"Information technology for cognitive support"

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Well designed Communication and Information Technology systems have great and unrealised potential to enhance the quality of life and independence for those with cognitive dysfunction, including elderly people by:

- Allowing them to retain a high level of independence and control over their lives
- Providing appropriate levels of monitoring and supervision of 'at risk' people, without violating privacy
- Keeping people intellectually and physically active
- Providing communication methods to reduce social isolation and foster social inclusion.

Using technology to augment human cognitive capacity is not a new idea, taking the term technology in its widest sense, to include tools and techniques which humans have developed to help them improve upon their limitations. The first cognitive function to be augmented was probably memory. Mnemonic methods help with this and are still in wide use today. One of the commonest (i.e. the method of loci) is to link what is to be remembered with a well established memory structure which is easy to recall, such as the layout of a familiar city, or a narrative which has already been memorised. The introduction of written language extended peoples cognitive abilities by allowing 'memories' to be recorded externally. Although at the time, some feared this was a backwards step that would allow people's memory powers to wither; it has since become apparent that the overriding effect has been to 'free-up' cognitive abilities that can further develop on the basis of the external support. The development of information processing technologies has continued this trend of extending the potential of most people's cognitive abilities. Thus there should be similar potential for computer technology to extend the cognitive abilities of those with some form of impairment or other limitation.

The increasing power and decreasing size of computer technology, along with its capacity to provide communication as well as computation and storage, offers the possibility of quite sophisticated help for cognitive impairments, if we can develop the appropriate software. Computers have the potential to act as a kind of scaffolding for cognitive tasks, taking over functions which have been affected by illness, accident, or aging. They could also provide prompts for daily living, if they were able to track successfully through the user's sequence of tasks and actions.

Particular strengths of computers as assistants for people with cognitive impairments include being consistent, tireless, and not becoming emotionally involved. In addition multi-media and multi-modal systems can provide a very rich interaction which may be particularly advantageous for users with cognitive dysfunction. For example such systems have great potential in addressing the problems of memory loss and the related difficulties presented by dementia. In addition, communication systems which use synthetic speech, predictive programmes which can facilitate writing, and a range of non linguistic methods of communication, can be used by those with speech and language dysfunction caused by cognitive impairments. A great deal of work will be required in order to realise this potential both in uncovering new knowledge about how cognition works and in developing assistive systems based on this knowledge.

Because of the wide range of skills and knowledge needed to understand the problems faced by people with cognitive impairment it is essential that research work in this field should be multi-disciplinary, including psychologists, and members of the health and therapeutic professions as well as engineers. It is also vital to involve potential users of the technology as partners in the research at all stages of development.

In addition, it is essential that interface designers be much more aware of the range of abilities that exist in any population of users. For example, access to the internet for disabled people is often thought to be synonymous with access for blind people, but in fact blind people form only a small percentage of the disabled population. Ogozalec (1997) pointed out that, if current trends continue in the USA, by 2030 one fifth of the population will be over 65 years of age, and comments: "It is difficult to categorise and draw conclusions about 'the elderly', since they comprise such a diverse and heterogeneous population". This diversity, particularly of cognitive function, ought to be taken into account if we are to make software and the internet available to as large a percentage of the population as possible.

We will describe the major types of cognitive impairment, and include within this discussion the effects of aging. We will then illustrate the development of systems to support people with a variety of cognitive impairment with specific projects in which we have been involved. They will not cover all aspects of cognitive impairment, but they do illustrate a methodology and an approach to developing assistive technology which may have a wider relevance.

In the concluding part of this chapter we will address the development of methodologies which we believe will be valuable for designers of systems to support people with cognitive impairment, and also assist designers of general systems to take into account the needs of people with cognitive impairments.

Cognitive impairment

The use of the term 'cognitive impairment' implies that two categories of human cognitive systems exist - impaired and unimpaired. This however is not the case, although it can reasonably be stated that there are 'normal' or 'average' cognitive systems. It is this 'normal' system that the vast majority of the experimental cognitive psychology literature relates to. In many contexts this level of explanation is suitable for indicating what most people are capable of. It should always be borne in mind, however, that in 'real world' situations there is no marked distinction between that which is 'normal' and that, which is not. In other words, everyone has some limits to their cognitive ability. Some have a highly specific impairment, some more diffuse problems, and there are also some that experience inter-related constellations of impairments. In addition the cognitive abilities of any one human being will change over longer and shorter periods of time. Aging can have substantial effects on cognitive ability, which is particularly marked in some age related conditions, such as dementia.

For ease of exposition, the forms of cognitive impairment identified and described below will in the main refer to general categories. It should be noted, however, that all these categories lie somewhere on a continuum and, whilst they are delineated on the basis of educational and/or clinical/medical criteria, such 'cut-off-points' are relatively arbitrary in the context of the wide variability of cognitive ability across the population. It is also worth noting that within the context of 'normal' cognitive systems there is significant diversity among people in regard to differential preferences for types of material and ways of approaching and processing information. For example, some people may be considered primarily 'verbal' and will tend to excel in language based tasks, relative to those considered 'visuo/spatial' (See, for example Lohman, 2000). Thus, many of the types of impairment addressed below can to an important extent be construed as the extremities of 'normal' diversity.

Intelligence quotient

The most widely known dimension of general cognitive ability is probably ‘intelligence’. Scientific investigation of this dimension has had a controversial past, and many aspects of this are beyond the scope of the present chapter (for a more comprehensive account, see Gould, 1997). One underlying reason for such controversy is that the word ‘intelligence’ has a rather nebulous definition. In day-to-day usage this is rarely problematic, but the differences between scientific and lay definitions can cause misunderstanding (e.g. Sternberg, 2000). Such misunderstanding can lead to controversy as most definitions of ‘intelligence’ include connotations that are considered socially important and thus can often be highly emotive. Despite these difficulties, the investigation of ‘intelligence’ has provided many insights into a wide range of more particular cognitive abilities, and has also developed methods for quantifying general intellectual ability such as the various forms of ‘IQ’ (intelligence quotient) test. Again, controversy has surrounded the use of these tests over the years (see Gould, 1997 & Kaufman, 2000), but such tests have been widely used and are accepted as a general benchmark of a person’s intellectual capability.

An IQ score of 100 is, by definition, ‘normal’ with about 50% of the population scoring above and 50% scoring below, but it should be noted that elderly people are not generally included in the standardisation of these scores. Approximately 50% of the population are considered to be within the bounds of ‘normality’ and deviate either side of 100 by no more than ten points. The ‘not normal’ 50% are about evenly distributed above and below this band. Thus about a quarter of the (non-elderly) population fall below the level of what is considered ‘normal’. Although the terminology varies across cultures and over time, around 20% of the population have IQ scores between 75 and 90 and would generally be classified as ‘slow learners’. The final 5% will generally have very special needs that on the whole are best addressed on an individual basis (Kaluger & Kolson, 1987). Further to this and as an example of the emotive connotations associated with the issue of 'intelligence', it is worth noting that the first official classification scheme (AAMR, 1921; see Detterman, Gabriel & Ruthsatz, 2000) associated with IQ tests further broke down this latter 5%. These classifications were; 'moron' (IQ 50-75) 'imbecile' (IQ 25-50) and 'idiot' (IQ <25), terms which today would be considered wholly unacceptable as a description of anyone with a cognitive impairment.

An IQ score reflects a person's intellectual ability as a whole. A low score may be due to the whole system functioning at a sub-optimal level, but a similar result can also be due to one or more component abilities being impaired. There are many tests of IQ, some of which give an indication of this whilst others do not. Some IQ tests are explicitly broken down into sub-tests that reflect the relative levels of ability in the component cognitive abilities, such as the 'verbal' and 'visuo/spatial' abilities mentioned above. The more common forms of cognitive impairment are described below in the context of a brief overview of the cognitive system.

For any information in the outside world to enter the cognitive system it must first be detected and transmitted by the sensory apparatus. In an important sense this is not simply the 'start' of the process because aspects of attention will influence what is and is not detected/transmitted, and, to a certain extent, how. Basic perceptual processing creates a sensory specific representation of the stimulus event. Streams of such stimulus events are summated into meaningful cognitive entities (e.g. strokes on a page, recognised as letters and numerals are summated into a name and telephone number). These will then be either passed immediately to short term memory (STM), further processed by working memory (WM) and/or 'rehearsed' for maintenance in STM or for encoding into longer term storage. 'Rehearsal' could, for example, refer to rote rehearsal of a telephone number between reading and dialling it, or to more elaborate processing to associate it with relevant extant memories to improve the chance of subsequent recall (e.g. method of loci, mentioned above).

Output from the cognitive system will generally be initiated in response to some form of external stimulus, or 'probe', by accessing extant memories relevant to the probe using 'executive' processes to 'organise' them in a task relevant way and then producing a response. 'Output' of this kind has been most commonly studied with the use of memory tests. This minimises the influence of 'intellectual processing' (problem solving etc.) *per se*, and emphasises the registration, rehearsal and encoding of information, the effects of 'decay', interference, and other forms of 'forgetting', and the effectiveness of different cues (probes) in eliciting specific memories (e.g. recall versus recognition).

Virtually all aspects of the processing outlined above are shaped by attention, and it is important to note that, regardless of impairment, while we all have some control over attention, it can also be the case that attention can have some control over us. That is to say, we can utilise attention to 'focus' on searching a list for a particular telephone number whilst ignoring the chatter of people around us. Having read the number, however, our attention can exert its own control if someone calls our name and asks if we have made that call yet. Despite our best efforts at rehearsal, it is likely that our attention will be 'grabbed' by our name, and the ensuing question, and this brief distraction, can be enough to lose the information from temporary storage.

In general terms, mild to moderate 'global' cognitive impairment will be associated with decrements in efficiency across most of the processing 'stages' outlined above and/or in aspects of the utilisation of attention. The following will describe some of the main decrements in cognitive ability related to interacting with computer type systems.

Interface design to support people with cognitive impairment

It is often important to develop special technology to provide support for people with various types of cognitive impairment, and some such projects are described later. It is also important, however, to address the challenge of providing access to more mainstream technology for people with cognitive impairments. When designing or specifying mainstream technology for such users it is important to focus on their characteristics, and to be fully aware of the range of cognitive diversity, even amongst those without clinical dysfunction. This is rarely mentioned in human interface design, where the cognitive diversity of the human race has not been the focus of much research. It is also important to consider the effects of age on cognitive function. As Worden et al. (1997) commented "It is known that, as people age, their cognitive perceptual and motor abilities decline with negative effects on their ability to perform many tasks. Computers can play an increasingly important role in helping older adults function well in society. Despite this little research has focused on computer use of older adults."

A key aspect of any intellectual task, in regard to interactive technology for people with mild or moderate 'global' cognitive impairment, is speed (Salthouse, 1991). This is to say, whatever level of performance a person can achieve in any given situation, it will be made worse if the task must be done under externally imposed time constraints whether actual or simply inferred by the user. Thus the design of any interaction should, wherever possible, allow every step to be carried out at the user's own pace. This issue also raises the first distinction between older and younger people. A relatively greater proportion of the extra time needed by older people is due to age related declines in their sensory systems, particularly in hearing and vision rather than cognitive impairment *per se*. For example, given comparable levels of cognitive impairment, an older person will need relatively more time to perceive the relevant stimulus before cognitive processes can be brought to bear on it. Thus for many older people the requirement for extra time can be reduced, though rarely removed, if care is taken to present text and other aspects of 'on-screen' layout in a suitably clear way (see, for example Carmichael, 1999; Charness & Bosman, 1994). Attention to text layout can also benefit people with specific learning difficulties, e.g. those with dyslexia, and people with limited literacy levels. Beyond this, 'clear' text and presentation layout will always be worth considering carefully as such aspects have been found to benefit those who do not specifically need it, albeit to a less marked extent (Freudenthal, 1999; Pirkl, 1994).

Another key concept related to interface design for people with cognitive impairment is 'complexity', and its avoidance. Complexity in interfaces can manifest itself in many different ways and at many different levels. A truly comprehensive coverage of this is beyond the scope of the present chapter, but some illustrative examples will be given to elucidate this idea.

The use of language in an interactive system should be given careful consideration and the syntax and vocabulary should be kept as straightforward and 'everyday' as the context allows. This is particularly pertinent for any form of instruction. If the requirements of a particular stage of an interaction cannot be captured in a few simple concrete statements, then serious consideration should be given to redesigning the interaction itself. Similarly any on-screen display should be kept as uncluttered as practicable and wherever possible should present the user with only a single issue (menu, subject, decision etc.) at any particular point in time. Similarly, but at a larger scale, progression through an interaction should be kept, again wherever practicable, as linear as possible. That is, the user should only need to consider one 'thing' at a time. Any requirement to deal with different 'things' in parallel will markedly increase the possibility of errors and general user dissatisfaction (Detterman et al., 2000; Salthouse, 1985).

Unfortunately, as the designers of a system will have a comprehensive understanding of the functions of that system, they are unlikely to be able to assess issues of complexity from the users' point of view, particularly that of a novice user. In addition to this, prescriptive 'check-lists' for avoiding complexity will ultimately be inadequate as the optimum approach will always depend of the specifics of the task the interactive system is intended to support (Carmichael 1999). This is one of the main issues that highlights the importance of early and rigorous user involvement in the design of interactive systems. This is particularly important in the case of young designers developing interfaces for older users.

Research into cognitive changes in later life has indicated the heuristic value of the concepts of 'fluid' and 'crystallised' abilities (Horn & Cattell, 1967). In general terms 'fluid' abilities (novel problem solving) are those that decline with age and 'crystallised' (existing 'world knowledge') are those which don't. Research that has looked at the 'very old' (80 yr. +) tends to find that ultimately everything declines but that the 'crystallised' abilities follow a markedly slower trajectory (Bäckman, Small, Wahlin & Larsson, 2000). This is another distinction between younger and older people, as the former will tend to have much less accumulated knowledge. It is also worth noting that there are advantages and disadvantages on both sides of this distinction. Rabbitt (1993) has shown that, in many circumstances, relevant accumulated knowledge can ameliorate decline in fluid ability (e.g. well learned strategies). In other circumstances, however, the opposite can be the case, wherein a well-learned, but essentially inappropriate, strategy can put a relatively greater burden on the associated 'fluid' abilities.

The effects of attention

Many of the constraints imposed by cognitive impairment can be further shaped by decrements in various aspects of attention. One major aspect of this is generally referred to as selective attention, which allows us to 'focus' on salient aspects of a task and at the same time helps us to actively ignore irrelevant aspects. The efficiency of selective attention is markedly diminished in most forms of cognitive impairment. This factor further supports the recommendation to present the user with just one 'thing' at a time, which will avoid the user erroneously devoting time and cognitive resources to processing irrelevant information. Similarly, if the nature of the interaction requires the user to attend to some 'critical' information at a particular time/location, appropriately obvious highlighting should be employed to 'grab' the users' attention. These issues become emphasised in situations where selective attention must be maintained over periods of more than just a few minutes.

Another aspect of attention known to be less efficient in cognitive impairment is referred to as 'divided attention'. In general this refers to the ability to allocate cognitive resources appropriately when trying to do two, or more, distinct cognitive tasks, or distinct portions of the same task, at the same time. Many scenarios, where the user is required to do more than one 'thing' at a time, can simply demand more cognitive resources than are available. Declines in the efficiency of divided attention, however, can mean that, even if the tasks involved demand no more than the resources available, they may not be allocated appropriately. Generally speaking the interactive system should be designed to relieve the user of this kind of burden. It is difficult to be prescriptive about suitable solutions to this problem, as the appropriate approach will depend on the specifics of the interaction involved, but some general ideas may be of use. For example the provision of some form of 'note-pad' function may be helpful for temporarily recording information for subsequent use, although great care is needed to ensure that the instantiation of such a function, and its utilisation, does not in itself put further cognitive load on the user. Another possibility would be the provision of an 'overview' of the task in hand which could show, or remind, the user 'where they are' and what they have and have not done.

Memory loss and dementia

Limitations in memory affect people with age- and non-age-related cognitive impairment. Thus, wherever practicable, interactive systems should be designed to take the burden of memory off the user, for example, by judicious use of prompts and reminders. Also careful consideration of the steps in an interaction, and the way they are presented to the user, can help mitigate the most common problem of deficient short-term and working memory. Even with the best design efforts, however, such problems are likely to make users with cognitive impairment relatively error prone. It is thus very important to ensure that the interactive system allows for error correction in an easy to use form. Also, to ensure that the user spots such errors, the system should provide feedback regarding user actions and where appropriate elicit active confirmation from them.

Various forms of dementia can exaggerate the relatively mild effects of ‘normal’ aging on the cognitive system. At the age of 60 years, about 1% of the population is diagnosed with dementia. This percentage approximately doubles for every subsequent 5 year age band, e.g. 4% at 70 yrs., 16% at 80 yrs. (Bäckman et al., 2000). Of the elderly population with dementia, Alzheimer’s disease accounts for about 60%, depending on the diagnostic criteria used and a further 25% is ‘vascular dementia’ (i.e. related to circulatory problems). Most of the vascular dementias are referred to as multi-infarct dementias and tend to be caused by series of mini-strokes, and thus tend to have more diffuse and less predictable effects on ability than a major stroke. The remaining 15% of dementias are made up of various relatively rare conditions (Bäckman et al, 2000).

Regardless of the various causes and effects, all forms of dementia involve damage to the brain, such damage being more or less widespread, affecting cortical and/or sub-cortical areas. In general, damage to the cortex results in cognitive/perceptual impairment, while damage to the sub-cortical areas is more related to physical impairment. There are, however, a number of well-known problems related to the diagnosis of dementia. Two of these are relevant here. The first involves the ‘grey area’ between the ‘worst’ effects of ‘normal’ aging and the initial effects of pathological aging at the onset of dementia. The second is that the effects of depression in later life can closely mimic those of dementia. These additional complexities further expand the overall diversity of cognitive impairment in relation to human interface design, both in regard to the general level of ability and in the variation of that level over periods of days, weeks, months and even years. The convolution of this situation is further added to by the effects of a relatively greater probability of ill health among older people. It is estimated that around 80% of those aged 65 and over have at least one chronic illness and many will have more than one. In addition to the effects of health *per se*, there is also potential for cognitive ability to be affected by a variety of medication, and by interactions between different medicines.

Despite the above there are some fairly systematic changes associated with extreme old age and dementia which are relevant to human interface design. In general, the first ability to deteriorate in dementia, particularly with Alzheimer's disease, is episodic as distinct from semantic memory. Episodic memory is memory for events, usually from the viewpoint of personal experience, rather than for 'facts'. That is to say, remembering that 'X is the capital of Y' is the product of semantic memory, whereas remembering when and where you were while you were reading that 'X is the capital of Y' is the product of episodic memory. This generalised decrement in episodic memory may be related to findings in 'normal' aging research such as disproportionate decrements in source memory (i.e. specifically remembering 'where' an item was rather than 'what' it was) and prospective memory (i.e. remembering to do something in the future). These changes have important implications for successful 'navigation' in interactive systems. For example, keeping track of where you have just been, is often an important prompt to where you are going now.

Visuo-spatial, iconic and verbal abilities

In addition to memory problems, there are, at least at the level of the population, marked deterioration of visuo-spatial and verbal abilities in older people. Decline in visuo-spatial abilities can cause difficulty with 'de-coding' layouts and utilising any inherent organisation. Related to this is a deterioration in iconic memory which, given the graphical nature of many interfaces can be problematic in its own right. Particular difficulties have also been found in the comprehension of abstract and metaphorical phrases, with the tendency being to take them literally. Such conditions can develop into more 'global' aphasia (e.g. Broca's aphasia, related to the production of speech and Wernicke's aphasia, related to comprehension). There is also a likelihood that the general difficulty with recall of proper nouns, found in 'normal' aging, can develop into more profound anomia. The depth of such problems may not be apparent to an outside observer as the ability to read aloud may be well preserved, although the content may not be properly understood

Another distinct form of 'global' cognitive impairment is autism, including a set of rarer but related syndromes (Kaluger, 1987). The precise causes of autism are not clearly understood. Briefly stated it is a general neurological disorder that impacts the normal development of the brain particularly in relation to social interaction and communication skills. Its effects will usually become apparent within the first three years of life. People with autism typically have difficulties in verbal and non-verbal communication and social interactions. The disorder makes it hard for them to communicate with others and relate to the outside world, they will also tend to have relatively low IQ scores. Closely related to autism is Asperger's Syndrome. People with Asperger's experience similar 'social communication' difficulties but will generally demonstrate a 'normal' IQ. Further to this, there are several generally similar conditions, some of which have varying physical and behavioural elements associated with them. These come under the collective heading of pervasive developmental disorders and all tend to produce difficulties with communication. An important element of these social communication difficulties in the context of the present chapter is an inability to grasp the implications of metaphorical or idiomatic language. This is similar to that mentioned above for dementia, but in autism tends to be more profound. There is, however, some evidence to show that people with autism or Asperger's syndrome are more able to communicate with computers than with people, or with people via computers, rather than face to face, and thus properly designed computer systems may have potential for assisting such user groups. A variety of other impairments could also be ameliorated with suitable designed support for communication.

Augmentative and Alternative Communication

Most interfaces use traditional orthography (the written word). However, cognitive limitations can have a major impact on the ability to encode and decode traditional orthography. People with acquired cognitive impairments (e.g. aphasia resulting from a stroke or cerebral vascular accident [CVA]) can experience varying degrees of difficulty with both expressive and receptive language. A person with aphasia may have slight word-finding problems through to more pervasive problems in understanding spoken language. While some individuals may retain some literacy skills, damage to the language processing centres will usually also affect symbolic representations of language.

Individuals with congenital language and/or intellectual disabilities (e.g. congenital aphasia and Down's syndrome) may never become literate. The physical inability to speak (e.g. dysarthria resulting from cerebral palsy) may also impact on literacy learning as basic skills required for reading and writing (e.g. phonemic awareness) may be absent.

Visual images, photographs and drawings, provide augmentative and alternative ways to access communication. Such images can be used to enhance text-based interfaces. In addition, sets of symbols (e.g. the Picture Communication System [PCS] {see http://www.mayerjohnson.com/} or Rebus, {see; http://www.widgit.com/} and semantic-based writing systems such as Blissymbolics) {see http://home.istar.ca/~bci/} can be used as an alternative to text (Beukelman, & Mirenda,1998, Wilson, 2003). The type of picture/symbol/graphic used will depend on the iconicity (ease of recognition), transparency (guessability), opaqueness (logic organisation) and learnability of the image. For instance, a photograph of a house may be transparent, ie it is easily recognisable, while a Blissymbol representing the emotion of happy has logic (heart =

feeling; up arrow = up) and is thus opaque and learning (fig below). The more concrete a representation, the more recognisable it will be. However, representations of abstract meanings, e.g. emotions, will involve less transparent images necessitating a longer learning curve. See table 1.

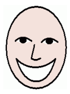
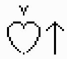
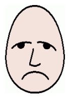
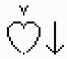
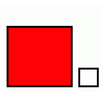
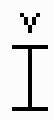
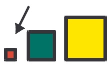
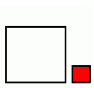
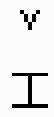
	PCS	Rebus	Blissymbols
house			
happy			
sad			
big			
small			
fall			

Table 1 Examples of three symbol sets which have been developed for augmentative and alternative communication – for more information see about these symbol systems see

Cognitive prostheses

In addition to providing better access to 'everyday' software, specially designed computer systems have great potential to offer more specific support for people with a wide variety of cognitive impairments. We will describe some specific examples of such systems so that the reader is able to see how such development can proceed. Within the Applied Computing Department at Dundee University, a number of projects have developed computer based systems to support people with cognitive dysfunction, and examples from the work of this group can illustrate the range of areas where this technology has particular potential. These examples will also demonstrate the need for appropriate methodologies for research in this area, including need for research into developing more sensitive and effective and methodologies.

Software as a cognitive scaffolding and a prompt for communication

One sequence of projects took as its starting point the improvement of communication systems for physically impaired non-speaking people. It became apparent that this could be done very effectively by developing models of the cognitive tasks involved in communication. This research has now spawned a new area of development, which is cognitive support for people with dementia, where communicative impairment is just part of their range of difficulties.

For severely physically impaired non-speaking people, even with current speech output technology, speaking rates of 2-10 words per minute are common, whereas unimpaired speech proceeds at 150-200 words per minute. In an attempt to improve this disparity, a certain amount of progress has been made in the area of using computers to replace or augment some of the cognitive aspects of communication. Although the cognitive processes underlying language use are incompletely understood, a number of theories which attempt to explain language use have been used to improve the functionality of communication systems for non-speaking people.

This approach to the problem usually involves taking a sociolinguistic view of language. Instead of focusing on the building blocks, taking a ‘bottom up’ approach, the interaction as a whole is analysed, paying attention to its goals, taking a ‘top-down’ approach to the communication. This may well be a realistic simulation of the natural process, since the production of speech by an unimpaired speaker occurs at such a rate that conscious processing and controlling of the speech at a micro-level is not possible. In common with other learned skills, speech is produced to some extent, automatically, with the speaker being aware of giving high level instructions to the speech production system, but leaving the details of its implementation to the system.

The non-conscious control of much of speech production has been modelled in the CHAT prototype (Alm et al., 1992). This produced quick greeting, farewell, and feedback remarks by giving the user 'semi-automatic' control of exactly what form the remarks would take, within parameters which the user had previously selected. This mimicked the phenomenon of a speaker responding automatically to greetings and other commonly occurring speech routines, without giving the process any detailed thought.

The CHAT-like conversation described illustrates an attempt to achieve a particular communicative goal, achieving social closeness by observing social etiquette. Some recent research efforts have been directed at finding ways to incorporate large chunks of text into an augmented conversation, to help users carry out topic discussion. This has been driven by the observation that a great deal of everyday discourse is reusable in multiple contexts.

Much of this type of discourse takes the form of conversational narratives. Research into the conversational narrative at a sociolinguistic level indicates several interesting characteristics. These include the way in which narratives are told and to whom they are told. For example, a recent event is told repeatedly for a limited time to most people with whom the speaker has contact. As the event recedes in history, the narrative is retold when it is relevant to the topic of conversation. The length of the narrative depends on its age (the older a story is, the more embellished it can become, particularly if it has previously ‘gone down well’) and the time available within the conversation. The ‘version’ of the story (the sequence of events may remain the same while the details or embellishments of a story can differ) depends on factors such as the conversational context and other interlocutor(s) present.

One of the ways to make the retrieval of text chunks easier is to anticipate the chunks which the user may want to use. This has been achieved by modelling the way in which conversational narratives are used using techniques from the fields of artificial intelligence and computational linguistics (Waller, 1992). The prototypes developed constantly adapt to the users’ language use, thus mirroring the user’s perception of where conversation items are stored. In this way, the system adapts to the way the user ‘thinks’ instead of having the user learn a new retrieval system.

One of the arguments against using such prediction was raised when word prediction systems were first developed in the early 1980’s. Therapists and teachers were concerned that non-speaking people, especially children, would select what was offered on the screen rather than what they originally wanted to say. Although this may happen, research into predictive systems applied to writing suggests that they may carry over the help they offer and have a wider effect on the users’ ability development. Some of this research reports an increase in written output by reluctant writers and people with spelling problems (Newell et al., 1992). A general improvement in spelling has also been noted. Children with language dysfunction and/or learning disabilities have shown improvement in text composition (Newell et al., 1991). This research is in the writing domain, but the results suggest that predictive systems can offer assistance without becoming mere substitutes for creative expression.

Also, it is true of ‘unimpaired’ conversation, that speakers often change direction in their communication depending on chance occurrences, or on the sudden recollection of a point they would like to include. Thus there is a degree of opportunism in all conversations. Another argument in favour of offering predicted phrases and sequences is that the current situation for most augmented communicators is that their conversations tend to be quite sparse, with control tending to reside with unaided speaking partner(s). If it is not possible to go boating on the lake, easily going off in any direction you please, is it not preferable to build a boardwalk out over the water than to stay on the shore?

One of the motivations to improve communication systems for non-speaking people is the fact that they are commonly perceived by people who do not know them as being less intellectually capable than they actually are. It is often reported by non-speaking people that they are considered unintelligent or immature by strangers. It may be that the issue of ‘perceived communicative competence’ is one which needs increased attention (McKinlay, 1991).

Related to this, an interesting finding emerged from work in which one of the authors was involved. Here, a prototype communication system was used to evaluate listeners’ impressions of the content of computer-aided communication based on pre-stored texts, as compared to naturally occurring dialogues. The “non-speaking” user was able to use only pre-stored texts in order to conduct the conversations. Most of the text was material about one subject (holidays). A number of rapidly accessible comments and quick feedback remarks were also available. The unaided conversations were between pairs of normally speaking volunteers who were asked to converse together on the topic of holidays. Transcripts of randomly sampled sections of the conversations and audio recordings of re-enactments of the samples with pauses removed were rated for social competence on a six-item scale (coefficient alpha=0.83) by 24 judges. The content of the computer-aided conversations was rated significantly higher than that of the unaided samples ($p < .001$). The judges also rated the individual contributions of the computer-aided communicator and the unaided partners on how ‘socially worthwhile and involving’ these appeared. There was no significant difference between the ratings of their respective contributions ($p > .05$) (Todman et al., 1995).

This finding came as something of a surprise to the researchers, since the original purpose had been to establish whether conversations using pre-stored material would simply be able to equal naturally occurring conversations in quality of content. Of course, the pauses in actual computer aided conversation (removed in the above analsis) do have an effect on listeners’ impressions of the quality of the communication, but this finding is still of interest, since it suggests that in some ways augmented communication could have an edge over naturally occurring talk. A plausible explanation for this finding is that naturally occurring talk is full of high-speed dysfluencies, mistakes, substitutions, and other ‘messy’ features which listeners tend to discount with their ability to infer what the speaker is intending to say. Pre-stored material is by its nature selected because it may be of particular interest, and it is expressed more carefully than quick flowing talk, and thus may appear more orderly and dense with meaning than natural talk.

In addition to conversational narratives, another common structure in everyday communication is the ‘script’, particularly where the speaker is undertaking some sort of transaction. Scripts may be a good basis for organising pre-stored utterances to attempt to overcome the problem of memory load when operating a complex communication system based on a large amount of pre-stored material. Users’ memory load can be reduced by making use of their existing long term memory to help them locate and select appropriate utterances from the communication system. Schank and Abelson (1977) proposed a theory that people remember frequently encountered situations in structures in long term memory which they termed ‘Scripts’. A script captures the essence of a stereotypical situation, and allows people to make sense of what is happening in a particular situation, and to predict what will happen next. Other research (e.g. Vanderheiden et al., 1992) has shown the potential that similar script-based techniques offer to this field.

An initial experiment was devised (Alm et al., 1995) to investigate the potential of a script-based approach to transactional interactions with a communication system, and a prototype system was developed to facilitate this experiment. The aim was to ascertain whether or not a transactional interaction could be conducted using a script-based communication system. It was decided to simulate a particular transactional interaction which could reasonably be expected to follow a predictable sequence of events, i.e. one which would be amenable to the script approach, in order to find out whether a computer-based script could enable a successful interaction.

The transaction chosen for the experiment was that of arranging the repair of a household appliance over the telephone. Although the script interface was a relatively simple one devised for the purpose of this experiment, it was successful in facilitating the interaction, and produced a significant saving in the amount of physical effort required.

To take this work further a large scale project was undertaken to incorporate scripts into a more widely usable device. The user interface of this system is made up of three main components: scripts, rapidly produced speech acts, and a unique text facility. The scripts component is used in the discussion phase of a conversation, and consists of a set of scripts with which the user can interact. The rapid speech act component contains high frequency utterances used in the opening and closing portions of a conversation and in giving feedback, and consists of groups of speech-act buttons. This facility is based on previous work with CHAT. The unique text component is used when there are no appropriate pre-stored utterances available, and consists of a virtual keyboard, a word prediction mechanism and a notebook facility.

To provide access to a set of scripts, an interface was devised which involved a pictorial representation of the scenes in the script. The pictorial approach was taken in order to give users easier access to the stored material, and to assist users with varying levels of literacy skills. In this interface scripts are presented to the user as a sequence of cartoon-style scenes. The scenes give the user an indication of the subject matter and purpose of the script, and assist the user to quickly assess whether the script is appropriate for current needs. Each scene is populated with realistic objects chosen to represent the conversation tasks that can be performed. The user thus receives a pictorial overview of the script, what happens in it, and what options are available. This assists the user to see quickly what the script will be able to do in the context of the current conversation. An example of the interface for the system can be seen in Figure 1, which shows a scene within the 'at the doctor' script (see below).

Research into picture recognition and memory structures has demonstrated that groups of objects organised into realistic scenes corresponding to stereotypical situations better assist recognition and memory compared to groups of arbitrarily placed objects (Mandler and Parker, 1976; Mandler, 1984). The scene-based interface using a realistic arrangement of objects within a scene was therefore chosen to facilitate recognition and remembering by the user and thus reduce the cognitive load required to locate suitable objects during a conversation.

As it would be impractical to provide scripts for every conceivable situation, it was decided to provide users with a limited number of scripts together with an authoring package with which they can develop their own custom scripts with help from their therapists.

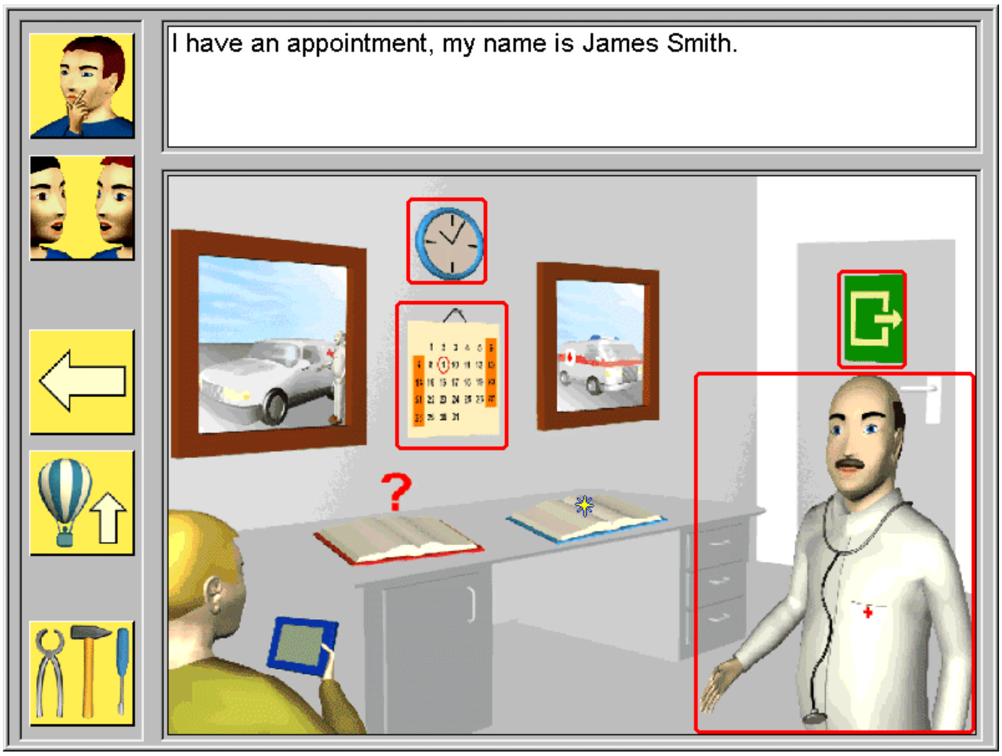


Figure 1: The script system user interface showing a scene from the doctor script

A text preview and display box appears at the top of the user interface. The main interface area (bottom right) contains the scene image. The function buttons on the left side of the interface are, from top to bottom: "I'm listening" rapid speech act button; button to access the main rapid speech act interface; scene navigation backtrack to previous scenes button; scene navigation overview button; tool button to access the notepad and additional system control facilities.

It was initially decided to develop six complete scripts. These were chosen after discussions with a user advisory group about situations in which they found difficulty communicating. The scripts developed were: 'at the doctor', 'at the restaurant', 'going shopping', 'activities of daily living', 'on the telephone', 'meeting someone new' and 'talking about emotions'.

The system uses the script to guide the user through a dialogue. There is a prediction mechanism which predicts the next most probable stage in the dialogue which the user will need (based on the script), so the user can usually follow a predicted path through a conversation.

This prediction mechanism monitors the sequences of objects selected and uses this information to modify future predictions.

Help for aphasia

Communication systems for non-speaking people have been described which in some way model the cognitive processes underlying communication. In the case of most physically disabled non-speaking people this is needed in order to speed up the communication process. However, in the case of speech problems which are caused by a stroke or other trauma (aphasia), the person trying to communicate will also have cognitive problems to deal with. Interestingly, it was the objections that conversation modelling might provide an active prompt to communication that suggested a way of possibly helping people who might need such a prompt in order to initiate communication at all.

In a research project investigating the possibility of prompting people with Broca's aphasia in their communication, a predictive communication system was developed with a very simple interface (Waller et al., 1998). The system held personal sentences and stories which were entered with the help of a carer. The user could then retrieve the prestored conversational items, with the system offering probable items based on previous use of the system. The interface was designed to be as simple as possible, and to be usable by people who were unfamiliar with technology, had language difficulties but had retained the ability to recognise familiar written topic words.

To access the sentences and stories, the user is led through a sequence of choices on the screen. First they are offered a choice of conversational partners, then a list of topics most likely to be appropriate for the chosen partner, then a list of the four most common sentences for that partner and that topic. The user can choose to speak one of the sentences through a speech synthesiser, or have the system look for more suggestions. The sentences and topic categories are personal to each user, and the order in which topic words or sentences are presented depends on the past use of the system. Thus the system is specific to users, both in the information content and how it adapts to individual ways of communicating.

The system was evaluated with five adults with non-fluent aphasia who were able to recognise, but not produce, familiar written sentences. There was little change in the underlying comprehension and expressive abilities of the participants while not using the system. When making use of the system, the results showed that some adults with non-fluent aphasia were able to initiate and retain control of the conversation to a greater extent when familiar sentences and narratives were predicted. In other words, users' existing/residual abilities (e.g. small vocabulary, pragmatic knowledge of conversation), were to a degree augmented by the computer functioning as a cognitive prosthesis. This project indicated that a communication system based on prompting could be of help to people with cognitive and communication difficulties.

Support for non-literate users

Children with complex disabilities may have a combination of physical and intellectual impairments which impact on the development of speech and language. Some individuals will learn to read and write, using this medium in combination with non-verbal means to communicate. Others will use an alternative graphic medium for interaction. One of the drawbacks of providing symbol based communication is the difficulty in providing access to novel vocabulary. The ongoing BlissWord project (Andreasen et al, 1998) is investigating ways in which users with physical and cognitive limitations can explore new vocabulary. Blissymbolics is a semantic-based natural written (pictographic) language, similar to Chinese. Because of its generative characteristics (Bliss words are 'spelled' using a sequence of one or more Bliss characters), predictive algorithms can be applied to Blissymbolics to assist users in the retrieval of words.

Bliss words are sequenced beginning with a classifier (e.g. all emotions begin with a heart). As illustrated in Figure 2, selecting a shape from the Bliss keyboard, the interface produces a list of Bliss words which begin with classifiers using that shape. Frequency and word lists can be used to further refine the Bliss words which are displayed. Users do not need to be literate to explore language and vocabulary. It is envisaged that video clips and spoken explanation could further augment learning through exploration.

Figure 2: Screenshot showing Blissymbol keyboard on left and prediction list on right. The Bliss word for "I/me" has been chosen and is in the sentence pane above. The heart shape has been selected resulting in the prediction of words relating to feelings.

Support for dementia

Dementia, which involves the loss of short term memory in elderly people, is a very serious problem for the person and for their family and carers. It can rule out most social activities and interactions, since these depend on a working short term memory for effective participation. This includes even the essential ability to communicate.

As well as being valuable with all older people, reminiscence is an important tool used to help elderly people who have dementia (Sheridan, 1992; Feil, 1993). This is because, while their short term memory may be impaired, their long term memory is often more or less intact (Rau, 1993). The difficulty is accessing these long term memories without the capability of keeping a conversation going, which depends on short-term memory. What can help are activities that do not require patients to maintain the structure of a conversation, for instance looking at and commenting on a series of photographs, which can provide a framework for meaningful person to person interaction.

The tools used in such reminiscence work can also include videos, sound, music and written materials. However, 'traditionally' these are all in separate media, and it can be very time-consuming searching for a particular photo, sound or film clip. Bringing all these media together into a 'digital' multi-media scrapbook could mean easier access to content for more lively reminiscence sessions. The intention of this project was to begin to develop a system which could act as a 'conversation prosthesis', giving the user the support needed to carry out a satisfying conversation about the past.

An investigation was undertaken to determine which aspects of multimedia would be most helpful for such a reminiscence experience, and the best way to present them. A number of prototype interfaces for a multimedia reminiscence experience were developed. These included text, photographs, videos and songs from the past life of the city. The materials were collected with the assistance of the University, Dundee City archives, and the Dundee Heritage Project. The prototypes were demonstrated for people with dementia and their care staff at a day centre run by Alzheimer Scotland Action on Dementia. The following issues were addressed in these evaluation sessions:

1. *Is it better for the display to use the metaphor of a real-life scrapbook or a standard computer screen?* Six of the staff members preferred the book presentation; three preferred the screen and two had no preference. Interestingly, this was almost a reversal of the preference shown by the people who had dementia, the majority preferring the screen presentation. The preference shown for the screen presentation could be due to reduced cognitive ability. The book presentation is a metaphor which may not be interpreted suitably by the person with dementia.

2. How should the scrapbook material be organised – by subject or by media type? The majority of the staff evaluators preferred the arrangement by subject saying it was more logical, some were unsure, however no-one showed a preference for the arrangement by media. The clients with dementia reflected these findings. Despite preferring the arrangement being by subject the majority of evaluators could see benefits from having access to both arrangements. It was concluded that for basic reminiscence sessions the arrangement by subject is preferable. But access to the arrangement by media should be an option, to make the software available for use in other ways.

3. How do the sounds, pictures, video and, music add to the reminiscence process, and what are their differential effects? Most of the videos and photographs and all the songs were able to spur conversations. However, it was found that with videos the clients were only able to strongly identify with them when they triggered off specific personal memories, whereas songs and photographs were more generally appreciated. Attention remained focused longest with the songs, which were particularly enjoyed when played repeatedly with everyone singing along. The staff did, however, feel that some individual clients had enjoyed the videos most.

One general finding was that the multimedia presentation as a whole produced a great deal of interest and motivation from the people with dementia. The staff were also very keen to see the idea developed further. A new project is now beginning which will fully develop the ideas produced by this preliminary work, and will produce a fully functional multimedia reminiscence system. The project will be carried out by a multidisciplinary team consisting of a software engineer, a designer, and a psychologist specialising in aging.

In addition to its benefits for the person with dementia, participation in reminiscence activities has been shown to have a positive outcome for the carers who take part. Thus help for reminiscence is not only a tool to stimulate interaction, but also a contributor to improved quality of life, for the person with dementia and their family.

Recent work on using videos to present life histories for people with dementia has shown that new technologies, where sensitively and appropriately applied, can bring a substantial added impact to supportive and therapeutic activities for people with cognitive problems (Cohen, 2000). The reminiscence system developed will we hope have the immediate application described above, and will also serve as an exploration in developing a range of computer-based entertainment systems for people with dementia.

Systems to support people with dyslexia

Dyslexia is a language disorder which is still in the process of being investigated and thoroughly understood. A word processing environment has been developed to alleviate some of the visual problems encountered by some people with dyslexia when they read and produce text. In the absence of a full understanding of the nature of dyslexia, however, the researchers' approach was to identify some of the most commonly noted problems which dyslexics. On the basis of these common difficulties, they identified ways in which each individual might be able to minimise the consequences of their own particular problems by manipulating the appearance of their word processing environment and text presented within it. This stage of the development process involved the start of an iterative cycle of prototype development and evaluation with dyslexic computer users. The work led to a software system which provides a highly (and easily) configurable environment for dyslexic people (who experience a very wide range of differing preferences and problems) to use for reading and producing text. The approach was to examine the parameters of the situation, including cost, cost benefit, existing software and user demand, with a view to finding an optimal path to the production of a software system which is of real use in practical situations. It should be noted that while users were extensively involved throughout the development process, the researchers did not always rely directly on their individual inputs for further development; rather they ensured that at all times the process was sensitive to user need and opinion, but informed by relevant sources ranging from documented wisdom about the subject to hunches about what might work.

This development of a word processor to assist dyslexics is thus a particularly illuminating example of how the needs of people with a particular type of cognitive impairment can be effectively factored into the design and development process. This research will thus be described in some depth, as an example of a development and to assist the reader in appreciating the generic importance of this approach, which requires knowledge of the underlying syndrome, and also a methodology which encourages an innovative approach to user involvement.

Dyslexia, as has been noted, is still being investigated as a language disorder, and at present it has a number of definitions. The British Dyslexia Association offers this description:

> “Dyslexia is best described as a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling and writing. Accompanying weaknesses may be identified in areas of speed of processing, short term memory, sequencing and organisation, auditory and/or visual perception, spoken language and motor skills. It is particularly related to mastering and using written language, which may include alphabetic, numeric and musical notation[1].”

The symptoms of dyslexia vary greatly and the reasons for the existence of these symptoms are also varied. However, two distinct types of dyslexia are recognised: acquired dyslexia and developmental dyslexia.

Acquired dyslexia is associated with those people who have difficulties caused by damage to the brain. Therefore, prior to the occurrence of brain damage, no difficulties would have been identified. This area can be subdivided into disorders in which the visual analysis system is damaged - peripheral dyslexia, and disorders in which processes beyond the visual analysis system are damaged, resulting in difficulties affecting the comprehension and/or pronunciation of written words - central dyslexia.

Peripheral dyslexia is associated with difficulties such as misreading letters within words and migrating letters between words. Central dyslexia on the other hand concerns issues such as bad comprehension due to an impaired semantic system, and the inability to read unfamiliar words, whilst familiar words are read easily. Examples would include ‘monkey’ being read as ‘ape’ (a semantic error), and ‘patient’ being read as ‘parent’ (a visual error).

[1] British Dyslexia Association website at; http://www.bdadyslexia.org.uk/faq.html#q1, January 2006

Developmental (or congenital) dyslexia is present from birth but will generally become apparent later, and has been described as follows (Critchley, 1964):

> "Developmental dyslexia is a learning disability which initially shows itself by difficulty in learning to read, and later by erratic spelling and by lack of facility in manipulating written as opposed to spoken words. The condition is cognitive in essence, and usually genetically determined. It is not due to intellectual inadequacy or to lack of sociocultural opportunity, or to emotional factors, or to any known structural brain defect."

One of the main features of dyslexia is the individual nature of the disorder. The condition is not typically characterised by one single difficulty, but by a range of difficulties which will vary in combination and in intensity between individuals, giving rise to an enormous variation between individuals in the problems encountered. Each dyslexic person thus has a range of difficulties which need to be addressed differently from those of others. Dyslexia is an example of the need to design for dynamic diversity.

The wide ranging characteristics of dyslexia provide a challenge for technological assistance, as a single approach will not be appropriate for the range of problems presented by the population of dyslexic people. Computer technology offers the opportunity to provide reading and writing systems which are highly configurable for each individual user but they need to be based on an understanding of the problems which dyslexics have in reading and writing, and some of the visual problems which can affect them. The approach adopted in this research was to offer dyslexic users a range of appropriate visual settings for the display of a word processor, together with the opportunity to very easily configure the way in which text is displayed to them. The user can select, by experimentation, the settings which best suit them. These settings are then saved and later recalled each time that person uses the word processor. It will be seen that this approach affords the potential to make computer based text significantly easier to read than printed text, as well as improving the usability of computer word processing systems for a wide range of dyslexics.

Some common problems of dyslexia

It was first necessary to determine the parameters which should be offered for configuration by the user. An initial investigation revealed that some of the most commonly encountered problems are as follows (adapted from Willows, Kruk,& Corcos, 1993 and Shaw, D. 1994, private communication):

1. *Number and letter recognition* .One of the fundamental problems faced by dyslexics is the recognition of individual alphanumeric symbols. This is often seen when letters which are similar in shape, such as ‘n’ and ‘h’, ‘f’ and ‘t’, are confused. The problem is exacerbated with the introduction of uppercase letters. In addition, many dyslexic adults, who are capable of reading printed letters, have difficulty in reading cursive writing.

2. *Letter reversals*. Many dyslexics are prone to reversing letters, which results in a particular letter being interpreted as another letter. Examples of these characters would be ‘b’, ‘d’, ‘p’ and ‘q’. This problem can result in poor word recognition with words containing reversal characters being substituted for other words such as ‘bad’ for ‘dad’.

3. Word recognition. As well as the substitution effect caused as a result of letter reversals, words which are similar in their outline shape (word contour) can be substituted by dyslexics. Typical examples of this problem are the words ‘either’ and ‘enter’. Both words have the same start and finishing characters and this, allied with their similar word contours, make them candidates for being substituted for each other when they occur in the text.

4. Number, letter and word recollection. Even if the ability to recognise numbers and letters is adequate, it can still prove difficult for a dyslexic individual to recall the actual form and shape of a character. Many dyslexics have so much difficulty recalling upper and lower case characters that they continue to print later in life. Similarly, poor visual memory means that dyslexics have little ability to distinguish whether or not a word 'looks right' or not.

5. Spelling problems. Due to the problems discussed in *1-4* above, dyslexics can have great difficulty with spelling and many dyslexics have very poor spelling. Much of the spelling of dyslexics appears to reflect a phonic strategy with words like 'of' and 'all' being spelt 'ov' and 'ohl'.

6. Punctuation recognition. As with characters, dyslexics appear to have difficulty recognising punctuation marks.

7. Saccadic and fixation problems. Another problem which is found in many dyslexics is their lack of ability to follow text without losing their place. Many find it difficult to move from the end of one line to the beginning of the next and also find themselves 'getting lost' in the text.

8. Word additions and omissions. Dyslexics may add or remove words from a passage of text, apparently at random. This is manifested by words being omitted or duplicated, extra words being added, or word order being reversed or otherwise 'jumbled'.

9. Poor comprehension. With the variety of errors caused by the factors described above, a dyslexic person may perceive a totally different (or 'impoverished') passage of text from the one which is actually in front of them. Dyslexics thus display poor comprehension skills due to text which they perceive being significantly different from the actual text.

Computer aid for the problems of dyslexia

In an attempt to alleviate some of the problems discussed above, dyslexics, particularly within the education system, are encouraged to use computers for text manipulation. The use of a computer keyboard has the potential to alleviate the problems of character recollection, but this only really helps with the recollection of characters, not the recognition of them once they are on the screen.

There is, however, strong evidence to suggest that the use of lexical and spelling aids can greatly assist with spelling problems exhibited by dyslexics (e.g. Newell & Booth, 1991). Merely highlighting an incorrect word and offering a replacement, however, may not be enough, since one of the other problems which some dyslexics face is an inability to tell if a word 'looks right', thus they will have difficulty selecting the appropriate correction(s).

Some dyslexics are sensitive to colour, and coloured acetate screens or tinted glasses as well as lighting conditions can improve their ability to read text. Many dyslexics also report interference from peripheral vision, indicating that anything that can be done to reduce screen 'clutter' outside the main screen window, such as making the document 'page' fill the whole screen, may be of benefit (Shaw, D. 1996, private communication).

Based on the above difficulties encountered by dyslexics, the researchers considered ways that the screen image of the text could be manipulated. These included, foreground and background colour, character typeface, font and spacing, making letters or words with similar shapes distinguishable by using different fonts, sizes and/or colours, and presenting text in narrower columns, or with different spacing between words and/or lines to reduce saccade and fixation problems. The researchers investigated potentially promising ideas by implementing prototypes and evaluating their utility with dyslexic users, with an overall view to developing a configuration system which will enable all dyslexics to set up their own optimised environment

An experimental text reader for dyslexics

The first stage of the research was to develop an experimental text reader. This prototype presented the user with an easily configurable interface which allowed for a number of display variables to be altered. Initially, these were background, foreground and text colours, font size and style, and the spacing between paragraphs, lines, words and characters. The interface was designed in such a way that it gave visual feedback on selections before they were confirmed and made minimal use of text instruction.

This was evaluated using twelve computer literate dyslexic students from higher education using 'think-aloud' techniques, as well as questionnaires and interviews. At various development stages, the helpers were asked to try out the system with a view to seeing if it was possible for them to put together a display which improved their ability to read text from the screen. All the users were able to find a setting which was subjectively superior for them to standard black text on a white background with Times Roman 10 or 12 point text, but the screen layouts which were developed by the test subjects were extremely varied. This highlighted the individual nature of the disorder, and the diverse characteristics of any interface which would be appropriate for this group.

Each appeared to have their own favourite colour combination, although brown text on a green background was liked by all the testers. Subjects were in greatest agreement about the selection of a typeface: the sans-serif Arial was rated the best by almost all the testers. All reported that increasing the spacing between the characters, words and lines was beneficial. The most interesting point which arose during the testing, however, was the fact that at the beginning of the evaluation period the dyslexic subjects did not appear to be aware that altering these variables might be of any use.

A second prototype was then developed based on Word for Windows (Microsoft, 1994) macros (Microsoft, 1995) to provide the required configuration interfaces. This was based on the concept of an evolutionary system, rather than a fixed prototype. It was clear that there would be a substantial advantage in developing a ‘dyslexic configuration’ but this design decision raised an interesting deviation from the received wisdom of the desirability of WYSIWYG (*What You See Is What You Get*). In the case of a dyslexic user, what you see should be whatever you can read best, and print previewing facilities would have to be used to show how the layout will appear when printed.

This prototype provided a facility to enhance characters prone to reversals (e.g. ‘b’, ‘d’), by using colour font type and size. This idea of colouring reversal characters provided very interesting and unanticipated results, which are described below. Fixation problems were tackled by reducing the page width, and a speech synthesiser which could read the text on the screen was also included.

There were two distinct parts to the overall solution, a ‘preference’ program and a reading/editing program. The first allowed users to experiment with the various parameters and the second made use of these preferences within a reading and editing environment. The preference program menu presents the user with various options and variables, together with a preview facility, to enable the user to experiment with, and finally store their data in a ‘preferences’ file .

The fact that a unique user environment, tailored to the need of each individual is provided means that the document is (deliberately) not WYSIWYG. A print option thus allows the user to print the document as it appeared with their preferred formatting applied to it, or as it would appear without any special formatting.

This second prototype was developed as an add-on module to Microsoft Word, and was evaluated by seven dyslexic users with an age range of 15 to 30 years, in a similar fashion to that above. The users found the system easy and intuitive to use, reporting that each of the options had an effect on their ability to read. The options which allowed the user to change the colour scheme of the document appeared to be the most helpful, but font size and spacing, column width and indications of reversals were also reported to assist reading by some or all of the users.

The reversals option provided the most interesting results of all. The reason for the improvement however was not always that the reversal characters were clearly distinguished and easy to read. Instead it was claimed that the sporadic colouring “broke the text up” and resulted in the user being less likely to “get lost”, i.e. the system was reducing fixation problems rather than recognition problems.

As the testing progressed the testers appeared to be surprised at times by the effect some of the changes had on their ability to read the document. Comments included: “I would never have thought of doing that”, or “I don’t think that will do me much good” before finding a feature did indeed help.

The prototypes were developed from the perspective that the user population was diverse, and that the design process must accommodate potential changes in preferences over time. The fact that dyslexia is a very idiosyncratic disorder and findings that the users were often unaware of how easy it was to improve their reading potential by changing visual aspects of the reading environment, illustrates how a standard user centred design methodology is not appropriate for such user groups.

Research methodologies

The research described above gives a flavour of successful approaches to developing human interfaces and software to support people with various types of cognitive impairment. Much of the methodology used in these developments, however, had to be developed *ab initio*. Traditional User Centred Design does not have the flexibility for these user groups, and most research and development in the field of communication and information technology to support people with disabilities has, to date, concentrated on the development of special 'assistive' systems and on accessibility features for younger, mainly physically or sensorially disabled people. Similarly the human interfaces to most computer systems for general use have been designed, either deliberately or by default, for a 'typical', younger user (Newell & Cairns, 1993; Newell, 1995; Newell & Gregor, 1997). Knowledge from these fields does not necessarily transfer comfortably to the challenges encompassed in universal design (Beirmann, 1997; Hypponen, 1999; Sleeman, 1998; Stephanidis, 2001) and, in particular, the widely varying and often declining abilities associated with the range of cognitive impairments.

This section addresses the particular issues for the design process which accompany cognitive impairment and suggests a paradigm and methodology to support the process of designing software which is as near to the universal accessibility ideal as is possible, derived from the approach to specific projects described above.

Software systems, which are aimed at the 'mainstream' (rather than being of a 'prosthetic' nature) need to address the wide variation in the types and severity of cognitive impairment between individuals. This demand is further complicated by the fact that, in general, as people grow older their abilities change. This process of change includes a decline over time in the cognitive, physical and sensory functions, and each of these will decline at different rates relative to one another for each individual. This pattern of capabilities varies widely between individuals, and as people grow older, the variability between people increases. In addition, any given individual's capabilities vary in the short term due, for example, to temporary decrease in, or loss of, function due to a variety of causes, such as the effects of drugs, illness, blood sugar levels and state of arousal.

This broad range and variability of change presents a fundamental problem for the designers of computing systems, whether they be generic systems for use by all ages, or specific systems to compensate for loss of function. Systems tend to be developed for a ´typical user` and either by design or by default, this 'user' tends to be young, fit, male, and crucially, has abilities which are static over time. These abilities are assumed to be broadly similar for everybody. Not only is this view wrong, in that it does not take account of the wide diversity of abilities among the wider population of users, but it also ignores the fact that for individuals, these abilities are dynamic over time.

Current software design also typically produces an artefact which is static and which has no, or very limited, means of adapting to the changing needs of users as their abilities change. Even the user-centred paradigm (e.g. ISO 13407, 1999; Nielsen, 1993; Preece, 1994, Shneiderman, 1992) looks typically at issues such as representative user groups, without regard for the fact that the user is not a static entity. It is thus important not only to be aware of the diverse characteristics of people with cognitive dysfunction, but also the dynamic aspects of their abilities.

It is clear that people with cognitive impairments, whatever their cause, can have very different characteristics to most human interface and software designers. It is also clear that in these circumstances User Centred Design (UCD) principles need to be employed if appropriate technology is to be developed for this user group (Gregor & Newell, 1999). These methodologies, however, have been developed for user groups with relatively homogonous characteristics. People with dementia, for example, are a diverse group and even small subsets of this group tend to have a greater diversity of functionality than is found in groups of able young people.

An additional complication is that there can be serious ethical issues related to the use of such people as participants in the software development process. Some of these are medically related, but also include, for example, the ability to obtain informed consent. It is thus suggested that the standard methodology of User Centred Design is not appropriate for designing for the inclusion of this user group. The importance of research and development taking into account the full diversity of the potential user population, including cognitive diversity was addressed by Newell in his keynote address to InterCHI '93, where the concept of 'Ordinary and Extra-ordinary Human Computer Interaction' was developed. (Newell 1993, Newell & Cairns ,1993, Newell & Gregor, 1997).

Market share is clearly an important consideration and this has been given impetus, not only by demographic trends, but also by recent legislation in the US, and other countries, on accessibility of computer systems for people with disabilities. In terms of the workplace, both the Americans with Disabilities Act and the UK Disability Discrimination Act put significant requirements on employers to ensure that people with disabilities are able to be employed within companies and to provide appropriate technology so that such employees had full access to the equipment and information necessary for their employment. Increasingly there is political pressure to increase this access, and more and more requirements for improved access by disabled people are being enshrined in legislation. However, 'access' does not only mean that people with wheelchairs can manoeuvre round buildings, it also means that there needs to be provision for people with cognitive (and sensory and other physical) impairments to be able to operate computers and other equipment essential to the workplace.

An important additional factor in the ‘value for money’ equation is that design which takes into account the needs of those with slight or moderate cognitive dysfunction can produce better design for everyone. An example where this has not occurred is illustrated by the problems that the majority of users have had with video tape recorders. If the designers had considered those with cognitive impairments within their user group, it is possible that they may have been able to design more usable systems.   Another example is an email system specifically designed to be simple to use by older people with reduced cognitive functioning, which was found to be preferred by executives to the standard email system which they were used to.

Some people are impaired from birth, but some may become temporarily or permanently disabled by accident or illness (suddenly or more slowly), or even by normal functioning within their employment. This is particularly noticeable in cognitive functioning. Short term changes in cognitive ability occur with everyone. These can be caused by fatigue, noise levels, blood sugar fluctuations, lapses in concentration, stress, or a combination of such factors, and can produce significant changes over minutes, hours, or days. In addition, alcohol and drugs can also induce serious changes in cognitive functioning, which is recognised in driving legislation, but not in terms of how easy it is to use computer based systems.

Most people at one time or another, will exhibit cognitive functional characteristics which are significantly outside the normal range. Although neither they, nor their peers, would consider these people disabled, their ability to operate standard equipment may well be significantly reduced.

The questions which designers need to consider include:

- Does the equipment which I provide comply with the legislation concerning use by employees who may be cognitively disabled?

- To what extent do I need to take into account the needs of employees who are not considered ‘disabled’, but have significant temporary or permanent cognitive dysfunction?

- Should I make specific accommodation for the known reductions in cognitive abilities which occur as employees get older (e.g. less requirement for short term memory, or the need to learn new operating procedures)?

- What are the specific obligations designers and employers have to provide systems which can be operated by employees whose cognitive ability has been reduced due to the stress, noise, or other characteristics of the workplace.

The argument is that it would be very unusual for anyone to go through their working life without at some stage, or many stages, being significantly cognitively disabled. If equipment designers took this into account, it is probable that the effectiveness and efficiency of the work force could be maintained at a higher level than would be the case if the design of the equipment was based on an idealistic model of the characteristics of the user and their work environment.

The disabling environment

In addition to the user having characteristics which can be considered ‘disabled’, it is also possible for them to be disabled by the environments within which they have to operate. Newell & Cairns (1993) made the point that the human machine interaction problems of an able bodied (ordinary) person operating in an high work load, high stress or otherwise ‘extreme’ (i.e. extra-ordinary) environment has very close parallels with a disabled (extra-ordinary) person, operating in an ordinary situation (e.g. an office).

High work loads and the stress levels to which this can lead often reduce the cognitive performance of the human operator. For example, a very noisy environment can not only create a similar situation to hearing or speech impairment, but can also lead to reduced cognitive performance. The stress level in the dealing room of financial houses can be very high and is often accompanied by high noise levels. A significant advance may be made if the software which was to be used in these houses was to be designed on the assumption that the users would be hearing impaired and have a relatively low cognitive performance. It is interesting to speculate as to whether such systems would produce higher productivity, better decision making and less stress on the operators. Other examples of extreme environments in which people have to operate are the battlefield, under water or out in space. The stress and fatigue caused by working within such environments means that their performance is similar to that which could be achieved by a very disabled person operating in a more normal environment. It is not always clear that the equipment such people need to operate has been designed with this view of the user.

It is very important to describe the users of technology in terms of their functional ability related to technology rather than generic definitions of either medical conditions, or primarily medical descriptions of their disabilities. Unfortunately most statistical data is presented as generic and medically categorisations of disability. Gill and Shipley (1999), however, did define disabled user groups in terms of their functional ability, with specific emphasis on the use of the telephone. They estimated that within the European Union, which has a population of 385 million, there were 9 million people with cognitive impairment which could lead to problems using the telephone. Theses figures do not take into account multiple impairments, and the authors point out that, in the elderly population in particular, there may be a tendency towards cognitive, hearing, vision and mobility impairments being all present to a varying extent, and these may interact when considering the use of technological systems. It is this multiple minor reduction in function (often together with a major disability) which means that the challenges to technological support for older people has significantly different characteristics to that of younger disabled people, and to the non-disabled non-elderly population.

There has been some movement in mainstream research and development in technology, both in academia and industry away from a technology led focus to a more user led approach, and this has led to the development of User Centred Design principles and practices in many industries. In addition a number of initiatives have been launched to promote a consideration of people with disabilities within the user group in mainstream product development teams with titles including: 'Universal Design', 'Design for All', 'Accessible Design', and 'Inclusive Design'. The 'Design for All'/'Universal Design' movement has been very valuable in raising the profile of disabled users of products, and has laid down some important principles. This approach however has tended not to place too much significance on cognitive impairment, and, particularly if this is included as a factor in the design process, then it becomes more difficult to use 'traditional' user centred design approaches.

Newell and Gregor (2000) have suggested that a new design approach should be developed, which would be based on the already accepted User Centred Design Methodology. There are some important distinctions between traditional User Centred Design with able-bodied users, and the approach needed when the user group either contains, or is exclusively made up of, people with cognitive dysfunction. These include:

- Much greater variety of user characteristics and functionality
- The difficulty in finding and recruiting 'representative users'
- Situations where 'design for all' is certainly not appropriate (e.g. where the task requires a high level of cognitive ability)
- The need to specify exactly the characteristics and functionality of the user group

- Conflicts of interest between user groups, including temporarily able-bodied
- Tailored, personalizable and adaptive interfaces
- Provision for accessibility using additional components (hardware and software)

The balance in the design process also needs to shift from a focus on user needs, to one on the users themselves. There will be additional problems when considering people with cognitive dysfunction, which will include:

- The lack of a truly representative user group
- That a different attitude of mind of the designer is required
- Ethical issues (Alm, 1994; Balandin & Raghavendra, 1999)
- It may be difficult to get informed consent from some users
- Difficulties of communication with users
- The users may not be able to (sufficiently) articulate their thoughts, or even may be 'incompetent' in a legal sense

Thus there can be particularly difficult ethical problems when involving users with cognitive impairments in the design process. In addition, it is often necessary to involve clinicians when such users are involved, so some of the 'user centred design' actually focuses on professional advice about the user, rather than direct involvement of the user. Even with these problems, however, it is possible to include users with cognitive dysfunction sensitively in the design process.

The inclusion of users with disabilities within research groups

In Dundee users with disabilities have a substantial involvement in the research, and they have made a significant contribution both to the research and to the commercial products that have grown from this research. There are two major ways in which users are involved:

- As disabled consultants on the research team, where they act essentially as 'test pilots' for prototype systems, and
- By the traditional user centred design methodology of having: user panels, formal case studies, and individual users who assess and evaluate the prototypes produced as part of the research.

The contribution made by clinicians is also vital to the research, and these are full members of the research team. Dundee's Applied Computing Department is also one of the few Computing Departments that has employed speech therapists, nurses, special education teachers, linguists and psychologists (both 'clinical' and 'cognitive').

User Sensitive Inclusive Design

Some significant changes must be introduced to the User Centred Design paradigm if users with disabilities are to be included, and this is particularly important if the users have cognitive impairment. In order to ensure that these differences are fully recognised by the field, the title 'User Sensitive Inclusive Design' has been suggested. The use of the term 'inclusive' rather than 'universal' reflects the view that 'inclusivity' is a more achievable, and in many situations, appropriate goal than 'universal design' or 'design for all'. 'Sensitive' replaces 'centred' to underline the extra levels of difficulty involved when the range of functionality and characteristics of the user groups can be so great that it is impossible in any meaningful way to produce a small representative sample of the user group, nor often to design a product which truly is accessible by all potential users.

Design for Dynamic Diversity

In addition to the aspects of user sensitive inclusive design described above, it is necessary to make designers fully aware of the range of diversity which can be expected with cognitively impaired people, and also the changing nature of the cognitive functioning of people. It has thus been suggested by Gregor & Newell (2000) that this be drawn particularly to the attention of designers by introducing the concept of *Designing for Dynamic Diversity*. This process, described above, entails recognition that people's abilities are diverse at any given age and that as they grow older this diversity grows dynamically; it also involves a recognition that any given individual's abilities will vary according to factors such as mood, fatigue, blood-sugar levels and so on. Only by taking on board the factors associated with Designing for Dynamic Diversity will software design produce artefacts which are not static and which have no, or very limited, means of adapting to the changing needs of users as their abilities change.

As has been seen above, metaphors and processes in use at present are limited in meeting the needs of this design paradigm or addressing the dynamic nature of diversity. New processes and practices are needed to address the design issues; awareness-raising among the design, economic and political communities has to start; research is needed to find methods to pin down this moving target.

A story-telling metaphor

In addition, researchers need to consider how best to disseminate the concepts behind universal usability and the results of User Sensitive Inclusive research. User Sensitive Inclusive Design needs to be an attitude of mind rather than simply the mechanistic application of 'design for all' guidelines. This offers a further challenge to the community.   The dangers of using such studies to produce more extensive guidelines has been referred to above, but it is important that the results of User Sensitive Inclusive Design are made available to other designers and researchers. It is, however, too early to be able to lay down principles and practices that must be followed by designers, and it may even be impossible to do this for some of the contexts and environments in which designers work. It is thus suggested that we follow a story telling approach, in which information about accessibility issues, and design methods which focus on accessibility is presented in narrative form, with particular examples to illustrate generic principles. This is, in some sense, an extension of the single case study methodology. This methodology could provide very useful insights to designers in a form that they will find easy to assimilate and act upon. This will thus assist in their education, and will help them to design more accessible products, and better products for everyone.

The use of theatre

As an extension of the story telling metaphor, the research group in Applied Computing at Dundee University has investigated the use of dramatic techniques and theatre as a way of addressing the challenges of user sensitive design. For example, as part of the UTOPIA (Usable Technology for Older People: Inclusive and Appropriate) project, they worked in collaboration with the Foxtrot Theatre Company to use theatre to encourage interaction between (older) users of technology and designers.   The outcome was the “UTOPIA Trilogy”, a series of short video plays addressing problems older people have in using technology (Carmichael et al, 2005). The films were dramatizations of some of the issues the researchers had encountered during the project. Based on real events, conversations and observations, they were the amalgamation of many and are intended to convey older people’s experiences with technology and the situations they encounter. These videos were evaluated with a variety of audiences including academics, practitioners, software engineers, relevant groups of undergraduates, and older people. This established that the videos provided a useful channel for communication between users of technology and designers, and changed the perceptions of both students and more mature designers of IT systems and products about older people's requirements. A similar technique has also been used in the requirements gathering phase for an IT system designed to monitor older people in case of falls at home (Marquis-Faulkes et al, 2003)

This research has shown that the use of theatre can be a very powerful method of encouraging dialogue between various professional groups particularly in a clinical environment, for keeping a focus for discussions, and also for providing a channel for communication between users of technology and designers. The researchers view is that the success of this approach was in large part due to the plays being narrative based rather than having a pedagogic style. That is, they illustrated the issues involved within interesting story lines, with all the characteristics of a good narrative - humour, tension, 'human interest', antagonists and protagonists. In addition the quality of the production, having been produced by theatre professionals, played a major part in the success of the venture.

Newell et al (2006) discuss the various ways in which actors and theatre can play a part in the design process for human computer interfaces. This could provide a particularly valuable methodology for the design process when the target users have cognitive impairment and thus may not be appropriate for including within standard user centred design methodologies.

Conclusion

Although it is not necessary for human interface designers whose systems may be used by people with cognition impairment to be fully versed in all aspects of cognition, it is important for them to have some background knowledge of the area. They should also be in contact with experts in other disciplines, such as psychology, and have access to appropriate clinical knowledge. In addition, the development of the concept of and a methodology for, User Sensitive Inclusive Design, Design for Dynamic Diversity, and development of story telling methods for communicating results, will facilitate researchers in this field, and also provide mainstream engineers with an effective and efficient way of including people with disabilities within the potential user groups for their projects. If both of these, can be achieved it will go some way towards providing appropriate technological support for people with cognitive impairment.

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http://www.stakes.fi/include

http://www.trace.wisc.edu

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