HUMAN COMPUTER INTERACTION

CHAPTER 1

1. THE HUMAN

- Humans are limited in their capacity to process information. This has important implications for design.
- Information is received and responses given via a number of input and output channels:
  – visual channel
  – auditory channel
  – haptic channel
  – movement.
- Information is stored in memory:
  – sensory memory
  – short-term (working) memory
  – long-term memory.
- Information is processed and applied:
  – reasoning
  – problem solving
  – skill acquisition
  – error.
- Emotion influences human capabilities.
- Users share common capabilities but are individuals with differences, which should not be ignored.

1.1 INTRODUCTION

WHAT IS HCI?

The term *human–computer interaction* has only been in widespread use since the early1980s, but has its roots in more established disciplines. Systematic study of human performance began in earnest at the beginning of the last century in factories, with an emphasis on manual tasks.

- Introduce the information within an organization.

- Traditionally concerned itself with the influence of technology in the workplace, and fitting the technology to the requirements and constraints of the job. These issues are also the concern of HCI.

- HCI involves the design, implementation and evaluation of interactive systems in the context of the user's task and work.

1.2 INPUT–OUTPUT CHANNELS

- A person's interaction with the outside world occurs through information being received and sent: input and output.
- In an interaction with a computer the user receives information that is output by the computer, and responds by providing input to the computer – the user's output becomes the computer's input and vice versa.
- Input in the human occurs mainly through the senses and output through the motor control of the effectors. There are five major senses: sight, hearing, touch, taste and smell. Of these, the first three are the most important to HCI.

- Taste and smell do not currently play a significant role in HCI. However, vision, hearing and touch are central.

- Similarly there are a number of effectors, including the limbs, fingers, eyes, head and vocal system.

- In the interaction with the computer, the fingers play the primary role, through typing or mouse control, with some use of voice, and eye, head and body position.

1.2.1 Vision

Human vision is a highly complex activity with a range of physical and perceptual limitations, yet it is the primary source of information for the average person.

The human eye

- Vision begins with light.
- The eye is a mechanism for receiving light and transforming it into electrical energy.
- Light is reflected from objects in the world and their image is focussed upside down on the back of the eye.
- The receptors in the eye transform it into electrical signals which are passed to the brain.

The eye has a number of important components.

- The *cornea* and *lens* at the front of the eye focus the light into a sharp image on the back of the eye, the *retina*.
- The retina is light sensitive and contains two types of *photoreceptor*: *rods* and *cones*.
- Rods are highly sensitive to light and therefore allow us to see under a low level of illumination.
- The cones do not operate either as they are suppressed by the rods.
- Cones are the second type of receptor in the eye. They are less sensitive to light than the rods and can therefore tolerate more light.
- There are three types of cone, each sensitive to a different wavelength of light. This allows color vision.
- The eye has approximately 6 million cones, mainly concentrated on the *fovea*, a small area of the retina on which images are fixated.

Visual perception

The information received by the visual apparatus must be filtered and passed to processing elements which allow us to recognize coherent scenes, disambiguate relative distances and differentiate color.

Perceiving size and depth Imagine you are standing on a hilltop. Beside you on the summit you can see rocks, sheep and a small tree. On the hillside is a farmhouse without buildings and farm vehicles.

Even in describing such a scene the notions of size and distance predominate. Our visual system is easily able to interpret the images which it receives to take account of these things.

- The size of that image is specified as a *visual angle*.
- The visual angle indicates how much of the field of view is taken by the object.
- Visual acuity is the ability of a person to perceive fine detail. A number of measurements have been established to test visual acuity, most of which are included in standard eye tests.

Perceiving brightness

- A second aspect of visual perception is the perception of *brightness*.
- Brightness is in fact a subjective reaction to levels of light.
- It is affected by *luminance* which is the amount of light emitted by an object.
- The luminance of an object is dependent on the amount of light falling on the object's surface and its reflective properties.
- *Contrast* is related to luminance: it is a function of the luminance of an object and the luminance of its background.

Perceiving color

- A third factor that we need to consider is perception of color.
- Color is usually regarded as being made up of three components: *hue*, *intensity* and *saturation*.
- Hue is determined by the spectral wavelength of the light.
- Color Blue have short wavelengths, greens medium and reds long.

Reading

There are several stages in the reading process. First, the visual pattern of the word on the page is perceived. It is then decoded with reference to an internal representation of language. The final stages of language processing include syntactic and semantic analysis and operate on phrases or sentences.

1.2.2 Hearing

The sense of hearing is often considered secondary to sight, but we tend to under estimate the amount of information that we receive through our ears.

The human ear

- Hearing begins with vibrations in the air or *sound waves*.
- The ear receives these vibrations and transmits them, through various stages, to the auditory nerves.
- The ear comprises three sections, commonly known as the *outer ear*, *middle ear* and *inner ear*.
- The outer ear is the visible part of the ear.
- It has two parts: the *pinna*, which is the structure that is attached to the sides of the head, and the *auditory canal*, along which sound waves are passed to the middle ear.

The outer ear serves two purposes.

- It protects the sensitive middle ear from damage.
- The pinna and auditory canal serve to amplify some sounds.

Processing sound

- Sound is changes or vibrations in air pressure.
- *Pitch* is the frequency of the sound.
- A low frequency produces a low pitch, a high frequency, a high pitch.
- *Loudness* is proportional to the amplitude of the sound;
- The frequency remains constant.
- The human ear can hear frequencies from about 20 Hz to 15 kHz.

Uses of non-speech sounds include the following:

- Attention – to attract the user's attention to a critical situation
- Status information – continuous background sounds can be used to convey Status information.
- Confirmation – a sound associated with an action to confirm that the action Has been carried out.
- Navigation – using changing sound to indicate where the user is in a system.

1.2.3 Touch

- The third and last of the senses that we will consider is touch or *haptic perception*.
- Touch provides us with vital information about our environment.

- The skin contains three types of sensory receptor: *thermoreceptors* respond to heat and cold, *nociceptors* respond to intense pressure, heat and pain, and *mechanoreceptors* respond to pressure.
- It is the last of these that we are concerned with in relation to human–computer interaction.

1.2.4 Movement

- A measure of motor skill is accuracy.
- One question that we should ask is whether speed of reaction results in reduced accuracy.
- This is dependent on the task and the user.
- In some cases, requiring increased reaction time reduces accuracy.
- This is the premise behind many arcade and video games where less skilled users fail at levels of play that require faster responses.
- Studies of keyboard operators have shown that, although the faster operators were up to twice as fast as the others, the slower ones made 10 times the errors.
- Speed and accuracy of movement are important considerations in the design of interactive systems, primarily in terms of the time taken to move to a particular target on a screen. The target may be a button, a menu item or an icon.

1.3 Human Memory

- Memory is the second part of our model of the human as an information-processing system.
- Memory is associated with each level of processing.
- There are three types of memory or memory function: *sensory buffers*, *short-term memory* or *working memory*, and *long-term memory*.

1.3.1 Sensory memory

- The sensory memories act as buffers for stimuli received through the senses.

A sensory memory exists for each sensory channel:

- *iconic memory* for visual stimuli,
- *echoic memory* for aural stimuli
- and *haptic memory* for touch. These memories are constantly overwritten by new information coming in on these channels.
- Information received by sensory memories is quickly passed into a morepermanent memory store, or overwritten and lost.

1.3.2. Short-term memory

- Short-term memory or working memory acts as a ‘scratch-pad’ for temporary recall of information.
- It is used to store information which is only required fleetingly.
- Short-term memory can be accessed rapidly, in the order of 70 ms.
- Short-term memory also has a limited capacity.

There are two basic methods form measuring memory capacity.

- The first involves determining the length of a sequence which can be remembered in order.
- The second allows items to be freely recalled in any order.
- The limited capacity of short-term memory produces a subconscious desire to create chunks, and so optimize the use of the memory.
- The successful formation of a chunk is known as *closure*.
- This process can be generalized to account for the desire to complete or close tasks held in short-term memory.

1.3.3 Long-term memory

- Long-term memory is our main resource.
- Here we store factual information, experiential knowledge, procedural rules of behavior – in fact, everything that we 'know'.
- First, it has a huge, if not unlimited, capacity.
- Secondly, it has a relatively slow access time of approximately a tenth of a second.
- Thirdly, forgetting occurs more slowly in long-term memory, if at all.
- Long-term memory is intended for the long-term storage of information.
- There are three main activities related to long-term memory: storage or remembering of information, forgetting and information retrieval.

Long-term memory structure

- There are two types of long-term memory: *episodic memory* and *semantic memory*.
- Episodic memory represents our memory of events and experiences in a serial form. It is from this memory that we can reconstruct the actual events that took place at a given point in our lives.
- Semantic memory, on the other hand, is a structured record of facts, concepts and skills that we have acquired. The information in semantic memory is derived from that in our episodic memory, such that we can learn new facts or concepts from our experiences.

The process of memory: information retrieval.

- Here we need to distinguish between two types of information retrieval, recall and recognition.
- In recall the information is reproduced from memory.
- In recognition, the presentation of the information provides the knowledge that the information has been seen before. Recognition is the less complex cognitive activity since the information is provided as a cue.

1.4 Thinking: reasoning and problem solving

Thinking can require different amounts of knowledge. Some thinking activities are very directed and the knowledge required is constrained. Others require vast amounts of knowledge from different domains.

1.4.1 Reasoning

Reasoning is the process by which we use the knowledge we have to draw conclusions or infer something new about the domain of interest.

There are a number of different types of reasoning:

- *deductive,*
- *inductive* and *abductive*.

Deductive reasoning

Deductive reasoning derives the logically necessary conclusion from the given premises.

For example,

If it is raining then the ground is dry

It is raining

Therefore the ground is dry. is a perfectly valid deduction, even though it conflicts with our knowledge of what is true in the world. Deductive reasoning is therefore often misapplied. It is at this point, where truth and validity clash, that human deduction is poorest.

We assume a certain amount of shared knowledge in our dealings with each other, which in turn allows us to interpret the inferences and deductions implied by others. If validity rather than truth was preferred, all premises would have to be made explicit.

Inductive reasoning

Induction is generalizing from cases we have seen to infer information about cases we have not seen.

For example, if every elephant we have ever seen has a trunk, we infer that all elephants have trunks. Of course, this inference is unreliable and can not be proved to be true; it can only be proved to be false.

Abductive reasoning

The third type of reasoning is abduction. Abduction reasons from a fact to the action or state that caused it. This is the method we use to derive explanations for the events we observe.

For example, suppose we know that Sam always drives too fast when she has been drinking. If we see Sam driving too fast we may infer that she has been drinking. Of course, this too is unreliable since there may be another reason why she is driving fast: she may have been called to an emergency.

1.4.2 Problem solving

- Problem solving is the process of finding a solution to an unfamiliar task, using the knowledge we have.
- Human problem solving is characterized by the ability to adapt the information we have to deal with new situations. However, often solutions seem to be original and creative.
- Problem solving is a matter of reproducing known responses or trial and error.
- Problem solving is both *productive* and *reproductive*.

- Reproductive problem solving draws on previous experience as the behaviorists claimed, but productive problem solving involves insight and restructuring of the problem.

Analogy in problem solving

- A third element of problem solving is the use of analogy.
- One suggestion is that this is done by mapping knowledge relating to a similar known domain to the new problem – called *analogical mapping*.
- Similarities between the known domain and the new one are noted and operators from the known domain are transferred to the new one.

1.4.3 Skill acquisition

All of the problem solving that we have considered so far has concentrated on handling unfamiliar problems. However, for much of the time, the problems that we face are not completely new. Instead, we gradually acquire skill in a particular domain area. We can gain insight into how skilled behavior works, and how skills are acquired, by considering the difference between novice and expert behavior in given domains.

This behavior is also seen among skilled computer programmers. They can also reconstruct programs more effectively than novices since they have the structures available to build appropriate chunks. They acquire plans representing code to solve particular problems. When that problem is encountered in a new domain or new program they will recall that particular plan and reuse it.
Three basic levels of skill:
1. The learner uses general-purpose rules which interpret facts about a problem.
This is slow and demanding on memory access.
2. The learner develops rules specific to the task.
3. The rules are tuned to speed up performance.

1.4.4 Errors and mental models

Human capability for interpreting and manipulating information is quite impressive. However, we do make mistakes. Some are trivial, resulting in no more than temporary inconvenience or annoyance. Others may be more serious, requiring substantial effort to correct. Occasionally an error may have catastrophic effects, as we see when ‘human error’ results in a plane crash or nuclear plant leak.

These have been termed *mental models*. They have a number of characteristics. Mental models are often partial: the person does not have a full understanding of the working of the whole system. They are unstable and are subject to change. They can be internally inconsistent, since the person may not have worked through the logical consequences of their beliefs. They are often unscientific and may be based on super station rather than evidence.

1.5 Emotion

Our emotional response to situations affects how we perform. For example, positive emotions enable us to think more creatively, to solve complex problems, whereas negative emotion pushes us into narrow, focussed thinking.

A problem that may be easy to solve when we are relaxed, will become difficult if we are frustrated or afraid.

Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks.

1.6 Individual Differences

- The psychological principles and properties that we have discussed apply to the majority of people.
- We should remember that, although we share processes in common, humans, and therefore users, are not all the same.
- We should be aware of individual differences so that we can account for them as far as possible within our designs.
- These differences may be long term, such as sex, physical capabilities and intellectual capabilities.
- Others are shorter term and include the effect of stress or fatigue on the user. Still others change through time, such as age.
- These differences should be taken into account in our designs.

1.7 Psychology and the design of interactive systems

So far we have looked briefly at the way in which humans receive, process andstore information, solve problems and acquire skill. But how can we apply what wehave learned to designing interactive systems?

- In order to apply a psychological principle or result properly in design, we need to understand its context,
- Both in terms of where it fits in the wider field of psychology and
- In terms of the details of the actual experiments, the measures used and the subjects involved.

Fortunately, principles and results from research in psychology have been distilled into guidelines for design, models to support design and techniques for evaluating design.

1.7.1 Guidelines

We have discussed the strengths and weaknesses of human cognitive and perceptual processes but, for the most part, we have avoided attempting to apply these directly to design.

This is because such an attempt could only be partial and simplistic, and may give the impression that this is all psychology has to offer.

1.7.2 Models to support design

- As guidelines and principles, psychological theory has led to the development of analytic and predictive models of user behavior.
- Some of these include a specific model of human problem solving, others of physical activity, and others attempt a more comprehensive view of cognition.
- Some predict how a typical computer user would behave in a given situation, others analyze why particular user behavior occurred.

1.7.3 Techniques for evaluation

- To providing us with a wealth of theoretical understanding of the human user, psychology also provides a range of empirical techniques which we can employ to evaluate our designs and our systems.

- In order to use these effectively we need to understand the scope and benefits of each method.