DESIGNING INTELLIGENT INTERFACES FOR USERS WITH MEMORY AND LANGUAGE LIMITATIONS

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Aphasiology, vol. 14, 2000

ABSTRACT

The main contribution of this paper is to discuss in depth the issues related to the design of computer interfaces for users with language limitations. Language limitations are found to various degrees in different users because of their age or health. In this paper, one of the largest applications of human-computer interaction, the Internet, is explored. This paper will discuss syntactic and semantic language limitations in brief and their implication on human computer communication. A number of solutions are offered that will lead to intelligent interfaces that facilitate not only visual needs of the user, but also their language needs.

Keywords: Language Limitations, Interface Design, Internet, Hypertext

1. MOTIVATION

The main motivation for this paper comes from previous work done by several researchers in the areas of language, psychology and communication. In the broad area of Human Computer Interaction (HCI), one of the main aim is to facilitate the communication link between humans and computers through intelligent means. In the past, several experimental and theoretical issues have been raised on the design of visual interfaces. Such issues are important for better usability and productivity of computer systems. However, the area of language has been largely ignored because of its immense complexity and subjectivity. Till now, that is. The Internet growth in all areas of our working life has spurred concerns on issues including security, networking, interface development, and information management. The information management domain may be broken up into three separate areas; information retrieval and information extraction, databases and software systems, and text analysis. The text analysis area still remains a virgin territory for investigation.

There is one critical issue: what are the methods and tools by which natural language manipulation or sophisticated interface development in Internet systems can give us enhanced communication abilities? These abilities are vital to the use of hypertext systems on a large scale where at present we have no standards, no consistency and no source responsibility. In this paper, we do not propose to give extended numerical results or offer solutions to all issues in natural language analysis for HCI. Perhaps there are more questions to ask than answer. The main contribution will be asking these difficult questions, and offering a concise list of solutions proposed by several researchers including the author to solve some fundamental problems in the design of interfaces and software systems that support these interfaces for hypertext systems. An extended description of our literature survey in the area of natural language impairments appears in the Journal of Communication paper (Singh et al., 1998). In this paper, we will focus specifically on language limitation of elderly and normal adult users and highlight their communication difficulties with hypertext Internet type systems. We will then explore possible solutions for generating visual, cognitive and linguistic aids through sophisticated interface design. The recommendations and discussion is also of value to a range of users with language limitations.

The overall paper is structured as follows. Section 2 describes various language limitations of normal elderly adults. These problems are compounded with stroke or illness affecting language production and comprehension. Section 3 discusses language problems in the context of using Internet. Word, sentence, and text-level problems are considered. In section 4, some solutions to query formulation and text understanding are proposed. This section also discusses in detail the visual presentation of information to users and the use of cues in different modalities to aid text understanding. Section 5 proposes a detailed list of tools that are needed for developing an intelligent interface for hypertext use by language limited users. This section forms the basis of proposal for future research in this area.

2. LANGUAGE LIMITATIONS OF HYPERTEXT USERS

In this paper we discuss two types of language limitations: those directly related to age and those related to anxiety and stress. For both cases we briefly summarise language limitations with the understanding and use of natural language.

2.1 Aging

Word finding

Word-finding problems are usually experienced by normal subjects over the age of sixty-five, (Burke et al., 1991). It is commonly observed that subjects over the age of fifty-five complain of difficulties with remembering names, dates and specific words. Normal adults above this age also produce sentences in writing which are syntactically simpler, (Kemper, 1992). It is not clear whether performance improves on reading tasks which are syntactically simpler.

Kempler and Zelinski (1994) argue that lexical knowledge is not degraded with age. However, there is an increased delay in its retrieval. Also, the errors made by normal adults are generally circumlocutions (e.g. "tea drinking pot" for "kettle") rather than semantic approximations as in the case of AD subjects (e.g. "plate" for "kettle"). This indicates that the semantic boundaries between words remain intact with aging. Word-finding problems in normal adults can be attributed to reduction in their working-memory capacity rather than a fundamental disruption of the lexical component of language as in dysphasia and AD. Kempler and Zelinski state:

"In normal aging, there is mild word-finding difficulty, attributed to decreased lexical retrieval. In dementia, decreased lexical access also exists, but two differences are apparent. First, the frequency of word-finding problems in itself sets the two groups apart. In normal aging, occasional anomia is observed: in the diary study of tip-of-the-tongue experiences (Burke et al., 1991), the frequency of such problems was about seven times a month for older people and four times a month for young people. By contrast, in dementia, word-finding difficulty can be a prominent symptom, occurring in every utterance... Since anomia creates a functional disability in dementia, but not in normal aging, the quantitative difference between the two has a qualitatively different consequences" (p. 338).

Hence, word-finding problems in normal aging are of a different kind than those observed in dysphasia and dementia, e.g. in dysphasia the selection of both open and closed class words depends on their frequency, whereas in normals, only open class lexical items are accessed depending on their frequency. They appear to be more dependent on lack of concentration and reduced efficiency of the working memory.

Syntax

There is little change in the knowledge of syntax as we grow old. However, there are some subtle changes. Kemper (1987) notes that normal subjects in their twenties use most sentences which have *three* clauses in them, whereas this number is halved by the time they are in their seventies. This does not imply that normal adults lose their syntactic capabilities with age, but rather they prefer to use simpler constructions. This simplification of syntax with age has been taken as support for the hypothesis that simpler structures stress memory to a lesser extent and are easier to process. Sentence comprehension, which requires the co-ordination of the working memory with the long-term memory, is facilitated with simpler syntax. In case the working memory store is reduced with age, as is often speculated, then only a limited amount of information can be processed in parallel. A compound sentence requires detailed processing (e.g. the sentence "We went to the market where we bought a bicycle and gave it as a present to David", needs a considerably large working store/ memory buffer to be processed. A simpler representation would be: "We went to the market. We bought a bicycle there. We gave the bicycle to David. It was a gift."). Normal adults often have problems holding subordinate clauses in their memory whilst processing the main clause: this problem can be solved by breaking up a compound sentence into simpler phrases. When there is no substantial memory demand, there is no decrease in syntactical ability.

2.2 Stress and anxiety

The effects of anxiety in language production in communication disorders, and for normal subjects, has been discussed by Cook(1969). Subjects with language disorders are vulnerable to high levels of anxiety. In the context of subjects using hypertext, e.g. as in Internet, transient anxiety can be caused due to long search times or whilst formulating searches. Anxiety can be caused because of misunderstanding information or as a result of not understanding system functioning or system messages, e.g. "What will happen if I click on the *Back* icon?" "Will I lose all my information?" "Should I click now or later?" Although the normal subjects are quite capable of controlling their anxieties during work, the same cannot be said of language disordered users who easily get frustrated with their efforts. In summary, computers offer little support specific to language disordered users with memory and attention constraints.

Preece et al. (1994) have discussed the concepts of "focused" and "divided" attention in the context of human-computer interaction. It is important for the user to have focused attention in order to reduce excessive load on their working memory. This is a direct function of time and the number of activities being performed at any one time, thus implying better attention with shorter search times and reduced information content on the screen. Preece et al. have recommended several methods of focusing attention at the interface such as: structuring information, providing spatial and temporal cues, manipulating screen layout and colour, and the use of altering techniques including flashing and reverse video, and auditory warnings. The use of *cognitive aids* as reminders is a particularly relevant suggestion based on implementing various strategies to remind the users of the actions they need to perform at a later stage. Furthermore, the command and icon names are of crucial importance: we have to ask ourselves whether the icons used on the Internet, e.g. Netscape screen, are *objective*, *familiar*, *non-confusing*, *meaningful*, etc. (the icons are *Back*, *Forward*, *Home*, *Reload*, *Images*, *Open*, *Print*, *Find*, *Stop*). At present, there can be less support for the argument that language disordered users will understand the functioning of these icons without training. Screen layout also contributes to the success or failure of focusing user attention for a long period of time. It is recommended by Preece et al. that important information should be presented with larger fonts and should always be displayed at a prominent place to catch the user's eye. Less important information could be allocated to less prominent places which the user is aware of in case of need.

Anxiety and stress are products of everyday interaction between humans and computers, and despite the fact that most of the software and hardware systems are not best designed, we do manage to operate at degraded, yet accepted, level of performance. For normal subjects, who have experience with computers, HCI issues are secondary in their importance compared to the basic functioning of the system. On the contrary, without addressing such secondary issues for language disordered users, computer systems cannot be used by them. It is not the aim of this paper to detail all relevant issues of software design here but it should be stressed that considerable research needs to be undertaken in this area to test novel prototypes that are built specifically for people with language disorders. In addition, we need to address in detail how we can minimize the stress and anxiety caused to the users when interacting with the Internet. Above all, there is an urgent need to develop standards for the structure and display of information on Internet interfaces.

3. HYPERTEXT UNDERSTANDING

The understanding of web information can be mentally exhausting for users that have language limitations due to their age (elderly users), health (users with an illness that affects language) or mental state (stress or anxiety). We will refer to such users as 'language limited' in the remainder of this paper. According to Preece et al. (1994), the process of text understanding is heavily dependent on two key factors: memory and attention. There are several word level and sentence level problems that emerge when the functioning of this normal model is disrupted. We list below a set of generic language related problems encountered by elderly users when reading hypertext in its traditional form. Most of the problems discussed here may seem to be generic for all types of text including paper-based material. A close inspection will however reveal that this problem is rather compounded for hypertext where different text links come from different authors and a single piece of text may not be necessarily uniform in its writing style. In addition, a large quantity of information on the Internet is not uniform with respect to its formatting and presentation thus making it difficult for users with special linguistic needs to adjust to this change.

3.1 *Word level problems when reading hypertext*

(i) Most of the words used in the text are unknown to the user, too technical or abstract to encode.

(ii) The same word appears with many different meanings.

(iii) Most of the words used are of low frequency, not familiar to the user.

(iv) Words used are of increasingly high semantic specificity.

(v) Words used have low imageability content.

(vi) Words used are difficult to pronounce and spell.

(vi) Words used are addressed as “It,” “That,” etc., without reinforcing their original reference.

(vii) Adjectives are ambiguous or imprecise.

(viii) The meaning of words used is over-contextualised.

3.2 *Sentence level problems when reading hypertext*

(i) Most of the sentences are passive rather than active.

(ii) The sentences are reversible: these can be easily misunderstood.

(iii) The sentences are long and compound.

(iv) The order of words in the sentence does not assist in its understanding.

(v) The sentences have more than one meaning.

(vi) The information in the sentence is not a real world possibility, but intended metaphorically.

(vii) The meaning of sentences is not clear.

(viii) Most of the words in a given sentence are semantically unrelated.

(ix) Sentences are self-contradictory and confusing.

(x) The words are used in an abstract manner.

(xi) The sentences require detailed processing with respect to temporal and spatial information in them.

(xii) The information content is either imprecise or uncertain.

The above list highlights a few of the problems that might be encountered by users with language limitations when reading hypertext. It is important to realise, that as a consequence, the reading process will be slower and response times longer. Also, too much information input at any one particular time (long sentences) would be obstructive to the reading performance, as for example when sentence structures contain too many propositions (Kintsch & Keenan, 1973). The size and presentation of information are important issues: reading a larger piece of text requires attention and detailed information processing, whereas a much smaller piece may be confusing. Also, proper structuring of the information is necessary to direct attention at relevant paragraphs. We will discuss some of these issues in later sections.

3.3 *Psycholinguistic factors and text understanding*

Normally in order to understand the sentence "James put the money in the bank", the user must have the implicit information: "James has money, and money can be deposited in banks". The second part of the sentence is more difficult to process since the word bank has more than one meaning. The understanding of sentences would be tremendously helped if they consist of unambiguous words within their expected contexts. Swinney (1979) has investigated the role of context for accessing word-meanings. Swinney finds that all words related to previously occurring words are activated, and become more easily accessible. For the sentence cited above, words such as money and river, become easier to access later in the sentence if the word bank was understood earlier. Hence, paragraphs with self-contained messages and a small set of related vocabulary, would be easily understood if context helps (Tulving & Gold, 1963). It should be noted here, however, that the repetition of limited vocabulary may lead to a loss in its meaning over a period of time (verbal satiation).

Psychologists have distinguished between, “semantic memory,” which comprises of specialised knowledge a person has about items and events, and “episodic memory,” which builds on life’s experiences. As a result of age or illness, these memories may be affected. The impairment can by category-specific, e.g. all information and concepts related to certain classes of objects may be lost. Hence, in order to facilitate the subject’s understanding of the meaning of a word, not only its definition is required, but also its functional role and relationship with already known objects should be specified. The loss of episodic memory weakens the subject’s understanding of where they have previously come across a particular word. In order to facilitate the understanding of words, their functional definitions, which may be available on request, should include related information (e.g. a car should be defined as: a vehicle with four wheels, used for driving on roads, carries passengers, consumes fuel (petrol or diesel), needs parking, stays in garage, etc.). This information cannot be provided for every single word since it would be impossible to store and retrieve such comprehensive details on a regular basis. It should be however recommended for user specific short active vocabulary that appears in a particular text.

The human language processing system constructs phrase markers (a ‘parser’) to derive propositional meaning (Caplan, 1993). The subject may also understand the sentence by observing the linear order of words in a sentence (heuristic rule) and/or through relating the meaning of the words to real-world possibilities (lexico-pragmatic rule). When these rules are used, active sentences such as "The batsman hit the ball" are easier to understand than passive sentences such as "The ball received by the batsman was hit". Propositional meaning is also difficult to extract if the nouns used in a sentence are of the same type allowing the sentence to be reversible (both concrete or both abstract), e.g. "John saw Ted". It is important to keep these rules in mind while developing written material for use by language disordered individuals.

In the above sections we have briefly discussed word-level and sentence-level difficulties encountered by language disordered subjects. Some of the psycholinguistic factors, including sentence semantics, were also discussed. In the course of this discussion, in some cases we have made some suggestions on how we may solve these difficulties. However, we have not discussed non-linguistic factors which influence information understanding when using the Internet. This is the topic of our further discussion.

3.4 *Media effects*

It is important to understand media effects on language understanding. Typical differences between paper and computer screen media come from the different characteristics of static paper and dynamic screens. Muter and Maurutto (1991) describe some attributes of computer based text and list some features which differ between paper book and computer reading:

- Distance between the reading material and the reader.
- Angle of the reading material.
- Visual angle of characters.
- Character shape.
- Actual size of characters.
- Characters per line, lines per page, and words per page.
- Inter-character spacing.

- Interline spacing.
- Left justification versus full justification.
- Margins and the use of frames.
- Resolution.
- Familiarity with medium.
- Intermittent versus continuous light (Wilkinson, 1986).
- Interference from reflections (Daniel & Reinking, 1987).
- Absence versus presence of incidental location cues (Wright & Lickorish, 1984), etc.

Researchers have steadily reported that reading from paper was faster than reading from screens, but no significant difference in comprehension was found (Kak, 1981; Gould & Grischkowsky, 1984; Cushman, 1986; Wilkinson & Robinshaw, 1987). However, in writing essays, users of the hypertext version scored significantly higher marks than users of the paper book (Egan, Remde, Landauer, Lochbaum & Gomez, 1989). Moreover, Muter and Maurutto (1991) find that reading continuous text from large and high resolution screens resulted in no significant difference in speed and comprehension from reading from paper, but skimming and scanning was still better in paper.

There are some important differences between hypertext and ordinary computer text. Hypertext is different since: i) it requires navigation and planning; (ii) all text nodes are not known in advance and there is no content menu for information that exists; (iii) hypertext can be condensed to detail information at different levels and the user can be thus helped with reducing information overload; and (iv) different hypertext node structures can be generated for the same information depending on specific requirements. Hence, user performance on text reading and understanding is easier to manipulate by enhancing the structure of hypertext than what may be possible with ordinary computer based text. Hypertext also offers a number of visual and auditory mechanisms that can be used for improving text understanding and decision making. There are several implications of these differences for language limited users. First, it is evident that hypertext requires navigation and planning in a more dynamic environment for which specialised software agents should be developed to assist language limited users. Second, hypertext information is arranged hierarchically and its exploration may be assisted by coherent text node labelling. In the absence of a visual representation of how information is arranged, language impaired users will find it difficult to navigate the system. Finally, a hypertext system should streamline and limit the quantity of information it provides to a user with language disorder -the vastness of the cyberspace can be deterring for such users!

4. PROPOSED SOLUTIONS

In the previous sections we gained some basic understanding of language limitations in terms of difficulties with formulating search queries and understanding text. In addition, we have also discussed sentence level problems, psycholinguistic factors and media effects which affect the understanding of hypertext when reading it. Some initial suggestions at this stage for solving these problems are summarised in Table 1.

Table 1

In Table 1 we have classified the generic language disorders as lexical retrieval problems, memory deficits, attention deficits and reading and planning deficits. The first two deficits make it difficult to formulate proper search queries. The last two deficits lead to difficulties with understanding information and taking decisions on them. For each category we have made recommendations most of which may be achieved using an intelligent natural language processing tool and a multimedia system.

In order to offer some further solutions in the context of hypertext systems, we need to specify what interface areas are in need of modification. Internet interfaces have two major components: a search engine and a text window. In the first half of this paper we discussed generic text understanding problems. It was recognised that language and memory limitations make it difficult for several users to formulate appropriate queries, navigate through the system and understand text. In the following discussion we offer some solutions to the query formulation and text understanding problems. These solutions can be implemented as either accessory or compulsory options in the design of interfaces.

4.1 *Facilitating searches through IR models*

It is well known that many users of text retrieval systems have difficulty in formulating search queries which are both precise and comprehensive (Bing, 1987), and some have gone so far as to suggest that conventional free-text retrieval systems (i.e. those retrieving only exact matches with search queries using boolean and proximity connectors) place impossible demands on users (Blair & Maron, 1985). Many alternatives to the conventional model have been proposed, often based on different methods of relevance ranking, and are the subject of considerable debate (see Savoy, 1994 for a recent review).

The two main measures of information retrieval are ‘recall’ and ‘precision’. These have clear analogues in terms of the connectivity of hypertext links. That is, high recall on an information retrieval query corresponds to a high degree of linkage to relevant documents. Similarly, high precision implies few irrelevant documents retrieved which is analogous to the presence of few links to irrelevant documents in a hypertext system. These demands may be reduced in a more visually oriented hypertext system. However, it is likely that there will be some limiting boundary conditions with respect of the complexity of the choices offered, beyond which even hypertext systems will be unusable, particularly for users with special linguistic needs.

Mapping disorders are the most common reason for the inaccessibility of query words for a web search. A number of language impaired users, and even normal older adults, often complain that they can literally see the words in their mind, but cannot label them. This phenomenon is caused by the failure of the mechanism which translates semantic messages into phonological shapes. Since it is feasible to class ideas into a set of categories (e.g. real objects (animals, organisations, places, etc.), actions (motion, rest, etc.), and so on), it is possible to represent these concepts as visual icons, which may be clicked by the web user to narrow down the choice to the final word or related words searched for. Although it is realised that a considerable amount of previous research has been futile in its attempt to achieve any standardisation with respect to labelling concepts with icons, a limited number of concrete concepts can still be labelled. This strategy may be employed in two modes: when the subject has no idea of any related words and the search starts from scratch; or when some initial stages may be skipped and the search could start from a specified level.

The use of iconic representation for language understanding and manipulation has been studied in the field of aphasia where sophisticated tools including C-VIC and Lingraphica have been developed. Computerised Visual Communication System (C-VIC) has been discussed in detail by Steele et al. (1989). It has been used extensively for improving language production of aphasic adults (Weinrich, Shelton, McCall and Cox, 1997; Weinrich, Shelton, Cox and McCall, 1997). Weinrich, Shelton, McCall and Cox (1997) describe C-VIC as: "C-VIC is a computerised, iconic communication system employed as a means of training severely nonfluent aphasic patients in sentence production…The system provides patients with an iconic "lexicon" and a limited set of syntactic roles…Communications are produced by retrieving icons and arranging them in serial order in a space provided on the computer screen" (p. 330). C-VIC uses a lexicon with 150 nouns, 24 verbs, 3 prepositions and 2 information markers. The vocabulary in C-VIC is organised hierarchically with abstract symbols representing different lexical categories (e.g. subjects, verbs, prepositions, objects) at the top of the hierarchy. A number of subcategories are also available, e.g. within the category "clothes", there are 21 subcategories such as "shoes", "pants", "socks", etc. Weinrich et al. (1989) have investigated whether subjects are able to generalise symbols for actions. It is important that iconic representations offer this ability so that they do not have a very limited value in language representation. C-VIC is of considerable value to researchers who wish to develop intelligent interfaces for language limited users. Although it has been developed specifically for studies in aphasia, its use is of generalisable value across various language impairments. For query formulation, discussed in the next section, iconic representations can be used for building queries. Past experience from C-VIC will be of great value in further research.

Lingraphica was developed between 1984 and 1990 as a tool for therapy service in aphasia. Since then it has become a patented, portable, interactive and stimulating medical tool (Harris et al., 1997). In 1990 it was developed into the LG system which has undergone four revisions since then. The current LG system has more than 2100 manipulable graphic icons covering the primary parts of speech such as nouns, verbs, adjectives, prepositions, etc. covering a range of contexts. Lingraphica has been used as an interactive tool for treating dysphasic patients and is specially designed to take language limitations into account for this. Needless to say, it provides a very useful repository of data, concepts and results that can be used for future research into the design of intelligent interfaces.

4.2 *Query formulation*

Query formulation presents a unique challenge for semantically limited users, e.g. EFL (English as a Foreign Language) speakers. Such patients are vulnerable to semantic misinterpretation of words and often stretch word boundaries to include unrelated topics. Hence, information on 'lamps' could be searched by such users with the keyword 'light'. At present web search engines are limited in their concept searching abilities and rankings are exclusively dependent on the query words used. In addition, they allow searches for items that may be non-words. The overall system can be improved, therefore, if: i) queries are confirmed by refining them through user interaction; and ii) checking for non-words. The first issue requires query agreement between the user and the system and some web system intelligence for the semantic integration of individual query words. The latter is easy to implement using a dictionary and a spell-check tool provided that the dictionary contains proper names and valid words not otherwise stored. The process of determining valid words not found in system dictionaries could be automated if the system is capable of keeping track of query words missing from the lexicon that did find a match in the text searched indicating their validity.

Several search engine interfaces offer a browsing ability. This is often useful when the user wants to examine a broader range of topics under specific categories by clicking on specific sub-headings. In most cases, this is time consuming for several users and a direct search strategy is preferred. The available search engines use search modification operators, e.g. Altavista and other search engines allow the use of + or - operators to eliminate or add words in a query. This does not amount to sophisticated provision of search formulation tools. Unfortunately, current search engines do not offer an advanced search refinement strategy before the search is carried out based on the assumption that the user is capable of precisely defining the key word. A more effective strategy would be to reach an agreement with the user on what is searched before performing the search itself. This agreement can be achieved by:

- Confirming a concrete noun with visual representation.
- Confirming a verb with video action.
- Presenting a set of synonyms and words within the range of the same context.
- Suggesting spelling mistakes and confirming non-words.
- Identifying the correct meaning of words in particular contexts.
- Employing intelligent search strategies (Marchionini, 1989).

In addition, an intelligent interface must also offer *semantic integration* of individual query words. The concept of semantic integration, though natural in its consequence, is difficult to achieve in practice. For example, the multi-word query "car engine cold" requires some form of semantic integration to search for information on "why does the car engine have problems starting on a cold day?" The latter is one natural language representation of the original query and translation to this form is currently limited in its use by most search engines. There are two separate issues here: how does the system respond to a natural word query intelligently; and is it at all possible for it to arrive at the latter natural representation if only individual keywords are supplied. The first issue is currently witnessing a large amount of interest. The second, more important and definitely more difficult, awaits further research.

The issue of information ranking is of critical importance too. An optimal query is at best workable if the required information is ranked very low. Most search engines are capable of retrieving thousands of documents but experience shows that even normal users do not bother to check more than forty to fifty titles at any one time. Sophisticated interface designs must allow the users the flexibility to dictate the information content that can be presented at a given time.

The second problem with the use of Internet and hypertext relates to the understanding of web information and navigation in web space. There are three important areas of research related to information understanding: (i) information layout; (ii) user interface; and (iii) information quality in terms of its composition. These areas have been widely researched and ACM conferences on intelligent user interfaces regularly report on current developments. The quality of information content is very much a research area for the near future, i.e. the development of tools or procedures that could enhance text composition with natural language processing techniques. The above issues are discussed in latter sections.

4.3 *Reduced information content*

Users with memory deficits can have difficulties with large amounts of screen information. There are two major approaches to reducing information content. First, by extracting natural language on demand depending on the context (Dale & Milosavljevic, 1996), and second by modifying the contents of existing documents based on some degree of their understanding. This is done by the provision of a fine grained hypertext structure, where the resolution will be at the natural language syntax level rather than document /component level, based on the statistical analysis of language disorders. Several studies in the past have investigated the language production and comprehension abilities of language limited users measuring the role of sentence and paragraph lengths in text understanding. On the basis of statistical evidence available, the hypertext system could be structured to reduce sentence and paragraph sizes to a level that improves user understanding. There are some commercial products available that automatically create hypertext links in an unstructured piece of text based on the high frequency of specific words. These products could be modified to take into account user demand on text, paragraph and sentence settings when defining hyperlinks. While larger number of hyperlinks should reduce the amount of text presented to the user, it can also make navigation of the system quite exhausting. An optimal balance needs to be reached between hyperlink resolution in the text and the size of sentences and paragraphs.

Moreover, it is important to understand the potential abilities of language disordered users when confronted with large amounts of hypertext information. It is possible that different readers adopt user specific reading strategies depending on whether the knowledge is processed in a deep or shallow manner. This choice is dependent on several factors including: causal connection between text nodes, local and global cohesion of text, and text layout (Colley, 1987). It is necessary that hypertext information is structured to facilitate a deep understanding of the subject matter.

4.4 *Information presentation on screen*

There are some clear advantages to computerised media when compared to paper (McNight, Dillon & Richardson, 1989; Egan, Remde, Landauer, Gomez, Landauer, Eberhardt, & Lochbaum, 1989; Shneiderman, 1987; Yankelovich, Meyrowitz & van Dam, 1985).

- Provision of interactivity and connectivity.
- Dynamic text presentation.
- Easy information search.
- Easy update.
- Parallel presentation with other media.
- Multiple windows and other various capabilities from dynamicity.

In addition, since Internet is based on the concept of linking information between different sources using text nodes and uses hypertext, other advantages for both information designers and users include:

- Detailed information may be embedded at various levels and therefore information content may be reduced during presentation.
- The planning aspect for retrieving information becomes very important, i.e. hypertext navigation is fundamentally different in its approach to other computer based texts.
- The readability factors are under the control of information provider who may manipulate them with relative ease.

It is important that the text layout facilitates the reading abilities of language limited subjects. We recommend the following:

<u>characters.</u>

- Uppercase seems to be better for searching (Vartabedian, 1971; Clauer, 1977), and lower case for reading continuous text (Rudnicky & Kolers, 1984).
- Variable character width may help faster reading than a fixed width (Beldie, Pastoor, & Schwartz, 1983).
- A proper combination of upper and lower case may be better for reading continuous text (Mills & Weldon, 1987).

<u>formatting.</u>

- Increasing interline spacing and decreasing horizontal spacing may be better for reading performance (Wilkins & Nimmo-Smith, 1987).
- Variable interline spacing seems to prevent visual fatigue (Lunn & Banks, 1986).
- Hyphenation at the ends of lines seems to cause slower reading (Nas, 1988).

<u>contrast and colour.</u>

- Positive polarity (dark characters on a light background) is preferred by readers and may help reading (Bauer & Cavonius, 1983; Bauer, 1987), and result in less visual fatigue (Cushman, 1986).
- To maximise discrimination between colors, the difference in hue and lightness should be maximised and differences in saturation should be minimised (Laar & Flavell, 1988).

screen.

- High resolution ratio may result in better visual search (Harpster, Freivalds, Shulman & Liebowitz, 1989).
- Large screens may enhance text processing (Lansdale, 1988; de Bruijn, de Mul & van Oostendorp, 1992).
- Multiple windows seem to be better for information relocation (Tombaugh, Lickorish & Wright, 1987).

dynamic presentation.

- Paging may be better than scrolling (Kolers, Duchnicky & Ferguson, 1981; Schwartz, Beldie & Pastoor, 1983).
- Highlighting techniques sometimes help (Nes, 1986; Shneiderman, 1987; Tullis, 1988) and sometimes disturb (Fisher & Tan, 1989).
- The reading efficiency of Rapid Serial Visual Presentation (RSVP) is close to that of normal page reading (Juola, Ward & McNamara, 1982).
- Times Square Format (TSF) seems to be as good as RSVP (Kang & Muter, 1989)

In addition, Dillon (1992), Mills and Weldon (1987) and Muter (1996) have also summarised some factors affecting readability. In summary, computerised information presentation can provide services to users which have not been possible with paper. Computers can mimic the static properties of paper. Furthermore, they support not only the dynamic properties of information like animation, but also dynamic properties of reading activity such as the use of scrolling and moving texts. WWW browsers and word processors are good examples of such properties. Especially, distributed information retrieval and universal presentation of WWW have significantly changed reading environments. The process of information understanding may be further facilitated by using auditory and visual cues.

4.5 *User interfaces: auditory and visual cues*

It is important to introduce, at this point in our discussion, a schematic model of how words are perceived when reading text. Crowder and Wagner (1992, p. 107) have presented a schematic model to describe this process. In this model there are different auditory and visual feature allocations in the memory. It should be noted that the auditory and visual features are acquired by subjects at various stages of their development, e.g. children know the word "toy" auditorily at an early age, but read it at a later age. It is therefore possible that the auditory features of some words may be intact in linguistically limited subjects whereas their visual features may be lost, e.g. the picture of a train may only be recognised by its whistling noise. Audio features should be used therefore for word recognition in cases where visual representations are lost; where a system includes relevant audio/visual information, retention and persuasiveness are enhanced. The writing of hypertexts should also take into account the emphasis placed on certain words, which is ordinarily done in spoken language through prosodic cues, i.e. stress elements. Hence, stress on particular parts of a sentence may be placed by using different font sizes or underlining, e.g. "WE rejected the offer," "We REJECTED the offer," and "We rejected the OFFER."

4.6 *Focussing attention*

Preece et al. (1994) discuss several methods of focussing attention at user interfaces. Some of the tools they recommend are aimed at structuring information, using spatial and temporal cues, and the use of colour and alerting techniques such as flashing and reverse video. The structuring aspect may be accomplished by segmenting the computer screen image into windows with different types of information using different colours for these. The aim should be to display important information in a prominent area to catch the user's eye, less urgent information should be allocated less prominent but specific areas of the screen where the user can find it, and information not needed on a regular basis should be made available on request only. In the context of reading hypertext, several linguistic signalling tools can be used by the author for focussing attention including "However," "Nevertheless," "On the other hand," etc. Finally, attention can be focussed using optimal font sizes, manipulating foreground and background colour, automatic scrolling, system messages and a menu system that facilitates a match between the user's knowledge in the head with the knowledge of the world. It is important to note here that tools for focussing attention and providing visual/auditory cues, though important in general, have special meaning for language disordered patients since these techniques may assist such subjects to use their compensatory mechanisms for understanding information and acting on it.

5. DEVELOPING THE INTELLIGENT INTERFACE

The development of an intelligent interface requires that we should address linguistic, navigational and visual aspects of communication. In Figure 1, it is recommended that nine different types of tools can be used for this purpose. These are described below:

(a) Query Formulation Tools: In sections 4.1 and 4.2 we discussed issues on query formulation. Query formulation tools should assist users in formulating a query. A query is represented by one or more words that can be semantically integrated and weighted if needed. One key component of such tools is a dictionary for spell checks. Visual cues can be used to assist the users in choosing the correct representation. Iconic concepts should be used for narrowing searches or for iconic

browsing. Obviously, the icons need to have some standardisation across different platforms. Animation and graphics use motion and pictures to aid query formulation-this is especially useful when a query word has multiple meaning and its graphical representation can be used to choose the correct meaning. Browsing in general provides an alternative to direct searching when the concept explored is of generic nature. As mentioned in section 3.3, functional description of objects, persons and actions can be stored as a functional dictionary-such a functional dictionary can be used by users upon request or when semantically searches are interpreted by the search software. Further tools are also needed for providing synonyms that often allow the user to specify a more accurate query. The interface tools may extend this concept to present a larger list of semantically related items that the user may choose from.

(b) Query Execution Tools: Such tools assist the execution of queries in hypertext systems. Spell check avoids the retrieval of unwanted documents. The interface can be made sophisticated if semantic integration of words is possible-obviously for such an integration some knowledge of real-world possibilities can be stored as a knowledge base. The interface should allow query weighing. The natural language input should also be acceptable to such a system as most users will prefer such queries. Tools are needed to learn contexts from some stored knowledge to refine their searches to relevant documents. An intelligent search engine will also translate words of low specificity to those of larger specificity through some form of synonym mapping leading to better results. Finally, an important feature should be query rejection-if the number of hits exceed some expected mark, the query should be rejected. Such an action implies a too general query where the results will be of too little value.

(c) Query Results Tool: These tools are responsible for presenting the results of searches in a proper format to the user. Media effects can be very useful in pointing user attention to the most relevant areas as discussed in section 4.4. The amount of text presented should be controlled to

some optimal level. The presentation may be through multiple windows that remain hidden till they are needed. The structure of text should be possible to manipulate automatically, e.g. paragraphing, sectioning or boxing. The results should be shown as weighted and ranked accordingly. Multiple windows can be used for results, their further explanation if clicked, graph structure, statistical details of the results on last query and so on. Finally, what is in the foreground and in the background at a given time should be decided automatically. Those areas that are currently being used should obviously be in the foreground, but background areas should have some easy pointers not to be lost in a multiple windows environment.

(d) Text Manipulation Tools: These tools allow the system to manipulate text both in its physical representational form as well as its linguistic form. This is needed as suggested in sections 2 and 3 earlier that most available hypertext may be unusable by language limited users. Graph structures can be used for this purpose, e.g. a subject-object-activity structure that can represent text as a graph. Such structures could allow users to navigate more easily than pure text. In addition, information extraction can be a very useful tool when the user is dealing with voluminous text. The user may wish to select some keywords to be able to extract all information on those topics within a document. Graph structures as well as a number of other IE techniques based on lexicons can be used for this. Highlighting important information is obviously important when there is too much of it. The system can highlight words except stop words that have the highest frequency along with words that are very rare. Text tools can also investigate text homogeneity, i.e. does a text piece, whose length is predefined, deal with similar concepts. Such areas can be represented under a common theme and hyper-linked to a detailed text within them thus condensing the size of the document. Text manipulation tools can also manipulate vocabulary by substituting easier words for user understanding, they can split compound sentence structures into simpler ones as well as break large chunks of texts into paragraphs that deal with

similar concepts. This of course is based on the assumption that we know how to build concepts from words.

(e) Text Understanding Tools: These tools help users understand both the syntactic as well as semantic content. Sentential stress can be used to direct user attention at specific words of interest. Such words can be automatically determined using some statistical features of words in the given text. The system should provide word definitions and reinforce referencing with proper names rather than with words such as "It, that, their, …" The sentences can also be made active from passive: it well known that active sentences are easier to understand. Items dealing with temporal and spatial concepts should be highlighted to avoid over referencing. Studies have shown that most people have like a bell shaped curve showing how many words are used for making clauses with the peak at about 7 to 8 words. When in a given piece of text we have more or less number of clauses, reading the text is more difficult. A linguistically intelligent system should be able to automatically adjust clause length. Such a system should also be able to prune text for portions that are irrelevant-initially the user can help the system achieve such performance. Finally, the user satisfaction with the system can be analysed using eye tracking-screen portions where the eye gaze is long lasted during normal reading represents areas for improvement.

(f) Text Navigation Tools: These tools are responsible for navigating the user through text space. The reading process can be assisted by automated scrolling of the screen which can be achieved through either a uniform set rate or through eye tracking. Visual cues can be used to help users navigate the system-in most cases such cues will form a part of a well thought out screen design. The navigational system can provide horizontal links (between different pages) or vertical links (between the same page). Both of these links should be used with multiple windows without taking away the text being read. The indexing of text for forming hyperlinks should be achieved

automatically and fortunately several tools for this have appeared in the market. The user should be allowed to navigate themselves using their own keywords and concepts.

(g) Memory Tools: These tools assist the users in text understanding by circumventing any short memory limitations. One of the key aids is to keep sentences short. Hypertext should be static, i.e. cross-referencing should not require moving out of current presentation of the screen. Colour effects can be used to user advantage for identifying certain words. This technique should be however used with care not to cause colour pollution. Mapping tools should allow mapping of words to their meaning through some functional dictionary and may use video and audio means for representing the meaning. The font sizes and text layout should be adaptable to suit user requirements and key commands, error messages as well as important details may need repetition. Highlighting through sentential stress and counter referencing can be very useful. The relations between different objects should be dynamically highlighted on demand, i.e. if a user clicks on a word, dynamically the system should be able to display in other window past references to the same and related words.

(h) Statistical Tools: Statistical tools allow the system to automatically perform some statistical linguistic analyses on different texts and classify and index them; this information is used by the system to inform user of text characteristics and choose appropriate tools for user facilitation. Text can be classified according to its style, lexical richness, technicality, topic/theme, and so on. Text richness is measured using stylometric methods. Lexical richness depends on the frequency of words from different lexical categories and the length of the text. One example is type-token ratio. Type token ratio is the ratio of total number of different words used divided by the total text length and usually lies between .25 and .40. The system can also perform clause analysis to produce statistics on the frequency statistics of how many words are used in a clause. The system can use these different measures to categorise documents on the basis of their lexical richness.

Statistical tools can also be used to detect the total number of hyperlinks in a document and on the basis of all of the above details, they can recommend rejection or acceptance of a document for reading purposes. Statistical methods can also be used to produce a ratio of text to images in a document and provide an estimate of the time it will take to download the document-images can also be classified according to content. Fortunately, several tools exists for stylometric analysis of language as well as for image indexing .

(i) Information Tools: These tools are linked to statistical and other type of tools to make direct recommendations to the user and issue commands to other tools. Such tools can label documents on the basis of their classification and code broader document characteristics than the fine level detailed obtained through statistical analysis. These tools can make recommendations on accepting or rejecting document retrieval or reading. Such tools can also recommend whether other tools should be used in automated mode or interactively with the user. Intelligent tools will allow the analysis of user interaction and try to learn user behaviour for providing better service in the future. Adaptive HCI represents a growing research area where interface design is only static in terms of how the system is designed; the actual knowledge that runs the system can continue to upgrade as the user interacts with the system. An adaptive system should be able to learn and adjust its parameters to suit different clients. Finally, all systems need some quality indexing to stress their worth. The quality is of course based on subjective activities such as user satisfaction, but more objective indices are needed.

6. CONCLUSION

In this paper we studied some language limitations of adult users. It was stressed that addressing such issues is as important in an intelligent interface design for hypertext systems as screen and visual considerations. In this paper we have suggested a system for the future even though all requirements of such a system are not totally futuristic. A number of recent developments in natural language analysis and linguistic computing allow us to embed more linguistic intelligence in existing systems. However, what exactly do we need to embed? The main contribution of this paper is that it narrates what is needed? What will a linguistically intelligent system do? and, What kind of tools are needed? The recommendations are generic and they will benefit a range of users.

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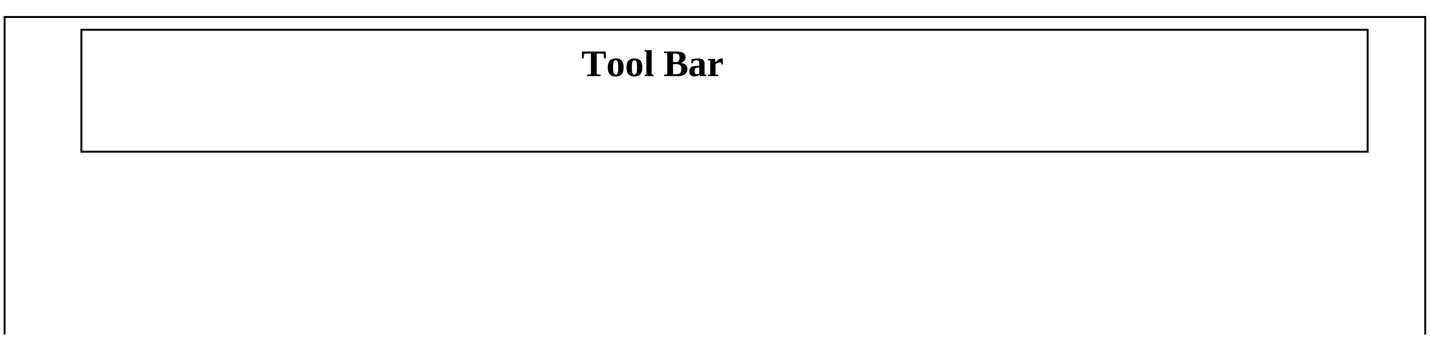
Table 1. Some disorders affecting language: recommendations for web information

Disorder	Effect	Recommendation
Lexical retrieval	imprecise queries	visual and auditory cues

		semantic integration of multi-words concept based icons synonym usage dictionary usage user confirmation of non-words
Memory Deficits	imprecise queries reading impairment	exploitation of semantic priming text simplification context manipulation for understanding understanding vocabulary limitations key information reinforcement
Attention deficits	slow reading speed frustration with the task	screen layout improvement information reduction colour manipulation, e.g. Stroop effect (Stroop, 1935), sentential stress
Reading and planning deficits	Incomplete understanding navigational problems	use of non-reversible sentences simple phrases and sentences local and global text cohesiveness causal relationship between paragraphs unambiguous link explanation hypertext nodes embedded to suit user learn about user's planning limitations

Figure 1. Interface development: tools for the language limited



Query Formulation Tools
- Dictionary
- Visual Cues
- Iconic concepts
- Animation/Graphics
- Browsing
- Functional description
- Synonyms and semantic stretching tool

Query Execution Tools
- Spell Check
- Semantic integration
- Query weighing
- NLP representation
- Context understanding
- Specificity conversion
- Query rejection based on excessive hits

Query Results Tools
- Media Effects
- Amount control
- Presentation
- Structure
- Weighted results
- Keyword summary
- Multiple window
- Foreground issues
- Background issues

Text Manipulation Tools
- Graph structures
- Information Extraction
- Highlighting
- Homogeneous areas
- Vocabulary manipulation
- Splitting compound structures
- Paragraphing

Text Understanding Tools
- Sentential stress
- Word definitions
- Original referencing
- Active sentencing
- Temporal/Spatial highlighting
- Clause lengths
- Text Pruning
- Eye tracking

Text Navigation Tools
- Automated scrolling
- Visual cues
- Screen layout
- Horizontal/Vertical links
- Automated indexing
- Eye tracking
- Keyword navigation
- Concept navigation

Memory Tools
- Short sentences
- Static hypertext
- Colour effects
- Mapping tools
- Font/media tools
- Repetition
- Sentential stress
- Functional definitions
- Dynamic highlighting of past relations

Statistical Tools
- Text classification
- Text richness
- Lexical content
- Type-token ratios
- Clause analysis
- Category analysis
- Hyperlink analysis
- Rejection analysis
- Text/image contents
- Image classification

Information Tools
- Document type
- Document characteristics
- Accept/Reject
- Tools to apply manually or auto
- User analysis
- Adaptive HCI
- Parameter optimization
- Quality index