Chapter 4

Cognitive Models for Performance Interaction

"The intellect is an organ composed of several groups of functions, divisible into two classes, the functions and faculties of the right hand, the functions and faculties of the left. The faculties of the right hand are comprehensive, creative and synthetic; the faculties of the left hand critical and analytic. . . The left limits itself to ascertained truth, the right grasps that which is elusive or unascertained. Both are essential to the completeness of the human reason"

[S. Aurobindo (Yogic Philosopher), 1910.]

Overview

This chapter explores the ways in which humans interact with objects when engaged in performance or real-time control. This is contrasted with the mode of operation which dominates the computing world; that of analysing and responding to data. The idea of a human cognitive 'performance mode' is suggested with the aim of promoting research into HCI systems which allow this kind of interaction to develop.

4.1 Asymmetry of Thought and Brain

There has been discussion throughout history about the different types of mental process of which humans are capable. The quote which opens this chapter is an example of how these have been sometimes categorised as attributes of the 'left side' and the 'right side'. More recent medical research has shown a degree of asymmetry in the human brain and the styles of thought process attributed to the left and right hemispheres.

4.1.1 Brain Hemispheric differences.

> *"The left hemisphere has been found to be predominantly involved with analytic processes, especially the production and understanding of language, and it appears to process input in a sequential manner. The right hemisphere appears to be responsible for certain spatial skills and musical abilities and to process information simultaneously and holistically"*
>
> [Springer, Deutsch 1993].

The claim outlined above is that differences in operation of the brain's two hemispheres are responsible for different characteristic types of thought process. Particularly notable is the suggestion that music and ‘holistic’ abilities (coping with many things at once and perceiving an integrated whole) are somehow separated from sequential and analytical thought processes. We shall return to this issue later in the chapter.

The first recorded hypothesis that the human brain had localised areas for different sorts of processing task was presented in 1836 by Marc Dax, a French county doctor. Dax had noticed a marked correlation between patients with head injuries who had received damage to the left side of the brain and those who suffered speech loss. His paper was almost ignored by the medical community at the time, but laid the foundation for future studies into the effects on patients of localised head injury.

Subsequent studies throughout this century have indeed shown that various tasks appear to be processed in distinct locations in the brain. It is the precise interpretation of these results that is still a source of controversy. Studies are generally carried out on so-called ‘split-brain’ patients (those whose nerve fibres normally connecting the brain's two hemispheres have been surgically severed) and on those who have had localised traumatic brain injury.

Joan Borod has studied many such patients and concludes :

> *“Emotional processing involves strategies and functions for which the right hemisphere is superior: strategies termed nonverbal, synthetic, integrative, holistic, and Gestalt, and functions such as pattern perception, visiospatial organisation, and visual imaging”*
>
> [Borod 1992].

Sally Springer and George Deutsch have attempted to integrate many hundreds of previous studies. In *Left-Brain, Right-Brain* they suggest :

"On the basis of split-brain studies, the most general statement that can be made about right-hemisphere specialisations is that they are non-linguistic functions that seem to involve complex visual and spatial processes. The perception of part-whole relations, for example, seems to be superior in the right hemisphere"

[Springer, Deutsch 1993].

Later in the book, they draw up a table of the essential differences of operation which various studies have noted between the brain's two sides. Part of this table is reproduced below :

Left Hemisphere	**Right Hemisphere**
Verbal	Nonverbal, visuospatial
Sequential, temporal	Simultaneous, spatial,
Logical, analytic	Gestalt, synthetic
Rational	Intuitive

[Springer, Deutsch 1993]

The eagerness to categorise brain function into two distinct types based on hemispheric differences is treated by many with some caution, so much so that the process has been termed `dichotomania' :

"It is becoming a familiar sight. Staring directly at the reader - frequently from a magazine cover - is an artist's rendition of the two halves of the brain. Surprinted athwart the left cerebral hemisphere are words such as "logical", "analytical" and "Western rationality". More luridly etched across the right hemisphere are "intuitive", "artistic" or "Eastern consciousness". Regrettably, the picture says more about a current popular science vogue than it does about the brain".

[Gardner, 1978].

A recent *New Scientist* article makes a similar point:

> *"whatever the story about lateralisation, simple dichotomies are out. It is how the two sides of the brain complement and combine that counts."*
>
> [McCrone, 1999]

The *Oxford Book of the Mind* defines the problem as follows:

> *"The distinctions between the roles of each hemisphere have been oversimplified in investigations hitherto, although broadly they are apparent. Nevertheless, research which correlates a patient's performance with damage to a particular brain structure, is gradually building up a picture which illuminates our understanding of the nature of musical skill."*

We therefore conclude that human beings are capable of radically different types of thought process, whether or not this is a dichotomy between 'analytic' and 'holistic' (as opposed to a continuum) and whether or not this can be directly mapped to brain physiology.

4.2 Cognitive Modes : Analytical / Holistic

We can say that humans are thinking in 'analytical mode' when their attention is directed towards the breaking down, or decoding, of information which they are perceiving. Analytical thinking is often directed towards a particular goal, for example trying to find a numerical solution to a problem. Parameters are studied one at a time, in sequential, logical order.

The 'holistic' mode is more difficult to define. One reason for this is that it usually exists beyond language, and as such language is a difficult tool for expressing it. This mode of thinking is likely to involve looking at the perceived object or subject as a whole. Individual details are less important than the overall effect. Many interrelated 'information streams' can be perceived at once and their relationships become apparent. The person thinking holistically can often be doing something else at the same time.

As an example, people can listen to music in either of these cognitive modes. In analytical mode, they may be following a score, or at least breaking down the perceived sound into identifiable instruments and patterns. Their purpose in this case is to draw conclusions, make comparisons, and produce data or information for future use. Usually, this data can be verbalised, for example "The cadence at bar 512 uses the chord of A minor for the first time in this section".

The same piece of music can be listened to in 'holistic' mode. In this mode of thinking the listeners will perceive the overall effect of the music, maybe not even being aware of following individual instrumental lines. The effect on the listener is often an emotional one and can generate an almost subconscious desire to move with the music. There is no 'goal' or 'information' here, but some would argue that this emotional response was the whole point of music.

A similar cognitive dichotomy is well known in the field of acoustics where the phrase 'holistic listening' (sometimes called 'synthetic listening') is regarded as the normal everyday way of hearing a set of related harmonic components as a single coherent sound. With training it is possible to listen analytically and to 'pick out' individual harmonics which were hitherto fused into a whole sound.

Another example of the two cognitive modes in action might be to consider the different ways in which people can analyse sales figures. One way involves focusing on the individual figures, studying them in a logical order, applying mathematical calculations and producing a set of prediction figures as an output. Another way involves quickly scanning several graphs and making very general and high-level predictions about future trends based on graphical trajectories.

The purpose of the remainder of this chapter is to suggest that these two distinct styles of thinking can be equally applied to the interaction of humans with computers, and that traditional HCI practice is perhaps unhealthily dominated by 'analytical' interaction.

4.3 Modal thought in HCI

> *"Ideally systems should be designed to provide information systematically about the status of an activity in terms of what has been done and what currently needs to be carried out. If users are distracted from the activity in hand, the system should then be able to inform them of where they were in that activity when they return to it"*
>
> [Preece, 1994].

4.3.1 Tasks and Sequential ordering

The above quote can be viewed as a summary of the current recommended design methodology for interactive systems. At first glance it appears to be a logical set of recommendations for a good user interface. On closer examination, it becomes clear that a certain restrictive set of assumptions have been made about the style of user interaction with any such system. It is assumed that:

- Users have unit tasks to do.
- The tasks have a logical and sequential order of execution.
- The computer is responsible for prompting the user as to what to do at any particular point.

The last of these assumptions harks back to the 'human as information processor' model of HCI (outlined in section 2.3.3), where the computer dominates the dialogue with the operator. This is hardly the best model for creative musical instruments or for machine control where the human operator needs to have freedom of action in order to cope intuitively with emergency situations.

The first two assumptions are related. If a process can be reduced to an ordered sequence of unit tasks (see the GOMS model in section 2.3.4), then the computer can control and order the data presentation so that it gets the information it needs from the operators at the correct time. This model becomes inappropriate where the concept of a unit task is questionable, and the pre-ordering of tasks would be ridiculous. For example, how could ordered unit tasks be defined for playing a musical instrument? Who would care to drive a car on a motorway following a strict ordered list of control instructions?

4.3.2 Automatic and Controlled functions

Chapter 2 (section 2.3.7) introduced the concepts of 'controlled' processes as those requiring cognitive effort, and 'automatic' processes as those which have been learnt so that practically no cognitive effort is required. It was also shown that menu-based systems actively encourage controlled processes to pre-dominate. People learn how to navigate menu systems, i.e. they learn how to constantly activate, read, analyse, and select from menu operations in order to home in on the required function. This reduces the need to remember the details of how a particular computer system works. This is a laudable goal for those machines where short-term use is all that is required (e.g. a cash-point machine). It is a highly suspect way of controlling complex machinery in real-time, since such situations require users to be intimately involved in the control process itself, not to be constantly navigating the interface.

From the review of literature in Chapter 2 we could conclude that the predominant aims of mainstream HCI are to analyse user's tasks into sequentially oriented goals, which can be selected by the user's cognitive processes.

In other words, many current approaches to HCI favour analytical operation.

4.3.3 Interactive control interfaces

In stark contrast to the commonly accepted choice-based approaches to HCI are the control interfaces for musical instruments and vehicles, where the human operator is totally in charge of the action. Many parameters are controlled simultaneously and the human operator has an overall view of what the system is doing. Feedback is gained not by on-screen prompts, but by experiencing the moment-by-moment effect of each action with the whole body.

This 'holistic' approach is echoed in the ideas of 'humans as actors' (2.3.8) and of Direct Manipulation (2.4.4). The interaction of a player with a musical instrument could be summarised quite appropriately by considering that the player directly manipulates a complex musical object, thus exploring the sonic and tactile environment which in turn provides continuous feedback. Similar analogies could be made about a person driving a car.

The attributes of an instrumental real-time control system seem to be:

- There is no fixed ordering to the human-computer dialogue.
- The human takes control of the situation. The computer is reactive.
- There is no single permitted set of options (e.g. choices from a menu) but rather a series of continuous controls.
- The overall control of the system (under the direction of the human operator) is the main goal, rather than the ordered transfer of information.
- The control mechanism is a physical and multi-parametric device which must be learnt by the user until the actions become automatic.
- Further practice develops increased control intimacy and thus competence of operation.

- The human operator, once familiar with the system, is free to perform other cognitive activities whilst operating the system (e.g. talking while driving a car).

4.4 Characteristics of performance mode

The above attributes of a real-time control system are very different from the state-of-the-art computer interface. They form the beginnings of the definition of 'Performance Mode', a term which has been coined for this study. One of the main characteristics of such a mode of operation is that it allows humans to *explore* an environment in a continuous manner, rather than to 'perform a series of unit tasks'.

4.4.1 Explorative Operation

Explorative operation means that the user discovers how to control a device by exploring different input control positions and combinations, thus gaining an immediate response from the system. The user may appear to be 'playing around' with the controls, but they are actually discovering hidden relationships between parameters within the system. Users feel that there is always something more that they could do; a movement they could learn or improve, an increase in subtlety, which would give them better control over the system. This is the experience of a typical acoustic instrumental musician; the instrument stays constant whilst the focus is on the improvement of the human player.

The primary feedback is sonic, tactile and kinaesthetic. Visual feedback is also provided, but advanced users make less use of this.

Cadoz [1990] describes musical gestures as having three functions: *ergotic* (controlling and manipulating the environment), *epistemic* (sensing or perceiving the environment) and *semiotic* (giving coded information to the environment). The epistemic effect is the feedback mentioned above, which comes primarily from the body moving the input device. Musical instruments also make sound, which gives a second level of feedback to the user. The visual sense can also be used to provide feedback to the user, but too often this predominates at the expense of the sonic, tactile and kinaesthetic feedback.

The proposal is that interactive systems should, where possible, provide an explorative mode of operation. This could be the entire system interface, or just a small part. An example is given here which shows the different cognitive modes in action in the MidiGrid program (section 3.3).

4.4.2 Performance mode in action

It is a highly illuminating experience to watch different people using MidiGrid for the first time. When presented with a mouse which can be used to play notes from a grid of harp-like sounds, some users go straight into an explorative mode. They move the mouse at various speeds, in various patterns, listening to and exploring the sounds and textures produced. Almost without exception they enjoy themselves. Some people have been asked to shut their eyes and explore the sonic effect of their various improvised hand movements. Interestingly, they are nearly all reluctant to shut out the visual interface, but when encouraged to do so are almost always rewarded by the feeling of total explorative control over the sounds.

In contrast, other users insist on ‘mastering’ the instrument before they will allow themselves any freedom of movement. Their first attempt is to play a tune. Most beginners will fail at this set task and become frustrated as they haven't yet discovered the relationship between the movement of the device and the sound produced. They cannot yet control their own movements to achieve the task they have set themselves.

The above two scenarios illustrate the danger of setting tasks for the user too early. Equally they show the benefits of encouraging exploration and creativity as a motivating goal to mastering the control of an interface. They also demonstrate the different potential human responses to ‘holistic’ and ‘analytical’ modes of operation. This is not to say that the analytical mode is somehow ‘bad’, but rather to show that sometimes it is inappropriate. Analysis and exploration are partners which should be allowed to co-exist throughout a user's interaction with a complex system.

4.5 Scalable Control Intimacy revisited

Fig 4.1 represents the traditional approach to the spectrum of HCI design possibilities. Either a system is easy to use or it is difficult to use (i.e. implying a bad design), or it is somewhere between the two.

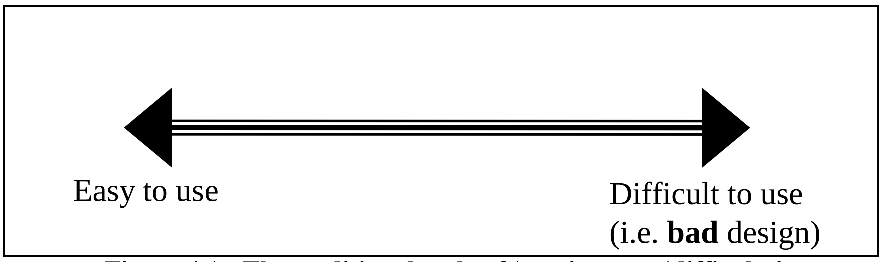

Figure 4.1: The traditional scale of 'ease' versus 'difficulty'

Fig 4.2 expands the above model to account for control intimacy which now appears as an extra dimension to the graph. The scale of 'difficulty' along the x-axis remains similar to Fig 4.1. At one end the interface is 'easy' to use and at the other extreme it is 'hard'. Note however that the y-axis now considers the expertise of the user. A new user will be a novice and will appear in the lower part of the graph ('surface use'). If users are given the opportunity for their control intimacy to increase, then they will move further up the graph towards 'expert use'.

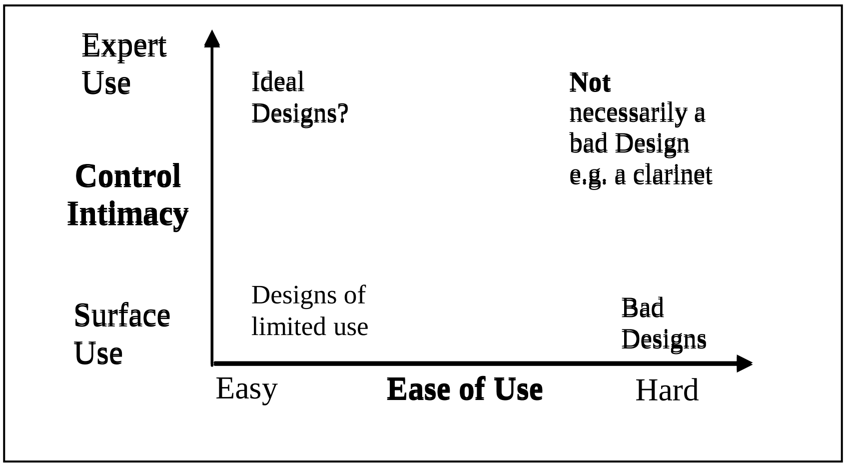

Figure 4.2: A 2-D space for considering Control Intimacy alongside Ease of Use

The implications of this are important. No longer is a bad design taken to mean 'anything which is difficult' (i.e. to the right of the graph). Rather, an interface is only bad if it is only ever intended for surface use and yet is hard (i.e. in the bottom right-hand corner of the graph. An example of this would be a photocopier interface which baffled 'surface-only' users with cryptic commands or complex menuing structures. However, an interface which **is** hard, but allows an increase in control intimacy might not be considered as 'bad'. An example of this is shown in the above Figure. A clarinet is extremely hard to play and beginners can achieve almost no sound. However with practice the range of possibilities increases greatly, but it is *still* hard to play. This situation is similar for most musical instruments (although some are easier for beginners to use).

Perhaps the best interfaces are indeed those which are easy for surface use yet allow a good range of control intimacy as the user becomes more expert.

4.6 Summary

Dangers can occur, within a traditionally accepted 'analytical' HCI model, when the primary goal of interface design is to make the system easy to use. When 'ease of use' is seen as the diametrical opposite of 'Bad machine-centred design' then there seems to be no other option for the designer than to make the system simple. However, traditional real-time systems, such as vehicles and musical instruments, are notoriously not easy to use (at least initially). This does not mean that they are 'bad' designs though; rather that the human operator cannot (and should not) be expected to instantly fathom the complex interactions of the control environment.

The advantage of a system which incorporates opportunities for the user to *explore* the environment is that the user's natural curiosity will be engaged. Humans appear to have an in-built desire to master a system and resentment when it is perceived that a system is mastering them. If we can encourage people to invest time in learning a system, then the opportunity is present for their control intimacy to increase. If this happens they may become better operators, and will feel more satisfied with the act of operation. The multiparametric interface developed as part of this DPhil allows users to do exactly this, and in Chapters 7 to 9 the quantitative and qualitative results of its performance are shown relative to other, more analytical, interfaces.

Above all, with such a system, the expert human in charge will be free to respond to situations which occur which could not have been foreseen by the programmer, and which could cause annoying, inartistic, if not dangerous or even fatal consequences if the system itself dictated the control.

Chapter 5 reintroduces the hypothesis and explains in more detail how the topics covered in Chapters 1 to 4 are related.