dependent is the relative clause. According to the principle of simplicity the introduction of a relative pronoun has been abandoned; the relative clause is merely signalled by the appearance of an identical pictogram in the embedded clause.

An example:

"Ein Hahn, der auf dem Baum saß..."



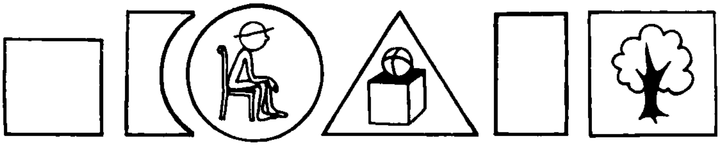
"Der Fuchs sah ein Eichkatzerl, das auf dem Baum saß."



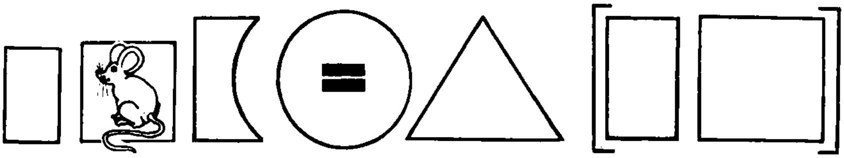
The rule would run as follows:
A nominal phrase succeeded by an embedded clause with an identical nominal part indicates that the second sentence is a relative clause and the identical noun must be transformed into the relative pronoun.

The pronominalization of questions and indefinite pronouns will serve as a last example for transformations that are oriented according to metalinguistic principles:

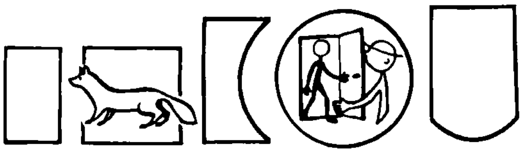
"Jemand sitzt auf dem Baum."



"Die Maus ist irgendwo."



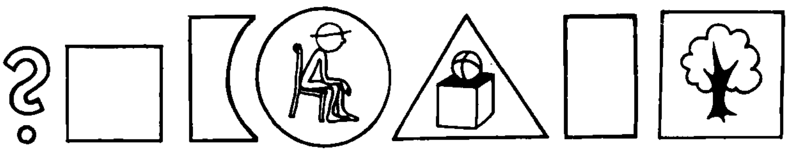
"Der Fuchs kommt irgendwann."



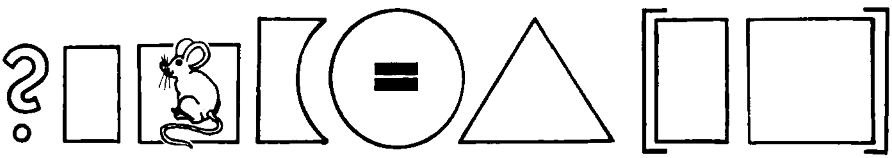
Here the rule is:

A nominal- or prepositional group without pictogram, i.e. without lexical entry, must be transformed into an indefinite pronoun. One could say that these are variables laid down by a given structure. The sentences are turned into wordquestions by adding a question operator.

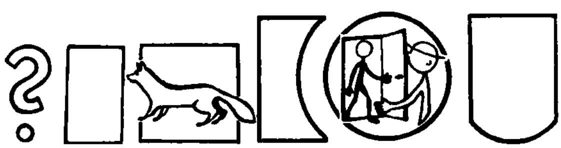
"Wer sitzt auf dem Baum?"



"Wo ist die Maus?"

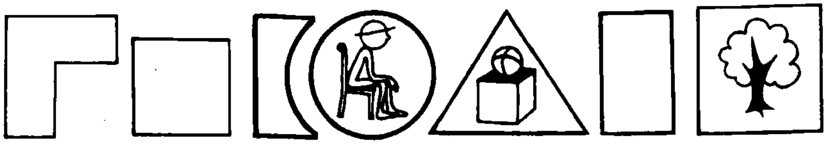


"Wann kommt der Fuchs?"

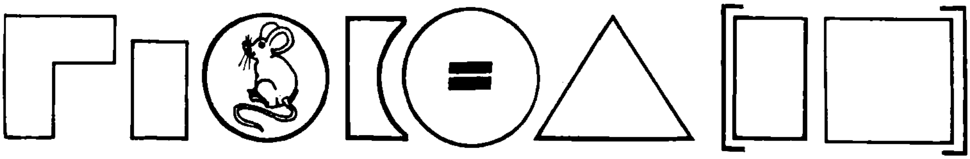


And in combination with a sentence operator (negation) we can construct the following sentences:

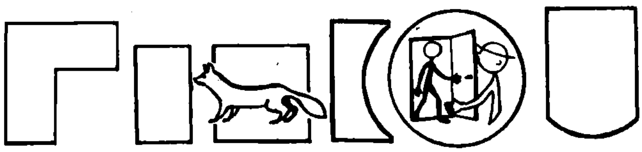
"Niemand sitzt auf dem Baum."



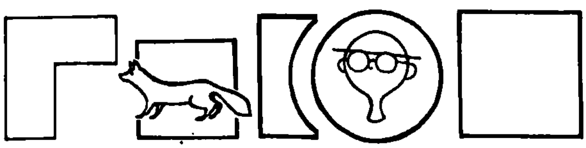
"Die Maus ist nirgends."



"Der Fuchs kommt niemals."

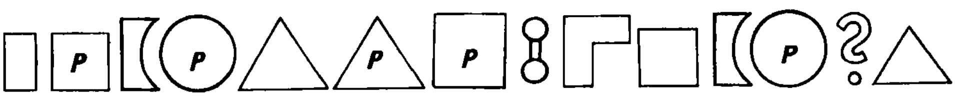


"Er sieht nichts."



The following sentence results from a combination of indefinite pronouns and was contrived by a nursery school teacher:

"Die Maus ist irgendwo im Haus, aber niemand weiß wo."



P-Pictogram

My thesis—as regards memory—is now in coordination with the construction of the sentence patterns we dealt with:
Rule system and construction of a grammar are received in the best possible way when they submit to the mentioned metalinguistic principles.

This becomes evident in the simplicity of how the rules are formulated and in the small number of grammatical symbols that are applied.

The combination of logical form, invariance and simple set-up of rules facilitates the reconstructability, the comparison with the stored sentence patterns, thus that with increasing realization of these metalinguistic principles the comprehension period decreases rapidly.

From my observations so far I can tell that children only take a fraction of time to grasp sentences like the ones given here, if you follow the movement of their eyes. I got full evidence when I presented them with funny and nonsensical sentences like

"Das Eichkatzerl klettert auf den Mond."

The children started to laugh long before one of them had read the sentence and when I asked why they laughed they told me indignantly that a squirrel couldn't possibly climb the moon.

There is a whole number of further rules that are also constructed according to the metalinguistic principles and that are applied in this pictography. But, my time is up and I just tried to put you on my track for a while and give an impetus so search for mutual strategies of perception, thinking and language.

My future work will be to investigate and perfect these principles concerning language acquisition with children who—at this stage—do not yet dispose of a complex language structure. I am talking about the children who will never know the miracle of an unaware acquisition of a language—deal and dumb children.

Not before then I shall be in a position to align these principles in detail and to place them within a model theoretical frame of language acquisition.

Saccadic Eye Movements and Fixations as Indicators of Detection and Discrimination During Attention Tasks

G. LÜER, B. MARTIN and U. WEBER

1. Introduction

The so-called concentration and attention tests have a special position in the psychodiagnostic instruments. They are usually distinguished by a high degree of objectivity and a comparatively very high reliability. The d2 test (BRICKENKAMP, 1975), for example, can point to reliability coefficients which reach a height of $r_{tt} = 0.98$. Many of these methods satisfy high test statistical standards as far as technical measurement characteristics are concerned. On the other hand, our knowledge as to the validity of such tests has remained fragmentary.

In the case that different concentration and attention tests measure the same trait, they should intercorrelate highly with one another. These intercorrelations should turn out substantially higher the more accurate the tests are able to measure this trait in a highly reliable way. If one examines the published correlation coefficients between the results of concentration and attention tests, it will be noted that the majority fall between $r = 0.30$ and 0.50 and only exceptionally reach values of $r = 0.70$ (BARTENWERFER, 1964, BRICKENKAMP, 1975, SOMMER, 1973). Apparently, the correlations between the tests indicate that different aspects of the two traits, concentration and attention, are being measured. This presumption is supported by factor analytic studies which have produced more dimensions specific to test tasks than constructs which make possible a continuing theoretical understanding of the traits under discussion (BARTENWERFER, 1964, BRICKENKAMP, 1975, JÄGER, 1967, SÜLLWOLD, 1954, TODT, 1973).

Just as it was not possible to make more exact statements about the validity of attention and concentration tests beyond those dealing with the concurrent validity, the method of using correlational analyses to intelligence tests proved to be just as fruitless. This failure is reflected in the correlations between concentration and attention tests on the one hand and intelligence tests on the other. Such coefficients vary between $r = 0.20$ and $r = 0.40$, with the greater part tending toward the lower values (BRICKENKAMP, 1975).

The low correlations with intelligence tests were usually welcomed by the authors of the tests, for in this way it was proven that the tests measure a trait which for the most part is independent of intelligence. The question remains unanswered, however, as to which trait we are dealing with.

In sum, it remains to be demonstrated that concentration and attention tests apparently have a great deal of specific variance to be clarified. The following experiment has been carried out with the aim of explaining this variance. We shall be concerned with the processes of gathering and processing information as they can be observed while solving tasks from the d2 attention test (BRICKENKAMP, 1975). If we are successful in describing the unique characteristics of such processes, then a step has been taken in explaining the validity of this diagnostic method.

2. Problem definition and experimental design

In order to achieve our experimental goal, namely describing the processes of information gathering and processing during the solution of d2 test tasks, it seemed meaningful to set up both of the following experimental conditions:

a) Elimination of distracting stimuli from the task material employed.
b) Speed of the information gathering.

We attempted to operationalize these conditions by defining the following independent variables:

a) To eliminate distracting stimuli: The sequence of symbols used as tasks was presented in two stages: a "close" succession which allows the possibility of distracting effects from neighbouring symbols (corresponds to the original form of the test); an "extended" succession with a two-fold distance between symbols (see fig. 1).
b) For the speed of information gathering: Varying performances on the d2 attention test in the gradations: good, average and poor test performance. In this way, "good" solution behavior can be compared to "poor" performance and the differences examined.

We chose attributes of eye movements as dependent variables describing the behavior during the solution process, and defined them in the following manner:

a) Number of forward steps (searching as a sequence of eye movements from the first to the last symbol of the material), which could be counted during the entire test solving process.
b) Number of backward steps (searching as a sequence of eye movements along the material in a backward direction), which appeared during the entire test solving process.
c) Total time required for solving the given tasks.

The enumerated variables chosen allowed two different aspects to be examined while subjects solved the tasks of the test:
a) It can be estimated whether the identification process is influenced by neighbouring symbols beyond processing of the single symbol. If such disturbances in the information gathering process can be proven, then it must be assumed that additional processes of discrimination are necessary in order to be able to meet the demands of the tasks.
b) It is possible to study the information gathering process of subjects in different performance groups as they examine the symbols.

Finally, to avoid favoring certain material by allowing possible practice effects, we permutated the presentation of experimental material. For this reason the experiments were performed so that each pattern appeared with the same frequency in each position within the entire experiment. A practice effect for certain material is thereby eliminated. If it should occur, however, that despite balanced positions certain material can be solved in a shorter amount of time than other tasks, then only peculiarities of this material can be held responsible for this result.

The experiment thus planned had to take place in two phases:

1. Phase: A random sample of subjects were tested with the original d2 test. The score values GZ–F (total score minus false identifications) were transformed into standard values. A calculation of the arithmetic mean of the standard values with the accompanying interval of confidence followed ($p = 5\%$). Those test results falling below the interval of confidence were classified as poor results, those in the interval as average, and those above the interval as good. Two parallel groups of subjects were formed for each category which were co-ordinated to the 2 × 3 fold plan.

2. Phase: The six groups of subjects were submitted to an experiment which aimed at registering their eye movements. Two types of material were presented corresponding to the first independent variable. Evaluation of dependent variables was carried out by means of an analysis of variance (2 × 3 factorial plans; SACHS, 1974).

3. Method

Altogether 44 subjects were given the original test. They were assigned to the six cells of the experimental plan, whereby an equal distribution of subjects to each cell

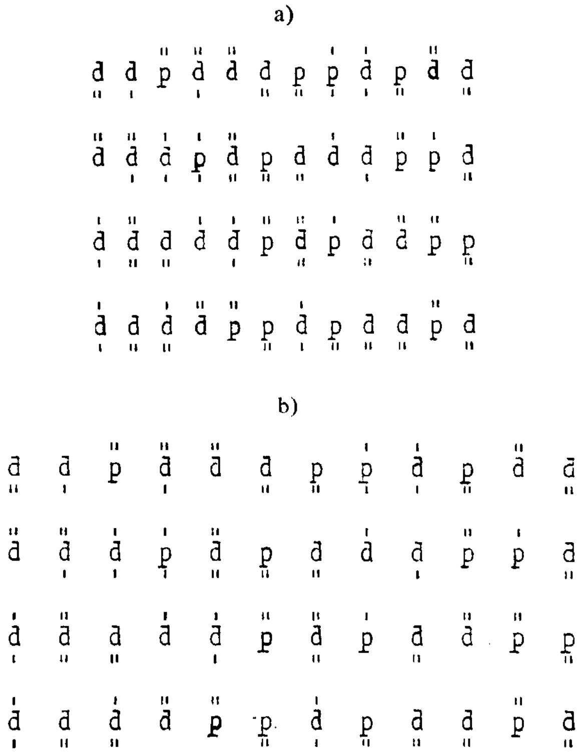


Fig. 1: Examples for the types of materials: a) original, b) extended distances between the symbols. The subject's task is to search for three different types of targets: d; $\ddot{d}$; d. These symbols have to be marked by the subject (adapted from BRICKENKAMP, 1975).

was not able to be attained. After being assigned to an experimental condition subjects participated in the main experiment, the registering of their eye movements.

The task material had to be enlarged to a DIN A 3-format for optimal measurement accuracy with the NAC-4-system for registering eye movements. Three patterns, each with four rows (one pattern with four rows corresponds to one row of the original form of the d2 test), were placed with each group of 12 symbols of the original material, so that the proportions of the original form concerning the distances between the symbols remained intact. Four rows were arranged with each group of 12 symbols in the same way for the three "extended" pieces of material, whereby merely the distance between the symbols relative to the other task group was doubled. Figure 1 depicts examples of both task groups.

In addition to the tasks being examined each subject received practice and example material at the beginning. After the camera which measured the eye movements had been adjusted to the norm material, the three test patterns with a total of 144 symbols were given following the practice and example tasks. Eye movements were recorded on video-tape.

4. Results

Eye movement recordings, equipped with a coordinated electronic timer, were run on to an instrument during the evaluation process which allowed a pace slow enough for individual analysis of each picture. Forward and backward steps and total time were read. Data acquired in this manner were grouped according to the experimental design and submitted to an analysis of variance.

a) *Dependent variable 1*: Forward steps

As a function of the type of material and level of performance we expected the following results:

$H_{0(1)}$: The type of material does not effect the average number of forward steps.
$H_{1(2)}$: Optimal optical searching conditions are provided by the "extended" material. The "closer" material must be more strongly discriminated which therefore leads to more "reassurances", causing the number of fixations and forward steps to increase.
$H_{0(3)}$: The average number of forward steps is the same for all (performance) groups.
$H_{1(4)}$: The average number of forward steps decreases as the level of performance increases.

Experimental data was tested for variance homogenity using the BARTLETT-test and yielded a $\chi^2 = 5.456$ with df = 5; $p < 0.5$.

Means and standard deviations are summed up in tab. 1. Results of the analysis of variance are to be found in tab. 2. Table 2 shows that the independent variable "type of material" has no effect on the average number of forward steps ($H_{0(1)}$ is retained), whereas the level of performance on the d2 test displays effects formulated in $H_{1(4)}$.

Tab. 1: *Means* (M) *and standard deviations* (s) *for the independent variable: forward steps*

		Performance groups			
		low (l)	average (a)	high (h)	
Type of material	original	M = 164.71 s = 12.40 N = 7	M = 156.66 s = 8.55 N = 6	M = 158.87 s = 10.94 N = 8	M_o = 160.08
	extended	M = 172.40 s = 14.48 N = 5	M = 153.85 s = 9.33 N = 7	M = 147.81 s = 6.22 N = 11	M_e = 158.02
		M_l = 168.55	M_a = 155.25	M_h = 153.34	

Tab. 2: ***Results of the analysis of variance: independent variable forward steps***

Source of variation	SQ	df	MS	F	*p*
Type of material	43.9947	1	43.9947	0.4312	n.s.
Performance groups	1897.0282	2	948.5141	9.2960	<0.01
Interaction	600.7622	2	304.8811	2.9880	n.s.
Error	3877.3304	38	102.0350		

b) *Dependent variable 2*: Backward steps

We expected the following results as a function of the type of material and the level of performance:

$H_{0(5)}$: Type of material does not effect the average number of backward steps.

$H_{1(6)}$: More backward steps are to be found on the average by the original form due to the greater need for discrimination between the closer symbols than by the "extended" material (once again due to the more frequent "reassurances").

$H_{0(7)}$: Level of performance does not have an effect on the number of backward steps.

$H_{1(8)}$: The higher the level of performance on the d2 test, the fewer backward steps are expected on the average.

Experimental data was tested for variance homogenity using the Bartlett-test and a $\chi^2 = 17.831$ for df = 5; $p < 0.005$ resulted. Score values were therefore logarithmically transformed to stabilize the variances.

Data was submitted to the BARTLETT-test for repeated examination, and the success of this measure was confirmed by the result: $\chi^2 = 8.582$ with df = 5; $p < 0.25$.

Means and standard deviations of the transformed values are summed up in tab. 3. Table 4 illustrates the results of the analysis of variance. As shown in tab. 4, merely the effect of the level of performance on the d2 test on the average number of backward steps was proven.

Tab. 3: *Means* (M) *and standard deviations* (s) *for the independent variable: backward steps (transformed data)*

Type of material		Performance groups: low (l)	average (a)	high (h)	
	original	M = 1.343 s = 0.133 N = 7	M = 1.079 s = 0.292 N = 6	M = 1.045 s = 0.104 N = 8	$M_o = 1.154$
	extended	M = 1.354 s = 0.270 N = 5	M = 1.046 s = 0.207 N = 7	M = 1.023 s = 0.254 N = 11	$M_e = 1.102$
		$M_l = 1.347$	$M_a = 1.061$	$M_h = 1.032$	

Tab. 4: *Results of the analysis of variance independent variable: backward steps (transformed data)*

Source of variation	SQ	df	MS	F	*p*
Type of material	0.0021	1	0.0021	0.0437	n.s.
Performance groups	0.8353	2	0.4176	8.7869	<0.025
Interaction	0.0036	2	0.0018	0.0375	n.s.
Error	1.8062	38	0.0475		

c) *Dependent variable 3*: Total time

We expected the following results as a function of the type of material and the level of performance on the d2 test:

$H_{0(9)}$: Type of material does not have an effect on the average time required for solving the tasks (processing time).

$H_{1(10)}$: A greater processing time is required for material where symbols appear closer together than where they are placed farther apart, due to the greater need for discriminating between symbols.

$H_{0(11)}$: Performance on the d2 test does not have any effect on the average processing time required.

$H_{1(12)}$: The better the level of performance on the d2 test, the less time is required for solving the task material.

Examination of experimental data for variance homogenity with the help of the BARTLETT-test resulted in a value of $\chi^2 = 8.429$ for df = 5; $p < 0.25$.

Means and standard deviations are summed up in tab. 5. Results of the analysis of variance are to be found in tab. 6. As shown, solely the quality of performance on the d2 test has an effect on the measured variable.

d) Analysis of the change in processing time in the first three rows.

Studies from HEINRICH (1973) suggest that subjects succeed in saving time on the third row of the d2 test.

Tab. 5: *Means* (M) *and standard deviations* (s) *for the independent variable: processing time* (*in* s)

Type of material		Performance groups: low (l)	average (a)	high (h)	
Type of material	original	M = 76.34 s = 8.98 N = 7	M = 66.89 s = 8.62 N = 6	M = 56.18 s = 2.88 N = 8	M_o = 66.47
	extended	M = 80.74 s = 9.02 N = 5	M = 67.36 s = 8.68 N = 7	M = 61.06 s = 6.53 N = 11	M_e = 69.72
		M_l = 78.54	M_a = 67.12	M_h = 58.62	

Tab. 6: ***Results of the analysis of variance: independent variable; processing time***

Source of variation	SQ	df	MS	F	*p*
Type of material	109.4312	1	109.4312	1.9616	n.s.
Performance groups	2762.6134	2	1381.3067	24.7610	<0.01
Interaction	40.4325	2	20.2163	0.3624	n.s.
Error	2119.8530	38	55.7856		

There could be two meaningful reasons for this fact:

a) Practice effects shorten the processing time.

b) Specific characteristics of the material favor a shorter processing time for the third row.

In our experiment the material (each piece of material corresponds to one row in the original test) was displayed in such a completely balanced manner that the practice effects referred to under (a), due to the changing positions, could not have caused differences between the types of material. Correspondingly we formulated the following hypotheses for a single-factor analysis of variance.

$H_{0(13)}$: A practice effect in the form of a saving of processing time between material types is not demonstrable, because the material was displayed according to a completely balanced design and is free from position effects.

$H_{1(14)}$: There are differences between the processing times such that $t_{v(1)} > t_{v(2)} > t_{v(3)}$. These differences appear in spite of the balanced position effects.

A single factor analysis of variance for dependent samples produced the following result:

Means of the processing times $M_{t(V1)} = 22.70$;

$$M_{t(V2)} = 22.51; \qquad M_{t(V3)} = 21.57.$$

Tab. 7: *Results of the analysis of variance for the three d2-rows: independent variable processing time*

Source of variation	SQ	df	MS	F	*p*
Rows of the d2 test	48.07	2	24.035	8.566	<0.01
Ss	1573.92	43			
Rest	241.40	86	2.806		

As shown in tab. 7, $H_{1(14)}$ can be accepted. An examination of the individual effects by means of the SCHEFFÉ-test demonstrates in addition that significant differences are evident only between the processing times of the third row and both of the others.

5. Discussion of the results

Certain regularities in the information gathering process can be recognized from the results of our experiment which can be more precisely described by the required execution of the d2 attention test. Subjects scoring well required on the average fewer fixations and fewer forward and backward steps then less successful subjects. Correspondingly, those subjects of the less qualified groups produced more forward and backward steps. Of course, these two eye movement parameters, forward and backward steps, are not completely independent of one another, for a backward step often (but not in all cases) is accompanied by an additional forward step. However, results show that the best performance group apparently is able to search more effectively and therefore shows a greater ability to gather information than the less successful subjects. While the latter reassure themselves by looking at the previous symbol once again, subjects displaying good levels of performance on the d2 test, "attentive" subjects, apparently make use of a more precise and careful procedure while solving the given tasks.

The time required for working on the tasks becomes shorter as the level of performance increases. This fact is due on the one hand to fewer fixations and on the other hand to a greater degree of confidence in their own methods.

In addition to the results derived directly from the analysis of variance one can also consider to what degree savings can be observed in the fixations. Because each subject had to examine a total of 144 symbols, a saving would exist if the fixations actually observed number less than 144. We could observe this result only with 5 subjects (= 11%). They belong to the middle ($N = 1$) and the best ($N = 4$) performance groups. If one additionally assumes that an additional forward step must follow every backward step and subtracts the backward steps from the forward steps for each subject, then one attains an estimation of the number of fixations for each test application without "reassurance" of the previous symbol. The average values for the three performance groups are:

$$M_l = 143.50; \quad M_a = 141.92; \quad M_h = 140.68.$$

One could now assume MACKWORTH'S (1976) hypothesis that subjects performing well on the attention test utilize a wider fixation field (wide scanner) than less effective subjects whose fixation fields can be assumed to be narrower (narrow scanner). If we calculate from our data the average number of symbols registered for each fixation, a mean of 1.024 symbols is found for the good subjects, 1.015 symbols for the subjects in the middle group and 1.003 symbols for the subjects displaying less effective ability.

Despite the numerical differences between the groups of subjects these differences appear too small for us to claim effective support for the above hypothesis of the differing widths of the fixation field. We prefer to relate the variation in procedures for gathering and processing information to the difference in the level of performance.

Varying the type of material used had no effect on the dependent variables; the number of forward and backward steps and the average processing time remained the same for both variations.

In connection with the previous results we consider it probable that subjects performing well on the d2 attention test do not process more information than mediocre subjects during each fixation. On the other hand, they are distinguished by their need for fewer forward and backward steps. We interpret this as a general style of an optical information gathering ability. This style can be described by the traits of precision, speed, confidence and carefulness. Less effective problem solving ability is characterized however by backward steps which signify a greater degree of insecurity because subjects must reassure themselves more frequently.

An additional question is whether the stability of the information gathering and processing style can be changed with practice. The results stemming from the literature suggest that practice effects are operative at best for the first rows of the test. We can test this hypothesis by completely balancing the position of the material and thereby eliminating the effectiveness of a practice effect in relation to a single piece of material.

If no differences had appeared between the types of material then a practice effect would have been equally distributed over all positions, making a conclusion about the effect itself impossible. It was found, however, that the third row of symbols of the original d 2 test (which corresponds to a pattern in our experiment) makes possible a clear saving of time. As this effect can not have been obtained by practice, certain characteristics of the series of symbols must be responsible for this saving of time.

An analysis of the symbol frequencies shows which traits the saving of time favors in the third row. The number of critical symbols can certainly be viewed as being equally distributed: 44,7% (first row), 46,8% (second row) and 44.7% (third row). However, it can be shown that the mean distance between the critical symbols of the third row is shorter and more uniform than for the symbols of the first and second rows. This fact may encourage a rhythmical searching pattern based on a certain number of critical symbols and therefore possibly lead to more rapid solutions.

If our assumption is correct that different levels of performance can be accounted for by information processing styles, then the possibility for validation of such tests is opened. According to our results the d2 test measures how controlled, precisely and economically subjects proceed in the gathering and processing of information while solving given tasks. It remains to be explained if these enumerated peculiarities of information gathering and processing are specific to the d2 test or if they also are valid for other concentration and attention tests. In this way it can be decided if the styles thus described offer durable explanations for the processes of concentration and attention.

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Comprehension of Active and Passive Sentences in Aphasia[1]

D. KĄDZIELAWA

The dynamic growth of psycholinguistics during the last two decades has led to intensified research on speech and language disorders in brain-damaged patients. In this research there is an increasing use of the term "neurolinguistics", evidence of that new direction of research has been marked. This new domain is integrating the knowledge of psycholinguistics, neuropsychology and the experience of neurologist—clinicians in the area of the brain functions regarding verbal communication and its pathology in cases of cerebral organic disfunction. Though there are more controversial questions in neurolinguistics than are usually assumed, one can already distinguish three trends in the empirical research.

Some researchers take as a basic problem a psycholinguistic model of human functioning and look for the brain correlations of this model. They discuss, for example, about the share of the dominant and subordinate hemispheres of the brain for normal speech processes.

Another group of researchers also focus on a psycholinguistic model of human functioning but draw empirical material from pathology. This group treats aphasia in a strictly instrumental fashion, as one way among others of demonstrating the psychological reality of the accepted model.

The third research trend is represented mainly by neuropsychologists for whom the principal question is aphasia, and who treat knowledge from cognitive psychology and psycholinguistics about the linguistic functioning of normal man, and also neurological and neurophysiological knowledge, as sources to clarify the pathomechanisms of speech disorders in aphasia. At the same time, knowledge of the loci of processes of speech production and reception, loci which can be electively disturbed in the various kinds of aphasia, is valuable in that it makes for psychological model of the normal structure of these processes.

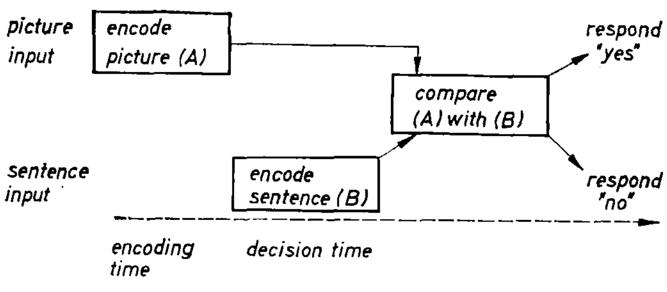

Fig 1.

[1] The author wishes to thank W. KOPACKA, former student of the Institute of Psychology, U. W., who conducted the experiment and performed the statistical analyses of the results.

Studies of sentence comprehension in active and passive form by patients with focal brain damage belong to the third trend mentioned. These studies aim to deepen our understanding of the pathomechanism of aphasic disturbances in comprehension of sentences with given grammatical structure, based on psycholinguistic data. The study I shall report here used the picture-sentence matching test on the assumption that the model of human functioning in such a task situation follows a course which can be schematized as follows (cf. fig. 1) (generalizing from models of CLARK and CHASE and of TRABASSO, after GLUCKSBERG and DANKS, 1975, p. 97):

1. Method

Material: 10 colored drawings and 60 sentences in 5 series were used. Each series was made up of 2 drawings and 12 sentences. Two pictures making up a pair presented the same objects in the roles of agent-of-action and object-of-action, with the difference that the roles were reversed. That is, the agent-of-action in one picture was the object-of-action in the second, and vice versa. One set of 12 sentences referred to one picture pair; of these 8 were experimental sentences and 4 were control sentences. The purpose of the control sentences was to provide some relaxation for the subjects during the task. Table 1 gives examples of sentences referring to the same picture. The sentences referring to the other picture in the pair had the corresponding changes.

Tab. 1: *Examples of sentences used in the study*

Sentence type	sentence	
	in Polish	in English
	Experimental sentences	
Active Conventional AC	Woda otacza drzewa.	Water surrounds the trees.
Active Reversal AR	Drzewa otacza woda.	The trees surrounds water.
Passive Conventional PC	Drzewa otoczone wodą.	The trees are surrounded by water.
Passive Reversal PR	Wodą otoczone drzewa.	By water are surrounded the trees.
	Neutral sentences	
Active Conventional	Staw jest mały. Pnie drzew są białe.	The lake is small. The trunks of the trees are white.

The experimental sentences were semantically equivalent in reference to one picture only. The distinguishing element was grammatical complexity which increased in the following order: AC < AR < PC < PR. The sentence types fell into two groups: AC–PR and AR–PC. These groups differ in the relation between the order of the objects mentioned in the surface structure of the sentence and the order of these same objects in the meaning taken from the sentence. Thus in AC and PR sentences the names of objects functioning as agents-of-action were placed first in the sentence, while in AR and PC sentences, the names of the objects functioning as agent-of-action had third place in the sentence.

Procedure: The picture-sentence matching test was used. The experimenter placed a column of two pictures in front of the subject and drew attention to the fact that they both showed the same kind of objects but were different one from the other (the patient looked at the pictures for 10 s). Then experimenter read the sentence, handed the subject a card with the sentence written on it and asked: "Which picture does this sentence match best? Which picture is this sentence true for?". There was no time limit for the response. Errors were noted.

Subjects: The experimental group was made up of 26 aphasic patients without disturbances of visual or auditory gnosis, with comprehension impairment only to a degree that would not prevent understanding the task situation and the instruction. These criteria were established in separate investigations. The group represented the following types of disorder.

Tab. 2: *Distribution of aphasic types in the experimental group*

Aphasic type	Dynamic	BROCA	LURIA	Semantic	Acoustic-mnestic
Number	5	5	5	5	6

The control group was made up of 26 healthy persons pairing one-to-one with the experimental group in term of sex, age and education.

2. Results

Analysis was based on comprehension impairment as manifested in errors performed in picture-sentence matching. Results for the control sentences are omitted in the calculations.

Tab. 3: *Number of errors for aphasic groups and for control groups according to sentence type*

Sentence type	BROCA	CG	Semantic	CG	AC-mn.	CG	LURIA	CG	Dynamic	CG	Σ_{EG}	Σ_{CG}
AC	21	4	25	0	16	1	9	1	7	3	78	9
AR	19	5	24	3	24	4	14	6	12	3	93	21
PC	24	3	11	0	21	1	12	0	10	2	78	6
PR	26	5	23	4	18	3	8	2	11	2	86	16
Σ	90	17	83	7	79	9	43	9	40	10	335	52

The aphasic group as a whole committed significantly more errors than the control group (KOLMOGOROV-SMIRNOV-test, $p < 0.01$). Similar significant differences were found between the number of errors for given types of aphasia and for the corresponding control groups (0.05).

The Broca patients made the largest number of errors, then the semantic aphasics, the acoustic-mnestic aphasics, and the Luria aphasics. The least difficulty in performing the task had the dynamic aphasics. In this study we could not check whether the differences in the number of errors for the aphasic types were statistically significant, since the groups of patients are not balanced for age and education (MANN-WHITNEY "U"-test, $p < 0.05$). These variables were found to be of significance when control and experimental groups were compared. By using MANN-WHITNEY'S "U"-test we found that the higher-educated controls made significantly fewer errors than those with secondary and primary education, also that the controls in the age group 20 to 39 made significantly fewer errors than those in the age group 55 to 67. In contrast there was no significant difference among the aphasics types for educational level. As for age—aphasics in the age group 55–67 made significantly more errors than aphasics in the lower age groups 40–54 and 20–39.

The BROCA aphasics showed a greater tendency to make errors in judging the AC and PR sentences than in judging the AR and PC sentences. And for the semantic aphasics the difference was statistically significant (WILCOXON-test, $p < 0.05$).

In the other aphasic groups—acoustic-mnestic, LURIA aphasia and dynamic aphasia—the number of errors for the AR and PC sentences were higher than for AC and PR sentences. Significance at the level of 0.05 was found only for the acoustic-mnestic aphasics.

3. Discussion

This study shows that sentence comprehension disorders comprise a general aphasic symptom, with differences of degree for the different types of aphasia. This is in accord with the views of LURIA (1975) and with experimental evidence (cf. AKHUTINA, 1975a, TSVETKOVA, 1975, GLOZMAN, 1974, GOODGLASS, 1968, KĄDZIELAWA, 1976). This conclusion however contradicts the beliefs of clinicians who establish the type of aphasia on the basis of the symptoms that are most evident in current contact with the patient, and for this reason speech comprehension disorders are attributed only to sensory aphasics. Their claim is that motor aphasics have intact comprehension and have difficulty mainly with verbal expression. Our investigation has however demonstrated that Broca aphasics have particular trouble in comprehending speech. The expressive speech of these patients which is usually in telegraphic style and their comprehension difficulties which are independent of grammatical structure suggest a problem in operating with the rules of surface syntax. They compensate for these difficulties only partially by using extra-linguistic indicators, for instance they are guided by the criterion of highest frequency for the conventional word order in which the first-position word of a sentence stands for the agent (AKHUTINA, 1975a), or by the criterion of social acceptability of facts referred to in the sentence. Sentences about socially acceptable facts are judged grammatically and semantically well-formed, while sentences about socially unacceptable facts are judged in an ungrammatical and incorrect way (KĄDZIELAWA, 1976).

Semantic aphasics as a group made most errors with order reversed sentences and sentences in which the order of mention of the objects corresponded with the order required for the interpretation of the sentence. In LURIA'S opinion (1975) the basic defect in this type of aphasia is a disorder in the synthesizing of information in simultaneous structure—quasi-spatial. AKHUTINA (1975a) developed this interpretation further by stating that these patients are unable to distinguish the agent of the action in a sentence and therefore can not grasp the deep structure of the sentence. In this case objects that serve the role of agent-of-action and object-of-action are equivalent, which in effect gives symmetry to the deep structure of the sentence. The choice of agent on the grounds of a logical stress or first position in the sentence make good explanations for most of the errors in reversed order sentences as compared with conventional order sentences. But the reason for the AR and PC sentences remains open.

The acoustic-mnestic aphasics had significantly less difficulties with sentences whose deep and surface structures accord. This result is in line with the interpretation of the pathomechanism of speech disorders for this type of aphasia. Acoustic-mnestic aphasics display a narrowed span of verbal memory, due to interference of memory traces which disturb the process of verbal coding of picture content and retention of the coding in working memory long enough to compare it with the coding of the content of the sentence as it is heard. Further, as GLUCKSBERG and DANKS (1975) point out, this comparison is more difficult when the codings differ.

Luria aphasics display a tendency similar to that of the acoustic-mnestic aphasics, but make much fewer errors. Due to disorders in elaborating the somesthetic sensations perceptions from the articulatory apparatus, these aphasics have difficulties in speaking—in repeating in inner speech both the sentences that code the content of the picture and the sentences heard—whether read by themselves or transformed in order to make comparisons. Therefore the more sentences are repeated and edited in inner speech thus engaging the articulatory apparatus if only subvocally, the greater the possibility of deviations from the input form of the sentence and the greater the chance for error in judgement.

The dynamic aphasics made the least errors, and they judged best of all active conventional sentences while for the other sentences types they made mistakes with similar frequencies. The mechanism of sentence comprehension disorders in this type of aphasia has not been clarified so far. AKHUTINA (1975b) suggests that these aphasics display a disorder in the programming of the utterance while they have intact ability to give it grammatical structure. At the same time in all behavioral forms these patients typically display inertia and stereotypy.

The question remains open about the relation between programming disorders and difficulties in sentence comprehension. Perhaps these difficulties are a result of disorders in decoding sentence content, the more the grammatical structure of the sentence is more complex and/or these difficulties are due to disorders in the processes of comparing contents of picture and sentence. The reported research does not answer this question.

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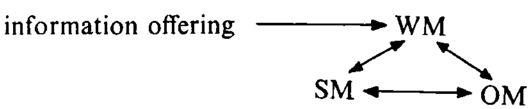
Differential Investigations on the Role of the Memory in Cognitive Processes

B. Krause, W. Krause and L. Sprung

Recent investigations on processes of information processing again concentrate on the role and function of memory in analysing cognitive processes. The very point is to study memory-related fundamentals of learning as a basis for explaining cognitive processes, the emphasis of corresponding analyses having shifted from the influence of structural components to the investigation of semantic relations. Thereby several functional units of the memory are distinguished in technical literature that are used for explaining memory processes:

a) The working memory/WM (Greeno, 1974, Baddeley and Hitch, 1974) as the activated part of the long-term memory (LTM) by way of which the cognitive processes essentially take place. According to Klix, this part of memory is both result and mean of perception.
b) The semantic memory/SM as that part of the LTM in which the knowledge of man is represented (comparable to the epistemic structure of Dörner, 1976).
c) The operative memory/OM as that part of the LTM in which behavioral sequences, decision rules etc. are stored (comparable to the heuristic structure of Dörner).

A relation exists between these components simply illustrated in the following diagram:



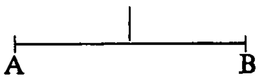
It becomes evident from these diagrams that the cognitive basis lies in the individual memory. If this is valid, the analysis of inter-individual differences offers a possibility to study—out of the differences—an approach to analysing information processing in thinking. Especially this, we regard—in addition to the general-psychological studies—as the concern of our contribution, i.e. we want to try to obtain propositions and results on the influence of memory effects in cognitive processes by analysing inter-individual differences in cognitive processes. For this purpose we choose—for different cognitive requirement situations—the methodical approach of the extreme-group-comparison as then the inter-individual differences can be more clearly proved and manipulated. The propositions that can be obtained by this approach on processes of cognitive information processing also being basic results for identifying and establishing diagnostic parameters shall be further demonstrated by means of selected examples.

By varying the cognitive requirement situation, on the one hand, the validity of our results shall be guaranteed and on the other hand, a differentiation as to the basic components of the LTM shall be enabled. In this sense, the experimental paradigms selected by us differ as to the fact whether they predominantly aim at propositions on the working, the semantic or the operational memory.

1st example:

The cognitive requirement consisted of the task to find a solution for the overtaking of two trains on a single-line track. For the solution of the problem, one siding was available to which none of the two trains could be completely shunted.

The situation was given in the following diagram



As to the trial we assumed that, dependent upon the information offering, an internal problem representation would be formed being the basis of behavioral decisions in the solution process. Thus, the knowledge stored in the semantic memory becomes the starting point for the solution process in which a modification of the memory is made according to the aim. The change of the problem representation is found out by test phases each after completed stages of the information offering:

test phase TP 0	before the very trial (starting level)
test phase TP 1	after instruction
test phase TP 2	after the first active trial
test phase TP 3	after the second active trial

A feature rating was used as a test in which the subjects had to evaluate feature lists belonging to the problem requirement as to their meaning for problem solving for given situational elements as slow train, goods-train etc. Features both relevant for a solution as "can be uncoupled", "drives alone" etc. and irrelevant as "with dining-car", "is late" etc. were included in the feature lists. In a first experiment (KAUL, 1976, KRAUSE, 1978), the validity of the scoring changes as to the real solution process, to be more exact—of behavioral decisions in the solution process, was proved.

In a second experiment (MUSOLD, 1977, see also KRAUSE et. al. 1978, KAUL, 1979), an ex-post-facto stratification in the sense of a differential analysis was carried out according to a learning progress measure Lp into two rough groups at first:

subjects with optimal learning progress $Lp = 1$
subjects with non-optimal learning progress $Lp < 1$.

An analysis of the effect of the processes of semantic information processing on memory representation was separately made for these two groups. At first, the effect on the change of memory representation as to two special parameters (see KRAUSE, 1977) was analysed:

C_r as parameter of restriction and C_e as parameter of expansion of the representation in question, being distinguished between originally high- and-low-rated features (fig. 1).

It was clearly shown that subjects with $Lp = 1$ used more the verbal instruction to build up an adequate problem representation being the basis of optimal solution progress. Subjects with $Lp < 1$ achieve these necessary corrections only after the 1st trial, for a part only after the 2nd trial. Thus, it is obvious that the difficulties of the subjects with Lp < 1 consist, above all, in achieving a correction of the representation and, therefore, of the effect of the semantic memory in goal direction.

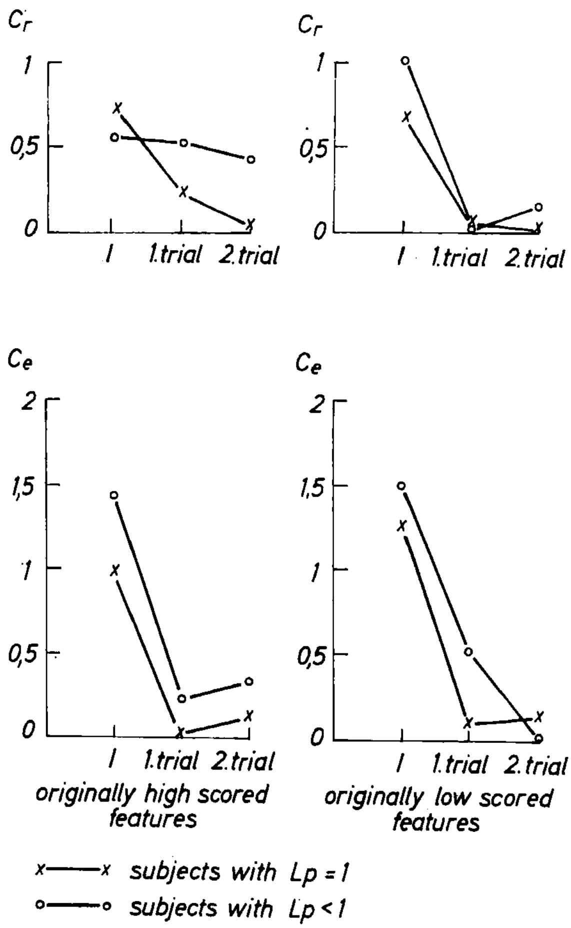


Fig. 1: Representation of the effect on the change of memory representation (after instruction I and the active trials 1 and 2 marked on the abscissa).

This process becomes more obvious when the formation of the problem representation is demonstrated by way of the various test phases. The following Fig. 2 shows for subjects with Lp = 1 this formation for two situational elements slow train Pz and goods-train Gz, the irrelevant feature being at the left of the situational element and the relevant feature at the right each numerically coded:
Obviously, there is a high degree of agreement especially for the goods-train, while this is only partly valid for the slow train.

(The reason for this latter difference is that the goods-train is shunted and disconnected by the subjects in the solution process, while the slow train is completely maintained as a unit. The result is that not all potentially relevant features must be applied in the solution process, but only a partial amount of them.)

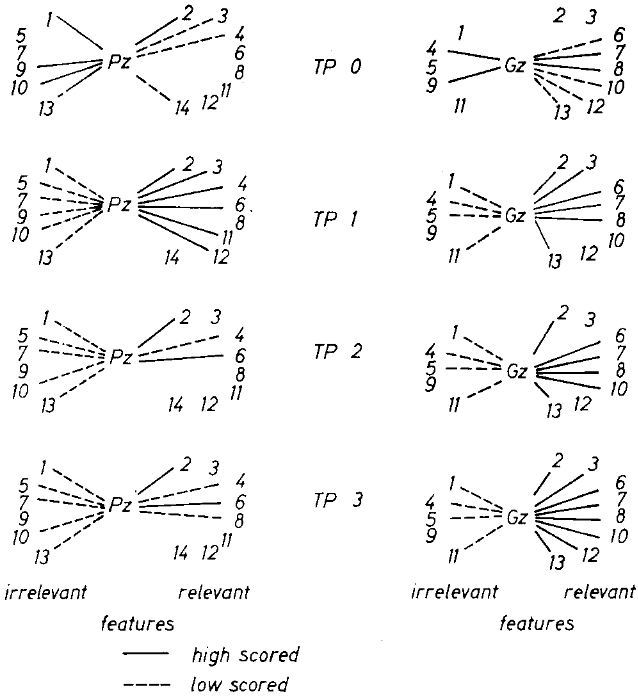


Fig. 2: Representation of formation of mental image for two situational elements for subjects with optimal learning progress Lp = 1.

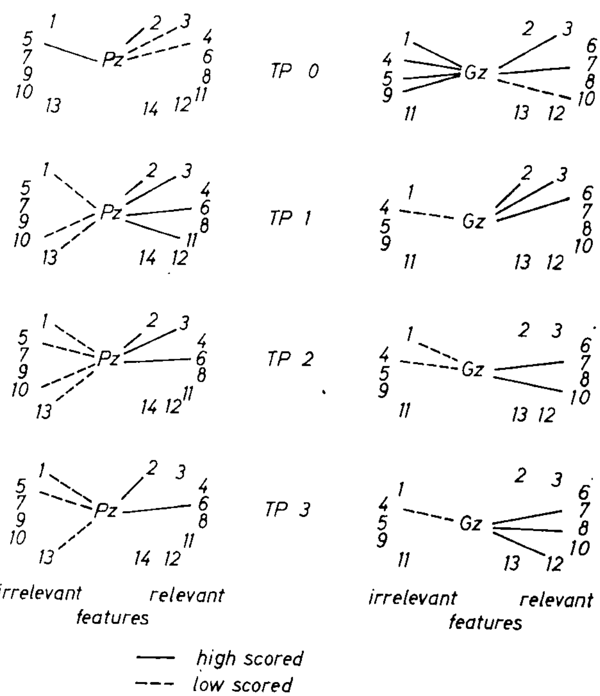


Fig. 3: Representation of formation of mental image for two situational elements for subjects with Lp < 1.

Also the consequent decrease of scoring unused features is typical for this group of subjects.

Above all, the difference as to the group with Lp < 1 is interesting from a differential point of view.

The difference as to the adequacy of problem representation is striking and confirms the above result concerning the strong influence of the experimental instruction on the formation of representation and the difficulty of the subjects with Lp < 1 to build up an adequate problem image and, thus, to overcome the solution-inhibiting influence of the semantic memory.

2nd example:

The cognitive requirement was an inferential performance in a more-term series problem of the form (see KRAUSE, 1977): X is taller than K and O is smaller than K.

Who is the smallest?

The function of the working memory is directly challenged by this experimental paradigm whereby the influence of the semantic as well as the operative memory can be largely ignored.

The *extreme groups* of normal and schizophrenic subjects had the task, after having understood the representation of facts of the first sentence, to answer the question presented after that. The results are shown in tab. 1 (see LAMPKA, 1977).

Tab. 1

	Normals	Schizophrenics
Processing time	5.2 s	12.6 s
Error rate	7%	54%

A detailed analysis confirmed the following basic statements: The integration of the single statements into an internal problem representation being a linear order in both groups takes place extremely delayed as to the schizophrenics. It should be noted that in a faultless case the elementary operations for building up the problem representation (selection, assignment, identification) not further mentioned here are all equally delayed. In addition, it follows from the high error rate of the schizophrenics that the different performance is caused above all by the selective information reception and the short-term storing performance and, thus, is dependent upon the working memory.

3rd example:

The cognitive requirement situation by which we strive for statements on the operative memory is an experiment on concept formation according to BRUNER with discrete-alternative feature material. Again, normal and schizophrenic subjects were tested whereby the process of hypothesis formation and its change should be especially analysed for this extreme-group-comparison. The subjects had the task to recognize a two-element conception with conjunctive or disjunctive connection. For this requirement, the checked hypothesis structure was analysed at first (RUHLAND, 1977).

Tab. 2

Group requirement	Hypothesis structure					
	Normals			Schizophrenics		
	one-element	conj.	disj.	one-element	conj.	disj.
Conjunctive	35.6%	38.1%	26.3%	62.8%	14.2%	23%
Disjunctive	35.7%	22.8%	41.5%	51.4%	26.5%	22.1%

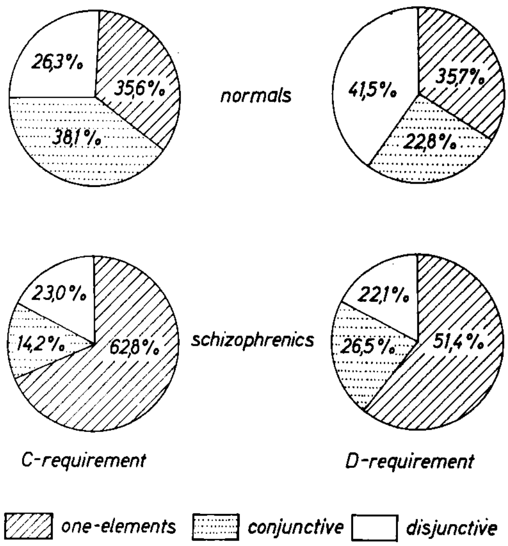


Fig. 4: Representation of the proportions of the hypothesis stru cture (as table and in graphic form.

The difference becomes evident in using the structural types in the hypotheses of the subjects, above all, in the fact that schizophrenics

a) build up more one-element hypotheses in the course of the trial,

b) essentially more seldom realize the transfer to two-element structural hypotheses and, above all, its disjunctive connection.

This result obviously showing differences in the operative memory can be differentiated if the process of hypothesis change is more exactly analysed. Thus fig. 5 shows the repetition frequency of already checked hypotheses.

Both requirement conditions confirm that schizophrenics show a higher repetition frequency. This agrees with an analogous result for this sample in the 2nd example and confirms the less short-term storing performance. As a third parameter, the application of the feedback that could be positive or negative was analysed for the hypothesis change. The result is shown in fig. 6.

It becomes evident that schizophrenics change their hypothesis during positive feedback more frequently and during negative feedback more seldom than normal subjects. Obviously, there takes place a different information processing of the feedback that could have its origin in different correction mechanisms of the operative memory. At the same time, we have the effect as in the first example (fig. 1) that worse

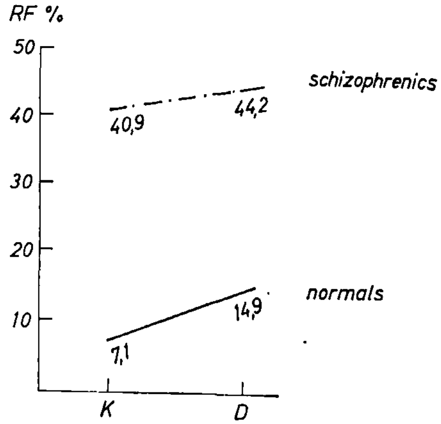


Fig. 5: Repetition frequency (RF %) as a parameter of hypothesis formation.

cognitive performances are caused, for instance, by the fact that the processing of negative information is not carried out according to the requirement.

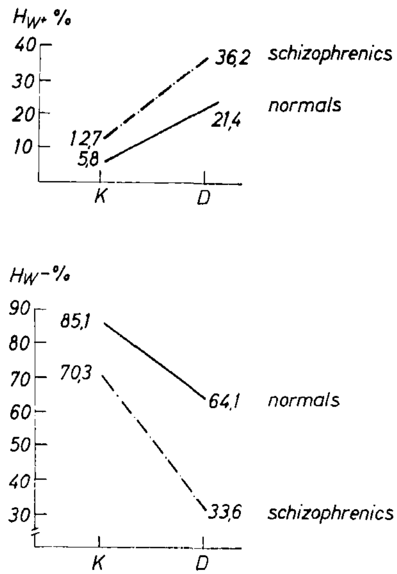


Fig. 6: Representation of the application of positive (Hw+) and negative (Hw−) feedback for the hypothesis change.

Thus, the inadequate memory structures both of the semantic and of the operative memory are to be regarded as reasons for cognitive differences in the performance.

To sum up:

Differential investigations on the analysis of cognitive processes offer possibilities to differentiate the correlation between memory representation and cognitive behavioral decision (SPRUNG and KRAUSE, 1978, SPRUNG, RICHTER and MÖLLER, 1979).

This is shown, above all, by the fact that
a) the different storing and processing of negative information considerably influences the process of modifying individual memory content and, thus is an essential component of the learning ability. This concerns both the represented knowledge in the semantic memory and the available operative memory.
b) the selective information reception and the short-term behavioral performances are important components during the building up of memory structures. In this connection, poor storing performances lead to an increase of the learning expenditure making possible a modification of memory content according to the requirement. At the same time, this influences together with the activated working memory the selection during the information reception.
Simultaneously, these results characterizing the influence of special memory components within the scope of cognitive processes contain diagnostic approaches for the proved parameters of cognitive behaviour which clearly show differences between the extreme groups involved.

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The Internal Representation of Curriculum-Based Conceptual Systems

H.-J. LANDER and U. SCHUSTER

1. A decisive role in psychological memory research is being played by studies of the attainment and internal representation of natural concepts and conceptual systems. Studies of this kind are relevant not only to general psychology. Their practical importance is obvious considering that natural conceptual systems could be taught much more rationally if the properties inherent in the structural organization of such conceptual systems were more thoroughly known and better utilized during the teaching process (DAWYDOW, 1967). This is more easily said than done since reflections on the internal conceptual organization of knowledge which represents realms of reality have not yet come to a satisfactory completion. Furthermore, there is a lack of clear notions of the infrastructural organization of long-term memory. Thus, the ideas underlying the subsequent study are of a hypothetical nature themselves.

The purpose of the study is to demonstrate the possibilities of an invariant structural description of well-defined natural conceptual systems and to test its validity by way of experiment. By a natural conceptual system we understand a linguistically labelled and induced conceptual structure whose elements are concepts over which inter-conceptual, mostly asymmetrical relations are defined. The attribute "natural" is to denote that a well-defined realm of reality is represented in this conceptual system, and the system term is to denote that conceptual organization is based on structure-forming principles (constellating factors). There are a wide variety of principles of the structuring of conceptual systems and, hence, their internal organization. At present, there is not a hard and fast classification for the grouping and organization of natural conceptual systems. Depending upon whether either a functionally or a taxonomically defined organizing principle is adopted as determining structure, roughly two types of conceptual systems may be differentiated as subjects of psychological studies. There are functional structurings if the elements they contain are in a part-whole relation, and there are taxonomic structurings if they are in a super-sub-ordination relation. Those are structural typologies on the basis of inclusion hierarchies; in the normal case, both hierarchical structurings are interwoven. Such concepts as cell, tissue, organ, organism etc. are in a part-whole relation, while such concepts as nervous cell, animal cell, cell etc. are in a hypotactical structural relation. Conceptual definition within a conceptual system is characterized by the fact that the definers (the defining properties of objects, or predicates) of a concept are a function of its integration and, hence, position within the conceptual system, that is, the conceptual contents (number of relevant attributes) are *relationally* defined (as a function of the context) in a conceptual system (BIERWISCH, 1974). It follows—in a way, as a methodical consequence for concept formation studies—that the internal structure of a concept cannot be determined before the internal structure of the conceptual system of which the concept is a part has been determined, that is, before its structural and, hence, relational position is exactly known. It follows also that concept attainment and the cognitive representation of concepts depend on the attainment and cognitive representation of the natural conceptual system concerned. Thus, in the natural case, all concept formation processes are linked with the attainment of a more or less highly dimensioned, complex conceptual system whose parts are organized in terms of the whole.

2. Methodological reflections serve to specify the initial conditions and goals of an investigation and to furnish a potential basis for the interpretation of the results obtained. In the present case, we have started to study concept formation and attainment processes in the context of a curriculum-based conceptual system as is taught in the class-room. Curriculum-based conceptual systems are always both a section of the whole conceptual system, in which the universe of discourse concerned is represented and a result of a long-drawn cognitive process. In the present case, we selected for our study the conceptual system taught in *cytology*, a 7th grade Polytechnical Ten-class High-School subject-area (involving about ten teaching units). The subject-area was selected for the following reasons:

- It is comparatively self-contained, not too comprehensive, and easy to survey.
- Area presentation and comprehension call for little prior knowledge of other subject-areas (dealt with before). It may be assumed, therefore, that the students' initial levels of previous knowledge when the teaching process started were relatively homogeneous.
- The subject-area is of fundamental importance to the teaching of biology in its entirety.

Both theoretical and practical aims were linked with the selection and investigation of the subject-area; *theoretically*, as far as the identification of patterns of cognitive representation of conceptual structures as knowledge is concerned; *practically*, with reference to the rationalization of the teaching process and, in this connection, of the availability of knowledge imparted. The present study first addresses the former problem area, as knowledge of this is an indispensable prerequisite to the investigation of the second area, which calls for comprehensive analyses of structure genesis under controlled conditions and thus a research program which is very time-consuming.

We thoroughly analyzed the subject-area, by examining the teaching materials accepted for the subject and actual subject presentation in the class-room (by way of samplings), and came to the following tentative conclusion about the structural organization of the conceptual system of "cell": The conceptual system comprises about 120 *individual concepts* to be taught. The organization of the conceptual system is partly functional, partly hypotactical. The functional organization shows a hierarchical system structure. The infrastructure of this system may be described in terms of hierarchical levels, which corresponds to an analysis of the system into individual sub-systems. Each hierarchical level is defined by one central concept (SHAVELSON, 1976). The conceptual system taught comprises a total of twelve structural levels (interrelated conceptual sub-systems). Each object defined by a central concept is relationally defined (by being anchored to the conceptual system) by a number of definers (predicates). The definers may be ordered in terms of certain conceptual classes (which apparently are characteristic not only of this conceptual system). Similarly, from the linguistic angle, a propositional structure is described in terms of functional-semantic units and relations which constitute the definers of the propositional structure. Those classes of predicates result from the functional and hypotactical organization of the elements of the conceptual system. The definers (the defining properties of objects) of a central concept may be divided into the following conceptual classes:

- complex concepts: the central concept to be defined has element relation to them;
- element concepts: they have element relation to the central concept to be defined;
- superordinate concepts: the central concept to be defined has subordinate concept relation to them;
- subordinate concepts: the central concept to be defined has superordinate relation to them;
- process concepts: they describe events which occur in the object defined by the central concept;
- trait concepts: they describe comparatively stable properties of the object defined by a central concept.

This predicative classification is invariant and paratactic at each structural level. The inter-conceptual[1] relations at a structural level are defined by certain properties that cannot be dealt with in detail here. The internal structure of a central concept can be illustrated by the following schematic representation (fig. 1).

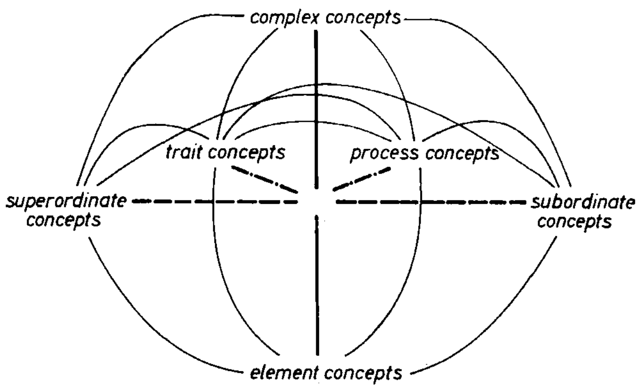

Fig. 1: A basic model of conceptual organisation—the internal structure of a central concept in natural conceptual systems.

The representation follows the "basic model of conceptual structures" developed by DÖRNER (1972, 1974). The basic model of conceptual organization as depicted in fig. 1 applies pars pro toto to the internal structuring of the entire conceptual system, depending on which structural level of which conceptual sub-system is chosen as a point of departure of the structural analysis. Thus, the choice of a point of departure may be regarded as a focussing of the conceptual system which then is of immediate operative importance for the reproduction and/or internal reorganization process. This basic model of conceptual organization was now adopted as an assumption about the internal representation and organization of the conceptual system of

[1] The term "inter-conceptual" is more narrowly defined by KLIX (in this volume).

"cell" that is taught in the class-room. Of course, this deductive procedure is fraught with problems. After all, structurings on the basis of other organizing principles can be conceived of. The present study purports to examine the extent to which the assumption, formulated a priori, about the internal representation and organization of our conceptual system has a psychological reality. The examination was first with reference to each central concept. In doing so, we identified level-specific relations only in an indirect way. They represent another subject of the investigation.

The extent of the identified class of predicates of a central concept is level-specific. In the present case, each class of predicates contains at least two elements. The number of predicative definers per central concept varies from 24 to 33 classifiable (in terms of the present structural hypothesis) elements. To account for the process of the internal representation and organization of the conceptual system on the basis of our deductively formulated assumption, we used G. A. MILLER'S (1956) recoding hypothesis which, as a principle of structure genesis, asserts in its most general version: If the elements (definers) entering a supply of information have parsing properties, the latter will be used, on the basis of a progressively generating conceptual system, for the structuring of the elements. This process corresponds to that of conceptual information condensation. When applied to the present case, this hypothesis can be specified as follows:

– In accordance with the recoding hypothesis, the predicative definers of a central concept which are usually taught in a distributive way are paratactically organized in terms of the classes of predicates defined above and thus constitute the structured knowledge about the subject-area taught.

– In the event of reproductive demands, this kind of organization that was established recodively and correspondingly fixed in memory comes to function reproductively, that is, the object properties defining a central concept are recodively reproduced and conceptually structured in terms of classes of predicates.

3. In order to determine the hypothesized structure of the curriculum-based conceptual system of "cell" with the afore-mentioned qualification, we used the following methods:

– *Incomplete triple comparison*: The elements are arranged in triples such that the anchor stimulus and a choice stimulus come from the same class of predicates.

– *Associative reproduction*: The elements are presented serially, with maximum serial distance of those elements that belong to the same class of predicates. The element to be associated must be a predicate of the object defined by the central concept.

– *Free recall*: In accordance with the afore-mentioned principle of serial ordering, the elements were twice presented serially in varied order. The reproductive demand was to enumerate the elements presented (predicates).

Several methods were employed to control dependence of the results on the methods used. The results were tabulated in reproduction matrices (contingency tables) whose elements are conditional, relative frequencies. The control variable used was the categorial degree of organization of the reproductions, defined over the number of pairs of elements belonging to the same class of predicates, relative to the total number of pairs occurring. We adopted the hypothesis that the reproduction process was based on a paratactical organization of elements if it deviated significantly from an expected paratactical organization. Non-distribution testing procedures were used to test the hypothesis. In addition, to test the validity of the hypothesis for free recall, a clustering measure was used which takes the expected value of a randomly produced, expected pairing of elements as the criterion of the categorial degree of organization reproduced in the experiment (BOUNSFIELD, 1953, DOUBILET and FRENDER, 1974, ARNOLD, 1975).

The study involved 400 students (14 Polytechnical Secondary School classes in the municipal and rural districts of Leipzig) in group experiment and was conducted immediately after treatment of the subject-area.

4. Data analysis from the deductive point of view and on the basis of the above-mentioned methods of structure determination and analysis has provided the following result which can only be summed up here:

– All the methods of structure determination used yielded an expected, structurally identical replication in the results. The results differed only in terms of the categorial degree of organization reached. The differences in the methods apparently resulted from the fact that when a certain reproduction task has to be performed the underlying internal conceptual organization (over the set of the elements to be reproduced) is required and, hence, used in varying degrees. The differences, however, are not significant statistically.

– In the triple comparison (decisive assignment process), the hypothesized organization was used to a great extent. The choice was in accordance with the hypothesis established, with the error probability being $\alpha < 0.1$ per cent. Potential differences between central concepts could not be demonstrated statistically. Nor were there any differences in the constant and variable anchor effects, or in the varying choice stimulus assigned to the anchor or in the fixed choice stimuli which do not belong to the anchor class, respectively.

– The association method (associative assignment process) provided a similar result. Associative reproduction was largely as had been expected. The associations formed where in accordance with the hypothesis established, with the error probability again being $\alpha < 0.1$ per cent.

– Free recall (serial ordering) using the above-mentioned clustering measure also confirmed the hypothesis. With an error probability of $\alpha = 5$ per cent, the recalled series showed the expected structuring of elements in terms of the classes of predicates hypothesized, which is evidence of a categorial degree of organization in free recall.

In the two latter reproduction methods, however, the findings apply only to the number of items actually reproduced, which is consistently smaller than the number of categorial definers taught in the class-room. It is only in the triple comparison that the hypothesis can be verified for the total number of items taught, but then with lower reproductive demands.

5. The findings may be interpreted in the sense of the hypothesis established and are largely consistent with it: The conceptual definers, taught in the class-room, of the objects of a structural level (sub-system) defined by central concepts are recoded in terms of paratactically ordered classes of predicates; thus, this conceptual organization comes to function reproductively. Dependencies on methods have been largely controlled here. The generality of this formulation, however, must be qualified because in the procedure we presented the results were obtained only deductively, i.e. on the

basis of a hypothesis about the nature of the structuring that was conceived *prior to* the experiment. Alternative organizing principles may be established prior to the experiment, but admit of an inductive, i.e. post-experimental formulation too. It should be examined, therefore, whether in the present case an inductive procedure, i.e. hypothesis-free analysis of the data would yield a similar result. If so, the results would support the hypothesis established prior to the experiment; if not, the data should be tested for the principle by which the reproductively obtained organization was recoded and whether those structurings are sufficiently consistent, that is, whether interindividual differences remain within the range of a conceptual organization that was inductively obtained. A further step would be to remove the methodical restriction to the central concept level (sub-systems) and to universally test the deductively and/or inductively obtained hypothesis about conceptual organization, i.e., to demonstrate its validity for the entire curriculum-based conceptual system of cytology.

6. The present study is concerned with the internal conceptual representation and organization of a curriculum-based conceptual system which is taught in the classroom (cytology, 7th grade, Polytechnical Ten-class High-School). To account for the internal representation of the subject-area, a hypothesis about conceptual organization was adopted as an assumption and tested for its psychological reality (experimental construct validation). Three methods of structure identification (triple comparison, associative reproduction, and free recall) were used to establish its validity. The data were first analyzed on a deductive basis, i.e., it was determined to what extent the data obtained were consistent with the hypothesis about the internal structuring of the conceptual system that was established prior to the experiment. Using various procedures of analysis, it was found that both the assignment process and the reproduction sequences showed a high degree of categorial organization and that the categorial organization was consistent with the structuring hypothesis.

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