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Computer Based Writing Support
for Dyslexic Adults
Using Language Constraints

by

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A doctoral thesis submitted in partial fulfilment of the requirements
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Abstract

Computers have been used effectively to provide support for people with a variety of special needs. One such group is adults with dyslexia. Dyslexia is commonly recognised as a learning disorder characterised by reading, writing and spelling difficulties. It inhibits recognition and processing of graphic symbols, particularly those pertaining to language. Computers are a useful aid for dyslexic adults, especially word processors and their associated spelling tools. However, there are still areas where improvements are needed. Creating an environment, which minimises visual discomfort associated with proof reading and making selections from lists would be of benefit. Furthermore providing the correct type and level of support for spelling, grammar and sentence construction may result in higher standards being achieved.

A survey of 250 dyslexic adults established their requirements and enabled the development of a specialist word processing system and associated spelling support tools. The hypothesis, that using a language with enforced structure and rigid constraints has a positive affect for dyslexic adults, was also tested. A support tool, which provided a controlled environment, to assist with sentence construction for dyslexic adults was developed from this. Three environments were created using the word processing system: environment 1 used the basic system with no support, environment 2 provided spelling support suggested by the survey subjects and environment 3 used the sentence constructing tool providing support and control. Using these environments in controlled experiments indicated that although environment 2 achieved high academic standards, environment 3 produced written work to an even higher standard and at the same time, the subjects derived greater satisfaction in using it.

This research proves that working in a controlled, rigid environment, where structure is enforced, substantially benefits dyslexic adults performing computer-based writing tasks.

Keywords: dyslexia; disability; computer-based support; sentence construction; spell checker; word processors; structured languages

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Chapter 1 Introduction to the thesis

1.1 Introduction

Dyslexia is commonly recognised as a learning disorder characterised by reading, writing and spelling reversals. Dyslexia inhibits recognition and processing of graphic symbols, particularly those used in natural languages such as English. There are many other symptoms associated with dyslexia (discussed in Chapter 3) but none are so apparent. Although uncommon, it is quite possible for dyslexics to reach adulthood and have very few written language difficulties. However, the majority of dyslexic adults require support to help them to achieve an acceptable standard of written English. Computers are ideal for providing such support and a general summary of the main concepts of computer-based support is given in Chapter 2.

More specifically, the use of word processors with their associated spelling tools has proven to be very useful for adults with dyslexia but there remain areas where improvements need to be made. Visual problems associated with dyslexia can make reading text from the computer screen difficult. This can affect their concentration levels, the ability to proof read their work and makes selections from lists or menus difficult. Most spell checkers are designed for people with minor spelling difficulties who are able to distinguish between lists of similar replacement words suggested. However, for many dyslexics this level of help is not sufficient. Moreover, many adults with dyslexia need support with sentence construction. This is not currently provided at an adequate level. This thesis suggests improvements, which would be more appropriate to the needs of dyslexic adults.

This research is concerned with several interrelated issues, which are brought together to provide an improved environment, specifically suited to dyslexic adults. The environment allows them to produce written work to a higher standard, while at the same time, gives them a greater level of satisfaction in producing their work. Initial investigations, described in Chapter 4, led to the development of a specialist word processing system and associated spelling tools. Although this is not an original concept in itself, it provides an ideal base from which comparisons can be made and enhancements developed. The

Chapter 1

originality of this research stems from the development and investigation of a research hypothesis. This establishes the degree to which dyslexia affects a person's ability when using different language types. The knowledge can be used to develop support tools. Two comparative language types were used: English, which is a natural language and high level computer programming languages[♦] referred to as structured languages. General comparisons were formed based on information provided by adults with dyslexia.

It is clear from initial research (discussed in Chapter 4) that, using languages with constraining rules, where structure is fixed, was favoured by the majority of dyslexics who have experience of such languages. The next stage is to see if this is the general case for all dyslexic adults. The development of a sentence construction tool for natural languages, such as English, which enforces constraints and uses a fixed structure, allows for the testing of this theory. The tool is used within the specialist word processing package and comparisons are formed by the creation of separate environments offering varying levels of support. This research aims to provide a better understanding of how adults with dyslexia work within different language structures and how support tools can be designed to be more useful. Although this thesis is concerned with dyslexic adults, an investigation to establish whether non-dyslexics may also benefit from this research was provided and some comparisons were made.

This chapter defines the statement of the problem leading to the research objectives and the research hypothesis. The scope and aim of the research are identified along with the thesis contribution, research limitations and publications. To complete this chapter a review of the remaining chapters is included.

1.2 The statement of the problem

Current word processors do not provide an ideal environment for adults with dyslexia. Improvements need to be made to the support, which is offered and the visual aspects of these systems. This research aims to prove that creating favourable environments will

[♦] There are many different high level computer programming languages, for the purpose of this research generalisations are made in terms of structure and number of rules, no particular language is specified.

lead to improved concentration, increased sense of satisfaction and a reduction in the number of errors made, thus resulting in higher standards of written work. The correlation between varying the type and level of support offered is investigated. This is done through the design and development of three different support environments within a specialist word processing package. The statement of the problem is associated with three main issues:

1. Does language structure affect a dyslexic adult's ability to write grammatically correct sentences (or statements in the case of structured languages)?
2. Can the favourable features from structured languages and their associated support tools be incorporated into the design of a sentence construction tool (used within a specialist word processing package), to support adults with dyslexia?
3. Can any improvements be made to the display methods used within current word processors and their associated support tools to assist dyslexics?

1.3 Research hypothesis

The research hypothesis has been developed from point (1) defined in Section 1.2, detailing the statement of the problem. The hypothesis is as follows:

There exists a link between the number of rules and level of constraints that a language has and the degree of problems that dyslexic subjects encounter.

Initially the research hypothesis is confirmed using a survey and a specialist word processing system is developed and used to qualify the hypothesis.

1.4 Research objectives

The key research objectives are categorised into three sections: investigation, deliverable tools and evaluation. Investigation objectives are:

- The difficulties adults with dyslexia have when writing in English and the areas in which further support is required

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- How useful current word processors and associated support tools are and whether subjects can suggest any improvements
- Whether the subjects have the same difficulties (or same degree of difficulties) with structured languages in comparison to natural languages
- What features (if any) contained within the structure of computer programming languages subjects found favourable
- How useful the support tools provided within computer programming environments are and how they could be used for natural languages
- Develop and confirm the research hypothesis based on how dyslexia affects a person's ability when using different language types

The deliverable tools are:

- A specialist word processor and spelling support tools to create an environment to support dyslexic adults with written English
- A sentence construction tool, which uses a structured approach with rigid control to support dyslexic adults with constructing sentences. This tool incorporates concepts from the research hypothesis and is designed to test the theory upon which it is based

The evaluation method used:

- Using the specialist word processing package, to form three separate environments, providing varying levels of support and control.
- Form comparisons to qualify the research hypothesis

1.5 The scope and aim of the research

The aim of this research was primarily to qualify the research hypothesis and use these concepts to develop methods for supporting adults with dyslexia. In order to achieve this a specialist word processing package was developed, using a design criteria requested by dyslexic subjects. This is referred to as environment 1. Spelling support tools requested by dyslexic subjects were developed and used within environment 1 to create environment 2. The concepts behind the research hypothesis were used to develop a tool

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to support sentence construction for adults with dyslexia. This tool is used within environment 1 to create environment 3. The consequent testing of the three environments ascertains which support is proven to be of greater benefit. These statistics are used to qualify the research hypothesis.

1.6 Thesis contribution

The contribution to original knowledge stems from investigating the degree to which dyslexia affects a person's ability when using two different types of language structures: natural (English) and structured (computer programming languages). This establishes whether there exists a link between the rigidity and number of rules a language has and how dyslexia affects their ability.

It is possible to create support environments for natural languages, which use concepts from structured languages, which this work proves to be effective for dyslexic adults. This research has led to the development of a specialist word processing package and devised a method of providing sentence construction support for adults with dyslexia. The prototype sentence construction tool was used to test the hypothesis and was proved at a significance level of 99%. A commercial system incorporating the general concepts could be developed to provide computer-based support for adults with dyslexia.

1.7 Limitations of the investigation

This research is concerned with a comparative study and investigates how a person's ability may differ when using structured languages in comparison to using a natural language. This research is not concerned with the mechanics of how the languages are formed from a linguistic viewpoint but with the overall considerations, such as the degree of rigidity within the language and how it affects dyslexic adults. The development of a grammar checker would enhance the usefulness of the tool but was not an essential requirement in order to fulfil the research objectives. Due to the time constraints a grammar checker was not implemented. However, the structure of the software has been developed to allow for the addition of a grammar checker in future modifications.

1.8 Publications

Two papers have been presented at conferences and published in the conference proceedings. The titles are:

- Evaluation of the Requirements for a Grammar and In-context spell checker for Dyslexic Adults
- An Evaluation of the Requirements for a New English Language Grammatical Tool and Teaching Environment

These papers are provided in Appendix A.17 and A.18. There is potential to produce further papers (from this thesis), which would be sent to the Dyslexia Annals. Suggested titles are presented.

- The development of a specialist word processor and sentence construction tool.
- How does dyslexia affect a person's ability within different language structures
- Analysis of adults with dyslexia and their use of computer programming languages
- Sentence construction tool for dyslexic students in higher education.

1.9 Terms and abbreviations used

These terms are used throughout this thesis.

Structured languages	-	computer programming languages
Natural languages	-	English (written form)
Environment 1, env1	-	specialist basic word processor
Environment 2, env2	-	spell checking tools and environment 1
Environment 3, env3	-	sentence construction tool and environment1
Sentence construction tool	-	control mode (support tool name)
Computer-based support	-	CBS
Computer-based learning	-	CBL

1.10 Thesis content

This section provides a brief review of the chapters included within this thesis.

Chapter 2 forms the first part of the literature review and is concerned with computer-based support. It discusses the important aspects in designing computer software on a general level. The two main application areas of interest are: word processing and computer programming development environments.

Chapter 3 forms the second part of the literature review and is primarily concerned with computer-based support applicable to dyslexia. It provides a general background to dyslexia and then offers a more detailed account of the specific areas of interest within dyslexia such as using computers and word processors. The chapter concludes with a look at dyslexia and different language structures including music, mathematics and computer programming languages.

Chapter 4 is concerned with the initial and follow up surveys carried out to confirm the research hypothesis and develop the design criteria for the specialist word processing package. Over two hundred and fifty adults with dyslexia took part and provided a great deal of research data. The chapter discusses the method of data collection, the material included in both surveys and the survey results. It concludes with an evaluation of these results and how they can be used.

Chapter 5 is the first of three chapters dedicated to the design and implementation of the research software. This chapter is concerned with the basic word processor referred to as environment 1. It discusses how Microsoft WordPad is used as the basic system and what alterations and enhancements were required. It details the features, menus and icons that are used. It also describes how the survey results (presented in Chapter 4) are used to design specific aspects of the word processing package.

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Chapter 6 is concerned with the design and implementation of the spell checker, word predictor and word meanings tools, referred to as environment 2. The chapter discusses how the survey results are used within the design process. It includes the design of the text highlighter and all the relevant dialog display boxes. Details concerning the file layout, file structures and a list of the spelling error routines are provided. How the system interfaces with environment 1 is also discussed.

Chapter 7 is the third and final design and implementation chapter concerned with the design of the sentence construction tool (control mode), referred to as environment 3. The chapter commences with a discussion on how the underlying hypothesis concepts are incorporated into the design of the support tool. It also discusses how features from computer programming support tools are included and lists the main design objectives. The design of the dialog boxes and functions are provided. How the system interfaces with environment 1 and the spell checker is also discussed.

Chapter 8 is concerned with the testing of the research hypothesis. It commences with detailing the testing sample attributes and how any bias has been minimised. It then gives details of the test topics used and offers an overview of the testing procedure. Examples of written text produced by the test subjects are also included.

Chapter 9 is concerned with the evaluation and final results. The chapter commences with detailing the methods of evaluation used. It then discusses the general test subject's profile. An analysis of the written English difficulties, written text produced by the test subjects and academic and test subject grades are provided.

Chapter 10 is the final chapter and commences with an evaluation of the research findings. The next section discusses the conclusions and relates them to the research hypothesis. The final section gives details of additional work, which, include further developments and issues for subsequent investigation.

Chapter 2 Literature Review – Computer-based support

2.1 Introduction

The development of computer software, which provides the user with the environment and support most appropriate for their requirements, is essential. This chapter is concerned with investigating issues, which need to be considered in order to achieve this. The material is very generalised and non-specific to any particular category of user. It forms the foundation for Chapter 3, which is specific to adults with dyslexia. The key areas of interest are environments used for writing tasks and developing computer programs. These areas are interlinked with the research hypothesis (discussed in Chapter 1) and are therefore of importance.

2.2 Computer-based support

Computer-based support (CBS) is a generic term used to describe activities where a computer is used to support human activities. Computers are capable of offering a range of highly supportive and responsive environments. CBS covers a vast number of areas from specific domains to everyday tasks. Common usage examples:

- Computer-based learning
- Word processing packages supporting writing tasks
- Computer programming development studios supporting program development
- Numerical calculations and analysis, for control and guidance systems
- Fault detection and decision-making of various kinds
- Data mining and warehousing

The first three examples are relevant to the development of the research software and therefore will be discussed in some detail. Although the research software will not provide teaching support directly, many of the concepts behind computer-based learning (CBL) are appropriate. This is particularly the case for the sentence construction component, which attempts to put rigid controls on the user and teaches through example (automating the sentences).

2.3 Computer-based learning

The term computer-based learning is used to describe activities whereby a computer (through the use of associated software) is used to teach human beings. Designing CBL materials is a complex task involving a number of factors. It involves careful consideration of many issues not least the context in which the materials will be used, the individual learners and the objectives of the product.

An example of CBL is Writing to Read program originally developed in 1986 [MF86] to support early literacy learning. To achieve its aims, the program incorporates intensive use of computers in the teaching and learning process. Writing to Read uses the computer to teach writing and reading skills and processes. A three year study was undertaken [Sin92a; Sin92b] and the results indicated that the pupils made gains in reading achievement that were well beyond that which would have been expected for their age. The study therefore, serves to demonstrate the versatility of the computer as a teaching and learning tool. Computers may be used to create a range of responsive teacher centred and learner centred environments.

2.4 Aspects of CBL applicable to CBS

Much of the material related to CBL can also be applied to other examples of CBS. The common objective is to provide an environment to allow computers and humans to interact in the most efficient method in order to complete the task in hand, whether that task is purely supportive or includes a learning aspect. Through the use of engaging and adaptable software, computers can provide an extremely effective method of support. The main features that make this possible are:

- **Adaptability**
Example: being able to change to suit the users' needs, style and pace
- **Dynamic display**
Examples: windows, scrolling and hypertext links
- **Memory**
Examples: record users' reactions, spelling pattern and preferred requirements

- **Patience**

Example: computers make no judgement if many attempts are needed

- **Tirelessness**

Example: never need to take a break or go on holiday

- **Interactivity**

Example: able to respond to users' reactions, behaviour and choices

2.4.1 Interactivity

The critical feature of CBS that makes it different from other methods is interactivity, that is, the power of the computer to engage, communicate and adapt to the user. Successful support depends on a high degree of interaction between the users and the computer. Interaction is not simply about making the users touch the keys or click on icons. It is about engaging their minds so they are sufficiently motivated. The degree of interaction [Cla01] depends on:

- Presenting the software in a motivating and engaging way
- Providing effective feedback when necessary
- Maximising the choices available to the users
- Providing support tools to make tasks easier
- Selection: to enable the system to be tailored to specific needs

Many choices can be offered to the users so that they can personally customise the environment associated with the particular task.

2.4.2 Navigation

Navigation is a key element in the design of CBS. It has a considerable influence on interactivity. When a person reads a textbook they are provided with a range of navigation aids such as a contents list, index, lists of figures and page numbers. These devices are easily transferable to the computer because CBS employs a variety of media types. Words can be brought to life and given depth. Searches and word replacements can be achieved quickly and accurately. The standard navigational buttons for viewing text are available and allow the user to scan through documents very quickly.

2.4.3 User characteristics

Characteristics of the users are an important consideration in the design of effective CBS software [Cla01]. This is very relevant to the research software. Characteristics can include some or all of the following:

- Age
- Computer ability
- Previous experience of CBS
- Educational level, and any learning disabilities
- Gender
- Physical characteristics, in particular eye sight problems
- Reading age

Design of CBS material might, for example, take into consideration characteristics such as: whether, or not, users are familiar with using a computer environment to the extent that clicking with a mouse etc. is so distracting to them that they are unable to benefit from the support offered. One male in twenty suffers from some form of colour blindness but only one in several hundred females are colour blind [CIP02], so material designed to use colour in any way as a feedback mechanism might not be perceived by a proportion of male users. Older users may not possess the manual dexterity to use the equipment in the way intended or to the degree of accuracy required.

2.4.4 Adult support

As this thesis is concerned with this issue it was felt important to present some of the key concepts, which need to be considered. They are:

- Be relevant and meaningful for adult users
- Design the software specifically for adults, not including any 'child like' features
- Allow for the different motives of the users
- Provide powerful support tools
- Allow for the different requirements and preferred styles of the adult users

2.4.5 Communication

Effective implementation of communication between users and CBS depends on identifying the key factors in the relationship between users, the task and the environment. The relationship between the three sets of factors can be complex. There are considerable differences between designing software for: a computer literate person compared to a computer novice; a person working at home in isolation compared to one working in a group environment and a straightforward task compared to a complex one [Cla01].

The term 'communication style' is a general expression for the way systems are designed in order that users can communicate with them. Many different styles have been developed for particular tasks and users, and standards vary between different operating systems and commercial software products, e.g. Macintosh and Microsoft. Several styles are now recognised as 'standards' but often a mixture of styles is employed. The standards that are most important in CBS are:

- **Direct commands**
Example: Q for Quit
- **Menus**
Examples: pop-up, pull-down and radio click
- **Form filling**
Often using the TAB key to switch between fields
- **Direct manipulation**
Often using icons and pointers
- **Natural language communication**

Natural language communication means using a spoken (or written) language that is natural to the user. This appears to promise a flexible and easy method of communicating since users will already know their language but there are certain limitations. These are:

- **Variation**
Ensuring the system can cope with grammar and spelling

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- **Vagueness**

Users can express themselves in several ways often conveying subtle differences in meaning

- **Ambiguity and errors**

Can the system cope with these problems?

2.4.6 Layout

Certain screen elements are now seen as essential. These include:

- Location and navigation information
- Controls
- Tutorial and help information
- Feedback messages

Consistency with the use of headings, icons, buttons, etc. is vital in ensuring users feel comfortable with the environment that they are working in. All CBS material must include user instructions and guidelines. Some consideration should be given to whether the text that is presented on the screen (guidelines, instructions, help information or learning material) should be justified or centred, the size and styles of fonts to be used, when to use highlighting and how to contrast between various styles to maintain the users' attention.

2.4.7 Use of colour

A method of displaying colours on a computer screen is to use a combination of three base (or prime) colours: red, blue and green, and the various degrees of hue, saturation and density that can be applied to each of these colours. A careful selection of these three variables gives the many shades of the prime colours that are available to CBS designers.

Judicious use of colour can serve a wide variety of purposes which include: attracting users' attention; aiding retention of information; emphasis; adding interest to displays and grouping objects or text together. Certain colours can be used to evoke particular

meanings to users. These include: red for danger; yellow for excitement and green for calm.

Nearly as important is consistency. Having chosen a colour scheme for use in CBS software, care must be taken to maintain consistency across other modules. The choice of colours is of considerably greater importance for users with visual difficulties.

2.5 Computer-based support for writing tasks

Word processing and desktop publishing packages are by far the most common applications of computer-based support. Word processing and desktop publishing programs are concerned essentially with the manipulation of information: textual and graphic. They allow users to process information and this is an activity that most people frequently need to do. Writing can very often be a recursive process as writers redraft their work [Emi82].

According to Vygotsky [Vyg78], our patterns of communication and interaction with others highly influence the ways in which we organise and interpret information. The computer quite naturally becomes a focus for interaction and collaboration among writers and its value in this respect has been emphasised many times, by [Bas96], [Som86] and [Tru86]. Gallagher [Gal85] claims that the special characteristics of word processing make it an instrument that lends itself, both psychologically and materially to the practice of collaborative learning. Similarly, Sudol [Sud85] states that the use of word processing offers an opportunity to reinvent the work-shop classroom model in which collaborative learning takes place and where the students are liberated from the idea that what they write is for teachers to evaluate.

2.5.1 Word processors

Word processing programs allow the user to input, edit, correct and present texts of any kind. While they differ widely in the facilities they offer writers, all offer opportunities for text insertion, substitution and rearrangement. Word processors offer considerable control over the final presentation of text: a variety of typefaces can be used; text can be

blocked or printed in columns and graphic images can be inserted in the document [Und94].

Word processing packages produced by software suppliers usually adhere to a standardised, graphical user interface for all of their products, although the standards can vary between suppliers. However, there are generic features applicable to each that is now described.

2.5.1.1 Graphical user interface

A graphical user interface is a program that takes advantage of the computer's graphics capabilities to make the program easier to use. Well-designed graphical user interfaces can free the user from learning complex command languages.

Graphical user interfaces, as used in Microsoft applications and Apple Macintosh applications for example, feature the following basic components: Windows, Icons, Menus and a Pointing device, often referred to as a WIMP environment. WIMP environments also use a standardised desktop.

Windows

The user can divide the screen into different areas. In each window, the user can run a different program or display a different file. The user can move windows around the display screen, and change their shape and size at will.

Icons

Icons are small pictures that represent commands, files, or windows. By moving the pointer to the icon and pressing a mouse button, the user can execute a command or convert the icon into a window. The user can also move the icons around the display screen as if they were real objects on the user's desk.

Menus

Most graphical user interfaces let the user execute commands by selecting a choice from a menu.

Pointer

A pointer is a symbol that appears on the display screen, which the user can move to select objects and commands. Usually, the pointer appears as a small angled arrow. Word processing applications, however, use an I-beam pointer that is shaped like a capital I. A pointing device is a device, such as a mouse or trackball, which enables the user to select objects on the display screen.

Desktop

The area on the display screen where icons are grouped is often referred to as the desktop because the icons are intended to represent real objects on a real desktop.

This standardisation has made it possible for users to use several different word processors without having to go through a period of learning how the basic system works.

2.5.2 Writing assistance

Ellis [Ell93] evaluated student's responses when using a computer tool known as Writing Partner. This tool provides an environment to stimulate students' thinking about story ideas and guides the process required in narrative text construction. The purpose of the research was to examine whether (a) guidance from the Writing Partner would enhance the quality of students' narrative text, (b) whether improvements in writing would be associated with a better understanding of the formal processes involved in text construction and (c) whether the usefulness of the tool was affected by whether the writers were a novice or an expert writer.

Six poor (novice) writers of average ability (with regards to general academic ability) and two accomplished (expert) writers of above average ability used the Writing Partner to support regular classroom story writing activities over one school term. The age range was 12 to 13 year olds from middle-class Australian families. Stories were evaluated on a 1-5 scale according to six criteria (overall global impression; plot(s); characterisation; mood; setting/time; dialogue; expression; mechanics) believed to represent the extent to which a story manifests features reflective of knowledge transforming processes [Zel91].

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Evaluations of novices' stories indicated considerable improvements in most areas. Novice writers became much more aware that the stories needed to be 'reader friendly' and that consideration of the audience was important throughout the whole composition process, not just the planning or revision phase.

For expert writers, there were less obvious improvements in writing performance. Their stories were already rated highly at the beginning of the study, which they maintained throughout the study. Improvements for experts were mainly in use of linguistic features that contributed to the plot organisation and overall narrative style.

Consistent with Bereiter and Scardamalia's [BS87] view of writing, the experts pre and post Writing Partner explanations of how to write a 'good story' reflected considerable awareness of the importance of planning, characterisation, plot development and text monitoring, reworking and revising in the light of audience needs. This was not the case for the novice writers whose pre knowledge was limited and post knowledge was greatly improved.

2.5.3 Environment settings

In order to maximise a user's concentration and limit the number of typing errors that are made, the correct setting of the environment variables are essential [Cla01]. An important aspect in the use of colour is the contrast between two or more colours. This applies especially to the text and background environment variables. Most importantly, the contrast between foreground and background colours is sufficiently great so as not to cause eyestrain, distract, tire or irritate the users.

Frequently black text on a white background is used but other combinations of colours are possible. It is worth the time to experiment with different colours until the preferred colours are found. The survey discussed in Chapter 4 showed that a Royal blue background with white text is a favoured combination for adults with dyslexia. The white letters seem to stand out from the screen and often increase concentration levels and reduce eyestrain.

Other important environment settings are the font type, size and spacing of the text. Some word processors use Times New Roman size 12 as the default font and size, which can be acceptable to many users but may cause eyestrain to others. However, a way to avoid eyestrain is to increase the size to (say) 14 and change the font style while entering text, before changing it back before printing. If reading from the screen is difficult, increasing the spacing between the lines can reduce the problem. Combined changes should make reading the text easier and will save time when proof reading.

2.5.4 Structure and layout

Screen layout is a crucial aspect of computer-based support for writing tasks. Certain screen elements are now seen as essential. These include: location and navigation information, controls and help information. Consistency with the use of headings, icons, buttons, etc. is vital in ensuring that the users feel comfortable with the environment they are working in.

Some features have evolved into *de facto* standards in (for example) Microsoft products. These include: ESC (escape key) to close a text or message pop-up box; a 'depth' dimension with buttons to indicate depression and thus selection of that button; and 'greying out' of menu choices that are unavailable in a particular mode of operation.

There are several other 'marginal' *de facto* standards that include things like the use of ALT+Q or ALT+X to leave a program, cntl S to save a document, cntl P to print a document, cntl N to open a new document, cntl O to open an existing document, cntl A to select all the text, cntl Z to undo last action, cntl F to find a string of text and the F1 key for help. Although these conventions are not universal.

Word processing packages usually maintain the same 'look and feel' for the user interface (WIMP). So that, for example, the position and layout of menus, icons (at the top), scroll bars (at the side and bottom) and document information (at the bottom), is consistent. What differs is the ease of how the layouts can be changed to suit the individual user, for example increasing the size of the icons for visually impaired users.

2.6 Environments for developing computer programs

This section is concerned with the environments and associated tools used when developing computer programming applications. The areas to be covered are computer programming languages (structured languages), a comparison between natural (English) and structured languages, computer programming environments, computer programming support tools and compilers.

2.6.1 Computer Programming languages

Human languages are often referred to as natural languages. Most computer programming languages use a highly structured format and are therefore known as structured languages. Computers are not sophisticated enough to understand natural languages. Each language has a unique set of keywords (a vocabulary) and a special syntax for organizing program instructions (grammatical rules).

Computers are inflexible machines that understand what is typed only if typed in the exact form that the computer expects. The expected form is called the syntax. Each programming language defines its own syntactical rules that control which words the computer understands, which combinations of words are meaningful, and what punctuation is necessary.

2.6.1.1 Classes of computer programming languages

There are many different classes of computer languages, including machine languages, programming languages and fourth-generation languages (4GLs). However, the term programming language in this thesis refers to high-level languages.

High-level programming languages, while simple compared to human languages, are more complex than the languages the computer actually understands, called machine languages. Ultimately, programs written in a high-level language must be translated into machine language by a compiler or interpreter. Each different type of computer has its own unique machine language, which is made up of binary digits.

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Lying between machine languages and high-level languages are assembly languages. Assembly languages are similar to machine languages, but they are much easier to program in because they allow a programmer to substitute names for numbers. Lying above high-level languages are fourth-and fifth-generation languages (5GLs). These are far removed from machine languages. A summary is shown below:

- First-generation: machine language
- Second-generation: assembly language
- Third-generation: high-level programming languages, such as C, C++, and Java
- Fourth-generation: assist the programmer by using such tools as directed editors and code generation tools
- Fifth-generation: a fourth-generation language with a knowledge-base included

A programming language such as C, FORTRAN or Pascal that enables a programmer to write programs that is more or less independent of a particular type of computer, are considered high-level because they are closer to human languages and further from machine languages. In contrast, assembly languages are considered low-level because they are very close to machine languages.

The main advantage of high-level languages over low-level languages is that they are easier to read, write, and maintain.

The first high-level programming languages were designed in the 1950s. Now there are dozens of different languages, including Ada, Algol, BASIC, COBOL, C, C++, FORTRAN, LISP, Pascal, and Prolog.

2.6.1.2 Selecting programming languages

Selecting which language is more suited for a particular application can be a difficult process. Every language has its strengths and weaknesses. For example, FORTRAN is a particularly good language for processing numerical data, but it does not lend itself very well to organizing large programs. Pascal is very good for writing well-structured and readable programs, but it is not as flexible as the C programming language. C++

embodies powerful object-oriented features, but it is complex and difficult to learn. The choice of which language to use depends on several parameters. These include: the type of computer the program is to be run on; the nature of the problem being solved and the expertise of the programmer.

2.6.2 Comparisons between structured and natural languages

Human languages and computer programming languages are very different from one another. This section will attempt to form a comparison between the different language structures. The research hypothesis is concerned with the effects of using different language structures and therefore it was felt necessary to provide some general background information.

Connolly [Con01] attempts to establish whether it is possible to accommodate natural languages (such as English) and structured languages (such as computer programming languages) within a single framework. He is concerned with the various aspects of contexts within both language types. The results from the paper seem to indicate, at least to a degree, a common framework is feasible. The paper is far too complex to review within this thesis, however common features have been noted.

One property that, both human languages (natural languages) and computer programming languages (structured languages) have in common is the general framework of the language. Written languages (both types) use symbols (that is, characters) to build words. The entire set of words is the language's vocabulary. The ways in which the words can be meaningfully combined is defined by the language's syntax and grammar. The actual meaning of words and combinations of words is defined by the language's semantics. The effect of the words is the language's pragmatics.

Probably the single most challenging problem in computer science is to develop computers that can understand natural languages. So far, the complete solution to this problem has proved elusive, although a great deal of progress has been made. 4GLs are relatively close to natural languages. Most 4GLs are used to access databases. For example, a typical 4GL command is

FIND ALL RECORDS WHERE NAME IS "SMITH"

However, 5GLs are in many respects closer to natural languages and some have been in use for a number of years, e.g. Chat80 [PG94]. Gazdar and Mellish [GM89] use directed acyclic graphs to represent all aspects from syntax to pragmatics.

2.6.3 Computer programming environments

Common usage terms for computer programming environments are syntax-directed programming environment and a visual integrated programming environment. There are various support tools, which can be used according to the requirements of the programmer and the type of programming language. The basic types of programming tools are:

- Syntax directed editors help to create and alter programs
- Compilers detect syntax errors
- Debuggers help to find syntax and semantic errors
- Wizards reduce the time needed and are supportive

There are several different types of computer programming environments; the most powerful and labour saving ones will now be reviewed.

2.6.3.1 Application development tool

An Application Development Tool (ADT) is a programming system that enables programmers to quickly build working programs. In general, the systems provide a number of tools to help build graphical user interfaces that would normally take a large development effort.

Historically, ADT systems have tended to emphasise reducing development time, sometimes at the expense of generating efficient executable code. Nowadays, though, many ADT systems produce extremely fast code. Conversely, many traditional programming environments now come with a number of visual tools to aid development.

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Therefore, the line between ADT systems and other development environments has become blurred.

Several examples of ADT systems for Windows are Visual Basic, Visual C++ and Delphi. In the case of Visual C++ two wizards (class and application) are provided, a class library (MFC) and many testing features to make programming easier.

2.6.3.2 Integrated development environment

An integrated development environment is a programming environment integrated into an application. For example, Microsoft Office applications support various versions of the BASIC programming language. Users can develop a WordBasic application while running Microsoft Word. Microsoft Excel will allow the use of Visual Basic within the spreadsheet.

2.6.3.3 Abstract window toolkit

This is a programming environment that enables programmers to develop Java applications with graphical user interface components, such as windows, buttons, and scroll bars. The Java Virtual Machine (VM) is responsible for translating the abstract window toolkit (AWT) calls into the appropriate calls to the host operating system. Ideally, the AWT should enable any Java application to appear the same whether it's run in a Windows, Macintosh or UNIX environment. In practice, however, most Java applications look slightly different depending on the platform on which they are executed.

2.6.3.4 Authoring tool

An authoring tool is a program that helps the user write hypertext or multimedia applications. Authoring tools usually enable the user to create a final application merely by linking together objects, such as a paragraph of text, an illustration, or a song. By defining the objects' relationships to each other, and by sequencing them in an appropriate order, authors (those who use authoring tools) can produce attractive and useful graphics applications. Most authoring systems also support a scripting language for more sophisticated applications.

The distinction between authoring tools and programming tools is not clear-cut. Typically, though, authoring tools require less technical knowledge to master and are used exclusively for applications that present a mixture of textual, graphical, and audio data.

2.6.4 Programming tools

Most programmers use programming tools to make the task of writing programs easier. Three such tools are syntax directed editors (for the creation and development stage), computer wizards (for the development stage) and debuggers (for the error detection phase).

2.6.4.1 Syntax directed editors

Syntax directed editor is an editing tool that is aware of the syntax of the language being edited, and which allows the user only to create syntactically correct programs. No such editors exist for natural languages such as English.

Syntax directed editors aid programmers in constructing and manipulating their programs. A program is a collection of syntactically and computationally meaningful objects such as identifiers, procedures, loops, and data types. Therefore, it is only natural to build editing tools that view programs as hierarchical collections of programming language constructs and allow programmers to create and manipulate their programs in terms of these language constructs.

In a syntax directed editor, the user edits a program, not a piece of text. The editor works directly on the program as a tree; matching the syntax trees by which the language is structured. The units worked with are not lines and characters but terms, expressions, statements and blocks. Since the editor works on a symbolic representation of the program it allows all kinds of editing operations at the semantic level. Examples for Java: transform a for-loop into a while-loop; renaming of a variable. For each programming construct, syntax-directed editors provide the programmer with a template. Templates depict the structure of the programming construct being represented and contain

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placeholders at positions where user-insertions are allowed. For example if a ‘for’ loop is required simply enter ‘for into the "Statement" placeholder and the format is created automatically, as shown:

```
for variable := start to finish do
begin
    Statement
end;
```

All that needs to be done is to fill in the blanks. At each blank, the programmer is provided with a menu of options.

Syntax-directed editors, such as some programming tools, and graphical, network editors, have the desirable effect of ensuring that the manipulated artefact is at least syntactically correct. For example, they ensure that a segment of program code contains no spurious or missing text items, or that an architectural drawing has doors placed in the walls instead of in the middle of rooms.

The main objectives of the editor are to enable the users to edit programs as easily and freely as with a conventional text editor and give them some extra features such as: template instantiation, automatic indentation and “pretty printing”, lexical and syntactic error handling.

A syntax-directed editor allows the writing of syntactically correct programs at any point during editing. Also the editor supports people learning a language and which are not familiar with the syntax. These editors usually dramatically improve the editing speed. Typing effort is reduced, and therefore, the possibility of introducing typing errors is minimised. Generated programs are syntactically correct, thereby eliminating the need to detect and correct syntax errors. These systems failed to become widely adopted by computer programmers. Some of this resistance stems from the fact that the early systems failed to address the basic usability issues arising from the use of structure based editing technology. Advantages gained through use of the advanced editors do not sufficiently outweigh the inconveniences involved in learning and using a complex tool.

2.6.4.2 Wizards

A wizard is a tool used within Microsoft applications. Although some other manufacturers provide similar tools giving them different names. It is a utility, which helps the user to use the application to perform particular tasks. Wizards are a way of constraining and guiding the behaviour of the user. They use an explicit template to ensure the correct structure is used. It is not true to claim that all wizards (or similar tools with a different name) are useful for everyone. They are by their very nature restrictive and enforce a degree of control. These concepts are similar to the developed hypothesis. Environment 3 (discussed in Chapter 7) incorporates several of these general concepts and uses the template method. Examples of wizards are, within the Visual C++ programming development studio, two wizards can be used: Application wizard; sets up new programming applications, and Class wizard sets up new or allows alterations to be made to classes. Another example is a 'letter wizard' within a Microsoft word processing application. It would lead the user through the steps of producing different types of correspondence.

2.6.4.3 Debuggers

A debugger is a special program used to find errors (bugs) in other programs. A debugger allows a programmer to stop a program at any point and examine and change the values of variables. A bug is an error or defect in software or hardware that causes a program to malfunction. According to folklore, the first computer bug was an actual bug. This was discovered by Lieutenant Grace Hopper in 1945 at Harvard, a moth trapped between two electrical relays of the Mark II Aiken Relay Calculator shut the machine down.

Debuggers do not enforce any constraints directly upon the programmer it uses implicit templates in order to verify the code. These work in a similar way to grammar checkers for natural languages. Results from Chapter 4 indicate that dyslexics find debugger tools more useful than they find current grammar checkers. Although this research does not include a grammar checker, it is mentioned within the further work section (Chapter 10) and concepts used for debuggers would be incorporated into the design.

2.6.5 Compilers

Programmers write programs in a form called source code. Source code must go through several steps before it becomes an executable program. The first step is to pass the source code through a compiler, which translates the high-level language instructions into object code. The compiler derives its name from the way it works, looking at the entire piece of source code and collecting and reorganizing the instructions. The final step in producing an executable program, after the compiler has produced object code is to pass the object code through a linker (producing machine code).

A compiler differs from an interpreter, which analyses and executes each line of source code in succession, without looking at the entire program. The advantage of interpreters is that they can execute a program immediately. Compilers require some time before an executable program emerges. However, programs produced by compilers run much faster than the same programs executed by an interpreter.

Every high-level programming language (except strictly interpretive languages) comes with a compiler. In effect, the compiler is the language, because it defines which instructions are acceptable. Compilers translate source code into object code, which is unique for each type of computer, so many compilers are available for the same language. For example, there is a FORTRAN compiler for PCs and another for Apple Macintosh computers. In addition, the compiler industry is quite competitive, so there are actually many compilers for each language on each type of computer. More than a dozen companies develop and sell C compilers for the PC.

2.7 Concluding remarks

This chapter initially provided a general review of computer-based support and listed the main features and concepts that need to be considered when designing support software.

These included:

- Interactivity – engage, communicate and adapt to the user
- Navigation – move around the system effectively
- User characteristics – such as computer ability

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- Adult support – removal of ‘child like’ features
- Communication – incorporating styles
- Layout – standardisation and colour contrasting – to support proof reading

As this thesis is concerned with the development of a word processor (computer-based support package) incorporating support tools designed on computer programming tools, a review of specific related application areas was provided. These application areas were word processors (to a lesser degree as they will be covered in the next chapter) and computer programming environments. A review of the type of programming tools, which are available, was provided. These included syntax directed editors, computer wizards and debuggers.

The differing programming environments were listed and outlined. Chapter 4 evaluates how useful these tools and environments are for supporting dyslexic adults. Useful concepts are used in the development of environment 3, which is discussed in Chapter 7. This chapter was concerned with providing a general foundation, which will be built upon in Chapter 3. The development of support packages for adults with dyslexia will be the main topic of the next chapter.

Chapter 3 Literature Review – Dyslexia

3.1 Introduction

The previous chapter was concerned with the development of computer environments and the issues that need to be considered. This chapter aims to provide a detailed account of dyslexia and forms the second part of the literature review. Section 3.2 provides a general introduction to dyslexia giving the general facts, concepts, definitions, associated problems and famous people with dyslexia. The field of computers and dyslexia is the topic of the following section. Section 3.4 is concerned with word processors and the use made of them by adults with dyslexia. This covers a review of the most widely used packages, special features and any unresolved problems with support tools used within these packages.

The topic of dyslexia and written English is covered in Section 3.5. This includes spelling patterns, difficulties with English grammar and sentence structuring. The field of dyslexia and different language structures is the subject of Section 3.6. This will include a discussion on dyslexia and mathematics, dyslexia and music, pictorial languages and structured languages (computer programming languages). The chapter concludes with a general summary.

3.2 Dyslexia

Despite the growing attention, which this elusive disorder has received, since it was first recognised in 1896-97 by two English physicians, W.P. Morgan and J. Kerr, dyslexia has remained a scientific enigma. It defies most attempts at medical understanding, diagnosis, prediction, treatment and prevention. This section gives a general introduction to dyslexia and provides the foundation for the remaining sections, which will offer a detailed account of the specific areas of interest.

3.2.1 Concepts and definitions

What is dyslexia, or what does it mean? From the Latin 'dys' means bad or hard and 'lexia' means language. A favoured definition of dyslexia is, "Functional Blindness relating to written material: being virtually blind to written material" [BDA02]. However, this definition does not take into consideration the different functions dyslexia affects, such as mathematics ability, linear thought functions, stuttering, "functional deafness" to spoken information, rhythmic dysfunction and others. There are many other varying definitions of dyslexia such as, "A permanent condition of varying severity that makes interpreting and expressing words, numbers and symbols difficult for some individuals" [ADO02]. Another widely used expanded definition of dyslexia is:

"Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterised by difficulties in single word decoding, usually reflecting insufficient phonological processing. These difficulties in single word decoding are often unexpected in relationship to age and other cognitive and academic abilities; they are not the result of generalised developmental disability or sensory impairment. Dyslexia is manifest by variable difficulties with different forms of language, often including, in addition to problems with reading, a conspicuous problem with proficiency in writing and spelling" [ODS95].

Although dyslexia has more than three categories, all other categories can be linked in some way within the three basic categories. They are visual dyslexia, auditory dyslexia and a combination of visual and auditory dyslexia.

Visual dyslexia is characterised by reversals of letters and numbers, faulty sequencing, coding and/or decoding of letters in words, numbers in a series and events in a narrative. Visual dyslexics also have problems with orientation in time, spatial relationships and problems in processing, interpreting and recalling visual images.

Auditory dyslexia is characterised by problems with integrating and processing what is heard. Auditory dyslexics also have problems with recalling sounds and being able to put

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a sound with the letter it represents. The third category is a combination of visual and auditory dyslexia, which is more pronounced. The British Dyslexia Association [BDA02], state that visual dyslexia is by far the most common of the three types.

Visually oriented dyslexics may be in an increasingly favourable position in future years because of the recent revival of visual approaches to scientific, mathematical and technological developments. The same set of traits that caused them so much difficulty in traditional verbally orientated education systems, may provide special advantages in emerging new fields that rely on visual methods of analysis: fields that use graphic workstations and super computers to visualise complex scientific data. Recent trends have led technical professionals to become aware that their own special talents seem to be associated with dyslexic traits [Wes94]. Similar mixed talents have been major factors in the accomplishments of a number of historical figures (i.e. Albert Einstein and Leonardo da Vinci).

3.2.2 Some facts

Dyslexia is a consequence of the way a person's brain is organised. Learning to read requires making the association between printed symbols and spoken words and spoken sounds. These associations must become firmly fixed in memory for reading to be fluent. People with dyslexia have great difficulty establishing these associations [ODS95].

Studies undertaken [BDA02] show that a dyslexic person is more likely to be male than female at a ratio of 3:1 and in some studies up to a 6:1 ratio. The National Institutes of Health in the USA have estimated that between ten to fifteen percent of the earth's population is affected by dyslexia in some way. However, in Britain it is estimated that approximately 4% of the population is affected by dyslexia. Genetic research suggests that dyslexia also tends to run in families.

Based on government-sponsored studies, the British Dyslexia Association estimates that 10% of children have some degree of dyslexia, while about 4% will be severely affected (an average of one in every class). A distinguishing characteristic of dyslexia is its persistence throughout life. Each dyslexic individual appears to have a unique profile;

many are highly gifted and creative. The severity of symptoms also varies; some of which are not always strikingly apparent. Girls for example seem to develop language skills and coping strategies at an early stage and this may mask underlying difficulties [Dys95].

3.2.3 Possible causes of dyslexia

Research into anatomical differences in the brains of people with dyslexia, dates back 80 years. A substantial amount of research has gone into the cause or possible causes of dyslexia. Dr. Albert Galaburd, a neurologist and Dr. Thomas Kemper, a neuropathologist, perfected a technique for examining the cell structure of the brain [GK79]. In 1979 this technique was used to examine the brain of a dyslexic man who died accidentally. Abnormalities were located in the man's brain, in areas known to be part of the auditory association, part of the cortex. Research has indicated that this area of the brain is involved in interpretation of sound and its recollection in shape and sequence. These abnormalities could not have been caused by medical injury at the time of birth, but had occurred during the formation of the brain tissue in the womb. Over the years, this area of research has continued and many more subjects have been examined.

The different functions of the left and right hemispheres of the brain, and the vital importance of the cross over links between the two hemispheres have been established for a long time. A simple summary of the left and right brain differences appear in *Body Language* by Jane Lyle [Lyl91]. Also a basic review of the brain differences in dyslexics can be found in *The Dyslexia Handbook* [Dys95]. Among the findings quoted in the handbook are the facts that dyslexics are often found to have:

- Larger than normal right hemispheres of the brain
- Evidence of unusual nerve connections in the brain
- Unusual connections between the two hemispheres of the brain

The recognition that the links between left and right hemisphere in dyslexics can be very different, leads to the realisation and the enormity of the difference that there can be between a dyslexic and a non-dyslexic.

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In 1978 it was discovered that the brain of the dyslexic has a greater developed area in the right parieto-occipital (A region which enables visuo spatial awareness), than that of the general population and that the language area (frontal-temporal region) on the left side of the brain is underdeveloped (used for logic, sequences and language). Due to the better than average visio spatial awareness, people with developmental dyslexia often produce certain kinds of superior talent, which leads to certain skills in the areas of art, architecture, engineering, photography, music and athletics.

An alternative view to the old school of thought can be found in the studies undertaken by Dr. Harold N. Levinson. These studies have shown that dyslexic problems are caused within the inner ear [Lev94] and not the prevailing neurological theory that dyslexia was due to a disturbance within the cerebrum - the 'thinking' brain. The remainder of this section is devoted to Dr. Levinson's theories [Lev80].

The inner-ear system has many functions, including the following:

- It acts like a gyroscope, giving a sense of balance
- It acts like a compass, giving an intuitive sense of direction
- It acts like a guided-missile system, co-ordinating movements and thoughts in time and space
- It acts like a sensory processor (or tuner) fine tuning information entering the brain including light, sound, motion, gravity, barometric pressure, temperature etc
- It regulates and dampens anxiety

If the inner-ear system is impaired, one, several or all of these functions may be impaired. Dr. Levinson carried out a study of 1000 dyslexic patients and found that only 1% of these cases showed evidence of cerebral dysfunction (low IQ, difficulty comprehending and formulating meaningful speech, epilepsy, left or right side weakness, etc.). However, more than 750 of 1000 patients exhibited distinct evidence of balance and co-ordination difficulties. The results were independently corroborated by the New York University Medical Centre (and several other hospitals). Hospitals revealed that 90% of these cases showed definite evidence of inner-ear dysfunction, further confirming his clinical findings.

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The various manifestations of inner-ear dysfunction may be evident in any or all of the following areas:

- Balance and coordination
- Vision and hearing
- Sense of direction
- Motion sensitivity
- Memory
- Concentration and distractibility
- Hyperactivity and over activity
- Obsessions and compulsions
- Academic performance
- Anxiety levels
- Depression

The inner ear processes all sensory information (sight, sound, smell, taste and touch) entering the brain, including visual information. If it is malfunctioning, visual input may drift or become scrambled. If the drift is 180 degrees, reversals may occur. Auditory input can also drift or be scrambled, resulting in misunderstandings, confusion, delayed comprehension, blending of foreground and background noises and a variety of other hearing-related symptoms. Thus, if the inner ear, the sensory processor, is impaired, difficulties in processing and retrieving information seen, read or learned will occur.

Motion sickness medications, antihistamines, vitamins and stimulants are used to treat inner-ear problems and Dr. Levinson's studies show that they can be used to treat other sensory input such as the dyslexic academic symptoms. The medications help regulate and fine-tune, so that the motor output and sensory input are better tuned, sequenced and co-ordinated, leading to symptomatic improvement and eventual compensation. The medications used to treat reading, writing, spelling and other symptoms in dyslexics were also found to improve the compass and timing mechanisms of the inner ear system. Almost 80% of the patients treated have found that many of their dyslexic symptoms have disappeared while taking the prescribed medication. However, when the medication is

stopped the symptoms tend to return and Dr. Levinson is continuing his research into prolonging the medication effects.

A recent (March 2002) article in a national newspaper claimed that biochemical imbalances in the body are at the root of the learning difficulties that many people with dyslexia have. This research is being carried out at Oxford University where they have developed a breath test to identify those who could benefit from this pioneering treatment for learning difficulties. It measures biochemical imbalances in the body. Researchers hope to treat the imbalance with refined fish oil supplements; thought to maintain brainpower [ODU02].

3.2.4 Common problems associated with dyslexia

Until quite recently dyslexia was naively assumed to be a learning disorder necessarily characterised by one, or both of the following:

- Severe reading problems
- Scrambling and or reversals in letters, and words (evident in spelling, writing and reading)

Therefore it was also assumed that if there was no scrambling, reversal, or reading problems, there was no dyslexia. In fact there are literally millions of dyslexics with no scrambling or reversal problems and no reading problems. These are only two of the symptoms of dyslexia. Dyslexia is a syndrome of many varied symptoms that co-exist in all combinations and severities. There are dozens of others, including concentration problems, memory problems, directional problems, balance problems, etc. Any or all of these may be present in a given dyslexic individual. These problems will be more noticeable, when the person is nervous, stressed, fatigued or in poor health.

It is important to look at traits that tend to be common among dyslexics to understand how varied and complex dyslexia is. The following is a list of such traits:

- Appears bright, highly intelligent and articulate but has difficulty with reading, writing or spelling

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- A poor speller, spells phonetically and inconsistently
- Often has trouble with b's & d's (lower case only)
- Often has trouble with 6's and 9's
- When first learning letters often draws many of them backwards
- Most skills take longer to grasp, however, once the concept is grasped, will often excel
- When first learning to read, complains of letters/numbers moving while reading, writing or copying
- Does not read for pleasure
- When reading or writing shows repetitions, transpositions, additions, omissions and reversals in letters, words and/or numbers
- Sometimes unable to remember/describe tasks that were just performed or items that were just read
- Sometimes has trouble remembering names of objects and friends (even friends the person has known for years)
- Had early or late developmental stages (crawling, walking, talking)
- Becomes bored easily: often described as 'Hyper'
- Will test well orally, but not on written tests
- Learns best through hands-on experience, demonstrations, visual aids, experimentation and observation
- Hears background sounds not apparent to others and easily distracted by sounds
- Difficulty putting thoughts in to words
- Stutters under stress, transposes phrases and words when speaking.
- Very observant
- Very high peripheral vision
- Handwriting varies, becomes illegible (as a way to hide spelling and grammatical problems, especially in school)
- May seem uncoordinated, difficulty with some types of motor skills and tasks
- Difficulty telling time, managing and being on time
- Loses track of time
- Easily lost/disoriented

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- Difficulty learning sequenced information or tasks
- Has dependence on finger counting and 'tricks' with mathematics
- Does better with advanced mathematics (algebra, calculus, geometry, etc.) than general mathematics
- Can count but sometimes difficulty counting; loses count easily
- Excellent long-term memory for films, experiences, for locations and faces (but often not the names of the films, locations or persons)
- Easily frustrated or emotional about school, reading, writing or mathematics
- Prone to allergies
- Often confuses left/right
- Often an extra deep or very light sleeper
- Extremely high or low tolerance to pain
- Sensitive, emotional, extreme mood swings
- Strives for perfection in areas of interest
- Most things tend to be in the extreme, no middle ground
- Prone to be a tactile, hands on person; needing to touch or feel objects

Dr. S. Moody, an independent psychological consultant who specialises in the assessment of adults with dyslexic difficulties, is concerned with the problems dyslexia causes for adults in their everyday working lives [BM00]. She identifies eight weaknesses caused by dyslexia, which affects a person's efficiency at work. These are listed below:

- **Literacy skills**

This is the most common and obvious problem for dyslexic adults. A dyslexic can find it hard to follow written instructions, (for instance, in a technical manual), to read or write reports quickly and efficiently (even if reading has become competent, it is still often slow and arduous), to write memos and letters in clear accurate English.

- **Memory**

Difficulties correctly remembering telephone numbers, messages and instructions; finding it hard to take notes or recall what was said at meetings.

- **Sequencing ability**

Poor sequencing ability makes it hard for a dyslexic to file documents in the correct sequence, to write down numbers correctly, to look up entries in dictionaries or directories.

- **Visual orientation**

A dyslexic easily gets lost in strange surroundings, and may lose their bearings even in familiar places. They may have difficulty in dealing with maps, tables and charts.

- **Hand-eye co-ordination**

Poor hand-eye co-ordination can result in slow and untidy handwriting, poor presentation of written work or figures and inaccurate keying on a word processor or calculator.

- **Speech**

Many dyslexics are voluble talkers; though they often feel that they talk in an over elaborate and disorganised way, especially in meetings or on the telephone. Stuttering can be a common problem particularly when under stress.

- **Organisation skills**

Dyslexics are often poorly organised in all areas of their life; they tend to miss appointments, get the times and places of meetings wrong, fail to meet deadlines and generally live and work in a chaotic and muddled fashion.

- **Emotional reactions**

The dyslexic has to deal not only with their own frustrations about their various inefficiencies but also with other people's lack of understanding of and respect for, their difficulties. As a result the dyslexic person is likely to feel a mixture of unpleasant emotions: despair, anger, embarrassment, anxiety, lack of confidence and as a result, may sometimes behave in an aloof, defensive or aggressive way.

3.2.5 Famous people with dyslexia

There have been many famous people with dyslexia. Table 3.1 presents famous people from the past.

Name	Occupation
Thomas Edison	Inventor of the electric light bulb
Albert Einstein	Developed the theory of relativity
Auguste Rodin	Sculpted the classic statue 'The Thinker'
Leonardo da Vinci	Polymath
Agatha Christie	Author
Hans Christian Anderson	Author
Marlon Brando	Actor
Winston Churchill	Prime minister
General George S. Patten	US General in 2 nd World war
William Butler Yeats	Poet

Table 3.1. Famous people in the past.

It can be seen that the occupations are varied but the contributions made by these people were considerable. The next table presents famous people of the current day. Although these people may not have contributed to the same degree as those in the previous table, they have all made it to the top of their chosen field.

Name	Occupation	Name	Occupation
Whoopi Goldberg	Actress	Cher	Actress/singer
Leslie Ash	Actress	Felicity Kendal	Actress
Tom Cruise	Actor	Anthony Hopkins	Actor
Anthea Turner	Presenter	Michael Barrymore	Television presenter
Brian Conley	Comedian/actor	Nicola Hicks	Sculptress
David Bailey	Photographer	Richard Branson	Entrepreneur
Anita Roddick	Founder: Body shop	Ronald Davis	Author
Lynda La Plante	Television writer	Noel Gallagher	Pop star
Robbie Williams	Pop star	Jodie Kidd	Model
Michael Heseltine	MP	Duncan Goodhew	Swimmer

Table 3.2. Famous people of the current day.

These famous individuals have more than dyslexia in common, they have a certain kind of superior talent.

3.3 Computers and dyslexia

This section considers how computers (and software) can be used to help people with dyslexia. It must be noted that computers are a very useful tool for everyone not just adults with dyslexia. Although wherever possible the content in this section attempts to highlight the specific benefits (and problems) for dyslexic adults. Most of the material for this section has been taken from the BDA computer booklet [HS96].

Dyslexia is a hidden handicap, which can cause great frustration. Computer use is a powerful way of helping dyslexic learners of all ages to fulfil their potential through success and improved self-esteem. Computers are part of everyday life and their proper and efficient use is increasingly seen as an important problem solver. Educational technology has taken a major step forward with the introduction of a new generation of affordable but very powerful computers. The availability of multimedia environments allows the smooth integration of text, graphics and synthesised or digitised speech. In addition the solutions to many of the problems facing an individual are assisted by the capability for interaction using 'point and click' rather than keyboard text entry.

3.3.1 Benefits associated with using computers

The computer can replace other ways of doing things. It can be used in the place of pen and paper for writing. Computers can do sums more accurately and far quicker than humans. It is an easy task to use spreadsheets to perform routine calculations and provide running totals that change every time new figures are added. Keeping details on a database saves time and mistakes. The lists of addresses or information can be updated and reprinted easily. Searching and sorting are two functions that are frequently used.

There is little doubt that the use of computers can be a tremendous help to dyslexics. One of the principle values of computer activities is that they can re-motivate the reluctant learner, boosting confidence and giving them the determination to overcome the difficulty

[Sin92a]. Dyslexics tend to learn best when using several senses simultaneously: touch, sound and sight. Computers, through multimedia, are able to offer this ideal learning environment [Sin94]. Computers do not judge, are endlessly patient and can be tailored very easily to individual needs.

3.3.1.1 Visual effects

Dyslexic people often report visual discomfort while reading, describing text that blurs or vibrates when they look at it. Difficulties associated with dyslexia that are visual, or capable of being ameliorated by alterations to the visual display, can be identified and used as parameters for the development of suitable software. These will now be discussed.

- **Meares-Irlen syndrome**

Some dyslexic readers cannot distinguish between different eye fixations, meaning that they see a confusing combination of letters when a normal reader would only perceive the results of the last fixation [SW97]. Placing a coloured overlay across the text helps to alleviate this problem [NG97, WL99].

- **Pattern Glare**

Dyslexic people and also people who suffer from migraines and epilepsy, can find patterns of stripes, like those produced by black text on a white background, painful to look at. They may see different colours surrounding the pattern, or perceive the lines to be moving or bending [WN87, Wil95].

- **Motor control**

Some dyslexic people show symptoms of poor hand-eye coordination, as well as problems with ocular motor control, for example, difficulty focusing on small targets [EBH99, Eve99]. This can also mean that when the dyslexic reader completes one line of text, they find it difficult to move their eyes to the beginning of the next line.

- **Short-term memory**

Dyslexia is often associated with mild short-term memory deficit and this means that when dyslexic people are using traditional word processors they can become disoriented by the menu systems, which demand successful recall of the location of commands [Kea00].

- **Visual memory**

As well as problems with short-term memory, many dyslexic people have difficulties with visual memory; this means that if they glance away from the page while reading, they will be unable to return to their place when they look back because they will have forgotten their position in the text [Ark97].

- **Number and letter recognition**

A central difficulty that dyslexic readers face is recognition of the symbols that represent sounds or numbers; this difficulty is exacerbated by a variety of shapes representing one sound, for example, the sound 'a' can be represented by 'A', 'a', 'ɑ', 'ǎ', without even changing the basic font. The way in which one letter can vary in appearance increases exponentially when it is handwritten [WT93].

- **Letter reversals**

Complicated as the recognition of most letters is, some present further problems in that one shape in different positions can represent several different sounds. The most problematic example of this is the four sounds 'p', 'q', 'b' and 'd', all of which are represented by similar or identical shapes. Reversals are quite common in dyslexia, with, for example, 'bad' being substituted for 'dad' [WT93].

- **Word recognition**

Difficulty recognising the shape of letters extends also to the shape of words; similar looking words like 'ambiguous' and 'ambitious' are easily confused since both start and finish with the same letter combinations and have quite a similar shape [WT93].

- **Spelling problems**

These problems with character and word recognition mean that dyslexics find spelling very difficult; the difficulty is exacerbated by poor phoneme/ grapheme correspondence in English and sometimes phonetic strategies are used, for example, 'all' might be spelt as 'olh' [WT93].

- **Word additions and omissions**

Poor fixation ability means that dyslexic readers regularly skip words in a text or may add words, duplicate them or reverse word order [WT93].

- **Poor comprehension**

The difficulties that dyslexic people face in reading text can mean that a dyslexic reader may perceive a significantly different text from the one they have actually started to read. Dyslexics thus show poor comprehension skills.

For many dyslexic readers, using a computer can reduce the severity of some of these difficulties, for example, using a keyboard makes it unnecessary to experiment with the shape of letters while writing; they simply need to be recognised from the keyboard. Specialists working with dyslexic students regard the use of computers as an important aid. For example Anita Keats, responsible for Information and Communications Technology (ICT) at the British Dyslexia Association writes, "ICT supports the entire process of writing, by supporting the individual skills involved in that process... The advantages of word processing for the dyslexic student cannot be over-emphasised" [Kea00].

3.3.2 Dyslexic students in higher education

This section provides written comments taken from dyslexic students in higher education. They were asked to comment on how useful their computer is. The extracts are taken from a book called *Dyslexia: students in need* [HM01].

'It's great to be able to produce a piece of work that looks decent. Without a computer I would never be able to create such a clear and precise layout, let alone correct a lot of basic errors.'

'My life was changed the day I got my voice-activated PC. My writing is appalling and it's so slow. My spelling is even worse! Now I speak to my computer and it prints what I say on the screen. Press another button and it will speak what I have written back to me. It still feels like a miracle.'

'A computer. What else is there to say? Without it I couldn't access the Net and that's where I can search out information for my course.'

‘My key resource just has to be the computer. Spell checkers can be brilliant. But I find the grammar checker hard to use. There are loads of software programs you can find for help with specific subjects.’

3.3.3 Computer programs

There are two main categories of computer programs used by dyslexic subjects: didactic programs (referred to as ‘drill and practice’) and content-free programs (for example word processors, which do not aim to teach anything, but to provide an environment which facilitates the writing process).

Didactic software is extremely useful for dyslexic subjects offering re-mediation support. The sheer complexity of the various processes involved in literacy skills requires the simultaneous execution of many different cognitive operations. Such skills cannot be performed well unless they are automatic and this can only come about as a result of appropriate and sufficient practice. Due to their memory difficulties a dyslexic learner requires much greater amounts of highly structured practice to achieve the same degree of mastery as the non-dyslexic person. Thus, the special value of didactic software for dyslexics provides exactly this practice in a convenient, enjoyable and cost-effective manner [Sin91].

In general most of the re-mediation software available for dyslexics are designed specifically for children. Dr. B. Hornsby, a psychologist and speech Therapist and Dr. F. Shear have developed a multimedia package designed specifically for children with dyslexia [HS94]. The package teaches reading and written language skills based on phonetic sounds. Dr. Hornsby uses a multi-sensory approach (aural, visual and tactile senses) with learning based on phonics, teaching individual constituent sounds of words. The package could also be used for adults if required, however, its primary use is for children.

A company called Dyslexia Educational Resources, provides educational software for dyslexics but is mainly concerned with products designed specifically for children. Xavier software, based at Bangor University, has developed a spelling programme based on

linguistic and phonological principles [MM94]. It approaches the spelling of English words in a structured way, beginning with simple regular words and moving through successive stages of gradually increasing difficulty. Also at Bangor University, Ann Cooke has developed a phonic multi-sensory teaching package designed for secondary school aged children [Coo93].

Content-free programs offer support and access to dyslexic adults allowing them to function more independently. Many dyslexics do not want re-mediation software when they have reached adulthood but require a great deal of support and guidance to help overcome their dyslexic problems. Software support such as spelling checkers and word prediction programs can prove to be invaluable.

3.3.4 Useful facilities

There are several computer facilities that support dyslexic adults when performing written tasks. These are:

- Spell checkers
- Thesaurus
- Word predictors
- Programs for planning
- Text highlighter (talking computers)
- Speech recognition (talk to your computer)

Each of these will be discussed in turn in order to give an understanding of what is currently available.

3.3.4.1 Spell checkers

A spell checker compares words in a document with a dictionary of words. It offers suggestions for words that it highlights. Many dyslexic people can read better than they can spell, so they can pick out the word they want. However, selecting a word from a list can be confusing to many dyslexics. Computer-based spell checkers are included in most word processors. They can check a single word, part of a text or a whole text. There are

also hand-held spell checkers, which are battery operated and quite small. Franklin manufacture several different types designed for specific needs [HS96]. It is down to the user to enter the word to be checked and then copy the word into the written text. This is more trouble than using a computer-based spell checker but they are very easy to carry around.

3.3.4.2 Thesaurus

A thesaurus offers words that are similar to the one entered. This may help to ensure the correct word is used. For example, if the word 'get' were entered, possible suggestions would be: 'obtain', 'earn', 'gain', 'secure' and 'acquire'.

3.3.4.3 Word predictors

A word predictor offers word suggestions based on the first one or two letters that have been entered. It usually offers several suggestions and it is down to the user to make the correct selection. This may lead to some confusion, as the suggested words will look very similar. The program 'learns' the words most often used and offers them as suggestions. This reduces the number of key presses needed for a word, which can be very useful for long words.

3.3.4.4 Planning tools

Most planning tools are designed to take advantage of a dyslexic person's good visual-spatial skill. Many dyslexics think more in pictures than words so these tools can be useful. The tools can use linked boxes and pictures to connect concepts and ideas. These can then be expanded upon.

3.3.4.5 Talking computers

The best way for dyslexic people to do tasks is in a multi-sensory way: hearing as well as seeing. They may be better at remembering what they hear than what they see. There are two kinds of speech. Digitised speech is recordings of real voices, which is used in some educational learning programs and in CD ROMs.

Synthesised speech can sound robotic. The software can analyse any text words (even made-up ones) and transform them into sounds. This is used in text reading in which the computer reads the word processed writing. This can be helpful for proof reading. It may be easier to notice a wrong word (or a correct word in the wrong place) if heard rather than simply looking at it. With a scanner it is possible to put text from paper, letter or book into a computer for a text reader to vocalise.

3.3.4.6 Talking to computers

The ability to talk to the computer as it produces the text is a powerful concept. However there are a few difficulties associated with this, which are:

- The software is expensive, although it is getting cheaper
- It has to learn the user's voice, which may take some time
- It has to be taught new words
- The user must speak very slowly and clearly
- A good proof reader is required to spot any mistakes

It might seem at first that dyslexics would be little better off with a speech recognition system that requires the user to check that the correct word has been placed in the text. However, research shows [Ell94] that dyslexics find it much easier to recognise that the correct word has appeared than to generate the required sequence of letters themselves. It is possible to combine speech input and speech output but the degree of success can be variable.

3.3.5 Selection of the most widely used software

This section provides an informative guide to the software that is available to support adults with dyslexia. The software categories are: planning, word prediction, spell checkers, grammar checkers, word processors, talk to the computer and talking computers. A comprehensive list is presented in Table 3.3 which is taken from [HS96].

Program	Publisher	Type
ARC SPELL 1 & 2	Xavier	Computer-based (Acorn)
BRAINBOX	PDSL	Planning software (PC)
CO:WRITER	Don Johnston	Word predictor (WIN)
DRAGON DICTATE	iANSYST	Talk to the computer (PC)
EXPRESSION	SCET	Planning software (MACS)
GRAMMATIK	iANSYST	Grammar checker (PC)
IBM-VOICETYPE	iANSYST	Talk to the computer (PC)
INSPIRATION	iANSYST	Planning software (WIN)
KEYSPELL	iANSYST	Spell checker
KEYSTONE SCREEN SPEAKER	iANSYST	Word processor (PC)
KURZWEIL VOICE	iANSYST	Talk to the computer (WIN)
KURZWEIL 3000	iANSYST	Word processor (WIN)
MIND MAPS PLUS	Cedar	Planning software (PC)
MINDREADER	Atlantic Coast	Word prediction (PC)
WRITE:OUTLOUD	Don Johnston	Word processor (WIN)
PAL PALSTAR	Lander	Word prediction (PC)
PC OUTLINE	Atlantic Coast	Planning software (PC)
PENFRIEND	iANSYST	Word prediction (WIN)
PROVOICE	-----	Text reader (WIN)
SMOOTH TALKER	-----	Text reader (WIN)
TALKING WORD	Microsoft	Talking software (PC)
TEXT ASSIST	iANSYST	Text reader (PC)
TEXT EASE 2000	-----	Word processor (WIN)
TEXT HELP	Lorien	Word processor (PC)
THINK SHEET	Fisher Marriott	Planning software (PC)
WRITE:OUTLOUD	Don Johnston	Talking software (MACS)

Table 3.3. Popular support packages.

A review of a selection of the most popular packages is now provided.

Speech recognition

An example of an established speech recognition package is DragonDictate for Windows [HS96], which is operated on personal computers. Generally, spoken input to DragonDictate is converted into a sequence of ASCII symbols appearing in the keyboard buffer and therefore indistinguishable from keyboard input. This allows spoken input to be provided directly to any applications software expecting input through the keyboard buffer. It also means that users are free to mix voice and keyboard input. DragonDictate can be used with any word processing system or other application software (such as spreadsheets, database and communication software, including e-mail) expecting keyboard or mouse input. Other available systems include Kurzweil Voice and IBM VoiceType, which work in a similar way to DragonDictate, and Via-voice.

Text reader

A typical text reader is TextAssist. Synthesised speech gives an instant feedback. Hearing the words and sentences that have been written as they are typed, helps identify mistakes. This should also help with punctuation to help detect where pauses in their text should be placed. TextAssist acts as a proof reader and comprehension is dramatically improved for many dyslexics. Other available packages are SmoothTalker, and ProVoice. They function in a similar way to TextAssist.

Hand held spell check

Many dyslexics use hand held spell checkers. An example of which is Franklin Wordmaster by FI Services. They can be used at any time to check the spelling of hand written work and will identify and define hundreds of the most commonly confused words. They can have several characteristics: reference to word meaning, book dictionary and a thesaurus.

Spell checker

KeySpell is a powerful spelling checker, which works as a standalone product, with speech recognition programs, and alongside Microsoft Word. It provides invaluable aid for early learners and those with literacy difficulties, helping them to understand how words are spelt, how they sound and the context in which they should be used.

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This unique system is able to handle the complex problems caused by dyslexia. Words like 'elephant' for example, can still be found when miss-spelt with a consonant ('lefamt'). With its direct link to Microsoft Word, KeySpell can be evoked as soon as Microsoft Word is unable to help; which many people find to be surprisingly often.

The easy-to-use, friendly, interface of KeySpell, allied to its detailed tutorial and comprehensive on-screen help, allow the user to ensure accuracy of correction through the use of a number of features. KeySpell's 250,000 word dictionary can be partitioned, using 32 categories, to suit the needs of the user either by age group or area of interest (Arts, Sciences, Sports, Business etc.). It also has a huge lexicon of British place names and personal names.

In Microsoft Word, a document can also be scanned for homophones, enabling the user to check each occurrence quickly and efficiently. KeySpell offers a selection of phonetically similar words and confusable terms and an example of those words in context to assist in the selection of the correct word. Searches can also be conducted based on the beginning or the end of the word according to the preference of the user. KeySpell incorporates the latest voice synthesis technology from Lernout and Hauspie to provide a text-to-speech capability - allowing selected text to be read out as it appears on the screen. KeySpell also helps with the pronunciation of words with phoneme-by-phoneme guides and allows the steps taken to correct a word to be retraced.

Lecture notes

The Dyslexia Group in the Computing Laboratory at the University of Kent [EW95] have been looking at the problems faced by dyslexic students coming into higher education. Students have to do a great deal of reading, about their subject, take accurate notes and compose essays. A computer program called HYPERSTUDY has been developed to aid dyslexic students. It is a framework into which lecturers can place their teaching material: text, graphs, pictures etc. The framework enables dyslexic students to read and assimilate the material more easily. It also incorporates a "notebook" so that any part of the teaching material can be copied into the student's own file (useful when collecting material for an essay).

Grammar checkers

Grammar checkers are available, such as Grammatik and Stylewriter to check spelling and punctuation. They are primarily designed for checking that the grammar of the text is correct and appropriate and provide a measure of complexity and 'reading ease' of the text. Programs of this type can be of some assistance to those who make simple grammatical slips or who wish to improve their style of writing. Their abilities to recognise grammatical errors, however, are limited and in their present form, are unlikely to be of significant value to those with severe language problems such as dyslexics. Current grammar checkers are not designed to interpret the unique dyslexic tendencies of reversing sentences and words. Also many dyslexics do not understand the feedback they are given from grammatical checkers and thus prefer not to use them. There does not seem to be any grammatical tools designed specifically with dyslexic adults in mind.

Word processor

'Write:Outloud' is a talking word processor designed for people with special needs (such as dyslexia). It is an easy yet powerful talking word processor with a talking spell checker. Its multi-sensory approach improves writing because students immediately hear if words are omitted or misplaced. Students can then select the right word and make any necessary changes. Its main features are:

- Speaks while users write, highlights word by word to give direct link between spoken and written words
- Imports graphics to support student's writing
- Includes Franklin spell checker, dictionary and homophone checker to find the right word
- MAC and PC versions are identical for better file portability
- Choice of male, female and child's voices for better listening comprehension
- Opens any size of file so users can read scanned documents

Word processor with Word predictor

Penfriend is a word processing package, which includes a word predictor and speech capabilities. Penfriend predicts the next word you are about to write by choosing suitable words after you have typed the first letter. This is achieved by learning about the users

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personal writing style, by selecting commonly used words, and by using advanced knowledge of English grammar. There is an optional speech output facility for reading all words and sentences out loud which can reduce the strain of proof reading significantly.

There is an on-screen keyboard for those that prefer not to use the computer keyboard. The system offers a choice of background colour, text size, font and colour in the prediction window. Each individual user's preferences can be saved at the same time as their named lexicon (file containing words used solely for them – spelling profile). Penfriend can read from other applications such as web pages and encyclopaedias.

Word prediction tool

A number of predictive word processors, which were originally intended for those with physical disability, offer help to dyslexic users. One of the first of its type is called PAL (Predictive Adaptive Lexicon) [NBB91] and works in conjunction with standard word processors. It exploits the redundancy in natural language to reduce the number of character entries necessary to produce a piece of text. The program attempts to predict the words which users input into a word processor.

The predictions are produced from a dictionary of words, which contains statistical information relating to frequency of use. Hence PAL attempts to offer the most recently, frequently used words. This may then be selected, if desired, by a mouse operation. Research by Alan Newell at Dundee has suggested that such programs improve spelling skills in dyslexics [NBB91]. Another word predictor called Prophet for Windows is available through the ACE Centre. This has similar features to PAL.

Co:Writer 4000 is the latest version of this word prediction tool aimed at those who struggle with writing due to injury, physical limitation, language delay or learning disability. Co:Writer lightens the physical or cognitive stress of text generation, for use with any word processor. Available for the MAC and PC, Co:Writer 4000 uses its built-in intelligence to prompt the student with words that fit the sentence.

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Word prediction helps teach users many basic writing process concepts: spelling, word decoding, simple sentence structure, and contextual practice. There is a choice of five word lists, from the core dictionary of 1,000 words up to the Advanced Writers' Dictionary of 40,000. This software aims to reduce the number of keystrokes needed to write and provides speech facility to allow the user to hear sentences.

Planning tool

Dyslexic people often think in pictures rather than in words. Idea mapping allows the building of a visual map of ideas using pictures, colours, shapes and relationships. This technique can be used for note taking, for remembering things and for organising ideas for written work. These pictures can be built on screen with Inspiration mind mapping software. With a single keystroke, the image can be converted into a linear outline. Users of this software can use their own pictures and change background colours, fonts and sizes to suit their own preferences.

Inspiration can be used to create: Idea Maps, Flow charts, Diagrams, Presentation Visuals, Outlines and Written Documents.

3.3.6 Comparison of spell checkers

The results of a comparison of five different spell checkers are shown in Table 3.4 [Szu02].

Bad word	Correct word	Write Outloud	Franklin hand held	Word 2000	Prototype	Read&Write 5
	Corrections offered (out of 18)	14	12	11	15	10
Eney	any	-	1/9	-	4/15	0/5
amarika	America	1/6	1/7	1/5	1/15	1/2
Athers	others	2/16	1/9	3/5	3/15	1/11
Colld	called	7/16	0/8	0/4	2/14	4/29
comftabl	comfortable	0/15	0/7	0/5	0/15	0/4
dynosar	dinosaur	1/5	1/7	1/2	1/15	0/0
elswar	elsewhere	0/4	1/6	0/5	5/15	0/0
exvatly	exactly	1/1	-	1/2	1/15	0/0
Frens	friends	1/14	0/10	0/5	5/15	0/28
Gosts	ghosts	4/14	1/9	2/5	1/15	7/10
Hom	home	1/16	1/11	1/5	1/15	16/31
intruptad	interrupted	1/12	1/7	1/1	1/15	0/0
liekt	liked	0/16	0/7	1/5	13/15	22/37
mager	major	8/16	3/9	0/5	0/15	11/23
maik	make	3/16	2/14	1/5	5/15	0/49
pepil	people	5/12	2/8	0/4	0/15	12/14
relavant	relevant	1/12	1/8	1/2	1/15	1/2
thear	there	4/16	0/11 (but their listed)	¾	10/15	13/37

Table 3.4. Comparison spell checkers.

The figures in the columns are explained as follows. For example, "1/6" means the software offered 6 alternatives to the incorrect spelling (column 1) of which the correct word required (column 2) was in position 1 in the list. Hence, "0/28" means the correct word was not found in 28 words offered.

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This shows that spell checkers still have some way to go before they meet the needs of people with serious spelling difficulties. Microsoft Word 2000 came one from last, which is not a good result. There is a popular, though unsubstantiated, belief that spell checkers are for people who can spell but just require confirmation. Whereas, for people who have serious spelling difficulties, spell checkers can be of little use. Another interesting point to be made is that some of the spell checkers offer a very large number of selections, which for poor spellers leads to confusion. For the purpose of the results shown in Table 3.4, if the correct word was there it was selected but in a true situation this would not always be the case.

3.3.7 Problems associated with using computers

On the whole computers support adults with dyslexia and make their lives easier. However, there are some negative points to using computers and these are presented to complete this section. They are as follows:

- In order to use computers effectively typing skills need to be mastered. This can be a problem for people who have hand-eye coordination problems
- Reading text from a screen can be a problem and for some it causes headaches and unnecessary anxiety
- Some people prefer traditional methods and are afraid of using 'modern' technology
- Cost of hardware and specialist software can be a problem
- Using unsuitable software can result in poor results and can be demoralising

3.4 Word processors and adults with dyslexia

This section covers the associated benefits of using word processors from the perspective of dyslexic adults. The main stages of the writing process are presented and comparisons made between pen and paper and using a word processor. The most frequently used packages are listed and a review of two packages is provided.

The majority of dyslexic subjects use standard word processors with add-on software to aid them. The use of speech recognition software and text highlighters, are proving to be

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a tremendous help to dyslexic subjects. These packages can work with standard word processors and provide a dyslexic adult with a tool which helps to overcome some of their dyslexic symptoms related to writing.

Speech synthesis systems, which can be used to 'read' and speak text from the screen have been available for many years. What has happened recently, however, is that the quality of the speech has improved substantially and the costs of such systems have fallen considerably.

3.4.1 Benefits of using word processors

Word processors (and spell checkers) improve a dyslexic's ability to communicate effectively in the written form. They offer the facility for correcting mistakes easily and thus the possibility of producing neat and correctly spelt text. In addition many dyslexics find that they can operate a keyboard much more easily and with fewer errors than they can produce hand-written text. There are three main stages during the process of writing [Ell94]. These are:

- Pre-writing (generating ideas and shape)
- Composition
- Transcription

Planning tools can be used to support pre-writing. In its simplest form, writing the key sentences on the screen and then expanding each one in turn can provide the disorganised writer with structure. Many word processors (for example Microsoft Word for Windows) currently provide a more sophisticated form of key sentences or outliners by allowing text to be collapsed, so that only the paragraph headings are visible. Switching between collapsed and expanded views allows the writer to concentrate on one part of the text at a time. The act of composition via the computer encourages a different approach from the traditional pen and paper model. Ideas can be drafted and redrafted; decisions can be made and remade, all with the aim of improving the effectiveness of the writing. A thesaurus can be of great benefit and so to can the cut and paste function.

Transcription is concerned with the appearance of the finished text. Tools such as spell checkers are invaluable, however, there is a basic level of reading and spelling skill required in order to use the spell checker effectively. If the learner cannot read most of the alternative suggestions provided by the computer, they will not be able to select the most appropriate. Spell checkers will allow the user to add words to the dictionary such as names of places, which can be very useful. However, a problem with spell checkers is that words that exist as real words in another context, e.g. there/their, will be accepted without question. Preferred character sets can be chosen and the character font size can be enlarged for easy reading. The colour of the background and foreground can also be selected for ease of reading. Research has shown that black characters on a white background are difficult to read for many dyslexics.

The power of supported word processing for dyslexic subjects is enormous. Word processors give the user freedom to make mistakes and then easily put them right. Also the user is given the freedom to expand on stored written text at a later date and restructure the text if required. One of the most common problems faced by dyslexics is poor hand writing skill. This is no longer a problem when using word processors.

3.4.2 Selection of the most widely used word processors

Software packages for dyslexics should be carefully structured, progressive, cumulative and multi-sensory. The most popular software packages used by dyslexics are word processors [HS96]. This section is concerned with word processing packages which dyslexic adults use. The most popular are:

- Microsoft Word
- Microsoft Works
- Claris Works
- Textease 2000
- Texthelp
- Kurzweil 3000

The latter three include a text-to-speech facility, which is useful for adults with dyslexia. A table comparing the key features for two packages is provided [Dys02].

Feature	TEXTHELP	KURZWEIL
Operating system	PC only	PC or MAC
Close integration with word	No	No
Use with any windows program	Yes	No
Works alongside Dragon on marked blocks.	Yes	No
Reads text back to you	Yes	Yes
Reads out icons, menus, help files, web pages	Yes	Yes
Spellchecker	Yes	Yes
Check for homophones	Yes	Yes
Word prediction	Yes	Yes (PC only)
Dictionary with definitions	No	Yes
Thesaurus	Yes	Yes
Foreign language support	No	Yes (PC only)
Study skills support	No	Yes MAC only
Scan from printed page	No	Yes

Table 3.5. Key features of TextHelp and Kurzweil.

This that both packages include a number of facilities proven to be useful for dyslexic adults.

3.4.2.1 A review of two specialist word processors

TextHelp, developed by Lorient, is a popular specialist word processing package. It combines word prediction with talking and spell checking. TextHelp's new text reader window has colour highlighting of words and sentences. Text can be read by word, sentence or highlighted paragraph and can be paused/resumed while reading. Feedback is available at all times along with coloured highlighting of words and sentences for visual reinforcement. Speech can be used to read any of the program's other features. The speech option menu enables speech to be adjusted by pitch, speed, volume and the length of pause between words.

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Sentences can be constructed with ease using the prediction feature, which provides suggestions of words frequently used and learns new words as they are entered. Words can be spoken from the list of suggestions, along with their meanings if they are homonyms. The prediction panel can now follow the insertion point as you type for ease of viewing and as a choice of up to twelve words. TextHelp only allows correctly spelt words to be predicted.

With textHelp's spelling checker, you can check your documents. It has the ability to solve the most complex pattern of spelling errors. It can automatically notify when a mistake is made and will make suggestions for corrections. These suggestions can be spoken along with the meanings of commonly confused words. It can also automatically correct the most common errors. UK, US and Australian dictionaries are included, and 180,000 words are standard, including medical, legal, scientific words and proper names. TextHelp can also be used after typing is completed. All spelling errors are highlighted and a list of suggestions is made for each. These can be read out and when chosen, placed into the document. Possible homonyms (like sounding words with different meanings) can also be highlighted and checked in the same way.

Another useful package is Textease 2000, which is a multimedia desktop publishing tool. It is a simple talking word processing package, which offers many of the facilities of desktop publishing in an easy to use form. It has the speech feedback that is so useful for dyslexic adults. Its main features are:

- Click anywhere on the page to start writing
- Easily change font, size and colour for single letters or whole chunks of text
- Create borders, shadows and other effects
- Drop in graphics, resize, move and rotate them until the desired effect is reached
- Full multimedia authoring and web page creation – add sounds, animations, video and links
- Full spell check facility
- Speech options to listen to letters, words, sentences or all text

3.4.3 Unresolved problems

Many dyslexic people find word processing difficult, often unsure of the correct words to use or how to spell them. Most re-mediation packages are designed purely for use by children. Much of the work undertaken for dyslexics focuses on the children and the National Curriculum, that one could be forgiven for thinking that dyslexia is one of those annoying conditions of childhood which learners grow out of. Unfortunately, 6 million adults in this country bear witness to the fact that poor reading and writing skills are not miraculously cured between the ages of 5 and 16. Once the needs of adults are examined it is easy to see why so many ready-made packages are inappropriate.

The needs of the adult dyslexic are given a low priority and although they benefit greatly from the use of word processors, the grammatical tools are of little help. For the remainder of this section the problems incurred by dyslexic adults when using standard word processing packages are discussed: including spell checkers, grammar checkers, word predictors and on-line help.

3.4.3.1 Grammar checkers

Many dyslexics can experience difficulties with grammar. Individuals with these difficulties find that grammar checkers do not provide the kind of support that they need. A good understanding of grammar is usually needed in order for this type of support to be of any help. Although many dyslexics can construct sentences, which are grammatically correct, their understanding of grammar is limited. A grammatical tool needs to provide simple examples, which identify possible solutions. A grammar checker needs to identify the following kinds of mistakes:

- Upper and lower case letters used in the wrong place
- Plurals and non-plurals used in the wrong place
- The correct word with the wrong meaning, for example **their** and **there** (homophones)
- Words used in the wrong context due to problems with letter reversals, for example **how** instead of **who** or **saw** instead of **was**

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- Mistakes made when using the spell checker, for example the use of the word **modal** instead of **model**
- Words which by themselves are correct but when used next to one another, they should be combined, for example **in to** instead of **into**
- Word reversals within a sentence, for example ‘The cat **on sat the** chair’ instead of ‘The cat **sat on the** chair’

This level of support is badly needed for individuals with dyslexia. These types of mistakes may be obvious to non-dyslexics but to the dyslexic, this kind of mistake is difficult to identify.

3.4.3.2 Spell checkers

Spell checkers are imperative to many dyslexics. Unfortunately several difficulties still occur. When a spell checker has found a miss-spelt word, it will provide the user with a list of suggestions. These suggestions are usually similar in shape but very different in meaning. It is very difficult for a dyslexic to distinguish between the words when the true meaning (of the words) may not be understood. Reading abilities vary tremendously and some subjects may be unable to even read the suggested words correctly. The following list identifies just a few mistakes made by dyslexic subjects:

- **compere** instead of **compare**
- **relay** instead of **rely**
- **evolution** instead of **evaluation**
- **aromatic** instead of **automatic**
- **spastic** instead of **specific**

The dyslexic needs an in-context spell checker. The spell checker would display the word in context. Many dyslexics spell phonetically, for example **for** as opposed to the word **four**. Thus, although they have spelt the word correctly, the word may have been used within the wrong context. Most spell checkers are not designed to look for phonetic spellings and do not offer suggestions on that basis. There needs to be a facility within a

spell checker which picks up on words that are spelt correctly but have more than one meaning. This type of facility needs to list the alternative spellings for the selected word.

3.4.3.3 Word predictors

Most word predictors have not been designed to deal with some of the common spelling patterns of dyslexic adults. These include phonetic, reversals and missing letters. Other difficulties can be experienced when using a word predictor. This is due to the amount of eye control, which is necessary in order to use this piece of software. The user has to continually look up and down a list of words. This type of eye control is difficult and tiring for individuals with poor tracking.

3.4.3.4 On-line help

On-line help facilities tend to cater for subjects, who can read fluently, learn easily and follow instructions accurately. Many dyslexics do not fall in to that category and therefore tend not to benefit from the on-line help available. Dyslexics need to be helped through the use of drawings along with the support of words. An in-context tutorial, which can run on top of an open file, would be useful. This would allow the user to select any one of the facilities provided by the software and enabling them to run the required tutorial. This type of facility must be interactive, enabling the user to put into practice the facilities, which the tutorial has demonstrated. Learning by example is a very powerful technique, well suited to those with dyslexia.

3.4.3.5 Layouts

This section is concerned with the general layout of the word processor. There are several areas, which would benefit dyslexic adults if suggested improvements were made.

Selecting documents from disk

Naming conventions can cause problems. Icons work better than spoken or written languages. Dyslexics need a wider range than the current systems provide (i.e. Macintosh and Microsoft Windows), although there is scope for widening these systems.

Icons and pull down menus

Poor hand-eye coordination makes using a mouse difficult with pull down menus. Freedom to enlarge the size of the icons and position them in an order and format to suit individual needs is required. Reduce the use of layered menus to a minimum, short term memory problems makes it difficult for dyslexics to remember where their chosen option is located.

Text

Reading text poses problems to individuals who have difficulty with tracking. This could be helped by the use of a highlighting bar within the editor. The current line could be highlighted and the user could step through the text moving the highlighted bar if required.

User interface

Only critical information should be brought to the attention of the user. The interface should be discreet, basic and display no unnecessary information. Most WIMP interfaces allow the removal of the unnecessary information but there is still a long way to go.

It is true to say that most dyslexics find their computer to be invaluable and would find it very difficult to produce written work without one. However, the dyslexic user has limitations and needs which are often not catered for.

3.5 Dyslexia and written English

This section takes a brief look at the type of problems adults with dyslexia have when writing in English. The largest section is concerned with viewing spelling patterns that have been associated with dyslexia. A brief look at grammar and sentence structuring concludes this section.

3.5.1 Spelling patterns

Dyslexic spelling mistakes are far more wide-ranging than an ordinary typist's. Dyslexics can write words, which trail off towards the end, which are constructed from incorrect

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spelling rules (such as not doubling the 'p' in 'dropped') or are spelt phonetically. Ordinary spelling checkers cannot correct these errors because the typed word is too different from the intended one. Also if a word is mis-typed as another real word, spell checkers assume it to be correct and do not suggest anything.

Spooner discusses the research undertaken to develop a writing aid for dyslexics [Spo96]. It is concerned with the design and implementation of an improved spell checker designed specifically for dyslexics needs. As well as being sensitive to those dyslexic errors, which most systems ignore, it "learns" the person's writing habits by monitoring their typing over time. It is powerful enough to not only look at each individual word but at its neighbour, thus identifying words which are out of context despite being correctly spelt.

Dyslexics tend to spell phonetically and tend not to know the spelling rules associated with English. Examples of these types of spelling mistakes are:

- almost, always, also – Commonly add an extra 'l', i.e. allmost
- taking, making, coming – Commonly add an 'e' before the 'ing', i.e. makeing
- putting, running, getting – Commonly forget the double consonant, i.e. geting
- knit, knelt, knight – Commonly miss off the silent 'k', i.e. nit
- physics, phone, photograph – Commonly use f in the place of ph
- it, is, if – Commonly reverse spelling, i.e. fi
- saw for was – Commonly confuse these words
- effect, affect, there, their – Mixing homophones
- thou, though, through – To a dyslexic person these words sound the same
- let's, we're, they're, she's – Words with apostrophes cause difficulties
- recommend, necessary – Dyslexics have problems with double consonants
- receive, conceive – Spelling rules i before the e are not followed

Researchers have come up with a list of words, which many dyslexics have difficulties spelling correctly [Spo96].

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at	about	again	ago	all	almost
also	always	an	and	another	any
anyhow	anyway	as	at	away	going
gone	went	have	yours	helpful	favourite
had	he's	her	hers	here	him
has	his	how	if	in	into
having	back	be	am	are	is
he	was	were	being	been	because
become	became	becoming	becomes	before	between
but	its	It's	just	last	leave
leaves	leaving	left	least	less	let
lets	let's	letting	like	liked	likes
liking	make	by	can	could	Can't
cannot	come	comes	coming	do	did
does	doing	dine	don't	doesn't	down
making	many	maybe	me	mine	more
most	much	my	neither	never	no
none	nor	not	now	of	off
each	either	else	even	ever	every
everything	for	from	front	full	get
gets	getting	got	go	goes	onto
or	other	others	otherwise	our	ours
out	over	puts	put	putting	run
ran	running	runs	same	see	saw
isn't	it	she	She's	shall	should
so	some	soon	stand	standing	stands

Table 3.6. Words which cause dyslexics spelling difficulties.

This shows that the majority of the words are less than five letters in length. This is one of the main characteristics of dyslexic adults. Many of them can spell quite difficult words but short words are frequently miss-spelt.

3.5.2 Difficulties with English grammar and sentence structuring

The most common problem that adults with dyslexia have in relation to English grammar is not knowing or understanding grammar rules. Current grammar checkers are designed to support users who already have a good knowledge of grammar. Thus making them of little use to many dyslexics. English grammar rules are complicated and there are many exceptions to the rules.

Learning and using the correct punctuation is also another problem, which many adults with dyslexia have. Often when dyslexic adults are asked about their use of punctuation, the response is 'I write the sentence then just add commas in an ad hoc manner'.

Using words that have the wrong meaning is an area of concern. Words that 'look' or 'sound' alike but have different meanings are often confused. It is relatively easy to remember the meaning of frequently used words such as 'their' and 'there' but there are so many such words that mistakes are often made. Words such as: were and where; here and hear; ware and wear; though and thought; weather and whether; has and as; affect and effect.

Adults with dyslexia may find that they have a rather limited vocabulary as they are either unsure of the spelling of a word or its meaning and therefore tend to use only words they are sure about. This can then lead to a poorer standard of written work.

Writing concise sentences can be a major problem for many adults with dyslexia. There is a tendency to write long unstructured sentences. Another difficulty is often the words within the sentence are not in the correct order and therefore do not make sense. In extreme cases all the words may be written in reverse order. There is no real explanation for this.

3.6 Dyslexia and different language structures

Research on the weaknesses of dyslexics in other languages has been relatively limited but is now growing and people of different countries are now collaborating with each

other over research. It is beginning to be appreciated that the ways in which dyslexia manifests itself are different in different languages. The reference book used for this section is 'Dyslexia a hundred years on' [MM99].

3.6.1 Dyslexia and mathematics

There is no doubt that it is possible to be dyslexic and yet be a highly successful mathematician. The evidence of individual cases makes this clear. Janson [Jan88], despite his early struggles as a dyslexic, obtained an appointment as a lecturer in mathematics at University College London. There is also evidence from Joffe [Jof83], who reports that a sample of 23 dyslexics aged between 8 and 17 years who had taken a mathematics test, ten per cent 'excelled' in the subject.

Many dyslexics appear to have difficulties with mathematics. The most likely conclusions seem to be that, although success is possible, there are certain areas of mathematics in which they are at risk of being held back. This, at least, is the conclusion that follows from a carefully conducted piece of research by Steves [Ste83]. She believed that some dyslexics exhibited a potential for mathematical talent while at the same time exhibiting a lack of computational efficiency. Steves concludes that there can be dyslexics with high reasoning power (and hence high mathematical potential) who nevertheless score only at average level on tests of computation and that their memory skills are inferior to those of non-dyslexics with lower reasoning power. On the basis of experiments with boys aged 12 to 16, Pritchard et al [Pri89] have argued that dyslexics have fewer 'number facts' available to them than non-dyslexics. A person is said to possess a number fact if he can give the answer to a sum immediately without having to work anything out (times tables).

Turner Ellis et al [Tur96] supplements this work in a more systematic way. Instead of simply asking their subjects if they could do the sum 'in one' Turner Ellis and colleagues used a timing device. It measured the time taken from the first exposure of the multiplication sum to the time when the subject signalled that they had completed it. The results showed that the youngest age group was the slowest and the oldest age group the quickest. A result that suggests that even in the case of dyslexics some degree of speeding up is possible, as they grow older.

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In a challenging paper, Hitch [Hit78] has called attention to the different requirements of mental arithmetic and written arithmetic. What can be achieved by mental arithmetic, he suggests, is limited by the need to hold information temporarily in a transient 'working store' and without rehearsal this information will soon decay. In contrast, 'in written calculation the visible page serves as a permanent working store which provides an effective substitute for human memory storage'.

Dyslexia involves difficulty with certain (though not all) aspects of language, it is hardly surprising that the vocabulary of mathematics (not the symbols but the actual words) can sometimes cause confusion. This is partly because some of the words used in mathematics will have been encountered by the dyslexic in other contexts, where they have a different meaning. In this connection E. Miles [MM92] has made a list of some of these words. For example, when it is said that "2 and 2 *makes* 4" this is quite unlike the situation where mother "*makes* a cake". Furthermore, "*take away*" might suggest a "Chinese *take-away*", while a "*dividend*" might be thought of as something that people win on the pools!

In the area of mathematics dyslexics have both weaknesses and strengths. In particular they are weak at remembering number facts and slow at deciphering unfamiliar symbols. In contrast, however, they are likely to be able to work well in a world of three-dimensional objects and pictorial representations and are likely to be good at recognizing patterns.

3.6.2 Dyslexia and pictorial languages

The two languages that will be considered are Chinese and Japanese. It was thought at one time that Japanese children were less prone to literacy problems than children in other parts of the world [Mak68]. It was speculated that this might be due to the fact that through their Kanji script they could adopt a logographic approach rather than a phonological one and that the same would apply to Chinese. The basis for the belief in comparative literacy in Japan was the lack of referrals to specialists and the fact that primary school teachers did not think that there was much of a problem. When this was systematically investigated, however, it was found that the view was mistaken [Ste82].

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Stevenson [Ste82] worked with colleagues from North America, Japan and Taiwan (Chinese speaking) on a comparative study. There were 2155 fifth grade children, aged about 10 to 11 years, of whom 453 were from Minneapolis, 770 from Sendai and 931 from Taipeh. Much care was taken to construct tests for each language containing vocabulary from the reading books used at each grade level. The children were scored on the proportion of words or characters read correctly.

The researchers found that the proportion of children with average ability in the lowest 10 percent of reading scores was 5.4 per cent in Japan, 7.5 per cent in Taiwan and 6.3 per cent in the US. They concluded that cultural differences of attitude had previously given rise to an incorrect impression and that the proportion of children with reading difficulties were in fact very similar in all three countries.

In the case of Chinese, however, despite the logographic appearance of the characters, there is also a phonological element, since each character represents a syllable. There are also a large number of compound characters, which include a 'phonetic' as a guide to pronunciation [Leo86]. The meaning element is most often being on the left and the phonetic on the right. The phonetic, however, is not so helpful because of sound changes over thousands of years it can at best provide only a vague suggestion.

Chinese is also a tonal language, which means that the same syllable may be pronounced in different tone: high rising, low falling, etc. The character can have a completely different meaning according to which tone is used.

This section is completed with a study undertaken on Japanese children [Ogl96]. A boy was referred to the Dyslexic Clinic in Hiroshima. This boy had great difficulty in reading words in Kana (the Japanese alphabetic script) and when he was tested on Kanji he also made numerous errors. Many of these errors were found to be mistakes over the detailed visual appearance of very similar complex characters; however there were also many selection errors. Yamada explains that some morphemes are 'bound', that is, cannot stand alone, like the '-ing' ending in English [Yam95]. Where there was a bound morpheme in Kanji the boy frequently selected the wrong part or recalled the wrong part from a phrase

that included the morpheme he had in front of him. This seems to resemble the muddle over syllables that dyslexics often show in an alphabetic script.

To sum up this discussion, it seems as if in Chinese characters there is also a phonological element but that there may be other difficulties for the dyslexic child that are connected with the complexity of the characters and the different combinations that they form. All of these have to be memorized and this would help to account for the similar proportion of dyslexics in Chinese-speaking countries to that in English-speaking countries.

3.6.3 Dyslexia and music

A field of study that has recently attracted attention is dyslexia and music. The most comprehensive work known on music and dyslexia is by Oglethorpe [Ogl96]. There has also been a booklet (British Dyslexia Association 1996) and a number of papers in journals and edited books. These include Oldfield [Old87], Hubicki [Hub90], [Hub91], [Hub94], Hubicki and Miles [HM91], Douglas and Willatts [DW94], Ganschow et al [GLM94] and Skeath [Ske96].

There is a common theme throughout all these writings: dyslexics may sometimes be highly gifted musicians but most of them experience problems with rhythm and with musical notation.

Oglethorpe offers practical advice to music teachers and discusses the issues of motor problems and memorizing and sight-reading. The research by Douglas and Willatts involved 40 girls and 38 boys, average age of 8 years. They were all given reading, spelling and vocabulary tests, along with tests of pitch discrimination: which of the two sounds was higher, lower or the same. They were also given a rhythm test; whether pairs of rhythmic patterns were the same or different. When the influence of vocabulary was parcelled out, the most striking finding was the relatively high correlations between rhythm and reading (0.306) and between rhythm and spelling (0.245). This result provides confirmation that some poor readers and spellers are also weak rhythmically. The authors also report a pilot study in which children who received rhythmic and pitch training obtained better scores on a reading test than a control group not so trained.

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In the British Dyslexia Association booklet [Dys95] members of the Music and Dyslexia Committee list some of the things that are likely to cause difficulty at any dyslexic person who is learning music. They point out musical notation consists of written symbols which represent sounds. A person who has difficulties with deciphering other written symbols may therefore also have problems with reading and writing music. The list of possible difficulties is a long one; it includes, for instance, left-right confusion, rhythmic difficulties, coping with repeat marks and transposing from one clef to another.

In addition Hubicki [Hub90] has called attention to the confusion that may be caused by some of the terms used in music, such as 'treble', 'note' and 'key', which in a musical context do not carry their familiar meanings. Further valuable information can be found in [Hub91] and [Hub94].

Skeath [Ske96] also provides some pertinent information about the difficulties experienced by dyslexic children in learning music. The extract is taken from her paper.

“Language problems can become a very great difficulty when the dyslexic student is faced with having to learn the jargon associated with tempo, style and dynamics. Words such as hemi-demi-semi-quaver can cause problems for the dyslexic who misses out the middle syllables. Memorising scales and arpeggios becomes a laborious exercise. Counting bars of rest can pose difficulties for the dyslexic unless clear strategies are taught to help the pupil count effectively.”

One of the adjustments that many people take for granted but which Oldfield [Old87] found difficult was adjusting to a different dimension. The paper by Ganschow et al [GLM94] provides evidence on seven dyslexic musicians. According to their self-reports all seven had difficulty with reading music and with time and rhythm, while all but one of them had difficulty in keeping pace. Overall there is no doubt that dyslexics can sometimes be successful musicians; their difficulties, it seems, are not with music as such but with musical notation. They need to master the notation in which musical ideas are expressed.

3.6.4 Dyslexia and structured languages

This is an area of particular interest and the research hypothesis has been developed around it. There seems to be no current research (that I have been able to find) taking place in this area at present. The term structured languages within this section refers to computer programming languages. Throughout this thesis there will be many additions concerning the benefits of using structured languages for adults with dyslexia. The main beneficial features of structured languages are:

- They are logical
- They have a fixed rigid structure
- They have a smaller language set
- They have a fixed set of rules
- There are no (or few) exceptions to the rules
- They offer useful support tools such as debugging tools
- They use compilers to detect errors
- They support a structure, which encourages the use of modules, allowing the splitting up of tasks into manageable units

Although there are many different programming languages most of them will include the stated features. The early programming languages were written in binary and then assembly languages. These would have not been easy to use but the development of later languages is quite different matter. Object oriented languages such as C++ have a very structured format, which is very beneficial for dyslexics. Also the concept of using objects with common attributes is relatively easy to visualise.

Languages such as Microsoft Visual C++ use wizards (a term used within Microsoft applications) to create much of the code for the user. These tools constrain and guide the programmer by using an explicit template. Although these types of languages can be hard to master at the beginning they are very powerful and enforced structure would benefit dyslexics. The concept of developing environments that can provide a more structured and logical approach to written English is at the core of this research.

3.7 Concluding comments

This chapter has provided a comprehensive view of dyslexia and contains a great deal of background information. This will provide the foundation for the remainder of this thesis.

The main areas of importance are:

- How computers can be used to assist people with dyslexia
- Word processors and their use by dyslexic adults
- Common written English difficulties associated with dyslexia
- Dyslexia and different language structures

Within this literature review several specialist word processing systems have been mentioned. The next chapter will provide the design criteria for the specialist word processor and spelling tools used to create environment 1 and 2. There is no claim of originality as indicated within Chapter 1 and it is acknowledged that other systems are available. However, the development of this system enabled the testing of three environments, one of which was based on the research hypothesis (environment 3), which represents an original concept. The chosen method of evaluation requested the subjects to indicate which other specialist tools they have used (dyslexia topic material). They were also asked to give the system a usability grade, which by its nature, will be based on a comparison with other systems that they have used. Thus, it gives a good indication of how this package fares in comparison with other available word processors and support tools. This concludes the literature review for the thesis.

Chapter 4 Surveys and analysis of dyslexic adults

4.1 Introduction

Most adults with dyslexia need support to help them with their written tasks. Although word processors are commonly available (and found to be very useful) and specialist tools have been developed, there is still much room for improvement. This is in terms of the methods used for presentation, making selections and communicating with the user on a suitable level. Many of the spell checkers are not designed to cope with the severity and variety of dyslexic spelling errors. Sentence structuring and English grammar are two key areas where more support is required. Developing the right kind of support is extremely important.

The research hypothesis is primarily concerned with investigating how dyslexia affects a subject's ability within different language structures, using English and computer programming languages for the comparisons. If it can be shown that dyslexics work more effectively within an environment where the rules are rigid and structure is enforced, a new method for supporting sentence construction can be developed.

This chapter is concerned with the collection and use of information provided by adults with dyslexia. The primary uses of which were to confirm the developed hypothesis (full definition in Chapter 1) and to establish the design requirements for a word processor and support tools to assist dyslexic adults with natural language. The main information areas are:

- How dyslexia affects a subject's ability to use different language structures (research hypothesis)
- Establishing how useful structured language support tools are
- Common difficulties with English grammar, sentence construction and spelling
- Investigating the use of current word processors
- Obtaining suggestions for improvements to current word processors

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4.1.1 Data collection method

Two main surveys were undertaken to collect the required information. The initial survey had the largest sample and in order to collect a broad range of survey data (for the initial survey), two methods of data collection were used. Firstly, survey forms (paper version) were given to subjects in both Loughborough and Leicester Universities. This represents approximately ten percent of the sample. Secondly, a Hypertext Mark-up Language (HTML) form was used and made available on the Internet.

Links to the form were established from other key dyslexic sources of information web sites. This was carried out and resulted in dyslexic adults from all over the world, replying to a request for information. The main countries were: UK, America and Australia. It is acknowledged that these subjects tended to be technologically proficient, as they required computer access to use the web and gain access to the survey form.

On completion of the first survey it was decided that a second survey (referred to as the follow-up survey) was undertaken, using agreeable subjects who had already taken part in the initial survey. A dyslexia-mailing forum was set up and eighty members agreed to join the research group. The second survey was then posted on the forum and results obtained. The dyslexia-mailing forum was frequently used over several months to test out ideas and gain valuable feedback. The results from this are presented in Section 4.8.

4.1.2 General aims of the surveys

A primary aim of the surveys was to establish exactly what support dyslexic adults would like to aid them with their everyday written tasks. The particular areas of interest were the type of support required to aid sentence structuring, grammar and spelling. Information was requested to establish how dyslexia affects a person's written English abilities in terms of the type of errors made. The results were then used to design several spelling support tools used within the specialist word processing package. Much of this information was gained from the follow up survey and covered in Section 4.5.

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An investigation into how dyslexia affects a person's ability when using other language types, such as structured languages was also undertaken. Structured languages (such as computer programming languages) are used in an environment where order and structure are essential. The results were used in firstly the confirmation of the research hypothesis (discussed in Chapter 1), and secondly the design of a sentence construction tool which provides support for forming grammatically correct sentences. Much of this information was gained from the initial survey and covered in Section 4.2. Information concerning the ideal word processing environment settings, layout and menu system was also investigated. The required information was collected using the dyslexia-mailing forum.

4.1.3 Survey design criteria

When designing surveys it is essential to ensure, that firstly the material is presented in a form that is suitable for the testing sample, and secondly the content is appropriate. Guidelines used were taken from the British Dyslexia Internet site [BDA02]. The presentation and content criteria for the research surveys are as follows:

- Text clearly laid out using one and half line spacing, font size 14
- The number of options per question kept to a minimum (to avoid confusion)
- Avoid having a middle option (5 options) as dyslexics when in doubt will choose to be non-committal
- Simple plain English used, limiting homophone usage
- Surveys kept short and concise
- Questions categorised with bold headings
- Avoidance of ambiguous questions

4.2 Initial survey

The initial survey was by far the most comprehensive covering a wide range of areas. The questions were relatively general in comparison to the second survey. The sample size was 259 subjects and the collection time period was six months. The results data tables are provided in Appendix A.1.

4.2.1 Main objective

The main objective of this survey is to test the research hypothesis (discussed in Chapter 1) and provide information to aid the design of the sentence construction tool. This was achieved by investigating how dyslexia affects a subject's ability within different language structures. The usefulness of natural and structured language support tools was investigated to aid the design process, by incorporating favourable features. The term grammatical tool and sentence construction tool are of the same form and both are concerned with supporting the construction of grammatically correct sentences.

4.2.2 Categories to be investigated

The main categories to be investigated are:

- General background
- Grammar and computer programming languages
- Detailed computer programming specifics
- Grammatical tools

Each of these categories contains several sub-categories and the results for each will be presented in the next section.

4.3 Summary analysis of responses to initial survey

This section is concerned with detailing the results from the initial survey. This is used to form the conclusion presented in Section 4.4.

4.3.1 General background

General information was requested from each person who responded to the survey. Initially background information was provided to ascertain the test subject's general profile. The survey questions are presented in italics and bold.

The question...

What is your age? 20 or under 21 - 45 46 or older

From the results it can be seen that the majority of the sample were aged 21 to 45. The survey requested information from adults only, therefore it would be expected that the age group 0 - 20 would have a relatively low percentage of subjects. The mid age group tends to be more computer literate than the 46 and over group, concluding that these results were to be expected.

Age Group	Percentage (%)
0-20	19
21- 45	70
46 and over	11

Table 4.1. Subject age groups.

The question...

Are you male or female?

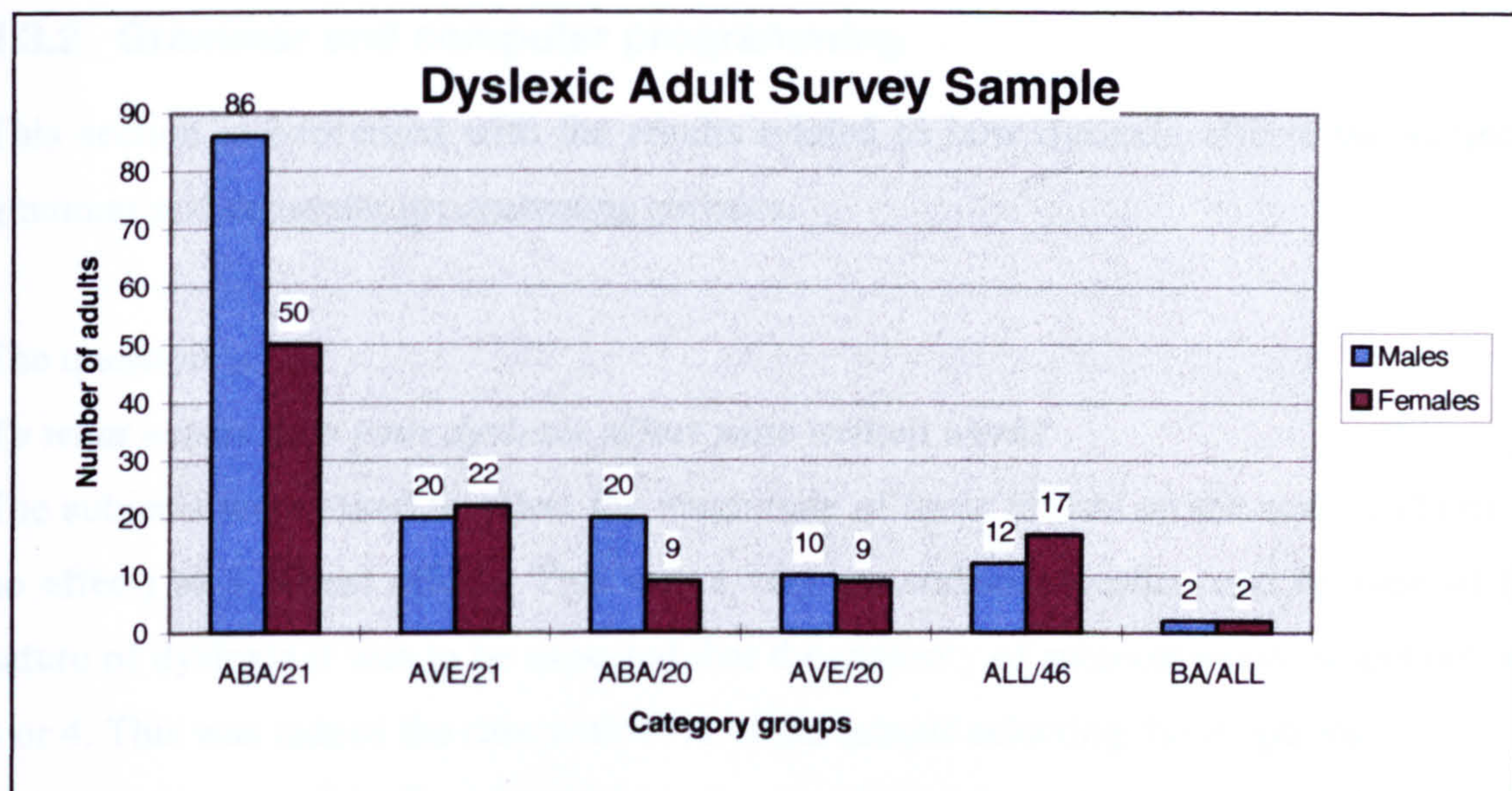
The results showed that a marginal majority of the sample, 58% were male and 42% were female. This result was quite surprising and did not follow the national statistics from the British Dyslexia Association [BDA02], which is a 3:1 ratio of male to female dyslexics. A possible reason for this is that females may be more likely to take the time to fill out a form and therefore the results show a higher number of females than would normally be expected.

The question...

Do you use computers a great deal a certain amount not at all

The results showed that a majority of 70% selected 'a great deal' category. The majority (90%) of data collection was established using the Internet and for that reason it would be expected that the majority of subjects would be regular computer users.

The results were evaluated to establish common background groups: gender, computer usage and age range. Figure 4.1 shows the total number of dyslexic adults in each grouping.



*Figure 4.1. Distribution of survey sample results.

Figure 4.1 shows that the two largest groups are Males and Females with above average computer usage in the age range 21 - 45.

The question...

Do you use computer programming languages yes no

From the sample 59% used computer programming languages in their everyday lives. This percentage is very encouraging and shows that the majority of test subjects, regardless of their dyslexia, were able to learn and use computer programming languages. This was essential in order for the survey to satisfy the general aims of the research and investigate comparative effects. The percentage of adults who use computer-programming languages in a sample of two hundred and fifty-nine average ability adults would normally be expected to be much lower. A survey was undertaken where 100 people (non-dyslexics) chosen at random (within Loughborough University campus) were asked if they had any computer programming experience. Twenty-one subjects had experience of using programming languages and 79 did not. In comparison to the dyslexic test sample this is substantially lower, as expected (see Appendix A.16).

* Abbreviations: ABA (ABove Average computer use), AVE (AVERage computer use), BA (Below Average computer use), 20 (20 and under) 21 (21 - 45), 46 (46 and above), ALL (all of a category).

4.3.2 Grammar and computer programming

This section is concerned with the results related to how dyslexia affects the subject's grammar and computer programming abilities.

The question...

To what extent does your dyslexia affect your written work?

The subjects were asked to select the magnitude of these effects on the scale 1 (Little or no effect) to 4 (Great effect). This was a very generalised question and because of the nature of dyslexia it was to be expected that the majority of subjects would select options 3 or 4. This was indeed the case with 77% of the sample selecting those options.

The question...

Does your dyslexia affect your programming abilities?

Those subjects that had computer programming experience (59% of the sample) were asked to select from the scale 1 (very little) to 4 (a great deal). 70% selected option 1 or 2. Figure 4.2 illustrates the responses in terms of the level to which dyslexia affects both grammar and computer programming skills (high or low). 47% of the sample have high English grammar effects and low computer programming effects. However, only 5% of the sample have low English grammar effects and high computer programming effects.

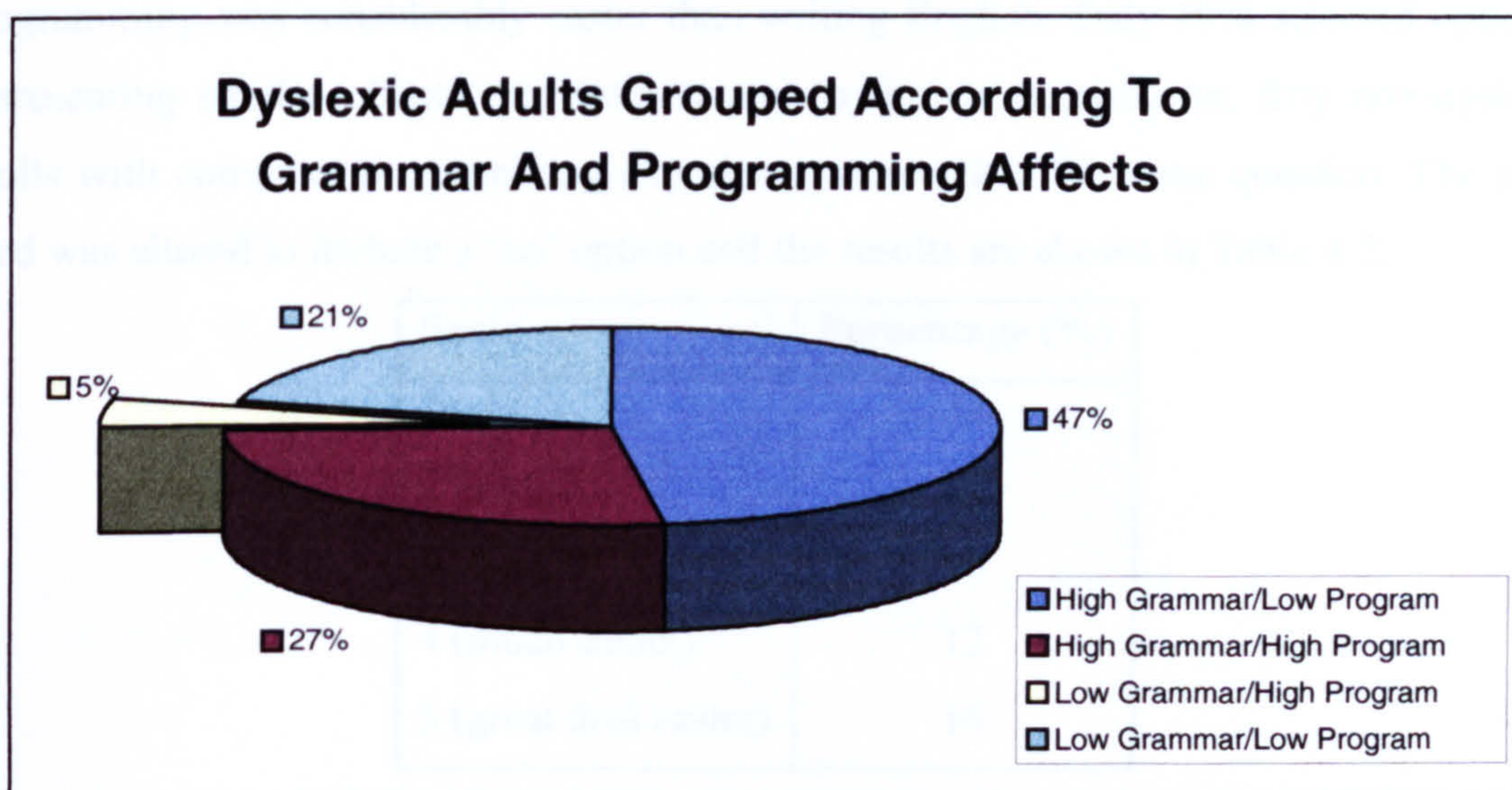


Figure 4.2. How dyslexia affects programming and grammar skills.

The question...

Do you find programming easier than writing English?

Those subjects that had computer programming experience (59% of the sample) were asked to select the magnitude of the effect of their dyslexia on a scale 1 (very little/similar affects) to 4 (great deal easier). Figure 4.3 shows the results from the question.

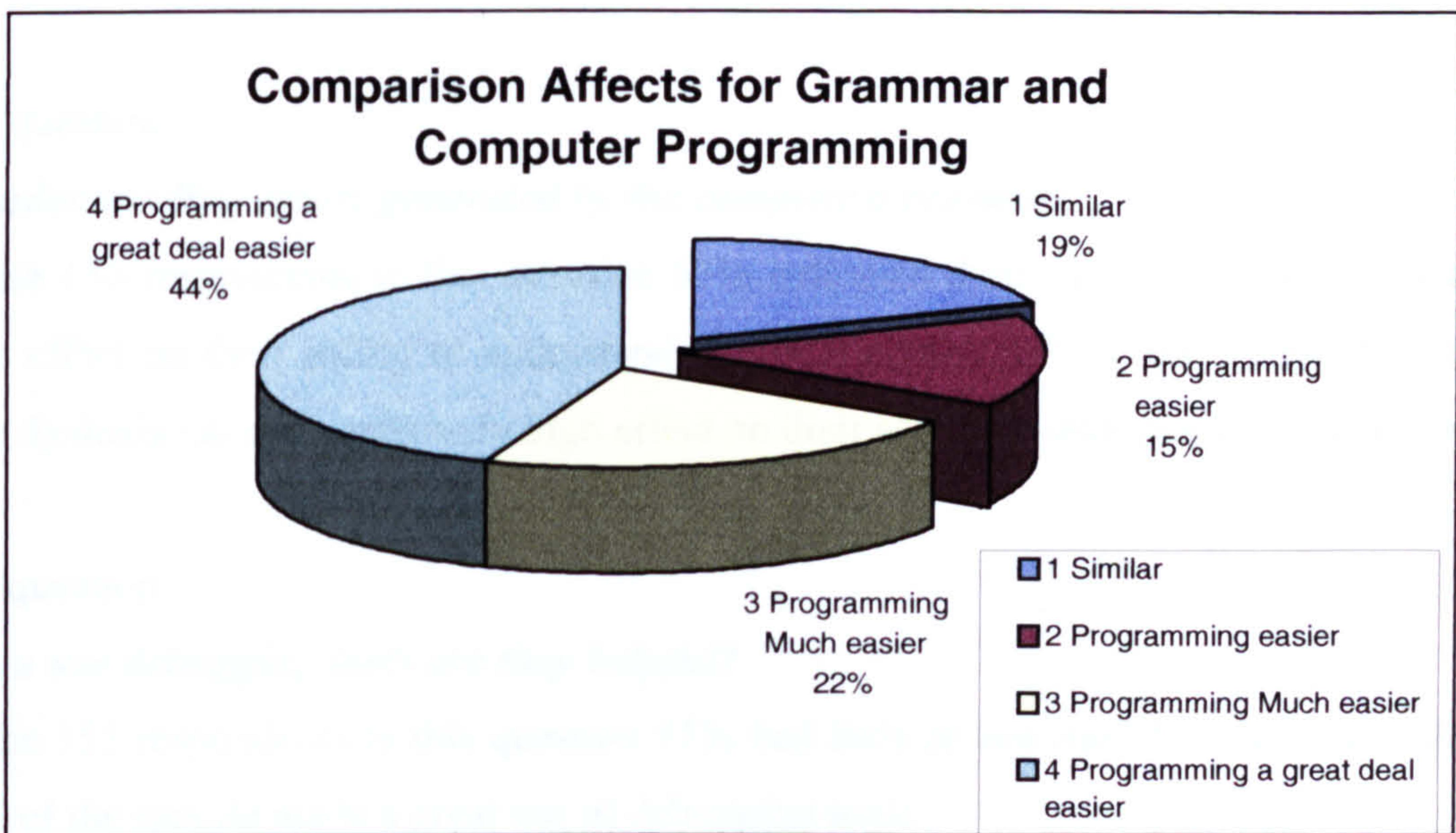


Figure 4.3. Comparison of subjects' programming and writing abilities.

Figure 4.3 shows that 66% of the sample selected options 3 or 4 indicating computer programming was considerably easier than writing English. Only 19% selected option 1 representing similar effects. For interest and to form a comparison, fifty non-dyslexic adults with computer programming experience were asked the same question. The scale used was altered to include a 'no' option and the results are shown in Table 4.2.

Scale	Percentage (%)
1 (no)	35
2 (similar)	22
3 (easier)	16
4 (much easier)	12
5 (great deal easier)	16

Table 4.2. Non-dyslexic comparison results.

44% found programming easier compared to 81% of dyslexics (see Appendix A.16).

4.3.3 Detailed computer programming specifics

This section was concerned with more detailed computer programming related questions. Subjects answered these questions if they had computer programming experience (155 adults). They were asked to select the magnitude of the effect of their dyslexia on the scale 1 (Little or no effect) to 4 (Great effect).

The question...

Is understanding errors generated by the compiler a problem?

Of the 155 respondents to this question 63% indicated their dyslexia caused a relatively little effect on their ability to understand compiler errors. 37% of the sample found that their dyslexia caused a relatively high effect on their ability to understand compiler errors.

The question...

If you use debugging tools are they helpful?

Of the 155 respondents to this question 51% had little or low use of debugging tools and 49% of the sample made a great use of debugging tools.

The question...

Is the construction of programming instructions a problem?

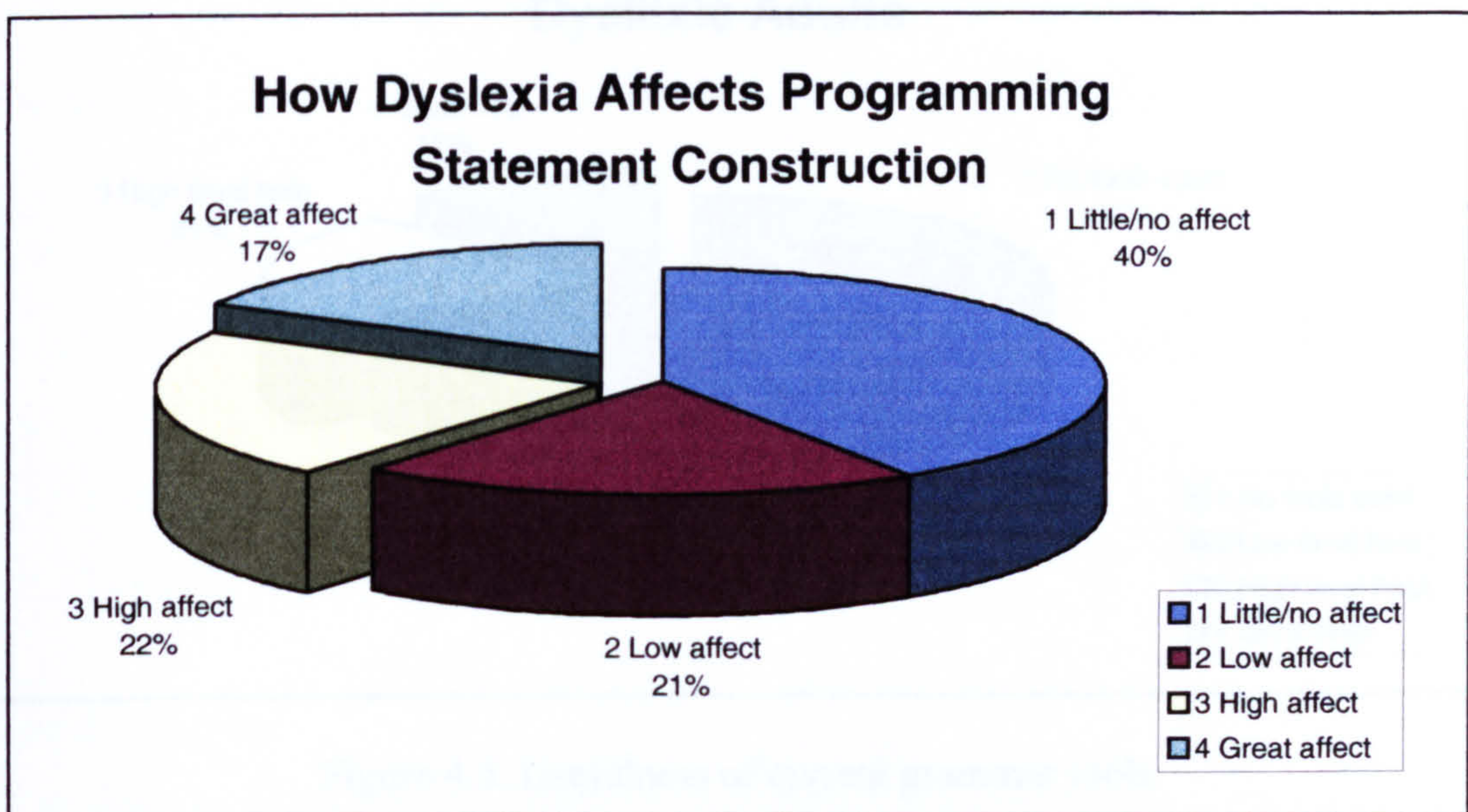


Figure 4.4. Subjects ability to construct program statements.

Figure 4.4 shows that 61% of the sample found their dyslexia had little or a low effect on their ability to construct programming statements. For comparative purposes the subjects were asked to comment on how their dyslexia affected word ordering in sentences. 51% selected the little/low effect options 1 or 2.

4.3.4 Grammatical tools

In order to establish the effectiveness of current grammatical tools (tools which aid the construction of sentences) and whether there is a demand for a new tool, the following questions were included.

The question...

Do the current available grammar tools help you?

There are several word processing packages available which incorporate grammatical tools, an example is textHelp distributed by Lorien. However, these packages are not designed specifically for the problems faced by dyslexics, i.e. phonetic spelling and writing sentences in reverse. Most teaching packages developed for dyslexic subjects are designed for children. Figure 4.5 illustrates the results from the question.

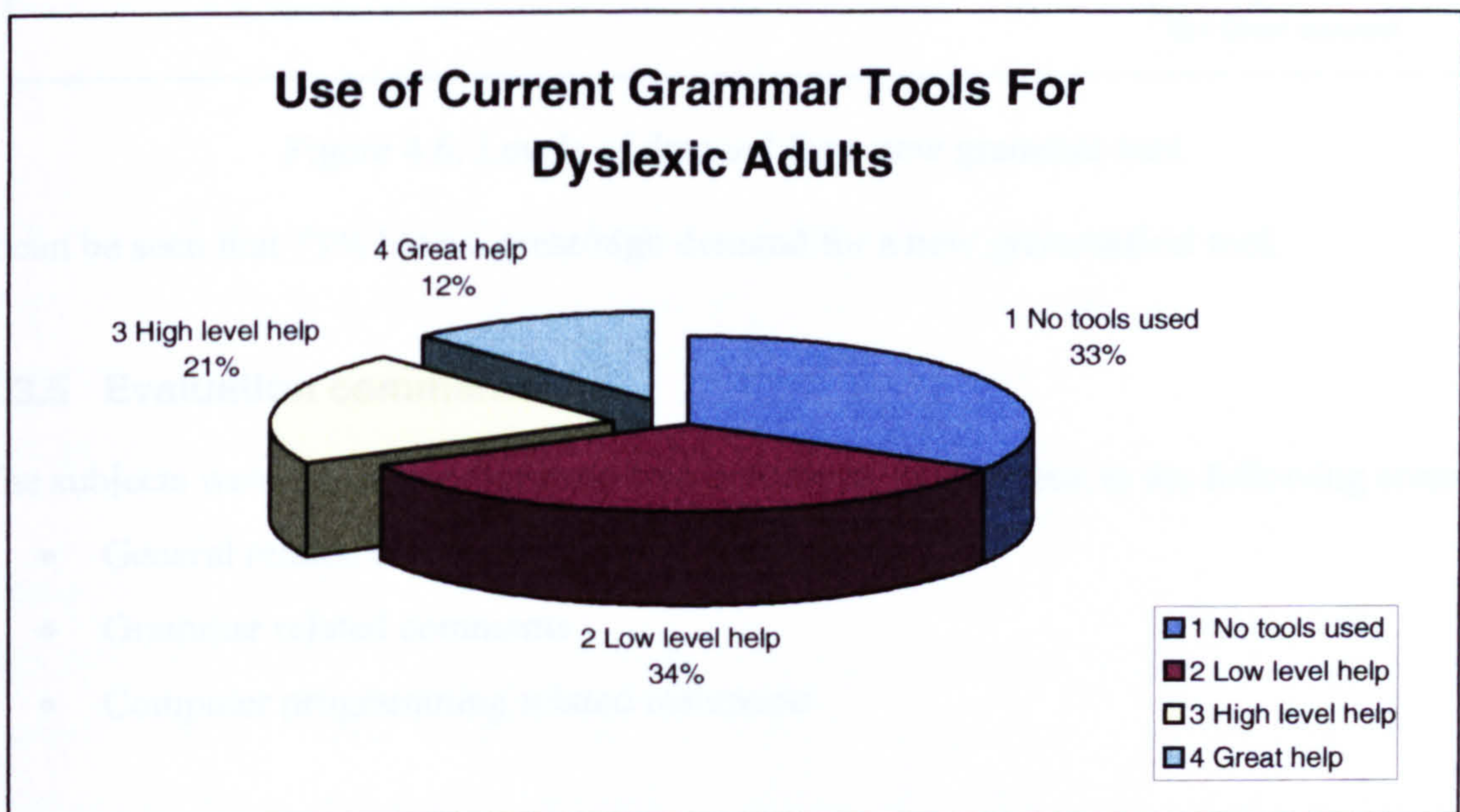


Figure 4.5. Usefulness of current grammar tools.

It can be seen from the results that 33% did not use any grammatical tools and 34% found the tools to be of little help. Only 33% found them useful.

The question...

Do you have a need for such a tool?

The subjects were asked if they have a need for a new grammatical tool designed specifically for dyslexic adults. Figure 4.6 displays the results.

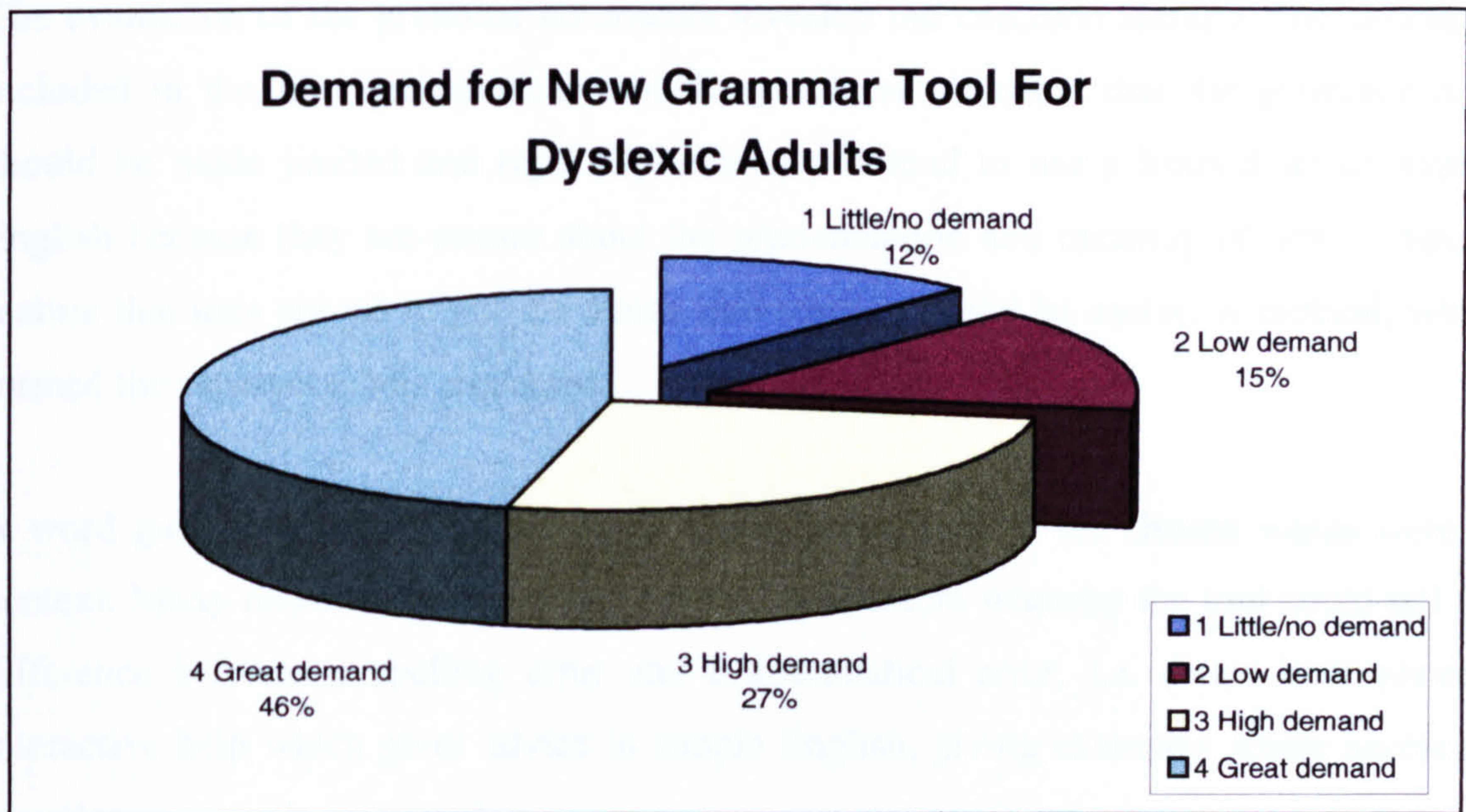


Figure 4.6. Levels of demand for a new grammar tool.

It can be seen that 73% have a great/high demand for a new grammatical tool.

4.3.5 Evaluation comments

The subjects were asked to provide written comments in reference to the following areas:

- General related comments
- Grammar related comments
- Computer programming related comments

General comments

The evaluation of the general comments revealed a requirement for a new grammatical tool. Respondents indicated that the use of pictures and diagrams is preferable to written

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explanation wherever possible. Where written text is to be used this should be limited to a small set of instructions presented in simple English. A further point was expressed that a combination with speech (the use of multimedia), simple examples and a logical approach would be beneficial. These findings may be seen to form the basic requirements for any tools, learning or productivity developed to aid those with dyslexic problems.

Grammar comments

The evaluation of the grammar comments revealed the common features that should be included in the new grammatical tool. Respondents indicated that the grammar rules should be made limited and rigid. Dyslexic adults tend to use a limited set of written English because they are unsure about the pronunciation and meaning of new words. A feature that uses speech to put the words into context would be useful. A method, which formed the sentences, was requested.

A word guess on first letters would be useful particularly if the chosen words were in context. Many respondents expressed a need for a feature whereby the tool could tell the difference between a spelling error and a grammatical error, i.e. detect homophones. Interactive help which gives advice in simple English, giving examples where necessary was also commonly requested.

The respondents requested text to speech feature with spoken vocabulary help, offering multi-level, user-friendly graphical interface. The tool must follow English rules not American (however, it may be possible to configure the tool to offer a choice) and can change from formal to informal rules. Ideally the tool would integrate with current work.

Computer programming comments

The evaluation of the computer comments resulted in respondent's suggestions to the reasons why they find computer programming languages easier to use than written English. Where possible these could be incorporated in the design of a new tool for helping with sentence construction. Respondents stated that computer programming code seems to make much more sense. This may be due to the limited spelling vocabulary required or the strict deterministic structure.

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Respondents stated that they use a logical approach to split the programming task into small steps (modular programming) to allow them to concentrate on small units. Respondents claimed the use of flowcharts to design structure was a great help and they would like to use a similar feature for English grammar.

From the comments it would seem that the main reason dyslexic adults find computer programming languages relatively easy to use is because clearly defined rigid rules are used. Respondents have stated that the current debuggers and compilers offer useful help and guidance. Computer programming languages have a high degree of logic and precision and can use short distinct variables. These methods all aid the dyslexic's common problem of poor memory.

4.4 Initial survey conclusion

This survey consisted of very generalised questions to attempt to establish how dyslexia affects the subject's English grammar and computer programming skills. The data tables are provided in Appendix A.1. The results show that a large percentage of the sample have an above average use of computers and use computer programming languages in their every day working lives.

General background

The majority of the test sample is in the age range 21-45 and stated they have above average computer usage. An encouragingly 59% of the test sample used computer programming languages in their everyday lives.

The results indicate that a relatively high percentage of dyslexic adults (from the test sample) used programming languages. It has to be noted that 90% of the test sample required access to a computer and the Internet in order to provide the requested information.

Comparative effects

Evidence from this survey suggests that the subjects' dyslexia does not impinge on their computer programming abilities. The majority of the subjects indicated that their dyslexia has a significant effect on their abilities with English grammar. It could be concluded that, adults have far lower effects caused by their dyslexia when using computer programming languages in comparison to written English. This was not the case for non-dyslexic adults where only 44% found programming languages easier than writing English. No further comparisons with non-dyslexics are formed as this thesis is concerned with dyslexic adults. However the data was included for interest.

These results increase confidence in the developed research hypothesis, in that there seems to exist a link between the number of rules (and level of constraints) a language has and the degree of problems dyslexic adults encounter. Structured languages differ from natural languages because they have a relatively small set of rigid rules with high levels of constraints. These structured languages seem to cause adults with dyslexia fewer problems than natural languages. In order to support dyslexic adults with constructing sentences the development of a controlled rigid environment was designed (discussed in Chapter 7).

Grammatical tools

From the results it can be seen that almost 70% of the sample do not find the current grammatical tools helpful and over 70% have a very high demand for a new grammatical tool. Over 60% of the sample also had a high demand for a learning grammar tool. These results indicate there is a definite requirement for a new grammatical tool to aid sentence construction. The Initial survey data tables are provided in Appendix A.1.

Further information

It is important to establish the type of written English errors that are made, which were used to design the support tools. For this reason a second (follow-up) survey was carried out.

4.5 Follow up survey

This survey was designed to provide further detailed information to support the initial survey. The survey was posted on the dyslexia-mailing forum, which was set up (because of this research) with the sole purpose of exchanging information about dyslexia and its effects. Approximately 80 adults with dyslexia responded to the questionnaire. The results data tables are provided in Appendix A.2.

4.5.1 Main objectives

The main objectives of the follow up questionnaire are presented.

- To collect general background information such as type of employment and country of residence.
- To establish the most common written English errors made by adults with dyslexia.
- To establish what current techniques and tools are useful.
- To find out which computing packages are used and any useful features.

4.6 Summary analysis of responses to follow up survey

This section is concerned with detailing the results from the follow up survey. Conclusions will be drawn and presented in Section 4.7.

4.6.1 General background

This section gives the general background details of the respondents to the questionnaire. It is used to form a general profile of the test subjects.

Country of Residence

- 31 subjects live in USA
- 4 subjects live in Australia or Canada
- 3 subjects live in Brazil or Germany or Ireland
- 42 subjects live in Great Britain

Occupation

- 16 subjects are in the computing industry

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- 19 subjects work in Universities
- 12 subjects are students/researchers in science subjects
- 33 subjects have varied occupations

Age range

- 7 subjects under 21
- 12 subjects over 45
- 51 subjects in the age range 21-45

Computing Experience

- 80% use computer programming languages
- 20% non - programmers

4.6.2 Common errors

This section contains a list of the most common errors made by the sample. These are:

- **Interchanging letters:** b/d p/q s/c c/k i/e f/ph wh/we
- **Capital letters:** Random use of capital letters
- **Punctuation:** Not using full stops, commas, apostrophise and semi-colons correctly
- **Ordering letters in words:** Writing words in reverse, leaving last letter off, missing off 'ed' and 's'
- **Words in sentences:** Missing out preposition (a, the, in, are)
repeating words in sentences
- **Spelling:** Spelling phonetically, i.e. shure for sure
- **letter/word reversal:** ai/ia ou/uo and reversing complete words, saw was
- **Verb tenses:** its/it's loose/lose
- **Homophones:** Mixing homophones, i.e. there for their
- **Words double consonants:** Incorrect spelling, i.e. necessary spelt necessary
- **Sentence structure:** Writing in passive tense, difficulties constructing sentences, subject - verb – object
- **Grammar:** Not knowing general grammatical rules
- **Spell checker picking lists:** Unable to select the correct word from the list

4.6.3 Helpful tools and features

The test subjects were asked to provide written comments concerning helpful tools and features. These results have been evaluated and presented. The use of computers and software (particularly word processing packages) has been a tremendous help to the majority of dyslexic adults. One of the most common features of a dyslexic adult is a poor standard of handwriting. The use of the keyboard has been beneficial and the cut/paste feature of word processing packages has been fully utilised.

Computers allow the user to select the size, type and colour of the letters which is most suited to them. This all helps to allow the subject to focus on what they have written. The spell checkers were also widely used, however, many subjects find it very difficult to choose from the picking list. Voice dictation software is now widely available and competitively priced, allowing both text to be read back and dictated text to be incorporated. The results from the questionnaire show that grammatical tools are seldom used. Most dyslexic adults do not understand the responses given by current standard grammatical tools. They find them to be very confusing and of little help.

4.6.4 Current tools used as a writing aid for English

The following is a list of current programs that subjects used for written English support.

- **Word processors:** Claris works
Word Perfect
Microsoft Word
TextHelp
- **Spell checkers:** Ispell (Unix platform)
Quark Express (PC)
Franklin Word master (hand-held)
- **Grammatical Tool:** Grammatik part of word perfect word processor
- **Voice dictation:** Dragon dictate (types as you talk)
TextAssist (text reader)
Kurzweil Voice (dictation software)

4.6.5 Graded questions

The subjects were asked to grade from 1 to 4 (1: low 4: high) how their dyslexia affects them in the following areas:

- Sequencing of letters/words/numbers: 64% high effect
- Short term memory: need repetition: 60% high effect
- Grammar, knowing rules: 51% high effect
- Spelling reversing word/exchanging letters: 35% high effect
- Reading: reading sentences right to left: 33% high effect

The subjects were asked to grade from 1 to 4 (1: low 4: high) how useful the following tools (and people) were:

- Spell checkers: 93% very useful
- Word processors: 85% very useful
- Friends/family: 61% very useful
- Grammatical tools: 30% very useful

4.7 Follow up survey conclusions

The test subjects profile indicates the majority are from Great Britain, aged between 21 and 45 and can use computer programming languages. This questionnaire has provided detailed information about the type of errors made by dyslexic adults. This was used in the design of the spell checker included in the specialist word processing package. From the survey, a list of current software used by adults with dyslexia has been compiled. It is important to investigate current packages and ensure the developed tool is unique and compatible with current word processors. The results show that spell checkers were found to be the most useful support tool, however, the method for selecting the correct replacement word was difficult to use. Grammatical tools were found to be the least useful with only 30% of the test subjects finding them helpful. Many commented that they did not understand the suggestions that were made. The sequencing of letters, words and numbers seem to cause the most problems and reading of sentences seemed to cause the least problems. The data results tables are provided in Appendix A.2.

4.8 Dyslexia-mailing forum

Requests were posted on the dyslexia-mailing forum to ascertain information concerning the requirements for a basic word processing system. This is in terms of the layout, menu selection process and the environment settings. The overall preferences are:

- Ability to easily change the colours of the background and text
- Set initial colours to white characters on a blue background
- Use icons in preference to menus and make them larger than standard size
- Use large font size for menu options
- Devise a method of implementing a menu which is easier to use

It was clear from the responses that the main problem with the layout of standard word processing systems was the display processes used. Many dyslexics have a problem reading from the computer screen therefore it is important to devise a method, which is more suited to their needs. This information was used for the design of the basic word processor, which is discussed in Chapter 5. Further requests were posted to ascertain requirements for writing support tools. The overall preferences are:

- A tool which provides word meanings in simple plain English
- A spell checker designed for dyslexic type spelling errors
- A tool to form sentences or offer guidelines
- A tool which suggests words when only the first few letters are known
- A spell checker which offers single suggestions avoiding lists
- A tool which lets the user concentrate on the content not the structure
- A tool which highlights sentences to aid proof reading
- A tool which helps to prevent the writing of long sentences
- A tool which helps correct grammar and punctuation mistakes

This information was used for the design of the support tools discussed in Chapter 6 and Chapter 7.

4.9 Concluding comments

The concept that dyslexia affects a person's abilities differently when using alternative language structures was investigated. The initial survey established that there seems to exist a link between the number of rules and level of constraints a language has and the degree of problems dyslexic adults encounter. This was a result of a comparison study of subject's experiences of using natural and structured languages. For interest, a survey was carried out on non-dyslexics adults with programming experience. The subjects did not find programming languages easier than writing English to the same degree (44% compared to 81%). This investigation was only undertaken in a minimal capacity and therefore not conclusive as this research is aimed towards dyslexic adults. It is quite possible that those people drawn to computer programming languages have dyslexia in a minor way and the sort of help required by those with dyslexia are needed by others. However, this falls outside the scope of this research.

The surveys also provided information about how useful current word processors were (and associated support tools) and what dyslexic subjects ideal support package would be. The dyslexia-mailing forum was used to establish the requirements of other support tools and to establish the ideal layout and preferred environment settings for the specialist word processor. The results were used to direct the design and implementation of a word processing package for assisting dyslexic adults with natural language. It was necessary to create three separate environments where varying support was provided within each. This was in order to use the word processing package to qualify the research hypothesis. All environments used the basic word processing system. Environment 1 (often abbreviated to env1) provided no further support (basic system only). Environment 2 (often abbreviated to env2) provided spelling support and environment 3 (often abbreviated to env3) provided support for sentence construction including spell checking. The development of environment 3 was based upon the research hypothesis. The method used, provided a rigid controlled environment where sentence construction was supported. The design of these three environments will be discussed later chapters. The results from the initial research discussed in this chapter have been published in two papers provided in Appendix A17 and A18.

Chapter 5 Design and Implementation of Environment 1

5.1 Introduction

This chapter is concerned with the design and implementation of a basic word processing environment for adults with dyslexia referred to as environment 1 (abbreviated to env1). The survey results discussed in Chapter 4 provided a list of requirements for this environment. These results have shown that many adults with dyslexia have problems reading text from computer screens and making selections using layered menus* or from long lists. These subjects require the use of a specialised word processor, which is suitable for the visual disabilities frequently associated with dyslexia.

Environment 1 provides an ideal environment for adults with dyslexia, with regards to the toolbar layout and size, selection methods used and environment settings. The developed environment's suitability for adults with dyslexia will be investigated and evaluated in later chapters of this thesis. No spelling, grammar or sentence construction support is provided within this environment. However, it is used as a platform for two further environments, where support and control are provided in varying levels. These environments are discussed in Chapter 6 and Chapter 7.

This chapter commences with highlighting the current problems with standard word processing environments. The model of word processing as laid down by Microsoft Word and its smaller sister WordPad provides the basis for the comparisons used within this chapter.

The next section discusses the problems with current applications and possible solutions to these problems. The subsequent section discusses how Microsoft WordPad was used to provide the starting basis for this environment and outlines the changes, which need to be made. The remaining sections are concerned with the design and implementation of environment 1.

* Where the selection of one option leads to another menu of options.

5.2 Problems with current applications

The results within this thesis have shown that dyslexic adults require modifications to the standard word processing packages currently available. This section will discuss these requirements and in the next section will show how these have been incorporated into the design of environment 1.

5.2.1 Using icons

This research has shown that dyslexics in general, prefer to use icons in preference to menus. Whilst most applications do allow the user to access at least selected functions (or tools) via the use of icons, these icons are usually small, making it difficult for a dyslexic user to click on them, as their hand eye coordination is poor. It is possible to change the standard icons to larger icons within Microsoft Word but this requires in depth knowledge and the need to use layered menus (the process is 'tools' menu, option 'Customize menu', option 'Large icons') which as previously mentioned is a problem for many dyslexics. Moreover enlarging the icons reduces the quality of the graphics making it difficult to recognise what the icon is representing. The icon graphics often cause confusion by not making it clear what the icon is used for. This forces the user to position the mouse over the icon for a certain time and read a text message to ascertain its purpose. This greatly lessens the usefulness of using icons for the dyslexic user.

5.2.2 Layout

If the option to enlarge the icons is chosen the icons become too large and the user has to make a choice of either only having a relatively small number of icons (which as dyslexics like to make selections via icons is not really satisfactory) or allowing the toolbar to become cluttered (see Section 5.10 for toolbar designs) which is also not favourable. This research has found that dyslexics prefer a simple uncomplicated system, which does not provide a comprehensive selection but concentrates on basic common usage features. With many applications the display appears too cluttered, with a large range of options (usually accessed via menus) for the user to choose from. Dyslexics find these displays confusing and difficult to use. They have indicated their preference would be a basic system, which was tailored to their needs.

5.2.3 Using menus

The standard font size used for menus is too small for a dyslexic user to read easily (often a font size of 10, with reference to Microsoft Word). The menus contain too many options, which can cause eyestrain as reading and making selections from a long list is a particular problem for many dyslexics. The development of a method of presenting a list of options that is more suited to dyslexics needs is an important concern.

Using a layered menu system should be avoided as this quickly leads to confusion, as short-term memory prevents them from remembering the required route to select the option again.

5.2.4 Setting defaults

The default font size for the document is usually too small (Word uses font size 12 and WordPad size 10) it should be set at font size 14. While this can be easily changed, it would be preferable if the default font size were set at the correct level making it more suitable for dyslexic users. This is a relatively minor issue of far greater importance is the setting of default environment colours. Word uses black text on an off white background which is not dissimilar to writing with pen and paper. These do not represent the best colour combination for dyslexics. This is an extremely important issue as it has been proven that using various contrasting colours can be beneficial for dyslexic adults [WL99].

Whilst it is true that current applications do include options designed to address some of these problems, it is still a difficult task to create the ideal environment, particularly if knowledge in this area is limited. This is especially the case when navigating through a system, which the user finds confusing and unhelpful. Clearly, it would be preferable for dyslexic users to have access to a word processor designed for their specific needs.

5.3 Design specification

The application should function as a windows–based environment using WIMP standards (Windows, Icons, Menus and Pointer). The standard word processing features should all be supported. These are:

- Editing features – cut, copy, paste and undo
- Text selection – selecting sections of text using either the keyboard or the mouse
- Text formatting – bold, italic, underline, changing font size and style
- Scroll bar – enable large documents to be viewed easily
- Navigation –move to specific areas of the document using mouse and arrow keys
- Paragraph formatting – can align paragraphs with left/right margins, centre text
- Standard file operations – save, save as, open, new document, print/print preview
- Fully compatible with other word processors

In addition to the basic features, the following, based on the survey results (which specified the needs of dyslexic adults, requests and suggestions) should also be implemented:

- Allow access to common usage functions via icons on the toolbar, in addition to menus
- Pull-down menus should use a large font size and options should be limited for a given menu, avoiding long lists
- Icons should be larger than the standard size and the graphics should indicate the function to be accessed
- Limited range of options on display, to avoid confusing the user
- No advanced word processing features are included, as these simply get in the way and are frequently not used
- Default background colour for the screen should be blue, with text in white
- Default font type should be Times New Roman or Ariel, size 14
- Make changing background and text colours simple by using a single dialog box
- Make changing font type and size simple by using a single dialog boxes

This environment is intended to be the central unit used by the other environments by incorporating various support tools. With this in mind, the application is designed in such a way that it is easy to integrate new tools. A toolbar icon is used to access the support tools used in environment 2 and environment 3 and is referred to as the 'pen' icon.

5.4 Using Microsoft WordPad

Permission was granted from Microsoft to take a copy of the WordPad code for research purposes. This would save time, comply with the standard format (WIMP) and ensure that the documents produced would be compatible. WordPad is a very basic word processor and is an ideal starting point for the development of environment 1. The system is shown in Figure 5.1.

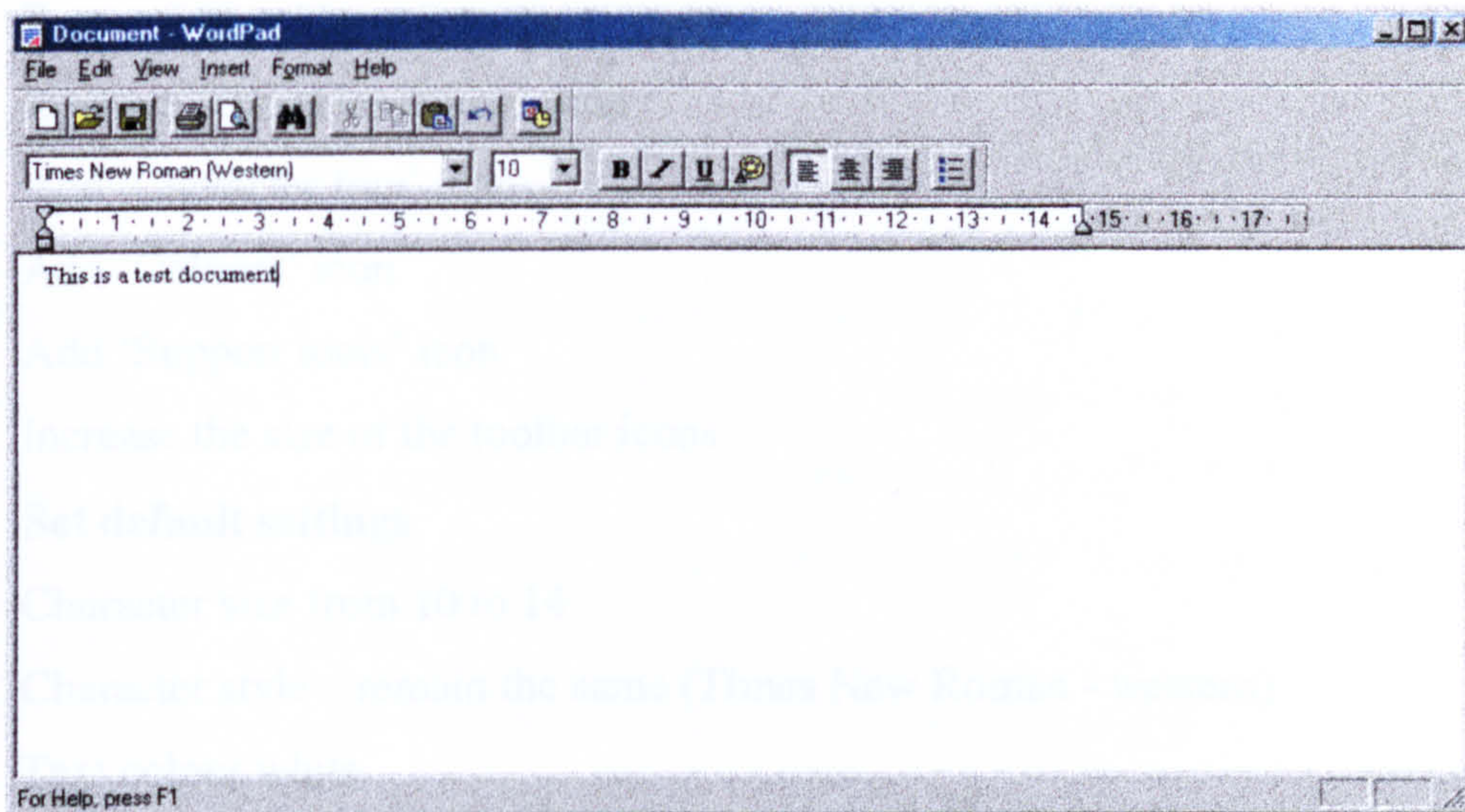


Figure 5.1. Microsoft WordPad layout.

From Figure 5.1 it is possible to identify the changes, which need to be made to the current system. The default font size and the available icons are too small. It is possible to change the colour of the text but not the background colour. Research has show that it is the combination of the two, which is important.

5.4.1 Modifications

WordPad was used as a starting point but several modifications and additions need to be made to ensure the environment is 'dyslexia' friendly. These changes are required to ensure adults with dyslexia are working in an environment, which is best suited to their needs. The changes, which need to be made to WordPad are:

- **Menus**

- Move 'object' option from 'Insert' menu to 'Format' menu

- Delete 'Insert' menu ('date' and 'time' options are not needed)

- Create an 'Environment' menu

- Add options to set the environment variables (font type, size and colour)

- **Icons**

- Remove 'date/time' icon

- Remove 'character colour' icon

- Add 'Character font' icon

- Add 'Colours' icon

- Add 'Support tools' icon

- Increase the size of the toolbar icons

- **Set default settings**

- Character size from 10 to 14

- Character style – remain the same (Times New Roman - western)

- Text colour white

- Background colour blue

- **Using dialog boxes to select environment variables**

- The addition of three dialog boxes:

- To select environment colours

- To select font styles and size

- To select required support tools

5.5 Environment variables

Research has shown that establishing the correct contrast between text and background colours (referred to as environment variables) can lead to increased concentration and far fewer typing errors (as more mistakes are detected by the user). This is particularly true for dyslexic subjects, many of which have difficulties reading text from computer screens (and paper). Moreover using a larger font size can further aid readability and compensate for visual disabilities often associated with dyslexia.

5.6 Menus

When designing an ideal environment it is important to use methods, which make the selection process for changing environment variables dyslexia friendly. In order to achieve this, dialog boxes are linked to the menu options and will allow the user to make their selections with ease. The design of these dialog boxes is covered in, Section 5.9.

It is also important to offer the user a choice of a menu or an icon to perform the same task, as icon usage is usually preferred (but not in all cases). The menu layouts for the unchanged WordPad and environment 1 are presented in Figure 5.2. Unfortunately, it was not possible to increase the text size for the menu titles and options, which was one of the initial design specifications.

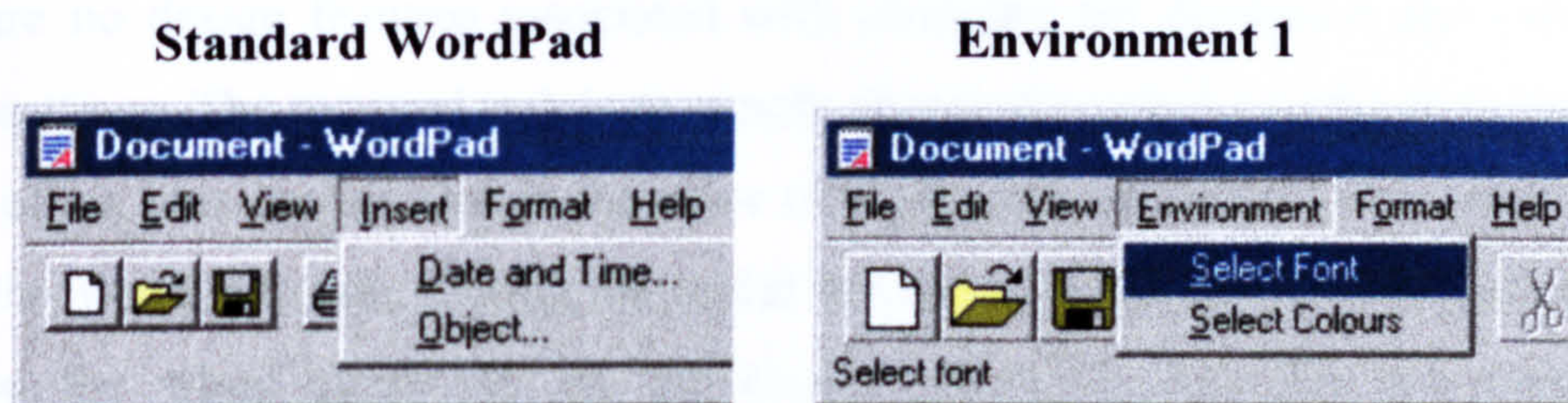


Figure 5.2. WordPad and environment 1 menus.

The 'Insert' menu has been removed and replaced by the 'Environment' menu. The 'Object' option has been moved to the format menu (not shown) as it was considered to be a useful feature. The dialog boxes, which are linked to the menu options, are defined in Section 5.9.

5.7 Icons

Making selections via icons, where pictures are used in place of words, is very beneficial for many adults with dyslexia. The standard icons within WordPad are used, although it was felt that the 'Insert date/time' icon was not necessary (unnecessary clutter) and the palette icon was also removed as this allows only colour changes to the text and not the background

Designs for the new icons are presented in Figure 5.3. The 'pen' icon is used to select the support tools (the pen pictorially representing a writing tool) used within environment 2 and environment 3. The 'character' icon (Aa) is used to set the font size and style and the 'colour' icon is used to select the environment colours. These icons use clear basic graphics and are linked to dialog boxes designed to make the task of changing environment variables simple and clear.

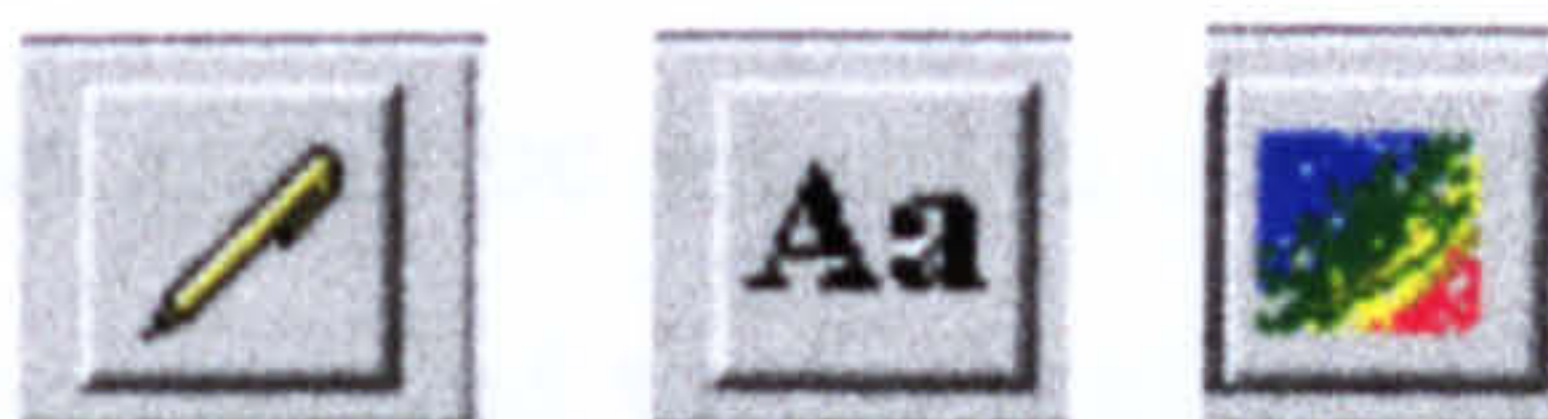


Figure 5.3. New icons used in env 1: pen, character and colour.

5.8 Document and environment default settings

There are no design features associated with changing the document and environment default settings. The required task is to simply change the existing settings to font size 14 instead of 10, blue background in the place of white, and white text in the place of black, within the WordPad code. During the initial investigation results showed dyslexic adults preferred the white characters on the chosen shade of blue has the contrast aids readability. Implementation details are covered in Appendix A.3.

5.9 Selection method using dialog boxes

This research has shown that many dyslexics find the task of selecting from a list difficult. They require a method, which uses larger sized text, which is evenly spaced. Also long lists must be avoided as this often causes confusion. The improved methods for presenting lists are shown and where possible comparisons with WordPad designs have

been provided. All the dialog display text is set at font size 14 to aid readability and is presented in a large format. The 'character' icon is linked to the choose font dialog box and is shown in Figure 5.4.

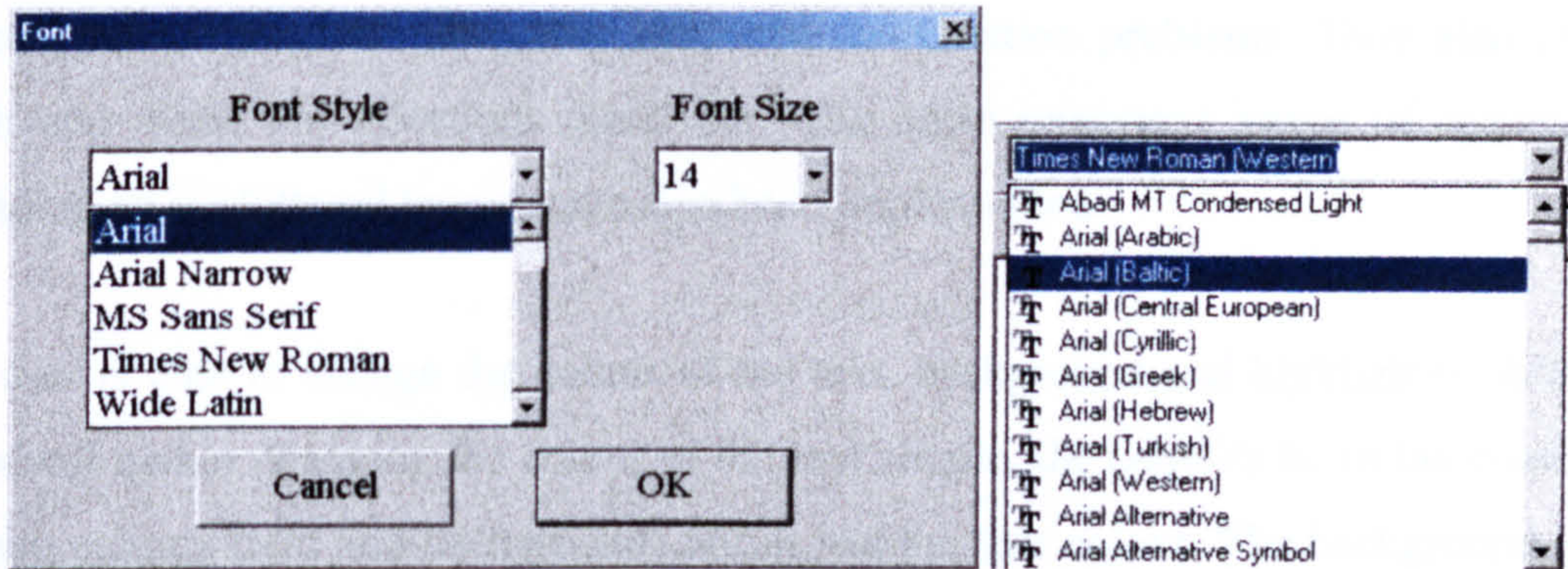


Figure 5.4. Comparison in methods used for selecting font styles.

Figure 5.4 shows a comparison between the selection methods used by environment 1 and WordPad. Within environment 1 the user is presented with a short list of the most frequently used styles. This can easily be set up to contain the selected preferences of the user. The font size can also be changed to the preferred preference. The layout is clear, uncomplicated and visually very effective making selection simple. From the initial investigations (detailed in Chapter 4) dyslexic users stated they did not like being presented with long lists of font styles written in very small text. The large number of options caused confusion and unnecessary eyestrain. WordPad uses a long list of available font styles displayed in this unsuitable format. It is hoped that they will favour the alternative method used in env1. The 'colour' icon is linked to the choose colour dialog box and is shown in Figure 5.5.

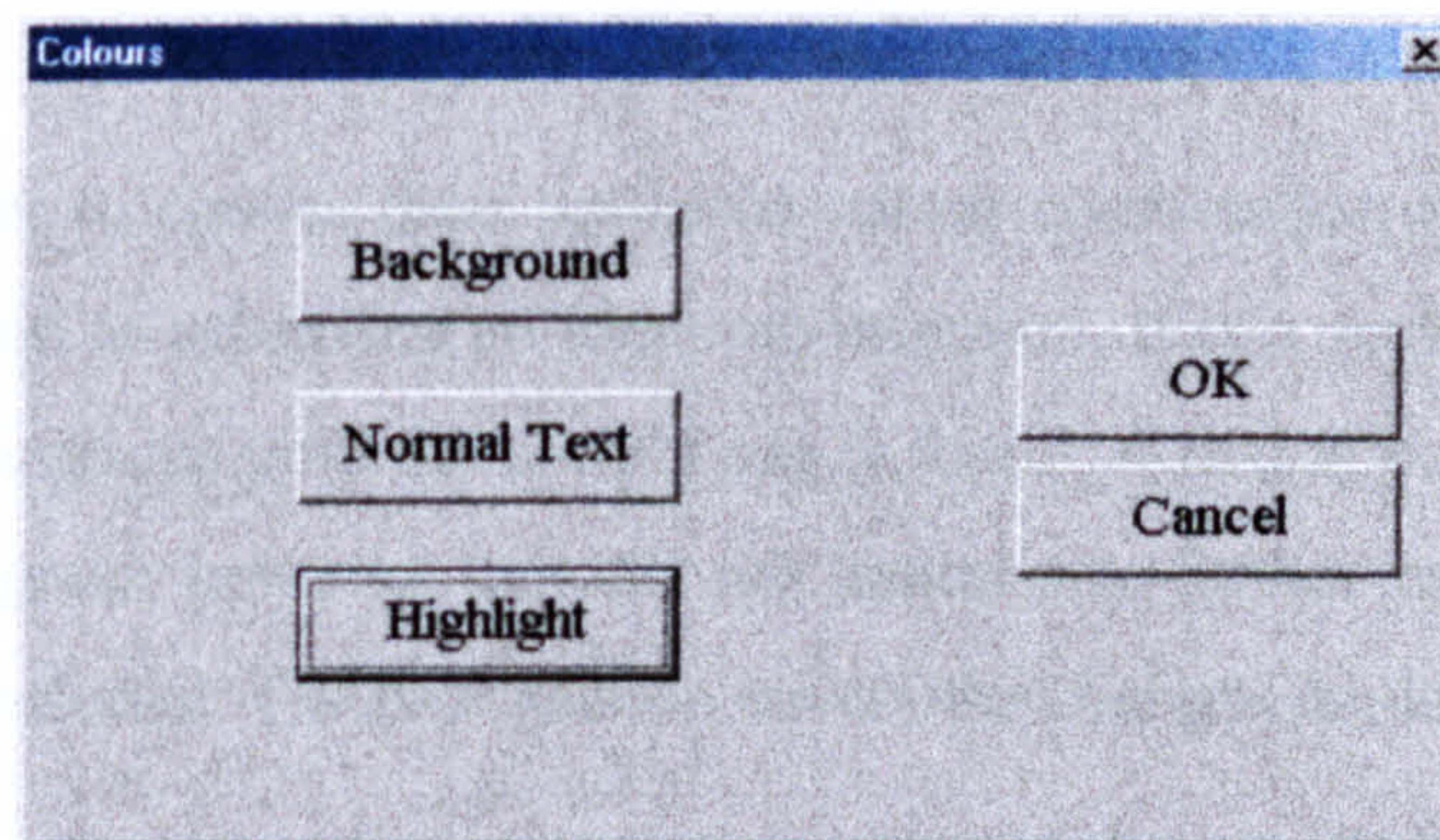


Figure 5.5. Changing the environment colours within environment 1.

There are no comparisons to be made with WordPad, as it does not provide the ability to change the background colour (only the text colour). Figure 5.5 shows the method used for displaying a menu containing very few options. Using buttons makes selection via the mouse pointer easier avoiding any hand-eye coordination problems. They also provide depth and make the selections stand out. The other important issues of spacing and providing an uncluttered layout have also been implemented.

The user is able to change the colour of the text, background and highlighter. Although Microsoft makes changing the colour of the text simple, the benefits lie in the contrast of the two colours (text and background) not in just the text colour. The background colour can be changed in Microsoft Word (not in WordPad) but the associated problems previously discussed are applicable (layered menus, poor memory). On selecting an option from the choose colour dialog box the user is presented with the dialog box presented in Figure 5.6.



Figure 5.6. Environment colours.

This allows the user to choose their preferred colour combination which should make a valuable contribution to achieving an ideal environment. It is a very simple task to keep changing the combinations until the correct one is found. A dialog box linked to the 'pen' icon was also designed, however this did not depict any further research concepts and therefore was not included. The next section covers the changes made to the toolbar.

5.10 Toolbar design

WordPad's original toolbar design is shown in Figure 5.7.

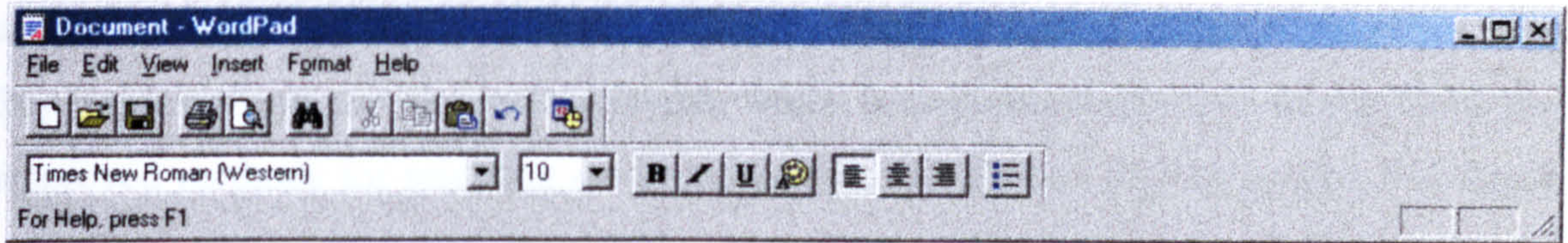


Figure 5.7. WordPad standard toolbar.

The icons need to be enlarged to aid the selection process. The improved design is shown in Figure 5.8 including the additions of the new icons and menu.



Figure 5.8. Toolbar used within environment 1

It can be seen that the improved design is much clearer which is beneficial for adults with dyslexia. As WordPad does not provide the option to enlarge icons it was not possible to form a direct comparison. However, Figure 5.9 shows Microsoft Word's toolbar when the preference to enlarge icons is selected.

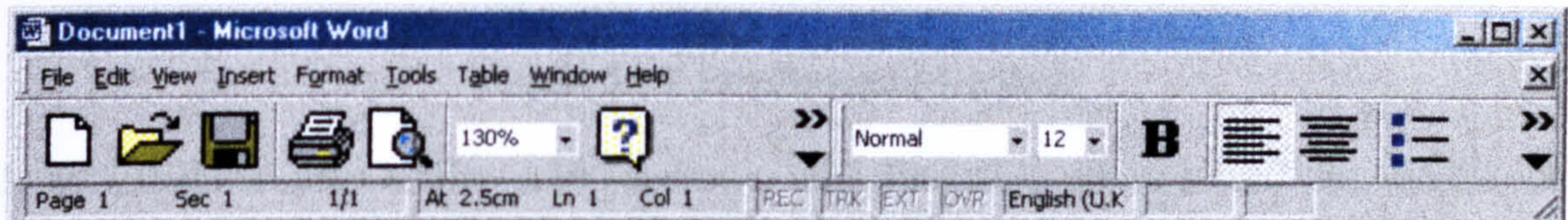


Figure 5.9. Microsoft Word toolbar in enlarged format.

It can be seen that the icons graphic quality is poor and the available options are very limited, even common usage features such as 'Find' have been removed. When more options are added the toolbar becomes too cluttered, a balance has not been reached.

5.11 Design review

The design improvements made to WordPad provide a more favourable environment for adults with dyslexia. To what degree will be evaluated in later chapters of this thesis. The key improvements are: the toolbar layout, which is uncluttered and uses larger icons; the improved methods for selecting environment options (colours and font styles and sizes) and the setting of more favourable document and environment default settings. Unfortunately, it was not possible to increase the text size for the menu titles and related options. This is one design specification, which was not included. Environment 1's general layout is shown in Figure 5.10.

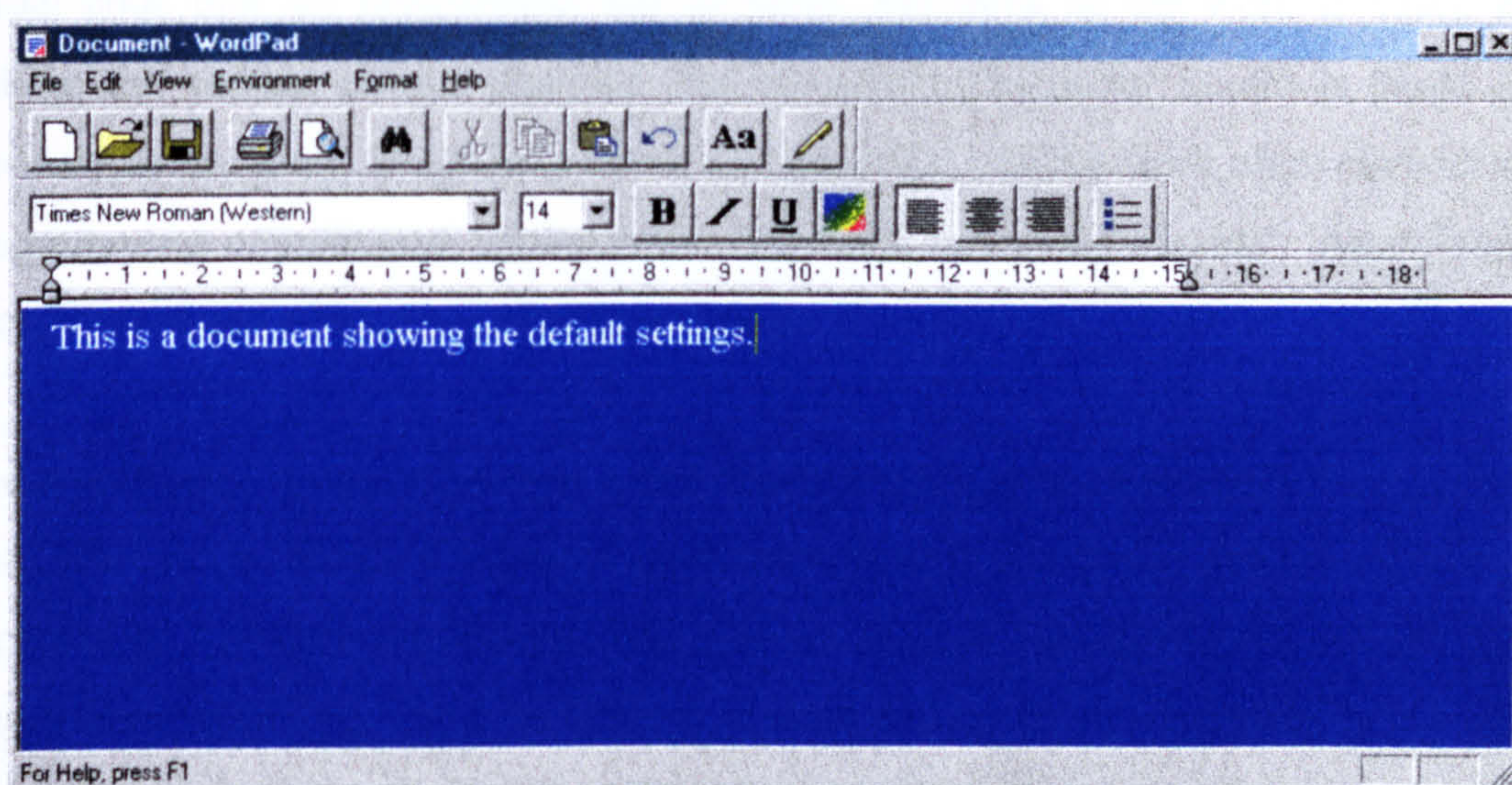


Figure 5.10. Environment 1 layout.

It is expected that adults with dyslexia will find this environment favourable in comparison to standard word processing environments, such as Microsoft Word. The remaining sections are concerned with implementation. The main technical issues, which needed to be considered when developing environment 1 are covered.

5.12 Implementation decisions: choice of programming language

The decision was taken early on in the research to use WordPad as the basis for the development of environment 1. The main reasons for this choice were to save time, as the basic system was already available and to ensure compatibility with other word processing packages. When this was decided the choice of programming language was

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never an issue, as the existing code was written in Visual C++ and therefore the changes and additions would be in the same language.

Visual C++ is a programming language designed for writing windows-based applications, based on the object-oriented C++ language. It is an extremely powerful language but it is also very complicated and takes time to master. Applications are developed via the Microsoft Developer Studio, which provides many tools and features designed to help the programmer. The obvious attraction of Visual C++ is the fact that the Microsoft Foundation Class library (MFC) can be accessed. This drastically reduces the amount of actual code that the programmer has to write, and most of the work is based around linking the various classes together. The Microsoft Developer Studio is based around three important tools, which help remove much of the tedious work often associated with programming complicated applications. The tools are two 'wizards': AppWizard and ClassWizard and a browser called InfoViewer.

The AppWizard is used whenever a new application is to be developed. With some input from the user it creates a skeleton application with much of the windows functionality expected of a modern application. This was not used, as the application (WordPad) code was already available. The ClassWizard is used during the development of a project, to perform a range of tasks for the programmer. Most of these tasks are basically just designed to generate any overhead code needed as the result of adding functions or classes to the application. Comments are added in the body of the function showing the programmer where to insert any additional code. ClassWizard was used when creating the three dialog boxes.

The InfoViewer is the tool that allows the user to access Visual C++ Books Online, a large collection of information and advice about Visual C++. Included are sample programs, tutorials and advice on how to use the Developer Studio. The most important feature of Books Online, however, is the MFC library. This is the library containing all of the pre-written classes that are designed to meet many of the demands of modern windows-based applications.

5.13 Alternative languages

Before the decision was reached to use WordPad as the basis for the development of environment 1 other 'visual' languages capable of producing windows-based applications were investigated. The two main alternatives (at the time) were Visual Basic and Delphi (essentially, 'Visual Pascal'). Delphi is, in many ways, quite similar to Visual C++. It is designed to do the same job, but is based on the Pascal programming language, rather than C++. Applications are usually constructed by combining components, in much the same way that the MFC is used in Visual C++, although the implementation of Delphi is somewhat less complicated than that of Visual C++. This makes learning to use Delphi easier, which is a positive point. However, some of the more complicated features might have required a larger amount of code without the MFC library to access. Overall, there is little to choose between Delphi and Visual C++ when developing this kind of application.

Visual Basic is a much easier language to master than Visual C++, and this would have meant that progress could have been made quicker in the earlier stages. However, Visual Basic does not possess the powerful tools available with Visual C++. Toolbars would have to be developed from scratch, and implementing such aspects as rich text format would have involved significantly more work. Visual Basic's pool of pre-defined functions is also very limited compared with the MFC library, with its thousands of pre-defined member functions. Overall Visual Basic would have been far less suitable. It is not capable of producing applications of this complexity without a great deal of work and programmer-written code (as opposed to Wizard-generated code or pre-written classes and functions).

If the research were commencing now, the main alternative language would be Java. The language has many excellent features including supporting object-oriented programming. The Java development kit comes with a rich collection of class libraries and provides wizards to help the programmer. The implementation of icons, menu items and dialog boxes are provided in AppendixA.4. The next chapter is concerned with the design and implementation of environment 2.

Chapter 6 Design and Implementation of Environment 2

6.1 Introduction

This chapter is concerned with the design and implementation of environment 2. This environment incorporates environment 1 (basic word processor) with the addition of specialist spelling support tools. These tools are: a specialist spell checker (which includes a text highlighter), word predictor and word meanings tool. Environment 2 is based on what dyslexic adults stated they would like to enable them to increase the quality of their written work (discussed in Chapter 4).

This environment was developed for four main reasons, firstly (and most importantly) to provide an environment to compare with environment 3 (in order to qualify the research hypothesis). Secondly, to provide conventional support, which can be used to form comparisons with current support tools provided in word processors, through the chosen testing process (usability grades and comments). Thirdly, to provide a spell checker which will be used within environment 3 (discussed in Chapter 7). Fourthly, it will provide a means of using the research material (discussed in Chapter 4) in order to evaluate its value.

Surveys were carried out (details given in Chapter 4) and a dyslexia-mailing forum was used to ascertain what adults with dyslexia felt they needed to assist them with their written tasks. A selection of this information was used in the Chapter 5 to design environment 1 (the basic word processing system) and also used in this chapter to design the spelling support tools. Due to time constraints, some of the requested features have only been included in a minimal capacity and this will be stated where applicable. The combination of the three support tools, used within the developed word processing system, should provide a favourable environment for adults with dyslexia (based on their opinion).

6.2 Problems with current spelling support tools

Products such as Microsoft Word do not provide the correct level of support for many dyslexic adults. They require spelling support, which is able to provide suggestions for some spelling errors, which are almost unique to dyslexics, such as word reversals. Dyslexic spelling patterns are so varied that it is impossible to provide support by simply using standard error checking validation routines to find word suggestions. The inclusion of files containing dyslexic spelling errors (and associated correct word) need to be used to provide sufficient support.

Presentation methods used for support tools needs to be improved in order to make them more suited to the needs of dyslexics. This is particularly required when presenting lists, i.e. word replacement suggestions. The ability to decide which word is correct from a list of very similar looking words is another problem, which needs to be tackled. Any information, that is displayed, should be font size 14 (Microsoft Word uses 10).

It is acknowledged that there are other specialist tools available (discussed in Chapter 3) and environment 2 does not contribute to an original concept in itself. At the time this tool was developed there were very few specialist support tools available and they were very limited in their capabilities. This situation has now changed but there is still along way to go before adults with dyslexia will be provided with the support, which is most suited to their needs. Current specialist tools cater for a wide range of learning disabilities and do not concentrate on one specific group, as this is not commercially viable. Through the chosen method of testing a comparison to establish how this environment fairs in the current field is performed. This is achieved by allowing the test subjects to grade the environment (referred to as usability grade) according to how useful they find the tool. This will be based on their experience with using other systems. They are also asked to comment on what other specialist tools they have used and how effective they are. Thus, environment 2 provides a basis to be used for comparisons. It also provides the spelling support needed to ensure environment 3 has some degree of flexibility (discussed in Chapter 7).

6.3 Overall design of environment 2

Environment 2 uses the basic word processor (environment 1) to enable the user to write the document text. Throughout this process the user has access to the word predictor, word meanings tools and spell checker (with inbuilt text highlighter). When designing this environment it was important to consider the method of testing to be used for evaluation (covered in detail in Chapter 8). The testing process requires the use of template documents where a series of headings and associated notes are provided and the user's task is to write a section of text under each heading. Therefore the spell checker was designed to accept blocks of text representing one section, thus, only the users text is checked (not the guidelines and prompt notes).

6.3.1 Dyslexic adults requirements

Initial research ascertained the requirements for writing tools for adults with dyslexia. The information was gathered from surveys and from using the dyslexia-mailing forum. Their main requirements, related to support tools, are:

1. A spell checker, which does not offer suggestions in the form of a list of similar words, in small text but offers single suggestions one at a time in a larger font
2. Word meanings for words that look or sound the same or are commonly confused
3. A spell checker, which corrects word reversals
4. A spell checker designed for dyslexic type spelling errors, as defined by them
5. Help to correct words used incorrectly, such as homophones
6. A support tool, which provides endings to words when only initial letters are known
7. A phonetic spell checker
8. A viewer to isolate sentences, to make detecting mistakes and reading text easier
9. Help with grammar
10. Help with sentence construction in particular reducing the occurrence of long sentences

To a varying degree these requirements have been incorporated into the design of environment 2 with the exception of the requirement for assistance with grammar.

6.3.2 Design objectives for environment 2

The main design objectives are:

- To provide support tools to minimise the number of errors left uncorrected
- To make word selection from a spell checker easier by offering one suggestion at a time, avoiding lists of similar words
- Include checks and replacements used in Microsoft Word misspellings
- Provide word meanings for words that often cause confusion
- Suggest words when only initial letters are given
- Use an extensive file of dyslexic spelling errors and associated correct spellings
- Use an extensive file of homophones and common misused words
- Use an extensive file of phonetic spellings linked to correct spellings
- Removal of repeated words, spaces and incorrect capital letter usage
- Add capital letters where needed
- Highlight one sentence at a time to allow the user to focus more easily on a smaller unit aiding proof reading and allowing the user to split large sentences into several smaller ones if necessary
- Use an extensive number of correction routines, including word reversals
- Provide sentence reversal option (reverse order of words)
- Use large uncluttered dialog boxes, font size 14 for presentation

6.3.3 Interfacing with the user

Dyslexic adults frequently experience visual discomfort when reading. Those with reading difficulties have to concentrate harder to interpret text. Eyestrain and tiredness can easily occur. Therefore it is essential to choose a method of interfacing with the user that minimises any discomfort. Environment 2 uses dialog boxes to perform this task. The main design objectives for these dialog boxes are:

- They must be uncluttered and large enough to avoid eye strain
- Use a large font size: 14
- There should be plenty of space between dialog box features
- Be easy to use and self explanatory

- Use contrasting colours, such as black letters on grey background, for ease of readability (benefits discussed in several chapters)

The support tools are accessed via the 'pen' icon (previously discussed in Chapter 5) located on the toolbar. The design of the word predictor will be discussed in the next section.

6.4 Word predictor

A word predictor is something that attempts to offer word suggestions based on the initial few letters that have been entered (see Section 6.3.1 bullet point 6 for dyslexic requirement). Ideally the system would use a comprehensive large lexicon to provide a high level of support. As time was limited this tool provides a taster of what can be provided, concentrating on providing support for words, which may be used within the written tasks.

6.4.1 Design objectives

Decisions need to be made to ensure the support tool will be suitable for dyslexic adults. Ease of use and presentation are key considerations. The main design objectives are:

- Dyslexia friendly interface by using dialog boxes designed for ease of readability
- Simple process to use
- Lexicon to contain 800 words that frequently cause spelling difficulties [Dic94a]
- Display single suggestion if not accepted continue search process
- Insert the chosen word at the current cursor position

6.4.2 File structure

The word predictor uses a text file to store the suggestion words. Table 6.1 shows example file records. There is a single space between the initial letters and the linked word.

Initial letters	Suggested word
acce	accelerate
acce	accessories
acci	accidentally
acco	Accommodate
achi	Achieve

Table 6.1. Predictor file format.

The current file contains 810 word pairs. This is enough to provide a prototype system to ascertain whether this sort of tool is useful and provides the correct level of support. It is of research interest to establish whether the user finds the method of presenting the suggested words favourable. It would be a relatively simple (but time consuming) task to increase the number of words used.

The word predictor uses a simple search, match and display process. The file is searched then when a match is found it is displayed to the user. If acceptable the word is stored in the document or the file search continues from the current position. Dialog boxes are used to accept word beginnings and provide suggestions. Example designs of these will be displayed in the next section.

6.4.3 Using the tool

Dialog boxes are used to interface with the user of the system. The general dialog box design objectives are provided in Section 6.3.3. Two further objectives specific for this support tool are:

- Text is entered using an edit box, which is simple to use
- Included features are: search, accept and next which are self-explanatory

Figure 6.1 shows an example dialog box, which is displayed when the word predictor is selected.

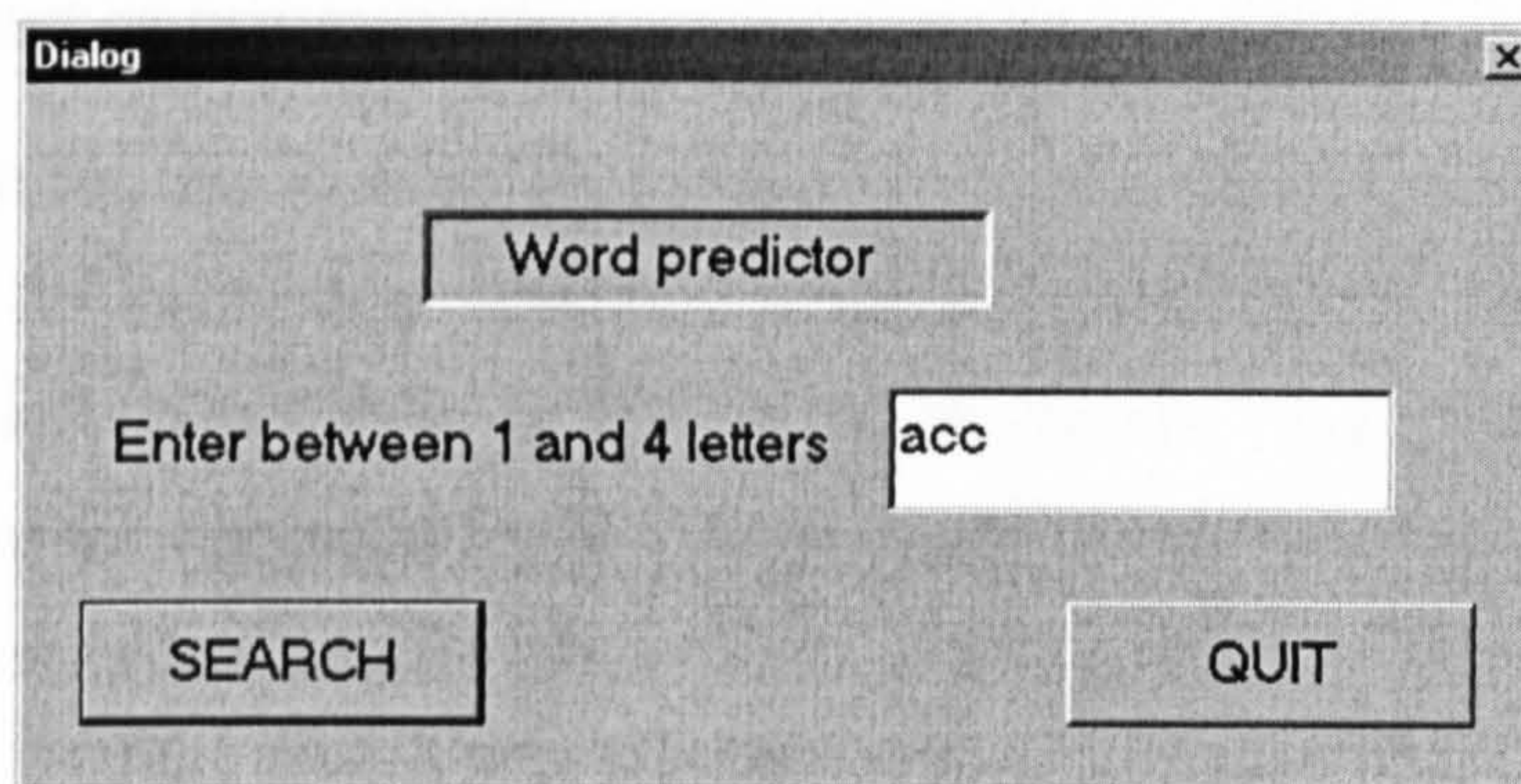


Figure 6.1. Word predictor user input dialog box.

This shows the simple layout making it an easy tool to use. In this example the user has entered three letters 'acc'. The more letters entered (max 4 used for comparison, although more can be entered but will be ignored) the fewer the suggestions. The user may activate the search by pressing the 'search' button or 'quit'. No other options are provided to ensure it is as simple as possible including no unnecessary features. An example word suggested is shown in Figure 6.2.

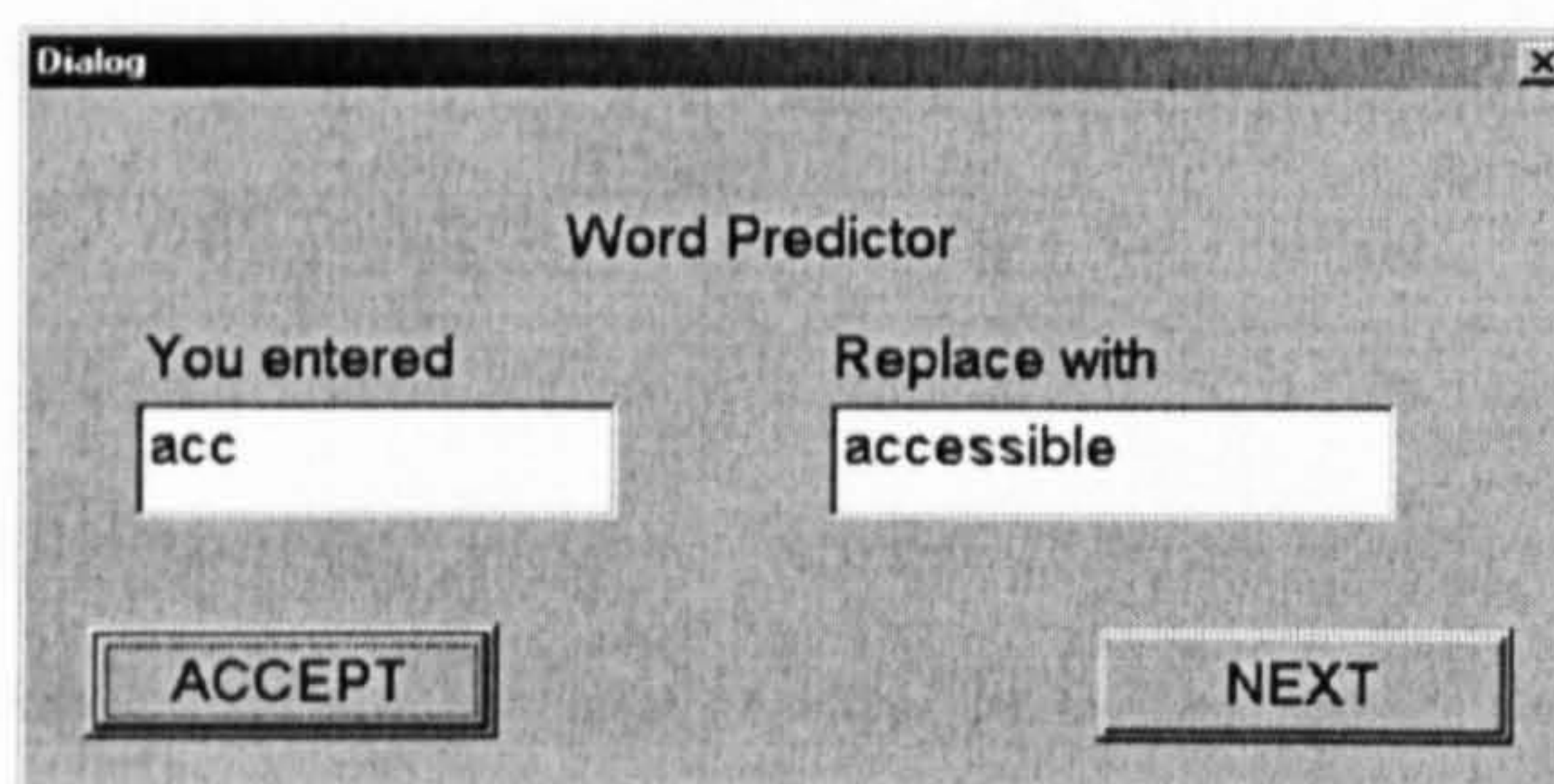


Figure 6.2. Word predictor suggestion dialog box.

Again this dialog box highlights how simple but effective the tool is. Only the minimal information is provided and two options: 'accept' or see 'next' word. One suggestion at a time is displayed to avoid confusion, as lists are not favoured. Fourteen further suggestions were offered. If the user had entered four letters (instead of 3), for example 'acco' only two suggestions would have been offered. Selecting the 'accept' button results in the suggested word being copied to the document at the current cursor position. The 'next' button continues with the file search. If the user does not find a suitable suggested word the tool displays an appropriate message and the user is returned to the text document. It is important to include comprehensive information messages to keep the user fully informed.

6.4.4 Suggested improvement

In its current form the tool requires the user to be able to choose which word to accept. It would be useful for those users who have a spelling problem but do not have reading difficulties. The system is simple to use but would benefit enormously from providing word meanings for the suggested words. Unfortunately due to time restrictions it was not possible to link this system directly to the word meanings tool.

6.5 Word meanings tool

Many adults with dyslexia have difficulties selecting the correct word to use when given two words that either look very similar or sound similar. Often they are forced to simply guess and rely on luck. Most current spell checkers accentuate this problem as they frequently provide lists of very similar looking words for the user to choose between. Having two words is difficult enough but a list of words can create major difficulties for many dyslexics. A solution to this problem would be to provide word meanings for these difficult words in simple plain English (see Section 6.3.1 point 2 for dyslexic requirement).

The concept of an in context spell checker would be the ideal solution. Suggested words would be linked to either their meaning or the word used in context. Due to time restrictions it was not possible to implement this for all words, however, the words meanings tool goes some way to providing this support for selected words.

6.5.1 Design objectives

Decisions need to be made to ensure the word meaning tool will be suitable for dyslexic adults. As with the previous tools, ease of use and presentation are key considerations.

The main design objectives are:

- Dyslexia friendly interface by using dialog boxes designed for ease of readability
- Simple process to use and self-explanatory features
- Lexicon to contain (almost 100) words which are frequently used incorrectly (by dyslexics and the general population) [Dic94b]
- Tool searches for one word then exits

6.5.2 File structure

The word meanings tool uses a text file to store the words and their associated meanings. Table 6.2 shows example file records.

Word	Meaning
There	indicates place, go over there
Their	indicates possession, their dog
Except	not including, apart from
Accept	to agree, to receive something
Stationary	not moving
Stationery	writing paper
Affect	cause a change, small affect
Effect	result, impression

Table 6.2. Word meaning example records

This shows that the meanings are short and written in simple plain English. A single space separates the word and its associated meaning. The chosen words include most common usage homophones [Dic94b]. The word meanings tool uses a simple search and match process. Dialog boxes are used to accept the chosen word and provide the associated meaning. The design of these will be discussed in the next section.

6.5.3 Using the tool

Dialog boxes are used to interact with the user. Edit boxes are used to accept words from the user. Figure 6.3 shows a word entry dialog boxes.

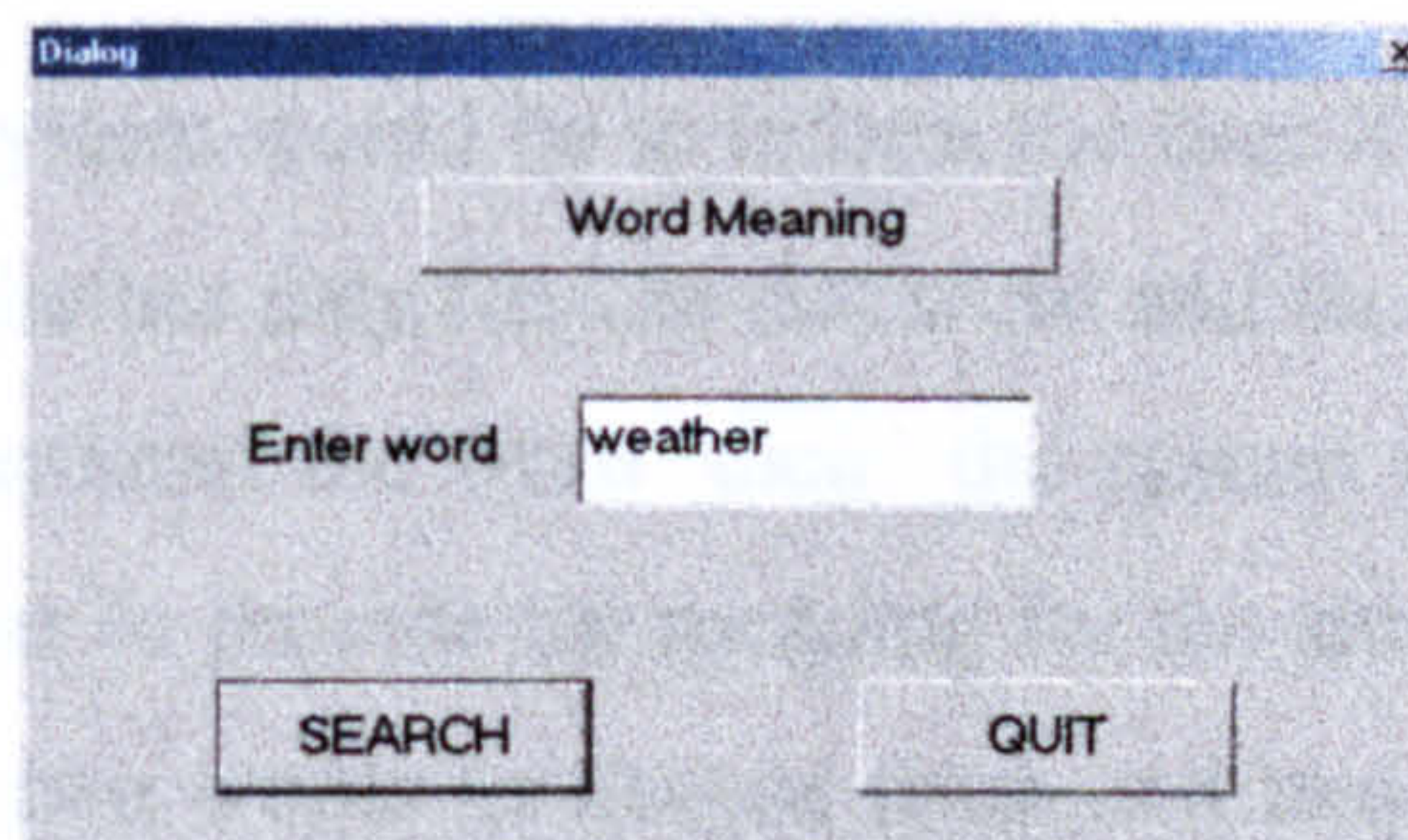


Figure 6.3. Using the word meanings tool.

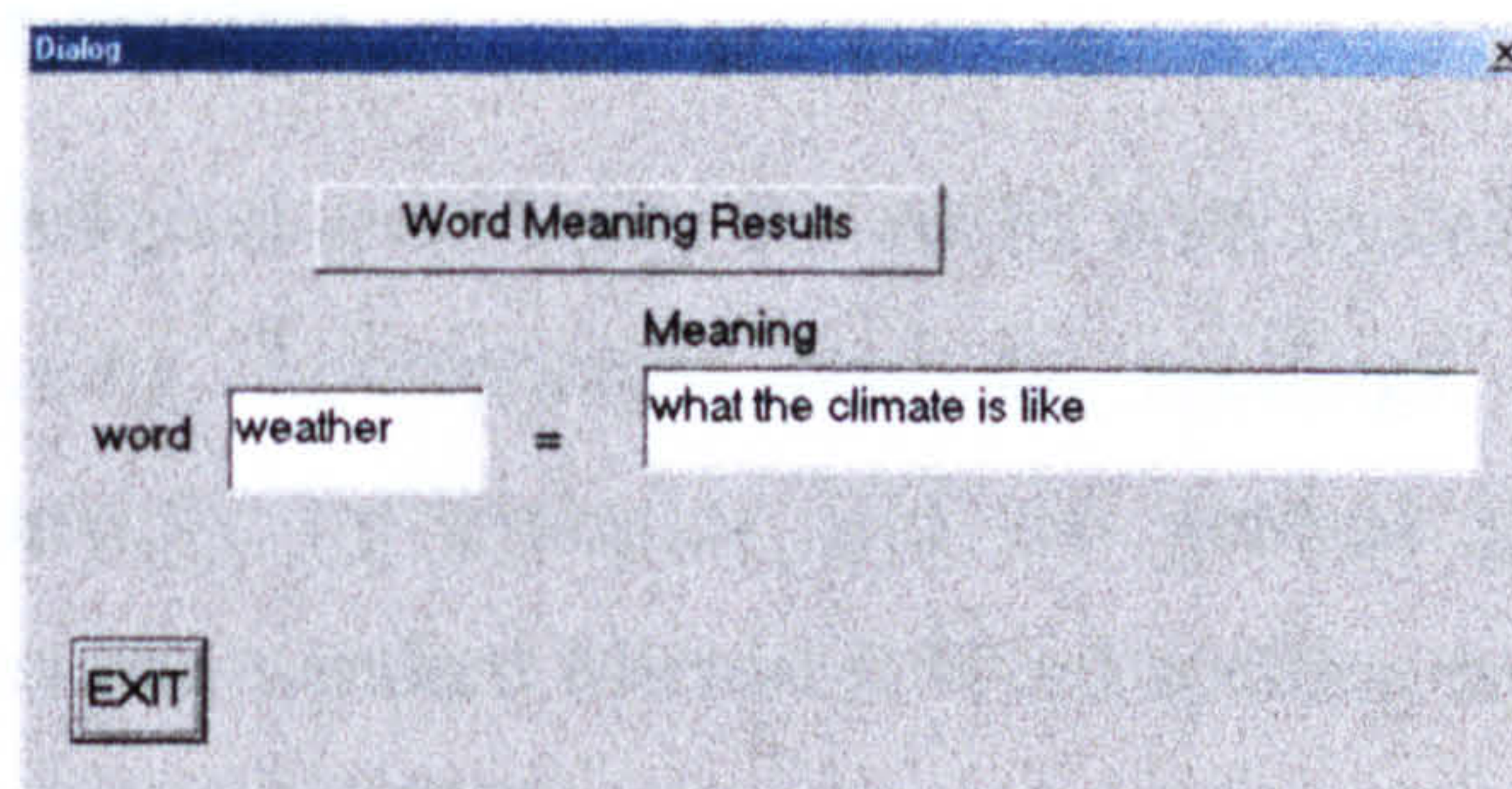


Figure 6.4. Results from the word meanings tool.

Figure 6.4 shows the results dialog box. It can be seen from these figures that the dialog box display is simple but effective. The user enters a word and if found a meaning is provided in simple terms. It is quite likely that the user would request definitions for two similar words if they were unsure which to use (selecting the tool twice). However, it is up to the user to access the tool as often as they feel is necessary, the design of the current tool only allows one word meaning at a time to be processed. This was in order to keep the simple approach, which has been adopted throughout.

The results dialog boxes provide the user with a short definition, which should be sufficient to allow them to choose the correct word. If the word is not in the current word meanings file the system displays an appropriate message. If the 'search' button is selected without entering a word an error message is displayed. It is very important to design support tools that keep the user fully informed of what is happening and highlight any errors they make when not using the tool correctly.

6.5.4 Suggested improvement

An improvement to this system would be to inform the user if there are any similar words to the chosen word and whether they require that word and its associated meaning as well. For example, if the user entered the word 'their' the system would provide the meaning for that word and then offer to provide the meaning for the similar word 'there'. Often the user would have at least two words to choose from and may require information about both words. Due to time restrictions this was not implemented.

6.6 Spell checker design

The spell checker is designed specifically for adults with dyslexia. It uses a number of extensive files containing, homophones, phonetic spellings, special words (words commonly spelt incorrectly by dyslexics and the general population), established common dyslexic errors and standard Microsoft Word spelling replacements. It also uses a comprehensive series of error checking routines to cope with a wide range of spelling mistakes. Word suggestions are presented in a dyslexia friendly manner minimising any confusion or visual difficulties.

This spell checker is unusual, as it is not used to verify single words but complete sentences. It provides some support for sentence manipulation and includes a feature, which allows the user to focus on a sentence rather than a larger block of text. This will highlight long sentences and allow the user to make modifications.

This spell checker has been designed solely for dyslexic adults. It carries out many more checks than a standard spell checker such as the one used in Microsoft Word. For example it uses a file containing over 500 common dyslexic spelling errors and the associate correct spellings. The dyslexia-mailing forum was used to establish this comprehensive list. The tool interface is completely dyslexia friendly in all aspects (from initial research).

6.6.1 Design objectives

The design objectives are:

- To develop a tool which is simple to use and meets the needs of dyslexic adults
- To be used in the testing process (covered in Chapter 8) for selecting blocks of text
- To enable the majority of the dyslexic spelling mistakes to be corrected
- To aid proof reading and reduce the occurrence of long sentences by providing a text highlighter, which isolates each sentence and allows modifications to be made
- To provide suggested replacement words in a form suitable for dyslexic users, avoiding lists of similar looking words

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- To provide support for users who have difficulties with selecting the correct homophone to use
- Using large uncluttered dialog boxes with font size 14 for presentation purposes
- Provide a comprehensive list of error correcting routines including word reversal

6.6.2 General design principles

This section discusses the general design of the spell checker and substantiates the design choices made.

6.6.2.1 Interface method

Dialog boxes are used to interface with the user. This has been covered in several sections within this chapter and design objectives defined in Section 6.3.3 apply here. If dyslexic subjects are asked what they most dislike about spell checkers there is a very high probability that they will say that the presentation of the suggested replacement words are not designed for their use. Long lists of similar looking words presented in a small font size in a cluttered format are all unsuitable for dyslexics to use. This system uses large uncluttered dialog boxes, with a font size of 14. All suggestions are presented separately and the word meanings tool can provide support when needed.

6.6.2.2 Using files

The system uses 4 large dictionary files (approximately 50,000 words in total). The words are listed in alphabetical order. The files contain words with an associated number relating to the grammar category. This is to allow for the inclusion of a grammar checker in future developments (discussed in Chapter 10).

A phonetic file is also used, which contains phonetic spellings and 500 common spelling errors made by dyslexic subjects. It also includes a selection of common spelling errors used within Microsoft Word. Although the file is given the name phonetic it is far more comprehensive. Separate files could have been used but for convenience they were saved in one file. The file contains word pairs (incorrect and correct versions). These were provided through this research work using the dyslexia-mailing forum.

An extensive homophone file is provided which contains all common usage homophones and also other commonly confused words, such as 'if and 'it'. Dyslexics often confuse letters that look very similar, i.e. 'f' and 't' can be confused. Finally an extensive prediction file of 800 words is provided. This is also used for the standalone word predictor.

The reasons for this design choice are:

- Using files of words can provide a far more comprehensive method of error correction. Dyslexics in comparison to non-dyslexics have extremely varied spelling patterns, which are not always easy to categorize. If only error-correcting routines were used the system would be less powerful and not achieve its aims
- Using files means they can be continually updated becoming more powerful as more use is made of the system

6.6.2.3 Selecting text for the spell checker

The user must select, a block of text before the spell checker is activated or the spell checker will attempt to validate the complete document, which can be very time consuming. This selected text must include at least one sentence terminator as the spell checker validates a complete sentence rather than a single word. The reasons for the design choice are:

- The system can offer a sentence reversal option (reversing the order of the words within the sentence), which was asked for during the ascertaining requirements phase
- It allows the system to use a text highlighter which displays the sentence for the user, for proof reading (focus on a smaller unit of text), to help them to reduce long sentences and add appropriate punctuation
- It allows for the inclusion of a grammar checker (discussed in Chapter 10) as a future enhancement

6.6.2.4 Pre-word validation stage

The spell checker's first task is to extract a sentence from the selected block. It then removes all unnecessary spaces, repeated words (user asked to confirm) and capital letters. The reasons for this design choice are:

- Dyslexics frequently insert capital letters in inappropriate places, this can even occur mid sentence. Therefore it seems sensible to remove all of them at the beginning. The dictionaries used include capital letters where necessary
- The inappropriate use of the space bar is also common practice. This does mean that if the user attempts to format their text in a strange manner by including spaces this will automatically be removed
- Dyslexics tend to easily get distracted and the occurrence of word duplication is quite common. The system will ask for confirmation before the duplicate word is removed. Therefore allowing such incidents of the words 'very very' not to be removed automatically

6.6.2.5 Text highlighter

On activating the spell checker the first complete sentence is displayed to the user using a dialog box. If it does not find a complete sentence (sentence terminator) a suitable message is displayed and the spell checker terminates. The system searches for a sentence terminator and will not perform validation tests if it cannot detect one.

A complete sentence is displayed and the user is able to make any modifications before the system validation process begins. They are provided with the option of homophone support (which is discussed in the next section). And then the file searches and error correction routines are performed. The sentence is then redisplayed and final modifications can be made. The reasons for the chosen design are:

- It allows the user of the system to concentrate purely on the sentence and often they will detect mistakes they did not see before
- The first time the sentence is displayed is for finding errors, changing the word order or adding words. The second time it is to review the punctuation of the sentence and to change any long sentences to several shorter sentences if

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necessary. The system encourages this to take place as the length of the sentence is more noticeable when highlighted and isolated

An example to show how the text highlighter is used is provided. Figure 6.5 shows a sentence being highlighted. It contains several mistakes and is far too long. The user of the system did not realise how long the sentence was until it was presented in isolation.

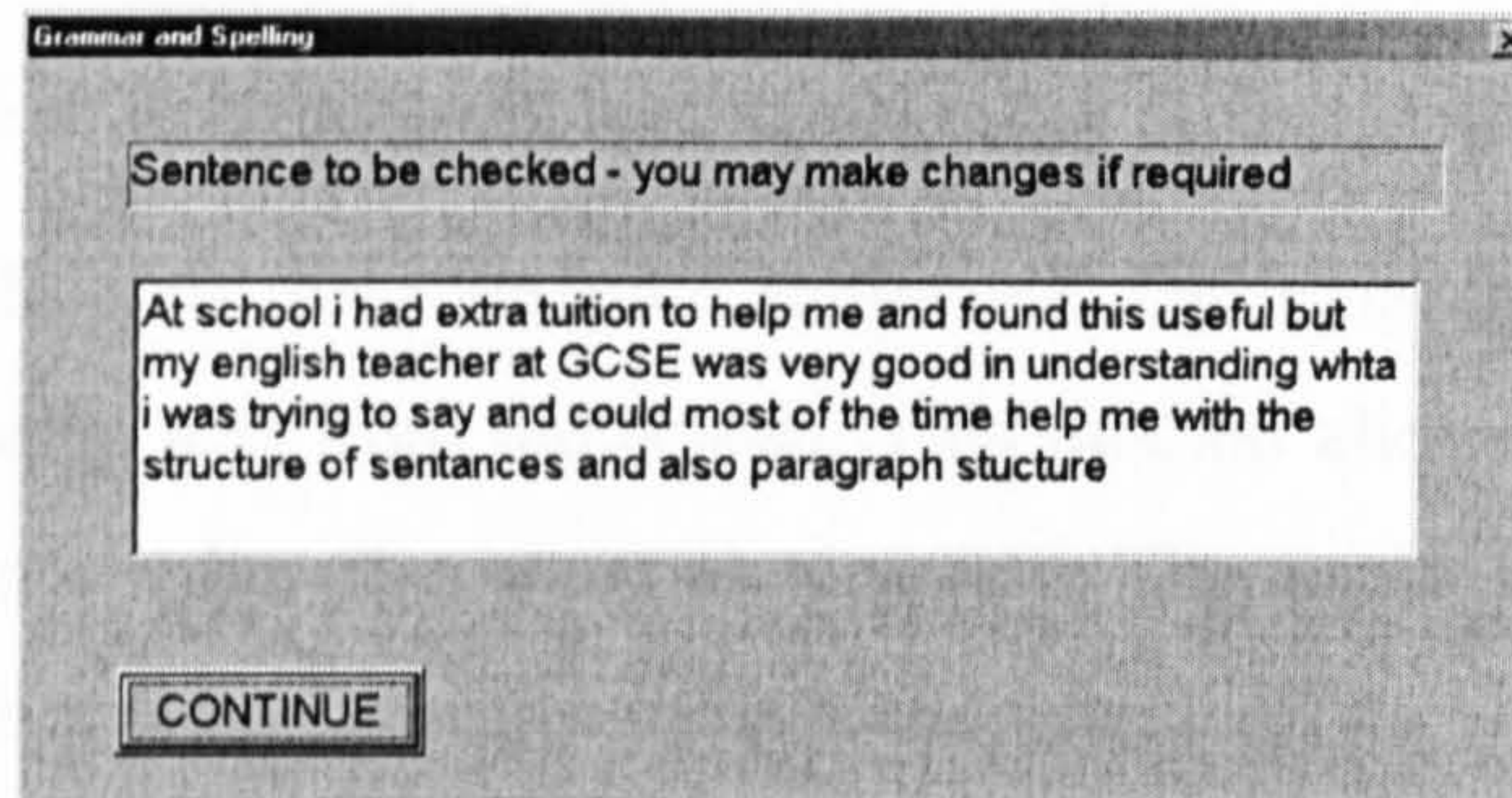


Figure 6.5. Using the text highlighter.

The sentence is presented in an edit box to enable the user to make changes if required. The user chose not to make any changes and did not request homophone support (discussed in Section 6.6.2.6). The validation process was started and the system detected three errors. These were presented to the user in turn. One such error is presented in Figure 6.6.

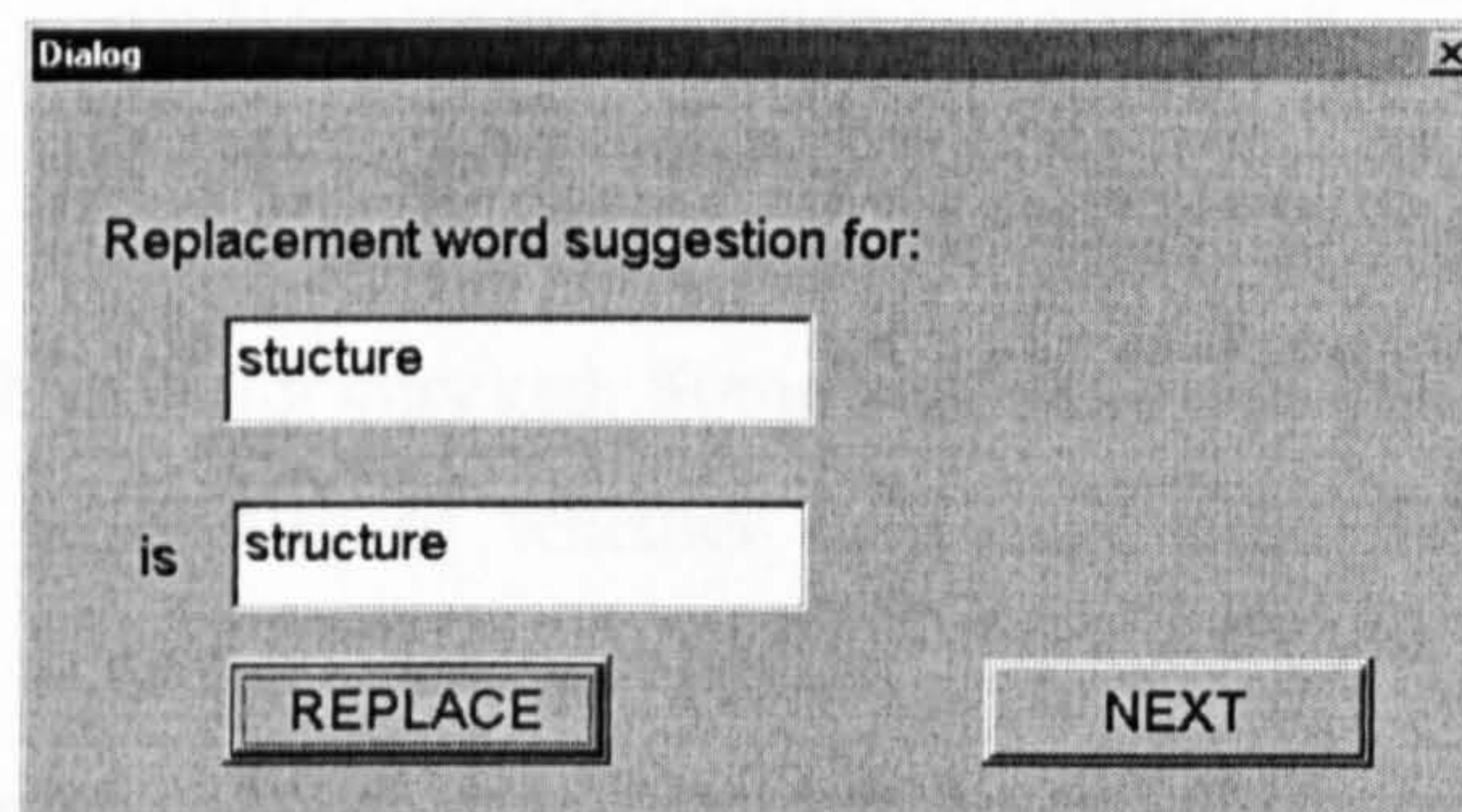


Figure 6.6. Using the spell checker.

The spell checker only displays one suggestion at a time. This is the most favoured method according to the subjects that took part in the initial research. The dialog box layout is functional and the suggestion word is presented in a form which minimises confusion. The other two remaining errors: 'whta' and 'sentances' were also corrected. The sentence was redisplayed to allow the user to make any changes to the sentence structure. Changes were made and shown in Figure 6.7.

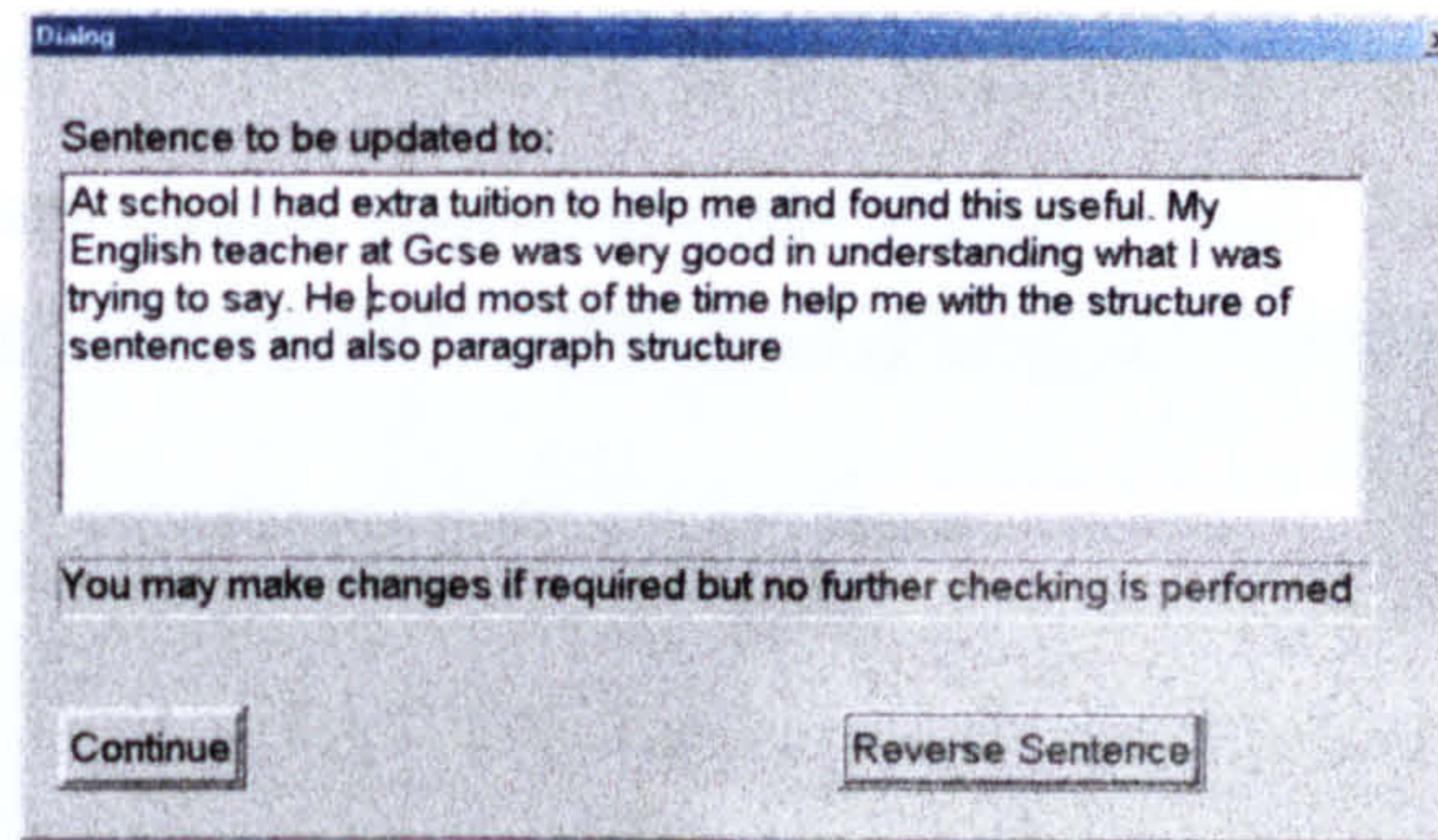


Figure 6.7. Restructuring a sentence using the text highlighter.

The sentence was split into three separate sentences. Dyslexia causes visual problems particularly when reading text from the screen. This method allowed them to focus on a limited number of words rather than a complete screen. The results were quite unexpected but very pleasing. This will be discussed in later chapters.

6.6.2.6 Homophone support

For each sentence the user is given the option of homophone support. Although it is referred to as homophone support the function also includes checks for other words, which are frequently used inappropriately (by dyslexics and the general population). If homophone support is selected the homophone file is searched to find matches with all words in the sentence that have been spelt correctly. The reasons for this design choice are:

- The user can use the homophone support when required, depending on the sentence, which is being checked. Some sentences will contain several words that the user may be unsure of whether they have used the correct word. Other sentences may contain no uncertain words
- The system is much slower when homophone support is selected and it would be inappropriate to use it all the time
- The tool must cater for a wide range of difficulties and this level of support may not be appropriate for all dyslexics

An example is provided to show how this function works. If the sentence, “there dog is nice” was being checked, Figure 6.8 shows an example of homophone support. The dialog boxes used within this function follow the same design principles, which have

been applied throughout the development of the research software. They contain minimal information with features clearly spaced and are simple to use.

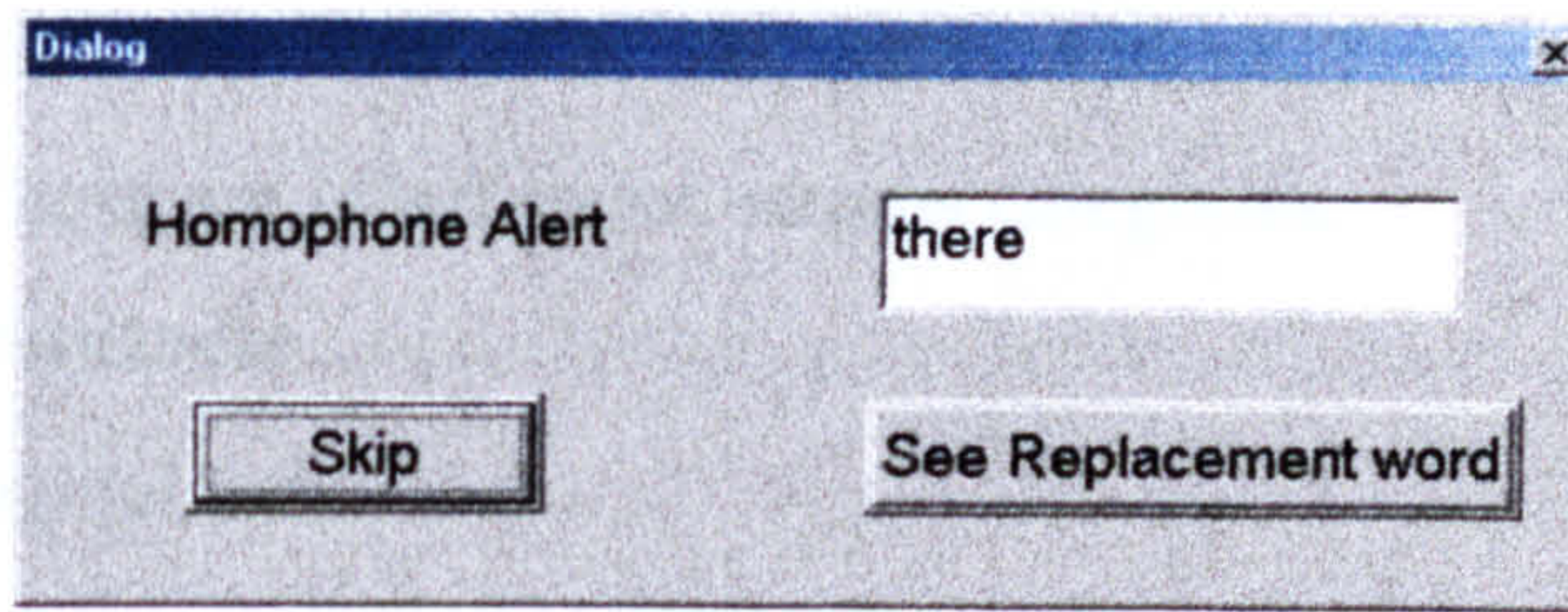


Figure 6.8. Using homophone support.

If the user chooses to see the replacement word the dialog box in Figure 6.9 is displayed. A selection of words within the homophone file are linked to meanings, which provide extra support. An updated version would provide meanings for all of the words.

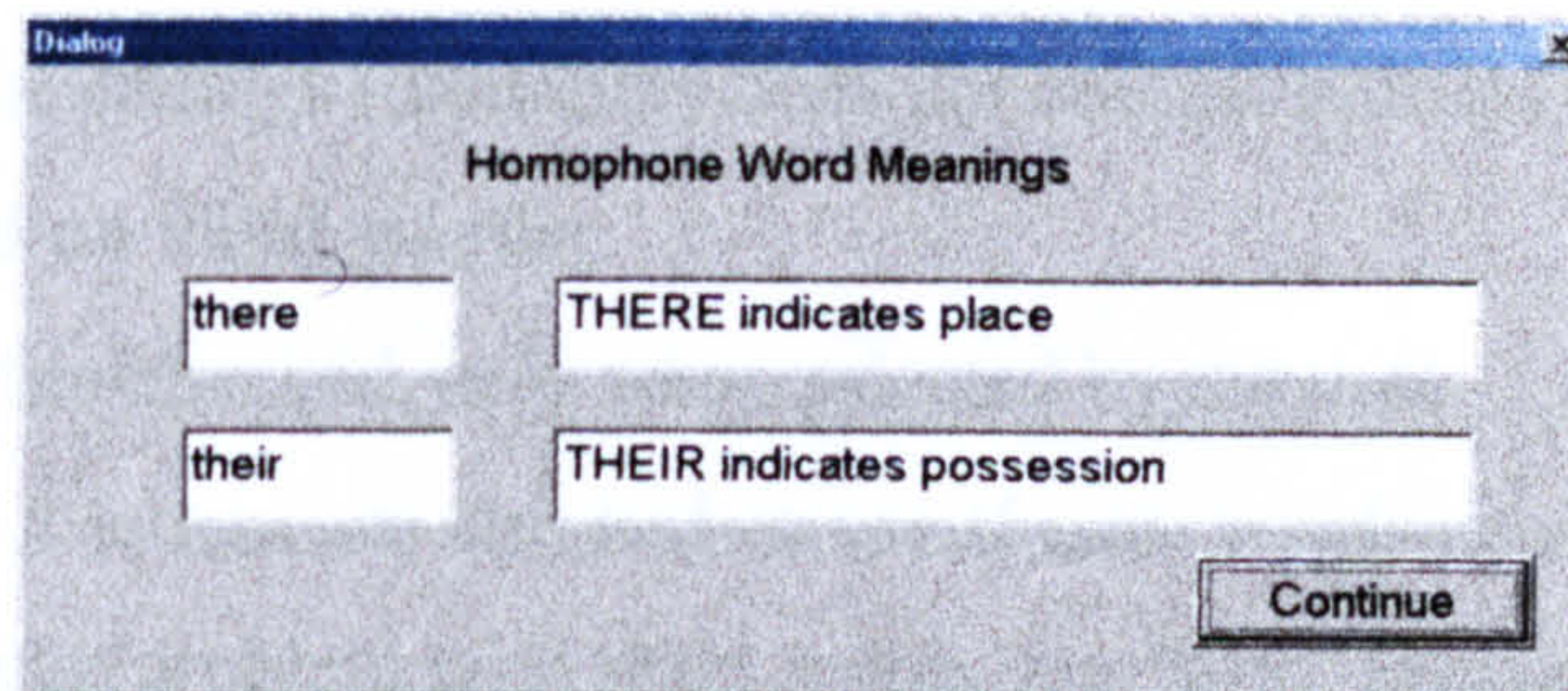


Figure 6.9. Homophone results.

On selecting 'continue' the dialog box in Figure 6.10 is displayed, recommending the user's chosen word be replaced. If 'next' is selected a further search to see if there are any other similar words will be performed.

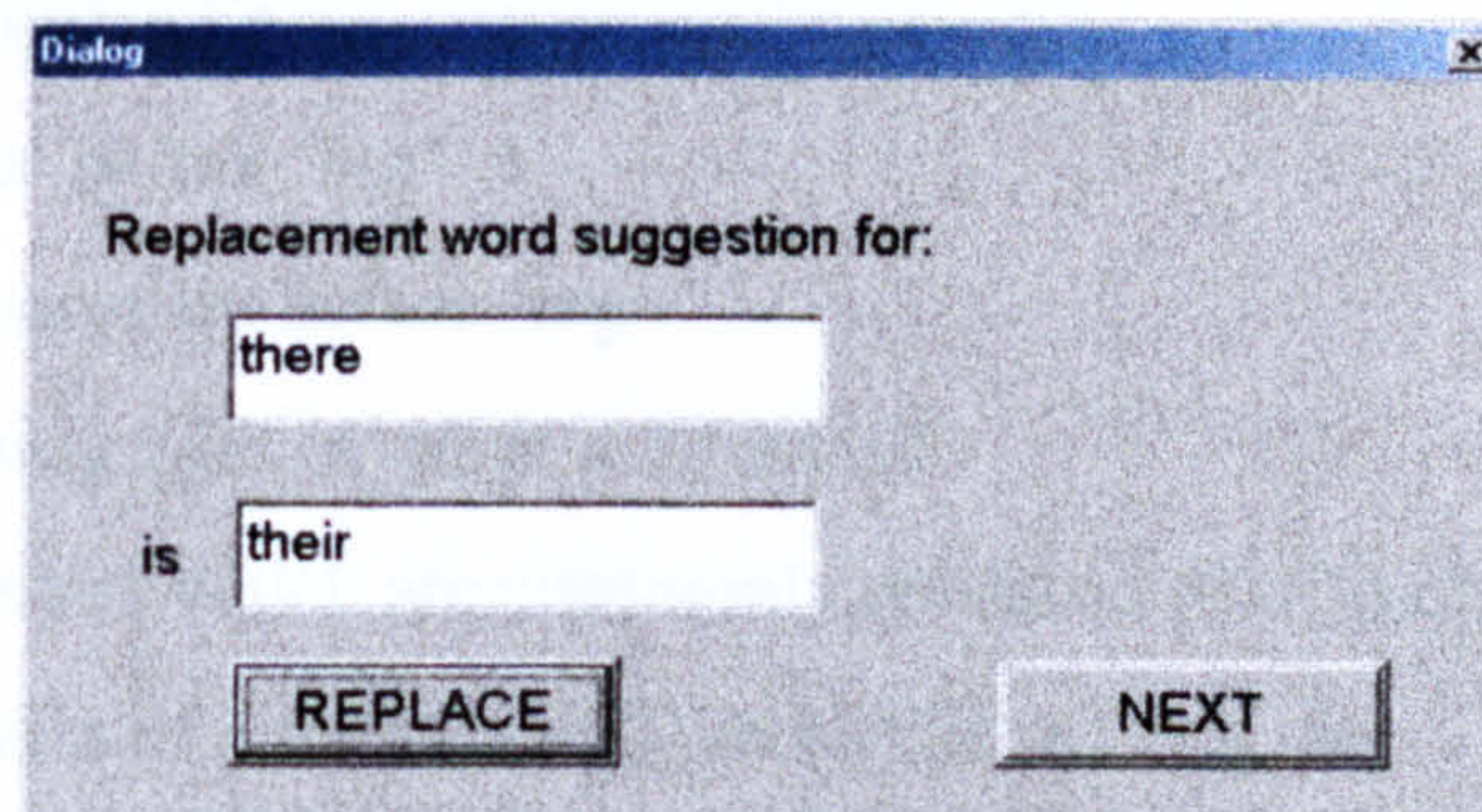


Figure 6.10. Homophone replacement word.

This function offers support for the user but it only advises them that their chosen word has an alternative. Grammar checking is not provided therefore it is up to the user to decide whether to replace the word with the suggestion.

6.6.2.7 Validating routines

Dyslexic spelling patterns were investigated in the initial research phase. Each word in the sentence is first checked to see if it is in the dictionary. This system uses a number of validating routines. These are listed under various categories.

Sentence checking routines:

- Removal of capital letters
- Removal of extra spaces and repeated punctuation
- Removal of repeated words, user must confirm this
- Reversing of word order, user must request this

Routines for removal of word endings:

- Check special words list for removal of endings and use replacement words
- Remove plural endings (dictionary does not contain plurals)

Routines performed on valid words:

- Homophone file checked, only when selected by the user
- Words up to 4 letters are checked to see if new words can be formed. Dyslexics have a particular problem with short words, i.e. 'who' instead of 'how'

Routines to check invalid words:

- Words with four letters or less undertake complete letter rearrangement
- Checked to see if it is in the phonetic spelling file
- Checked to see if it is in the predictor spelling file
- Removal of double l's
- Removal of 'e' before 'ing'
- Double the consonant before 'ing'
- Words beginning with 'n' have a 'k' added
- Interchange letters which are commonly confused [b,d],[p,q],[s,c],[c,k] and [i,e]
- Interchange pairs of letters [ia,ai],[[uo,ou],[ei,ie],[wh,we]
- If word contains the letter 'm' add a silent letter after it
- Words beginning with 'f' are converted to 'ph'
- Reverse all letters within the word

Each time a possible replacement word is found the user is asked to accept the new word or continue with the validation process.

6.7 Implementation language

The spelling tools have been implemented using Microsoft C++ and Visual C++. These languages were used because the tools need to interface with environment 1 and environment 2 and they were written in Visual C++. C++ is an object orientated language and was very suited to the task. Integration was a simple task the code was contained in one program and linked to the 'pen' icon used in environment 1. The program used a main control function, which coordinated all the error detection functions and file searches. It also controlled the displaying of the dialog boxes. The program has been developed to allow the inclusion of a grammar checker in future developments.

6.8 Concluding comments

Environment 2 includes three useful spelling tools and should provide a suitable level of support for dyslexic adults. The spell checker validates complete sentences (rather than individual words), which provides added benefits such as, reducing the occurrence of long sentences and making proof reading easier (using the text highlighter). Most of the requirements suggested by the selected dyslexics have been included to varying levels. This environment provides an improved method of presenting replacement suggestion words and offers a spell checker, which is tailored specifically for the needs of dyslexics. Support to correct valid words used inappropriately is provided via homophone function.

The secondary support tools also provide useful help with making sure the correct words are used appropriately (word meanings) and supporting those who need prompting to assist with their spelling. The next chapter is concerned with the design of environment 3.

Chapter 7 Design and Implementation of Environment 3

7.1 Introduction

This chapter completes the design and implementation of the research software and is concerned with environment 3 and the way it interfaces with the other environments. This environment uses concepts from the research hypothesis and is designed to test whether enforcing structure and language constraints on a natural language allows adults with dyslexia to achieve higher standards. The issue of increased satisfaction gained from using such an environment is also an important concern. This is achieved by creating an environment, which offers the support in a form that is most suited to their needs.

The chosen method of presentation is a key concern as dyslexia often causes visual problems when reading computer screens. This is most apparent when lists or menus are presented and selections need to be made. Initial research has indicated that dyslexic adults favour the use of large uncluttered dialog boxes, to implement lists where selections need to be made. The general system provides a simplistic but effective approach to the structuring of natural language sentences and the overall structure of the written assignment. It guides the user through a series of sections, which are used to incorporate the general structure of the written text. Each section consists of a number of related questions and associated options, presented in dialog boxes. These are linked to sentence templates, which are used to incorporate the user's selections and automate the construction of sentences.

The system is based on the concepts used for computer programming syntax editors and Microsoft Wizards, which use templates to impose constraints (discussed in Chapter 2). The key concept with which this method is based upon is enforcing structure and constraints, however, features are provided to allow some flexibility to incorporate personal creative style. Environment 3 offers the highest level of support compared to the other environments with strict controls on the user. It is referred to as the 'control mode' for the purpose of support tool selection within the specialist word processing system.

7.2 Design objectives

This section defines the main design objectives for environment 3. These are:

- Interfacing with environment 1
- Creating a rigid controlled environment
- Enforcing a structured approach to a natural language
- Using 'dyslexia friendly' communication methods
- Offering flexibility at the appropriate level
- Using the spell checker developed for environment 2
- Dealing with dialog box errors and providing support
- Using the system to support a wide range of requirements
- Designing the topic material

These design objectives will be covered in this chapter, where the key elements will be defined.

7.3 Interfacing with Environment 1

Environment 3 is a support tool accessed from environment 1 (basic word processor) toolbar using the 'pen icon' to select the 'control mode' (support tool name for environment 3). Figure 7.1 shows the 'topic selection' dialog box, which is presented on activating this tool. From this point environment 1 will be in the background (visible but not active), the user cannot 'switch' to environment 1 unless they have reached an exit point¹ in environment 3. The created text will be stored in environment 1 and can be viewed at all times. Modifications can be made when environment 1 becomes the active window (exit point reached). The user will then be able to use all the available word processing features to format the text and make any necessary alterations.

¹ At the end of a topic section or on completion of the selected topic.

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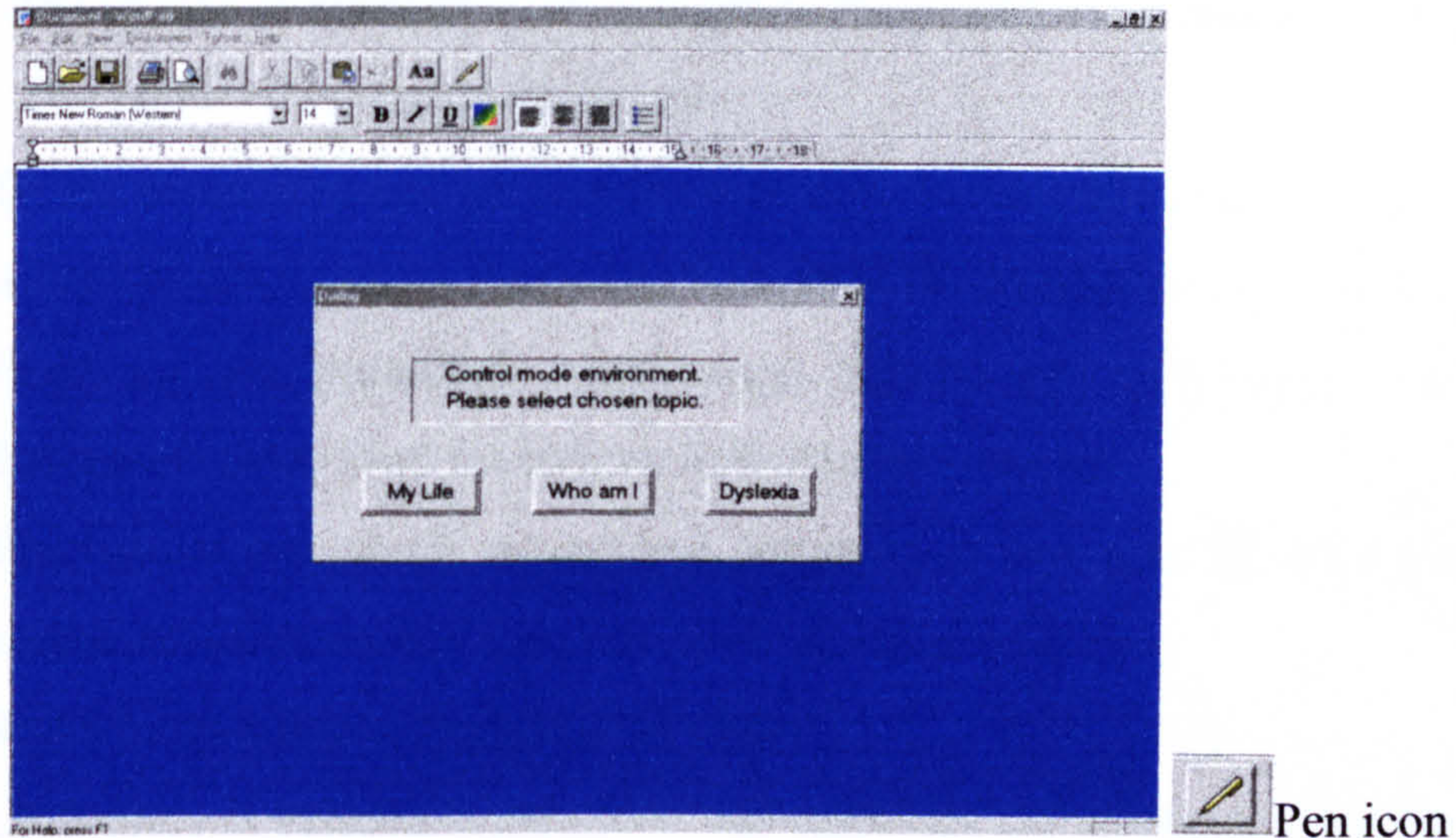


Figure 7.1. Implementing a menu with three options.

Figure 7.1 provides an example of the chosen method for implementing a menu, which has very few options. The options are clearly spaced and the dialog box is large and uncluttered. The font size is set at 14 (preferred size) and using raised buttons makes positioning the pointer easier. Figure 7.2 shows how the two environments are linked, allowing the user to view the created text while within environment 3.

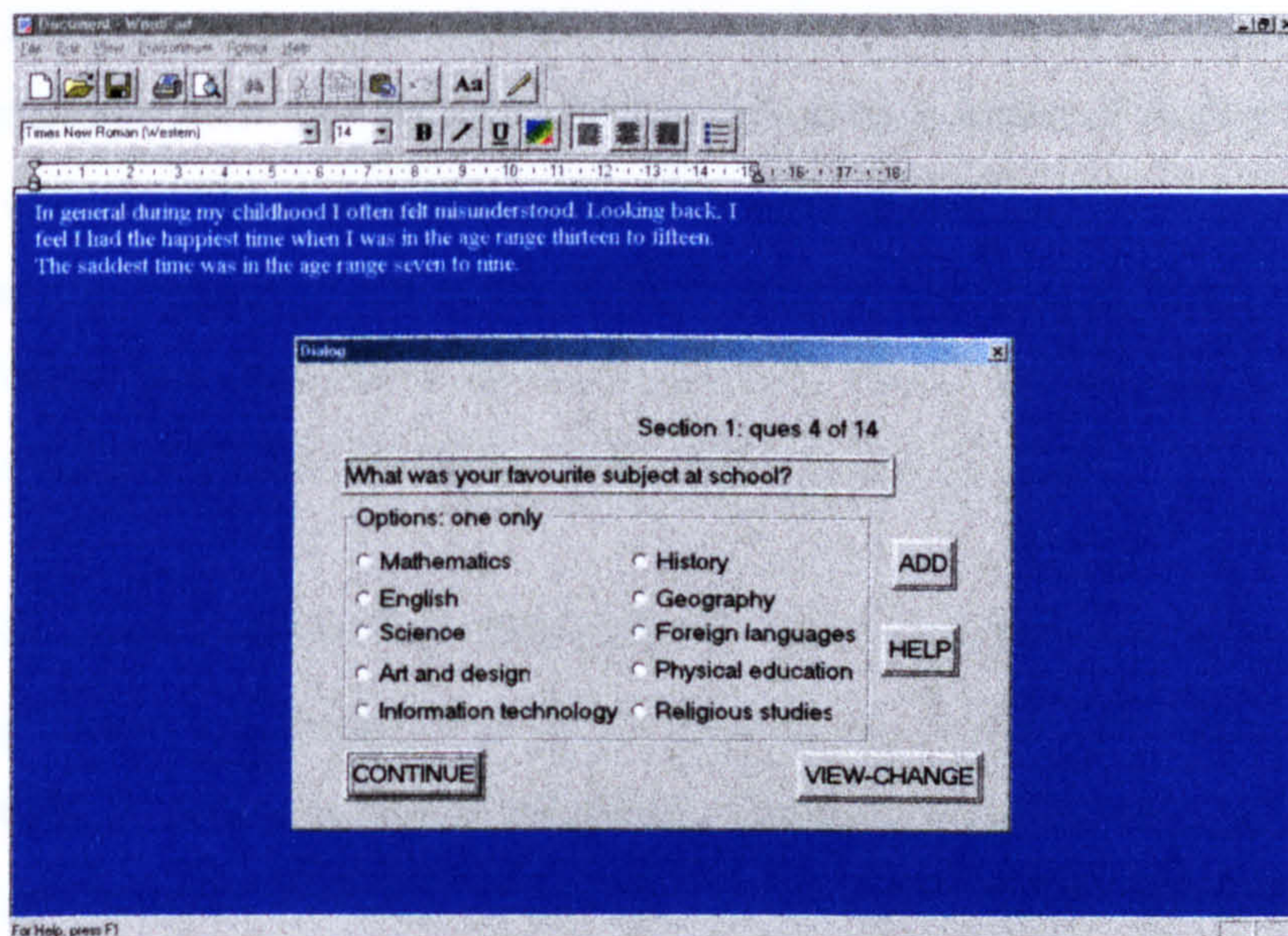


Figure 7.2. Example showing how env3 is linked to env1.

Figure 7.2 provides an example of a standard question dialog box. This is the chosen method used for implementing a menu where one selection must be made from several

options. The choice of whether to use a function (help, add, view-change) is dependant on the user. The points of research interest are:

- To aid readability and prevent the text from looking cluttered, a large dialog box is used which is shown relative to the size of the word processing screen
- Functions are presented using raised buttons for uniformity, and to easily distinguish them from the options linked to the question
- The options are evenly spaced and presented in font size 14 and a group box is used to partition them
- Radio buttons allow changes to be made
- Uniformity is extremely important and dyslexics are informed at the beginning of each section that radio buttons indicate one selection and check boxes indicate one or more selections. The difference would not be obvious if presented in a standard menu format

7.4 Creating a rigid controlled environment

Environment 3 creates an environment, which is representational of the research hypothesis by enforcing rigid control and structure. Sentence components must be connected in a predetermined manner. The system uses a series of dialog boxes to guide and control the user. These dialog boxes provide, guidelines, support, error detection, and prompt questions, related to the selected topic (which are used to form sentences). The user must follow the framework of dialog boxes, which the control mode uses. This framework is used to create and structure the text on a chosen topic.

The user will select options from the question dialog boxes when they are displayed. These dialog boxes are linked to sentence templates, which combined with the user options are used to form structured sentences. The user is unable to 'skip over' a dialog box or change the order they are presented. This is controlled by the system. However, they are able to make modifications to the created sentences, if they feel this is required. This is achieved by using the view-change function. The add function can be used to enable them to create their own option. Both these functions will be discussed in Section

7.8. Sections are used to group together related question dialog boxes. A section must be completed before the user is able to access the created document text.

7.5 Enforcing a structured approach to a natural language

A natural language, such as English, uses a large set of grammar rules but there are many exceptions to those rules. The level of language constraints is minimal as there are usually many alternative constructions when combining sentence components. The survey results (discussed in Chapter 4) have shown that dyslexic subjects work more efficiently and successfully when using a language with a small set of rigid rules where structure is enforced. Initial research has shown that structured languages (computer programming languages), where order is vital, have been proven to be easier for dyslexics to use in comparison to natural languages.

A language with complicated rules, many exceptions and many alternative constructions is not favourable for adults with dyslexia. Environment 3 removes some of these difficulties by increasing language constraints, removing exceptions and limiting choice. The system uses sentence templates [Dav96]. Syntax directed editors use a similar concept, whereby templates are provided for programming structures. These are used in some computer programming development environments and were favoured by dyslexic programmers (discussed in Chapter 2).

Environment 3 attempts to treat written English as if it was a structured language. The user selects options via dialog question prompts. The options are incorporated into the related sentence templates to form structured sentences. Users are able to create their own options but must be guided by the sentence templates. This system enforces order into the language (options inserted in a predetermined fixed order) resulting in increased language constraints. This should allow dyslexic adults to work within an environment, which removes many of the problems they are usually faced with, and prevent the common problem of writing long unstructured sentences.

7.6 Using 'dyslexia friendly' communication methods

The method of communication is via dialog boxes. These have been designed to ensure they are suitable for adults with dyslexia. The design objectives used are:

- Dialog boxes are large and not cluttered with text
- Uniformity is inbuilt, for example all functions represented by raised buttons
- The list of options is not too long to avoid causing confusion or eyestrain
- The options allow for a wide variety of users
- No ambiguous words are used
- Dialog boxes are numbered so relative position is known
- Option selection is simple
- Changing options is straight forward
- Help provided for each question
- The font size is 14 which is favoured by dyslexic adults
- Colour scheme used makes it clear and easy to read by using contrasting colours

[WL99]

7.7 Dialog box design

The previous section has defined the general design objectives for dialog boxes. This section will discuss the useful features, which have been incorporated into many of the dialog boxes. It will also define the various different tasks the dialog boxes are used for.

Figure 7.3 shows two typical dialog boxes, which between them include all the dialog box features, used within the control mode (environment 3).

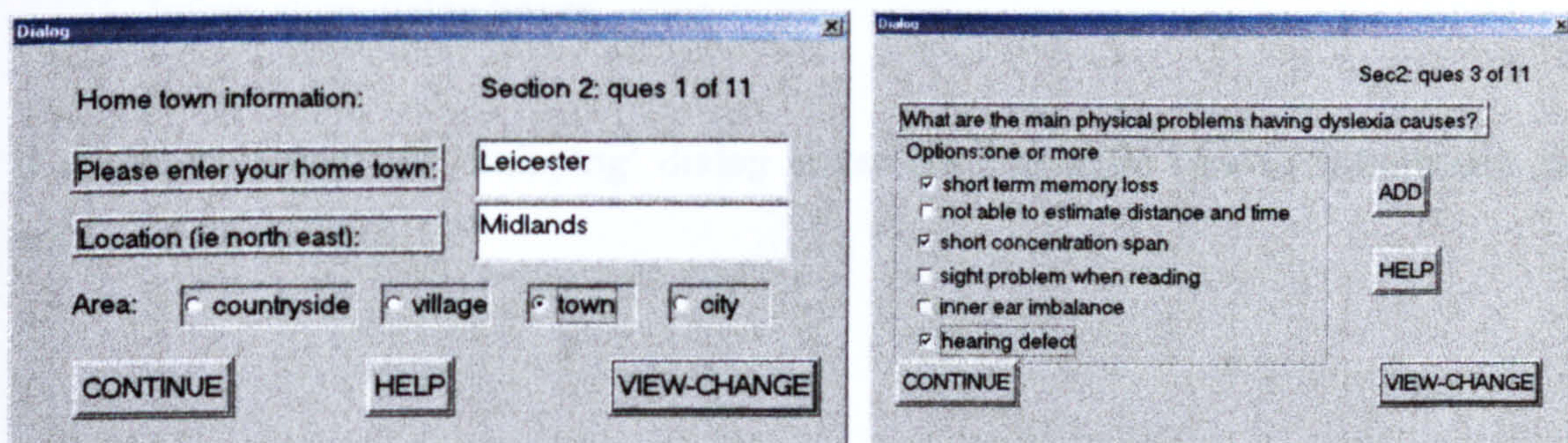


Figure 7.3. Example question dialog boxes showing all available features.

Sentence templates require options from the user in order to create sentences. The two example question dialog boxes shown in Figure 7.3 depicts three ways in which this can be achieved; edit boxes where predefined options are not provided; radio buttons where one option must be selected and check boxes where one or more options must be selected. The add function can also be used to create an option defined by the users. Uniformity is important so questions are presented in a standard form and are short and use plain simple English. Each dialog box informs the user where they are in relation to the question and section number. This is required as dyslexics have a short concentration span and therefore it is important for them to be aware of when a break can be taken (exit point at the end of each section if required).

7.7.1 Different uses

There are several different tasks that dialog boxes are used for:

- Getting user options for sentence templates, referred to as question dialog boxes
- To allow users to create their own option using the Add dialog boxes
- To allow users to view the created sentence and make changes if required using View-change dialog boxes
- To provide differing levels of support using Help dialog boxes
- Informing users when selections have not been made using Error dialog boxes
- Inform the user that the system is skipping questions which are not relevant to them using Skipping dialog boxes
- Providing information to use the system in an effective manner (guidelines) using Information dialog boxes

It should be noted that 'Skipping' dialog boxes are a specific type of information box with a single purpose.

7.8 Offering flexibility at the correct level

The system needs to be flexible enough to allow users to be expressive. This is achieved in two ways. Firstly they can use the view-change function, which allows them to view the sentence and make changes. Secondly, they can use the add function, which allows them to create their own options. Figure 7.4 shows an example of the use of the add function.

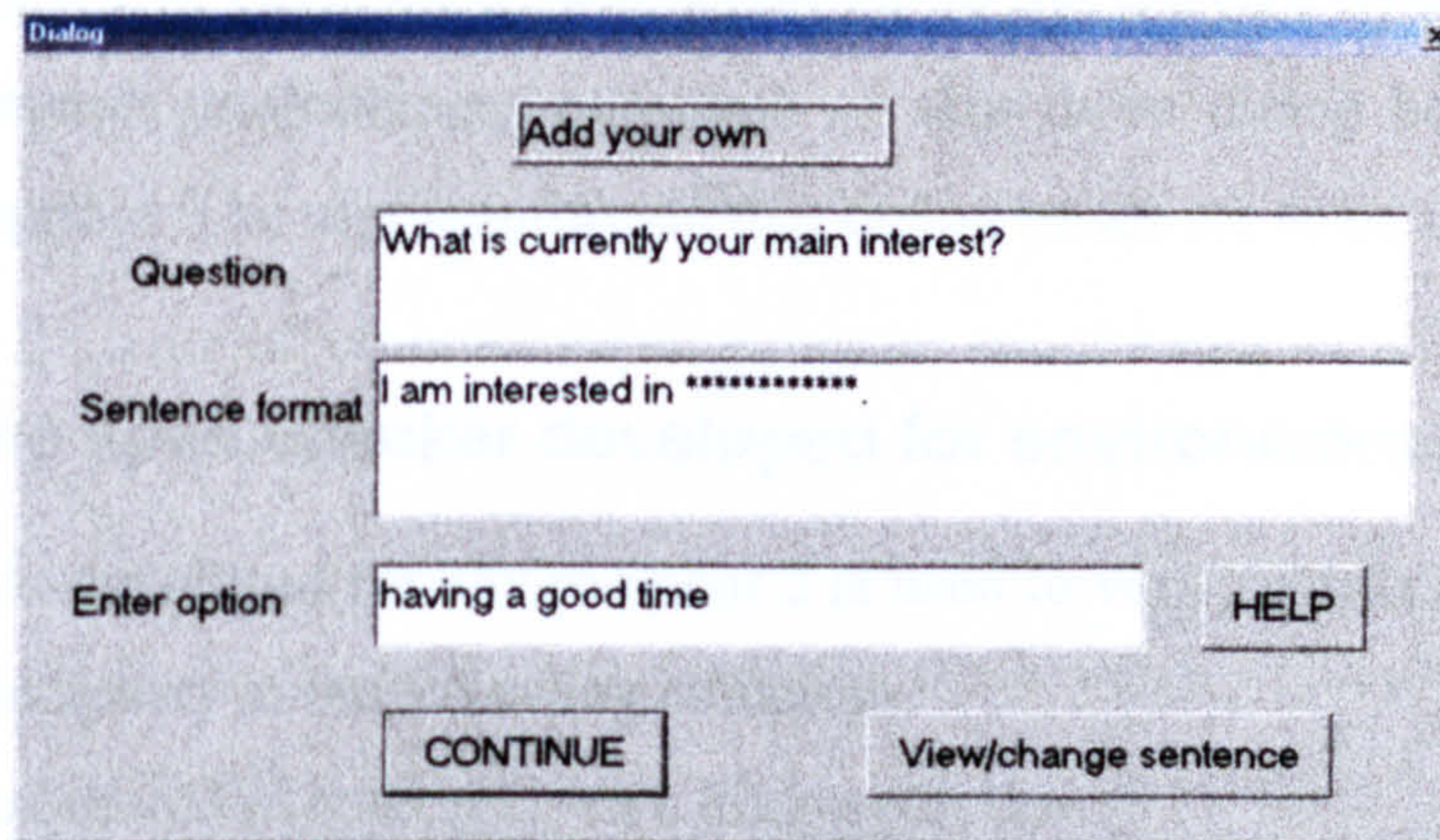


Figure 7.4. Example showing the use of the add function.

The question is displayed and the sentence template, which will be used, is defined. The user enters text in the 'Enter option' edit box. If 'continue' is selected they will be presented with the created sentence and changes can then be made. If view-change function is selected changes can be made before the spell checker validates the sentence. Figure 7.5 shows the dialog box displayed if the view-change function is selected.

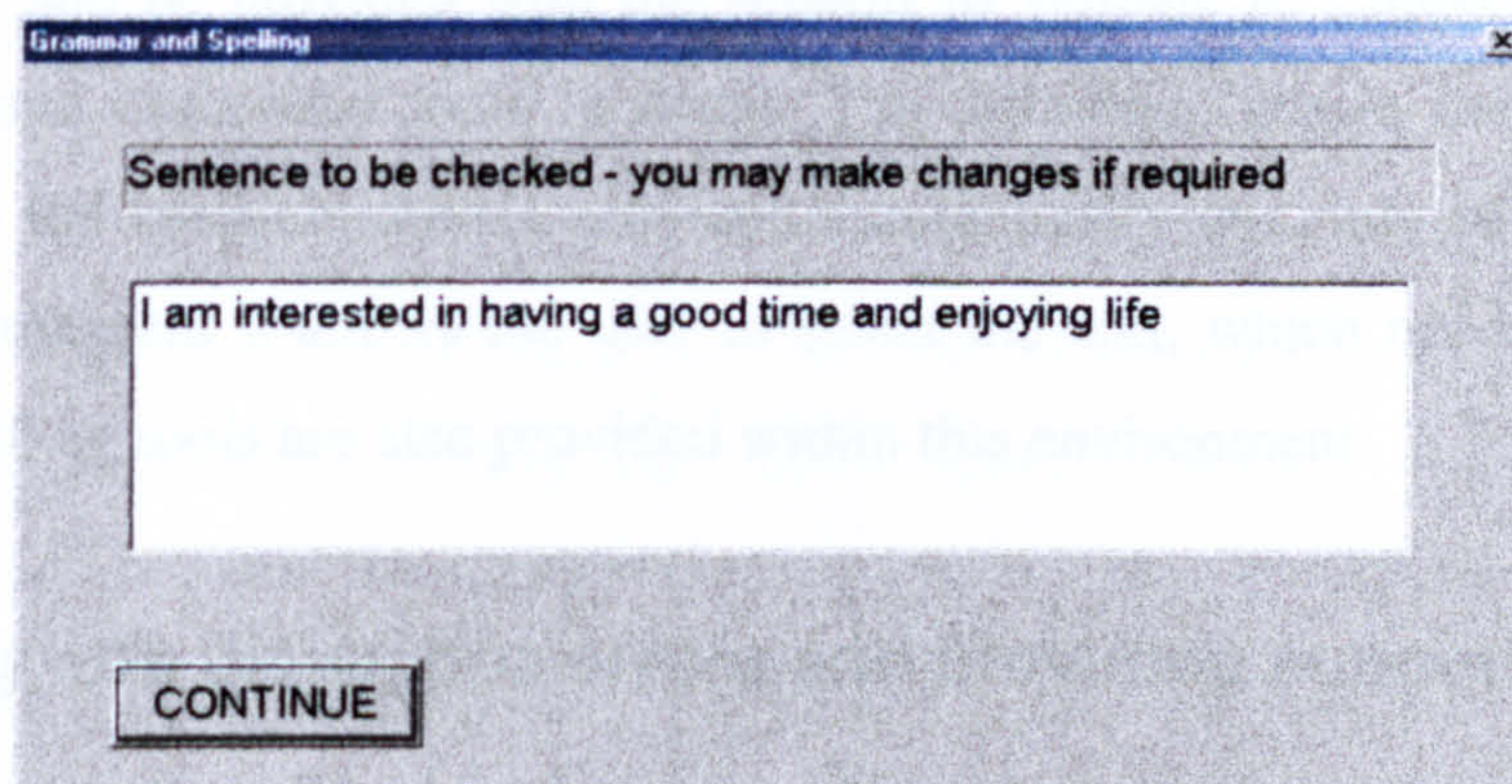


Figure 7.5. Using the view-change function.

Text was added (in this example 'and enjoying life') to complete the sentence. The sentence is validated and errors corrected. This environment allows flexibility to those

users who are confident enough to use it. It also provides a high degree of support to those that require it.

The structure of the text is tailored to the options selected by the user. There are many question dialog boxes to which the selection of the next question dialog box is related to the option selected by the user. For example, a question asking 'whether the user has any computer programming experience' will according to the selected option either go on to ask related computer programming questions or skip those dialog boxes as they were deemed inappropriate. The user is informed that dialog boxes are to be skipped.

7.9 Using the spell checker developed for environment 2

The spell checker developed for environment 2 is used to verify words added by the user. This would be necessary in the following situations:

- User is requested to enter text via a dialog edit box
- Add function is used
- View-change function is used and modifications made

Modifications needed to be made to the original system (used in environment 2) so that the spell checker can automatically be activated when any of the above situations occur. The spell checker enables the system to incorporate flexibility by allowing the user to add or change text and be provided with the support to validate it. Chapter 6 discusses the spell checker and associated tools in detail. The difference lies in the fact that within environment 3 the spell checker is activated automatically and only verifies the current sentence. Environment 2 allows the user to select the text, which needs to be validated and further spelling tools are also provided within this environment.

7.10 Dealing with dialog box errors and providing support

A feature of environment 3 is the control aspect, which is enforced. Therefore the system must include comprehensive error routines to ensure this is achieved. Examples where error routines are used are:

- If the continue button is selected when no option has been provided

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- If view-change is selected when no option is provided
- If an incorrect number of options has been selected, some dialog boxes require a number of responses to several related questions
- If a special case option has been selected with another option which is deemed to be inappropriate

Radio buttons will not allow more than one selection to be made removing the need to provide an error checking routine for this.

The help function is available for all dialog boxes and offers varying levels of support depending on the associated question dialog box. This is in the form of word definitions, explaining the question in a different way and providing options for edit boxes, which cannot be displayed in the original question dialog box. Help boxes are used to ensure the question dialog boxes do not become cluttered as extra information is provided separately for those that require it. Useful tools are those, which cater for a wide variety of users and providing this support ensures this is the case.

7.11 Using the system for a wide range of abilities

Environment 3 is designed to cater for a wide range of differing academic abilities. This section will describe how this environment can be used to support groups of users who have differing written English problems.

7.11.1 Spelling and sentence construction problems

If the user has problems with spelling and sentence construction they should, wherever possible, make their selection from the list of options linked to each question. The sentences will be formed automatically and no spelling mistakes will be made. If they do want to add some of their own options, the add function can be used and the spell checker provides support to correct their mistakes. However, they increase the likelihood of mistakes being made as grammar errors are not corrected.

7.11.2 Spelling problems

If the users main problem is spelling they should predominantly use the options linked to each question. The help function should also be used if edit boxes need to be filled in. This group of users should make frequent use of the view-change function, which allows them to make changes to the sentences. As sentence construction is not a problem they should take advantage of the flexibility of the system, which encourages creativity. The spell checker can help to correct any spelling mistakes that are made.

7.11.3 Sentence construction problems

If sentence construction is the users only problem they should use the add function to create their options. The add dialog box shows the user which sentence template is used and the sentence construction is automated.

7.11.4 Using incorrect words

These users should mainly use the lists of linked options to avoid the problem of using inappropriate words. They should also make frequent use of the help function, which provides word definitions. If they do wish to add their own option, the spell checker includes a comprehensive homophone detector, which provides word meanings to aid the selection process. This should provide these users with the support they need.

7.11.5 Punctuation

These users can either use the linked options or add their own options, as the punctuation will be performed automatically. This problem is fully supported within environment 3.

7.11.6 All categories

If a user has all of the written English difficulties previously specified (punctuation, spelling, using incorrect words and sentence construction) they should use the linked options and avoid adding their own options. Although the system will be more limited in allowing the user to be expressive the resulting text will contain no errors, which academically is more important. The spell checker is available for support if required.

Also the help function can be very useful providing extra support which this group may need.

7.12 Design of topic material

Environment 3 uses three topics which are: 'Dyslexia', 'Who am I', and 'My life'. These topics were chosen because they are areas in which all test subjects would be knowledgeable.

The topics also require different writing skills. The 'Who am I' topic tests the subjects ability on descriptive terminology. The 'Dyslexia' topic is more factual. The 'My life' topic will require the use of different tenses which can cause confusion. The next chapter is concerned with the testing of the three environments and will cover this area in detail.

Designing the material to be presented in the question dialog boxes was a long process. General considerations are:

- The options must be suitable for a wide variety of people
- The questions should be short and precise using plain English
- Pre-testing should be carried out to check the balance of option choice and required reading time
- All topics should take approximately the same length of time to complete
- The same variety of dialog boxes (and associated features) and level of support should be provided for all topics
- The completed text from all topics should be of the same academic standard when only linked options are selected.
- All topics use the same evaluation section

7.12.1 Dyslexia

Much of the material used in the dyslexia topic (options) came from the dyslexia-mailing forum (see Chapter 4). Questions were posted and the most common responses were used in the creation of the dialog options. There are 5 sections (same for all topics) and a total of fifty-seven questions. Section headings are:

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- How did dyslexia affect you as a child - 11 questions
- Coping with dyslexia as an adult - 11 questions
- Dyslexia and different language structures - 8 questions
- Using computers to help with written English - 15 questions
- Using this control environment: User evaluation - 12 questions

7.12.2 My life

This topic is concerned with the test subject's life. This is in terms of their past, present, university experiences and future. There are 5 sections (same for all topics) and a total of fifty-eight questions. Section headings are:

- My childhood - 14 questions
- The present - 11 questions
- University life (experience) - 12 questions
- Future ambitions - 9 questions
- Using this control environment: User evaluation - 12 questions

7.12.3 Who am I

This topic is concerned with what makes the person who they are. This is in terms of their physical and inner self. This topic is also concerned with the subject's family. There are 5 sections (same for all topics) and a total of forty-seven questions (some questions have several sub-parts). Section headings are:

- General details - 9 questions
- Family - 9 questions
- Physical description - 11 questions
- Inner self - 6 questions
- Using this control environment: User evaluation - 12 questions

7.13 Designing sentence templates

The main issues to be considered when designing sentence templates are:

- Selection of appropriate tense
- Use of correct punctuation according to users selected options (and number of options)
- Ensure sentences are grammatically correct for all options linked to templates
- Linking several templates to selected question dialog boxes to cater for all presented options, including special cases
- Sentences should be concise, structured and short
- Maximum of two clauses used

Many of the question dialog boxes have several sentence templates linked to them. The template is selected according to which options the user selects and how many. The number selected determines the punctuation to use. In some cases a completely different sentence template is used when certain options are selected. Figure 7.6 shows an example question dialog box, which is linked to a number of different sentence templates.

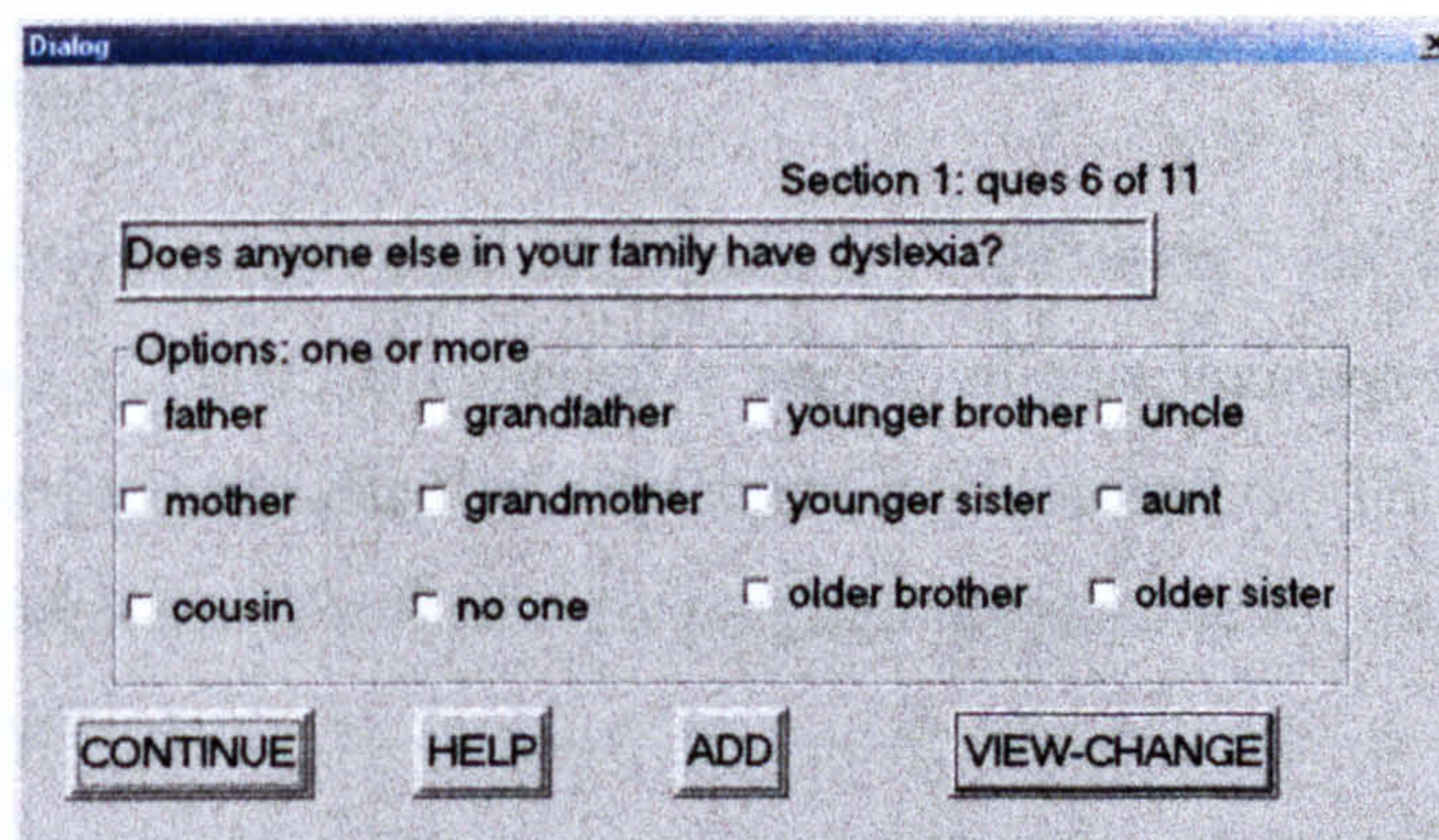


Figure 7.6. Example question box linked to several sentence templates

The system makes checks for special case options and counts the number of selected options to ensure the appropriate words and punctuation is used. Using the example shown in Figure 7.6 the example question dialog box uses several linked sentence templates. Which template is used is dependant on the option (or options) selected by the user (selected option in ***bold italics***, resulting sentence in *italics*).

If the option *no one* is selected the system checks and finds it is a special case option and the resulting sentence is:

There is no one else in my family who suffers with dyslexia.

If another option (or options) is selected as well as the special case option the system displays an error message and asks the user to re-select their options as the selections are deemed inappropriate.

If the option 'mother' is selected the resulting sentence is:

My mother is the only other member of my family who is also dyslexic.

If the options 'father' and 'older brother' are selected the resulting sentence is:

My father and older brother are also dyslexic.

If more than two options are selected punctuation changes are made. The resulting sentence is:

My father, mother and older brother are also dyslexic.

7.14 Implementation

The implementation languages used are Visual C++ (Chapter 5 included a review of this language) and C++ (Chapter 6 included a review of this language). Additions will be made to the same program used to implement environment 1. This program is called 'Wordpvw.cpp' and is the WordPad view program responsible for implementing what the user views on screen.

Environment 3 is implemented using one main control function, (within Wordpvw.cpp) which all other programs are called from. This function is called 'OnPentoggle()' and is accessed whenever the 'pen' icon is selected. Code was also added to this function for the implementation of environment 2 (discussed in Chapter 6).

7.14.1 Control function tasks

This function performs numerous tasks, which are:

- **Determines the order of the dialog boxes and displays them**

Checks must be made to see if the next question dialog box is relevant or should be skipped. This is achieved by using a skip variable, which is set when certain linked question options are selected

- **Displays the associated help dialog box when requested then re-displays question dialog box**

A default help dialog box is used and data is passed to it according to the question dialog box currently being used

- **Ensures sections are performed in the correct order and allows the user to return to environment 1 when an exit point is reached**

A section menu is used and checks are provided to ensure the same section is not performed twice and the sections are completed in the set order. An option to exit environment 3 is provided to allow the user to make any modifications to the written text. It is then possible to resume at a later date. The same section menu is presented at the end of each section for uniformity reasons, which is essential for dyslexic adults

- **Checks for any dialog box usage errors**

Displays appropriate error message and re-displays dialog question box if error occurs. Error checks are provided and include: selecting the view-change function when options have not been selected; selecting a special case option and another option which is not appropriate; selecting continue when no option has been selected

- **Passes data values to the dialog boxes**

If modifications are made to the created sentence either via the use of the add function or view-change function the control function updates the sentence and sends it back via the view-change dialog box to allow the user to view the changes

- **Accepts data values from the dialog boxes**

The users options are passed to the control function in order to form the sentence using the correct template. All requests for using functions (help, view-change, add) are sent and the appropriate dialog box is displayed

- **Checks for special case options**

Special case options are linked to separate templates; string comparisons are performed to detect this

- **Selects the appropriate sentence template**

Each dialog box is linked to one or more sentence template(s), which is used is determined by the option (or options) selected

- **Incorporates the user selections and creates the sentence**

The user options are incorporated into the sentence template, and is achieved using string functions

- **Provide the correct punctuation according to the number of options selected**

The number of options are counted and punctuation is added accordingly, also words are changed where appropriate, such as replacing 'is' for 'are'

- **Activates the spell checker when necessary**

If the add function is used or edit boxes have been used the spell checker is activated and the created sentence is passed to the spell checking programme. On completion the validated sentence is displayed to the user to accept any changes

- **Saves any modifications that are made to the sentences when view-change function is used**

The modified sentence is saved and any validation is performed

- **Displays the sentence in environment 1**

The accepted sentence is copied to the word document and displayed in environment 1

- **Allows the user to switch to environment 1 when exit points are reached**

The section menu provides an option to exit environment 3 and make environment 1 the active window

Further details related to the implementation are provided in Appendix A.4.

7.15 Concluding comments

The nature of the software is such, that there are so many differing situations to which it has been programmed to cater for. The current system is a prototype and is designed to allow a subject to produce a structured written assignment for any of the three available topics. This environment tests the concepts used in the hypothesis and attempts to establish whether subjects find this level of support useful or too restrictive. The environment incorporates features from Microsoft Wizards by providing implicit templates. Also features used in syntax directed editors where the structure is implied and only the options need to be selected.

This chapter completes the design and implementation of the research software. The next chapter is concerned with the testing method used to evaluate the research hypothesis using the research software.

Chapter 8 Testing

8.1 Introduction

This chapter provides a concise account of the testing procedure used, to qualify the research hypothesis. The key areas of concern are, justifying the sample size and selection of the test subjects and how the level of bias was kept to a minimum. Also the testing method used to evaluate the three environments (occasionally abbreviated to env1, env2 and env3) and how this relates to the qualifying of the research hypothesis (defined in Chapter 1). Concluding remarks are provided to complete this chapter.

8.2 Testing sample

This section is concerned with the testing sample in terms of specifying common attributes and justifying the chosen sample size.

8.2.1 Test subject common attributes

In order to qualify to take part in the testing process the subjects need to have a selection of common attributes, which are:

- Registered dyslexic either through the university or the dyslexia association
- Must have minor difficulties with at least one category within written English: spelling, grammar, sentence construction and reading/writing speed
- At least minimal experience of using computers to enter text
- Not have any other learning disability other than dyslexia
- Must have reached higher education level (completed A' level or equivalent studies successfully)
- Adults eighteen and over

It is also important to state that no test subject was directly approached; each subject came forward freely and made contact. This was to reduce any bias that may exist, i.e. specifically contacting adults with dyslexia who are competent computer programmers.

8.2.2 Number of test subjects

Rarely is the size of the test sample known before testing is complete. The popular feeling is that the larger the sample size the more conclusive the results are. This is of course true but the constraining factors of time and availability of willing subjects is a major problem. The essential factor to be considered is that the test sample must be large enough to qualify the hypothesis. For this research the test subjects were asked to spend approximately two hours (in total) undertaking the testing process. That in itself presents a major commitment on their part.

At the onset of the testing procedure the ideal target number of test subjects was set at sixty. This figure was chosen, as there were three environments to be evaluated using three topic categories. The decision was made to have three combination groups (explained in detail in Section 8.3.1) in terms of environment and allocated topic. A test sample size of sixty would result in three groups of twenty test subjects repeating the exact testing procedure (the same selected topic and environment).

The testing took place but unfortunately due to time constraints it was not possible to reach the initial set target. However, in total fifty test subjects contributed which was quite satisfactory.

The issue of whether the sample size is large enough to be conclusive is a difficult question to answer. The theory behind sampling distributions is part of a mathematical theory based on the central limit theorem. Details of this theorem lie outside the scope of this thesis. However, as a result of this theorem it can be accepted that the sampling distribution is normal even if the population frequency distribution is not normal, provided that the sample size is sufficiently large (greater than 30) [Han97]. This means it is possible to take a sample from the population and apply methods of estimation. Thus a sample size of fifty should be sufficient as it is greater than thirty.

8.3 Test topics

Three test topics were used to ensure a separate topic was issued for each environment. It was very important to choose topics which all test subjects would be capable of writing about. The three test topics used were:

- ‘Who am I’ (also referred to as topicW)
- ‘Dyslexia’ (also referred to as topicD)
- ‘My life’ (also referred to as topicM)

For each of these topics two master template documents containing the guidelines, section headings and associated prompt notes were created. The first template to be used for environment 1 and the second to be used for environment 2. The differences between the two templates were the evaluation section notes and guidelines (the prompt questions for all other sections were the same). Each test subject was allocated a copy of one template for each of the first two environments (environment 1 and 2), according to the topics they were allocated. The headings and prompt notes used in these templates are provided in Sections 8.3.2, 8.3.3 and 8.3.4. Some topics may be easier to write about than others so for that reason much thought was put into the selection method used.

8.3.1 Selection method

The essential focus point is that the environments are being tested not the subjects ability to write about a particular topic. Therefore no topic was linked to a particular environment. In other words a selection of test subjects used environment 1 with the ‘dyslexia’ topic, another selection used environment 1 with the ‘my life’ topic and so on. Three combination groups (environment and topic) were formed to ensure an even distribution. Great care was taken to allocate approximately the same number of test subjects to each of the three combination groups. This information is shown in Table 8.1.

Session 1	Session 2	Session 3	No of test subjects
Env1:topicD	Env2:topicW	Env3:topicM	17
Env1:topicM	Env2:topicD	Env3:topicW	16
Env1:topicW	Env2:topicM	Env3:topicD	17

Table 8.1. Allocation of test subjects to environments and selected topics.

From Table 8.1 the session headings represent the three stages of testing, which will be covered in later sections. It can be seen that the test subjects were divided equally (where possible) between the three combination groups. For example:

- Seventeen written assignments using environment 1 would be about 'dyslexia'.
- Sixteen written assignments using environment 1 would be about 'my life'.
- Seventeen written assignments using environment 1 would be about 'who am I'.

Thus, environment 1 can be evaluated on its own merit regardless of the selected topic. The final issue that needs to be covered within this section is how was each test subject allocated to a combination group. The best method of explanation is by using an example, as shown in Table 8.2.

Test subject	Environment 1	Environment 2	Environment 3
Student6	topicM	topicD	topicW
Student7	topicW	topicM	topicD
Student8	topicD	topicW	topicM
Student9	topicM	topicD	topicW

Table 8.2. Selection process used to form combination groups.

It can be seen in Table 8.2 that the topics rotate from each environment in order. The pattern is repeated every fourth subject. Thus student6 and student9 have the same combination and student10 will be the same as student7 and so on.

8.3.2 Topic 1: Who am I

As the topic title suggests the test subjects are asked to write about who they are (or think they are). The test subjects choose the style of writing, however, they must write complete sentences under each heading using the prompt notes as a guide. The headings and prompt notes for this topic are as follows:

- **General details about yourself**
 - First name, age (nearest year), male or female
 - Birth sign month/season born, are you left handed
 - Favourite colour, lucky number
 - Are you a student, if so, what is your year of study

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- How are you getting on in study terms, do you need any extra help (if so in what way) when sitting exams
- If not a student, did you attend university, if so did you receive any extra help
- **About your family**
 - Family members (names and relationship), closest family member
 - Universities other family members have attended
 - Family home (location, specify type area: town, village, city)
 - Pets, favourite family holiday locations
- **Describe your physical self**
 - Hair, eyes, facial features, face shape, skin tone and type
 - Legs, build, height, best/least liked features
 - Improvements you would like to make
- **Describe your inner self**
 - Personality, character, likes, dislikes, strengths, weaknesses
 - Things that make you happy/sad
- **User evaluation**

The notes depend on whether the test subject is using environment 1 or environment 2. The prompt notes will be discussed in Sections 8.6.3 and 8.7.3.

8.3.3 Topic 2: Dyslexia

As the topic title suggests the subject matter is dyslexia and in particular the test subjects related experiences. They are asked to write complete sentences under each heading using the prompt notes as a guide. The headings and prompt notes for this topic are as follows:

- **How did dyslexia affect you as a child**
 - Physical/academic/social problems and benefits
 - Level of support offered at school (and at home)
 - Methods used to overcome academic problems
 - How did dyslexia affect you emotionally

- **Coping with dyslexia as an adult**
 - Physical/academic/social problems and benefits
 - Support: counselling, extra tuition, coping with course work and exams
 - Techniques used to overcome problems
 - Detailed explanation of problem subjects and preferred subjects
 - How does dyslexia affect you emotionally
- **Dyslexia and different language structures**
 - English: problem with spelling, grammar, sentence structuring, speed
 - Foreign languages: can you write in, if so form a comparison to written English (with regards to language structure and number of spelling rules)
 - Computer programming languages: which languages used, are compilers useful, does using a structured language cause fewer problems in comparison to written English
- **Using computers to help with written English**
 - Preferences: screen/text colours, use of menus/icons, font type/size
 - Software packages: titles, good/bad points, support/teaching methods
 - Help needed: use of spell and grammar checkers, word predictors
 - Problems with current systems: how could they be more useful
- **User evaluation**

The notes depend on whether the test subject is using environment 1 or environment 2. The prompt notes will be discussed in Sections 8.6.3 and 8.7.3.

8.3.4 Topic 3: My Life

As the topic title suggests the test subjects are asked to write about their life in terms of their childhood, present and future. They must write complete sentences under each heading using the prompt notes as a guide. The headings and prompt notes for this topic are as follows:

- **Your childhood**
 - What was your childhood like
 - Favourite: subjects at school, teachers, television programmes, pop stars
 - What interests or hobbies did you have

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- Worst/best subjects at school
- Future career hopes
- **The present**
 - Describe your present life
 - What hobbies, interests goals, dreams, ambitions do you have
 - Write about any jobs you have, living accommodation, state of mind
 - What industry do you want to work in (or are working in)
- **University life**
 - If you are not a student write about your previous university experience
 - What course(s) are you taking, which department
 - Preferred and worst subjects within course
 - Academic strengths and weaknesses
 - Campus description and improvements
 - Student life: best and worst points, support needed for dyslexia
- **Future**
 - What are your ambitions, goals and dreams
 - What is your ideal: place to live, job, partner, number of children
 - Do you think you will fulfil your potential
 - What are your feelings about the future

- **User evaluation**

The notes depend on whether the test subject is using environment 1 or environment 2. The prompt notes will be discussed in Sections 8.6.3 and 8.7.3.

8.4 Testing procedure

The testing procedure is an extremely important part of this research. The results will be used to qualify the research hypothesis. Each test subject will spend approximately two hours using the environments and evaluating each one in turn. This section will provide a general overview of the testing procedure.

8.4.1 Limiting bias within the sample

It is essential to keep the level of bias to an absolute minimum to ensure the results are representational of the population of dyslexic adults in general (or at least those which have reached higher education). In order to limit the level of bias within the test group these guidelines were used:

- All test subjects were treated in the same manner and were free to ask for any technical help, at any time, throughout the testing period
- The testing place was the same; in a quiet office on a one-to-one basis
- The test subjects used the same equipment; a laptop computer
- No help was given with regards to written English queries
- Each subject followed the same pattern of testing with regards to the order the environments were evaluated
- The basic word processing system was the same for all environments the difference lies with the support tools that were made available
- All environments provided support with the subject matter, either with prompt notes in the case of the first two environments or pre-defined options for environment 3

8.4.2 Method

The testing method followed by all test subjects was:

- The test subjects were asked to attend three separate sessions, each lasting between thirty and forty-five minutes
- At the first session they were issued with a reference name, i.e. student39
- Env1 was evaluated in session 1, env2 in session 2 and env3 in session 3
- At the beginning of each session the test subjects were given a short demonstration of the main features available for the environment they were going to use
- Topics were pre-allocated (using the method explained in Section 8.3.1)
- For environment 1 and 2 assistance was given to display a copy of the template used for the pre-allocated topic and associated environment

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- For environment 3 assistance was given to activate the control mode (support tool name for selection purposes) referred to as environment 3 and the pre-allocated topic was selected
- Test subjects completed their written assignment using the available support, this included an evaluation of the environment they were using
- Throughout each session test subjects were free to ask for any technical assistance

On completion of the testing for all subjects the written assignments were independently evaluated and given an academic grade.

8.4.3 Relating the testing process to qualifying the research hypothesis

The research hypothesis is concerned with investigating how language constraints can affect a dyslexic's ability. This thesis aims to qualify the hypothesis and show how it can be used to devise a writing support tool. This is achieved by developing an environment, which restricts the user (dyslexic adult) and enforces a rigid structure in order to provide support for sentence construction. This is represented by environment 3. Environment 1 represents the basic word processor designed to represent an ideal environment but provide no support. This is used to evaluate the degree of improvement made by using the other two environments.

In order to test how effective this is it was necessary to develop a further environment for comparisons to be made. This environment represents what a selected population of adults with dyslexia (approximately 250) stated they required in order to support them with written English. This is represented by environment 2. This environment gives conventional support and provides a means of establishing its suitability in comparison to current available support tools. If environment 2 is favoured its comparison with environment 3 will provide a true evaluation.

The test subjects are asked to use each environment to produce a written assignment. Included within the assignment is an evaluation section where subjects are given the opportunity to comment on the environment features and give a grade in terms of

usability. The written assignment is also graded on an academic level by an independent body. These results will be used to qualify the research hypothesis by forming comparisons.

8.5 Methods of evaluation

This section comprises two main sub-sections that provide details of the assessment methods used. Test subjects graded each of the three environments. An academic grade was given to each of the three written pieces of work produced, using the given environments. Test subjects also provided written comments for each environment, which are evaluated separately.

8.5.1 Test subject's evaluation of environments

The test subjects were asked to grade each of the three environments in terms of how much they liked the environments and how easy it was for them to complete the written task, to a standard that they were satisfied with. They were asked to take into consideration the environment layout and level of support offered and how that suited their individual requirements. Their personal experience of current systems will affect the grades given. These grades will be referred to as usability grades.

8.5.1.1 Test subject's grade scale

The usability grade scale was from '1' to '4' whereby '1' represents an ideal environment and '4' represents a totally unsuitable environment. If grade level 2 was selected this would represent an environment which could be used but requires some changes to be made to reach ideal status. If grade level 3 was selected this would represent an environment which had some elements which were liked but would require a number of modifications to be of any real use. In general the test subjects were not asked to grade on a comparative basis (comparing all environments with each other) as grades were given on completion of each task not at the end of all the tasks. Therefore the results show a true reflection of the usefulness of each environment, which establishes a more conclusive result. However, on completion (all three environments) some comparison grades were provided.

It is the norm to provide five options, using the mid option to represent ‘satisfied or average’ category. Adults with dyslexia find making selections from long lists of options a problem and confusion often arises. Therefore the number of options was set at a minimum (in this case four). Also using four options will encourage the subjects to make a distinct choice rather than to select the mid range option which is relatively inconclusive.

8.5.2 Academic evaluation of test subject’s written tasks

An academic evaluator was appointed to grade each of the one hundred and fifty written tasks submitted by the fifty test subjects (three per test subject). The academic evaluator was a practising Senior School English teacher. The written task papers for each environment were submitted in a block and graded together. The evaluator did not at anytime draw direct comparisons by comparing the three written tasks for each test subject.

8.5.2.1 Academic grade scale

The academic grade scale was from ‘1’ to ‘4’ whereby ‘1’ represents the highest grade and ‘4’ represents the lowest grade. The academic evaluator selected the grading method that was used when given the grade range to work within. The academic grade is calculated by using *spell* (number of spelling errors) and *cgd* (content, grammar, description) values. The *spell* value represents the total number of spelling errors made per written task. The *cgd* value is calculated according to general content, grammar and descriptive ability. Table 8.3 define the *spell* and *cgd* values used.

Values	<i>spell</i> - number of errors	<i>cgd</i> - categories
0.5	below 8	High standard for 3 areas
1	8-15	High standard for 2 areas
1.5	16-25	Low standard for 2 areas
2	above 25	Low standard for 3 areas

Table 8.3 Calculating the *spell* and *cgd* values

The two values are then added together and rounded up to the nearest integer, which equates to an academic grade. Table 8.4 shows the academic grades calculated from these values.

Total=Spell + cgd values	Academic grade
1	1
Range 1.5 – 2	2
Range 2.5 – 3	3
Range 3.5 - 4	4

Table 8.4. Calculating the academic grade

An example is shown in Table 8.5 where the subject made six spelling mistakes and achieved a high standard in two cgd categories. The total value is 1.5. Using Table 8.5 the academic grade would be 2.

Spelling	spell value	Content	Grammar	Description	cgd value
6	0.5	High	High	Low	1

Table 8.5. Example showing spell and cgd values for a test subject

8.6 Environment 1: Basic word processor

This section will provide a detailed account of the testing procedure undertaken by the test subjects for environment 1. This section includes an introduction for this environment and an account of the level of support offered. The guidelines and evaluation notes used in the document template are included. A selection of the written assignments produced by the test subjects using this environment are presented and a small number of test subject's evaluation comments are provided.

8.6.1 Introduction

The test subject is asked to use environment 1 which is the basic word processor with no support tools. Their pre-selected topic template document (for environment 1) is opened using the basic word processor. The test subject is shown how to change the text and background colours via the icons and menus. The guidelines are explained and they are asked to write under each heading using the provided prompt notes. The time is noted and they are informed that the time limit is a maximum of forty-five minutes. On completion

the time is noted and the document is saved. The test subjects are offered a printed copy of their written work.

8.6.2 Level of support

The level of support offered within this environment is minimal. The test subjects are provided with prompt notes to make the task simpler as the aim is not to test their knowledge of a particular topic. They are provided with support to enable them to set up their ideal environment in terms of screen and font colours using user-friendly methods. They are not provided with any assistance to help them with their spelling, grammar or sentence structuring. This environment represents the lowest level of support and no control is used.

8.6.3 Document templates

Document templates are used to provide the test subject with a framework to complete their written task. There are three different templates associated with this environment, one for each of the three topics. The topic information has been covered in Sections 8.3.2, 8.3.3 and 8.3.4. This section will present the guidelines and evaluation notes used by the test subjects. These are the same for all three templates only the topic information differs.

Guidelines

Task 1: Write complete sentences under each of the headings.

Notes are provided as a guide only.

There are no spelling aids.

Use the menus and icons to set up your ideal environment.

Do not use the pen icon.

User evaluation

Notes: What do you think of this environment: chosen environment settings, menus, icons, too basic, good and bad points, did you miss the use of a spell checker?

What additions would you like to make the task easier?

Were you able to write enough under the chosen headings?

Were the notes helpful?

Are you happy with your chosen words and sentence structures?

Did you find the task easy or hard to complete in the time?

Grade the system (usability), 1 – 4 (1 highest level).

8.6.4 Selection of test subject's written text

This section presents two examples of written assignments created using this environment. They were selected because they represent extreme cases in terms of the number of errors they contain. Extracts taken from the assignments are presented the complete text can be found in Appendix A.5. This in a small way will highlight the diversity within the test group. Spelling errors and incorrect word usage are highlighted in bold.

Reference name: student49

Pre-selected topic: Topic My life

Status: female, member of staff at Loughborough University

Time taken: 30 minutes.

Extracts taken from written assignment

I also have some of the same **freinds**. I loved **bagpuss** and **latr** on the young ones. A **fraind** and I recently watched her son's **bagpus** video. Two **fo** them nearly had a **fallong** out over who would dress as **Boy** for our **30th pary**. But then, he had so many looks to **chose** from. I am pleased with my **liveing accomodation** as I own it **mself**, well, the **bulfign** society does technically. It is perfect for dogs and cats as there is a **perk** at the back of the house, **nad** not too far for me to nip **outto** the shops. There is even a iron mongers so when decorating I don't have to **trapse** to a **gib** superstore. There **seams** little else to do but **critiices** others. I think the notes were **helpfull** , **couldn ot** have written on each of the notes in the time allowed though. Grade 3.

Evaluation

This test subject made a very large number of spelling errors, in the region of 90. The classic trait of being able to spell quite difficult words correctly like, criticism but not able to spell the word 'friend' was evident. Also inconsistencies by spelling the same word in different ways: fraind, freind. Homophone errors and punctuation errors were also a problem: chose for choose and seams for seems. Spelling phonetically (trapse), incorrect letter order for short words (nad) and joining words together (outto) were also evident. Examples of adding extra letters or missing out letters (helpfull, pary) and not following spelling rules (liveing) were also present. The writing speed was very quick indeed which is evident from the amount written in thirty minutes (see Appendix A.5 for complete assignment). The test subject gave the system a grade 3 because the level of support was not what was required. An academic grade 4: 2 for spelling (over 25 spelling errors) and 1.5 cgd (low for grammar and description, satisfactory content) was given.

Reference name: student1

Pre-selected topic: Topic Who am I

Status: male, second year student at Loughborough University

Time taken: 28 minutes.

Extracts taken from written assignment

I am Left handed, my favourite colour is Red. My Mum and Dads names are Susan and William. In exams I am allowed 25% extra time, which though helping **considerablely** I feel that I am often still at a disadvantage. **Nowerdays** I try to accept people for who they are and think that everyone has a good and a bad side. I think that I spell words quite well but still have to make **alot** of corrections due to not typing what I meant to type. I feel that I should have been able to write more in the time. Grade 3.

Evaluation

This subject did not have a spelling problem, only 4 mistakes made (see Appendix A.5 for completed assignments). The common problem of using alot instead of a lot was evident. Most word processors correct this automatically, unfortunately this also means that people will continue to join the two words and when hand written no automated

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corrections are performed. The test subject's main problem was the inappropriate use of capital letters. The writing speed was also very slow and from the test subjects comments reading speed is also very slow. The usability grade 3 was given for this environment. This was mainly due to the subject feeling he did not write enough because he spent so much time re-checking, as there was no spelling support to do it for him. An academic grade 1: 0.5 spelling and 0.5 cgd was given.

These two examples have shown the various degrees of difficulties test subjects have. Interestingly enough although their support needs were very different each gave the same usability grade of 3 representing improvements are needed. This was to be expected.

8.6.5 Selection of test subject's evaluation comments

This section contains a selection of the test subject's evaluation comments for environment 1. They were chosen to give an insight to the features that were available to the test subjects. These evaluations were selected totally at random and the same test subject's evaluations for the other two environments will be used.

Reference name: student50

The environment is great as its like working in an office. I found it easy and the it seemed a bit basic but the layout is easy 2 use which helped alot I would rate the system grade 1.

Reference name: student47

I like the colours it is quite relaxing. The layout is simple and clutter free, which I like, but I would need some support such as a spell checker. The task was easy to do the notes helpful and I completed within the time. I am quite happy with my chosen words and sentences and I tried to limit my spelling errors. I would grade the system a 3 but it would be higher if there was some support tools.

Reference name: student45

The environment I have worked in has be good. The color has helped get more involved. I am not sure why but it has. The menu is simple and very easy to use. I miss using the spell checker. The notes were very helpful and allowed me to write more in the spaces. I

am happy with some of my sentences but not all. I found the task hard to complete in the time. I would give the system a grade 2.

Reference name: student41

I changed the colour to purple near the end because this is the colour that works for me. It was good to just be able to click on one button and be able to change things instead of having to go into a menu because that just get confusing because I can never remember were to go! I didn't miss the spell check because I never spell check **untill** the end of what I am writing so that I don't lose my flow because each heading **seamed** to vast a question, so what I did was answer the questions of the notes, which meant that I didn't think for myself but I didn't get confused either! I think I have gone well over time! I give it a 1.

From this small sample it can be seen that the main features of the system were liked but more support was required. Two subjects gave the system a 1 because they were comparing its features to Microsoft Word but were not really considering the lack of support as being a problem. This environment provided the true academic ability of the group.

8.7 Environment 2: Word processor and support tools

This section will provide a detailed account of the testing procedure undertaken by the test subjects for environment 2. This section includes an introduction for this environment and an account of the level of support offered. The guidelines and evaluation notes provided in the document template are included. A selection of the written assignments produced by the test subjects using this environment are presented and a small number of test subject's evaluation comments are also provided.

8.7.1 Introduction

The test subjects are asked to use environment 2, which is the word processor with associated support tools. Their pre-selected topic template document (for environment 2) is opened using the word processor. The test subjects are shown how to use the word predictor, word meanings tool and spell checker with associated text highlighter. The

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guidelines are explained and they are asked to write under each heading using the provided prompt notes as a guide. The time is noted and they are informed that the time limit is a maximum of forty-five minutes. On completion the time is noted and the document is saved. The test subject is offered a printed copy of their written work.

8.7.2 Level of support

The test subjects are provided initially with the same level of support as in environment 1 in terms of prompt notes and setting up their ideal environment. They are then encouraged to select the 'pen icon', which allows them to access the specially designed support tools.

The test subjects are provided with specialist tools to help them with their spelling, homophone selection, reducing the use of incorrect words (wrong meanings), proof reading by displaying individual sentences for modifications and the splitting up of long sentences. These tools were designed specifically for adults with dyslexia and the support they offer matches the requirements of the dyslexic subjects who took part in the initial surveys (see Chapter 4).

8.7.3 Document templates

The document templates used for environment 2 are similar to those used in the previous environment. The difference lies in the guidelines and user evaluation prompt notes. The templates provide the test subject with a framework to complete their written task. There are three different templates associated with this environment, one for each of the three topics. The topic information has been covered in Sections 8.3.2, 8.3.3 and 8.3.4. This section will present the guidelines and evaluation notes used by the test subjects. These are the same for all three templates only the topic information differs.

Guidelines

Task 2: You will use the spelling aids to help you with the written task.

Please write complete sentences under each of the headed sections

Use the notes as a guide only, you are free to choose the content.

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At the end of each section, highlight the text and click on the pen icon.

Select the spell checker button.

Repeat this process for all sections writing between 5-10 lines for each section.

Online help is available by clicking the pen icon and either selecting the 'word predictor' (enter up to 4 letters, words suggested) or click the 'word meaning' button (offers meanings to common usage words, that sound the same but have different meanings).

User evaluation notes

General: ease of use, good/bad points.

Help: did you find tools helped correct your mistakes, was help given at the right level?

Problems: were there any problems when using the tool.

Spellings: did tools help with your spelling, were the suggested words presented clearly?

Features: did you use the word predictor option, did you use the word meanings option, did you use the reverse sentence option?

Suggestions: any improvements required, any new features that would be useful to you.

Results: are you happy with the resulting sentences.

Grade the system according to usability: 1 – 4 (1 highest).

8.7.4 Selection of test subject's written text

This section presents two selected written assignments created using this environment. The same test subjects written text as previously are used for comparisons. (They were selected from the results from environment 1 because they represent extreme cases in terms of the number of errors they contain.) Extracts taken from the assignments are presented the complete text can be found in Appendix A.6. The spell checker has been used on these documents; the words, which were corrected by the spell checker, appear in italics with the original word in brackets. Any remaining spelling errors or incorrect word usage are highlighted in bold.

Reference name: student49

Pre-selected topic: Topic Who am I

Status: female, member of staff at Loughborough University

Time taken: 30 minutes.

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Extracts taken from written assignment

My name is Ursula as *pronunciation* (ponunciation) is easy in *German* (German) and English. One person said I had a nice “infectious *powerful* (powerfull) smile”, I think he was creeping. I always worried *about* (baout) my *ability* (ability) to wear clothes, but I was always told I had no dress sense so *often* (oftern) I *believed* (blieved) it. A *friend* (freind) *did* (di) say I bought this for *your* (meant you) as you are the only person I know who can wear such an *awful* (awfull) colour. This would *certainly* (certsinly) help a lot with recognising *where* (meant whether) they are long and being able to *thin* (meant think) about just the text in that long *sentence* (sentance). I think it will make essay *writing* (writting) much better. RATE: 2.

Evaluation

The spell checker certainly helped this test subject. There were 41 spelling mistakes prior to using the spell checker. The remaining errors were of the type of inappropriate use. The words were spelled correctly but used in the wrong context. There were still a large number of grammar errors in particular punctuation errors. This subject requires support with sentence construction and grammar. The test subject was given an academic grade of 2: 0.5 spelling (under 8 errors), 1.5 cgd (low content and grammar) for this written work (see Appendix A.6 for complete assignment).

Reference name: student1

Pre-selected topic: Topic Dyslexia

Status: male, second year student at Loughborough University

Time taken: 29 minutes.

Extracts taken from written assignment

I can remember being tested at school by a *psychologist* (psycologist) but my mother told me that the outcome of that test mainly blamed my poor eyesight. On leaving school I got a job as a mechanic, which mainly involved me performing physically rather than *academically* (accodemically). I think that it is *much* (mush) harder for me to understand any foreign languages. I seem to like things that have a *definite* (definate) structure to them, I like hard rules with no *grey* (gray) areas. I think computers have helped *a lot*

(alot) with my problem. A self learning predictor that completed words as you typed might be *advantageous* (advantagous). Grade 2.

Evaluation

This subject had less than 10 spelling mistakes, which were all corrected by the spell checker. The text highlighter allowed the test subject to split some of the longer sentences. This environment was set at the right level of support for the subject. The subject's comments indicated that the main problem is writing and reading speed. The test subject was given an academic grade 1: 0.5 spelling, 0.5 cgd for this written text.

It can be seen from the two examples that this environment offers a very wide level of support. It is lacking in the grammar area, which some subjects have a problem with. Although homophone support is provided several words are still not being corrected as the test subject is not requesting alternatives to be given. If the system was used for longer different results may be produced.

8.7.5 Selection of test subject's evaluation comments

This section contains a selection of the test subject's evaluation comments for environment 2. They were chosen to give an insight to the features that were available to the test subjects. The same test subjects as for environment 1 have been selected.

Reference name: student50

I didn't use the word predictor but the spell checker really helped and it was very easy 2 use. I made 1 mistake and deleted part of what I had written so had 2 start again but otherwise it was fine. The way it was set out was clear and again made it easy 2 understand. I didn't understand the reverse sentence option and that's how the mistake happened. An improvement that I would make is that the spelling mistake b underlined by the computer so I can look closely as I have a very visual memory! I'm happy with the changes I made and I would grade it with a level 2.

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Reference name: student47

This system is very good I used all the tools and they did help. Although I did not make that many mistakes the text highlighter helped me structure my sentences which was a great help. The word meanings helped me to select the right word. The task was easy to do. I would grade the system 2. It would get a 1 if there was some help with grammar.

Reference name student45

The use of the programme was very good. It was simple to use and understand. I was happy with the way that the machine asked you about the spelling which would help to learn from my mistakes. The tool used helped me a great deal. The grade I would give the system would be 2.

Reference name: student41

I found using the spell checker helpful, as it gave me a chance to read though each sentence and check that it could work on it's own. I was able to correct all my spelling mistakes although most of them were only missing a few letters so I don't know how it would have coped with some of my bizarre spellings. I give a 1 as it is easy to use and does what it needs to so you can't get confused. New feature if it could take sentences that start after a full stop that you have forgotten to put the space in.

The selected evaluation comments show that the main features were liked and used. The usability grades given were three grade 2's and one grade 1. Chapter 9 confirms these results are indicative of the whole test group.

8.8 Environment 3: Sentence constructor

This section will provide a detailed account of the testing procedure undertaken by the test subjects for environment 3. This section includes an introduction for this environment and an account of the level of support offered. The guidelines and evaluation notes provided in the document template are included. A selection of the written assignments produced by the test subjects using this environment are presented and a small number of test subject's evaluation comments are also provided.

8.8.1 Introduction

The test subject is asked to use environment 3, which is the word processor with the sentence constructor. The test subject is shown how to select the control mode (which uses the sentence constructor) via the pen icon. The remaining topic is selected from the introduction dialog box. The control mode is then fully explained including the use of the function buttons (help, add, view-change) and the selection of predefined options. They are made aware that the spell checker will verify any text they wish to add. The start time is then noted and the test subject uses the control mode to create the written text. On completion the time is noted and the subjects are offered a copy of their work.

8.8.2 Level of support

This environment offers the highest level of support in terms of spelling, grammar and sentence structuring. It does require the test subject to do a relatively large amount of reading which may present a problem for some test subjects.

8.8.2.1 Specialist tools

The main tool associated with this environment is the sentence constructor. This uses sentence templates to devise the structure of all the sentences. The overall structure of the written text is controlled by the use of questions that must be answered in the set order. The tool uses the spell checker to verify any text that is entered by the test subject. The end result is a word document that is grammatically correct, free of spelling errors and well structured. This tool is designed to help dyslexic adults who have difficulties with spelling, grammar and sentence structuring. It will also help those adults who have a very slow writing speed as text can be produced very quickly. This system does require a fair amount of reading, which may prove to be a problem for those subjects who are slow readers. Much research has been carried out to ensure the method of presentation is favourable for dyslexics and eyestrain is minimised.

8.8.2.2 Level of control

This environment uses a highly controlled and rigid format. It removes the grey areas within written English and reduces the grammar rules as the sentence components can only be put together in a predefined order. The control system 'sits' upon the basic word processing environment. On completion of the control mode the system reverts back to the word processing environment in order to allow the test subjects to structure the text (in a presentation sense) and make any changes that they may wish to make. The spell checker will still be available for verification.

8.8.3 Selection of test subject's written text

This section contains the selected two test subjects written text, created using environment 3. Extracts taken from the assignments are presented the complete text can be found in Appendix A.7. All spelling and grammar errors will be presented in bold.

Reference name: student49

Pre-selected topic: Dyslexia

Status: female, member of staff at Loughborough University

Time taken: 14 minutes.

Extracts taken from written assignment

The main physical problems dyslexia caused me as a child was: not being able to estimate time, (should be comma) a short concentration span, (should be comma) a sight problem when reading and **coordination of hand eye**. In my opinion this control environment produces a higher standard compared to the other environments. This is mainly due to being allowed to concentrate on the content rather than the sentence syntax. I would class the system as first rate with regards to helping me with my sentence construction.

Evaluation

This written work was given an academic grade 2: 0.5 given for spelling, 1 given for cgd. The test subject was given the support needed for grammar and sentence structuring. Two pages of text were completed in only 14 minutes. The add button was used to enter text

and the spell checker corrected any spelling mistakes that were made (see Appendix A.7 for complete assignment). However some grammar mistakes were still made and not corrected by the system.

Reference name: student1

Pre-selected topic: Topic My life

Status: male, second year student at Loughborough University

Time taken: 25 minutes.

Extracts taken from written assignment

I am interested in keeping fit and my main hobby is Internet surfing and computers. I am studying Computer Science BSc in the Computer Science department. I felt that the system was a little limited in allowing me to write about the chosen topic. One change I would like to see made is the reduction of the number of options **because it result in less reading.** In order to increase the usefulness of the control environment I think the inclusion of a dictate system to avoid reading options. I would class the system as second rate with regards to helping me with my sentence construction.

Evaluation

This subject did not have a problem with spelling or sentence structuring with the exception of a tendency to write rather long sentences. This subject did not require the level of support this system offered and graded the system a 2. The subject's main problem was writing and reading speed. Although this system would support the slow writing problem, the amount of reading can be a problem. The subject commented that reading from the screen was a problem. A dictate and reader would make this tool more useful.

8.8.4 Selection of test subject's evaluation comments

This section contains a selection of the test subject's evaluation comments for environment 3. The evaluations are from the same test subjects as for the previous two environments. They were chosen to give an insight to the features that are available to the test subjects. The comments are summarised the complete text is given in Appendix A.8.

Chapter 8

Reference name: student50

System does achieve its main aim and dialog display presentation was clear and easy to follow. Did not need to use the help button. Add button used often in order to define my views. Occasionally used view button. Control environment produces a higher standard compared to the other environments due to being allowed to concentrate on the content rather than the sentence syntax. I would class the system as second rate with regards to helping me with my sentence construction.

Reference name: student47

System definitely achieves its main aim of automating sentence construction and dialog display presentation was very clear and easy to follow. I frequently used the help button and it was helpful. I frequently used the add button and it made the system flexible. I frequently used the view button. This control environment definitely produces a higher standard compared to the other environments. This is mainly due to the reduction of spelling and grammar errors. I would class the system as first rate with regards to helping me with my sentence construction.

Reference name: student45

The system does achieve its main aim of automating sentence construction and dialog display presentation was clear and easy to follow. I frequently used the help button and it was helpful. I occasionally used the add button. I occasionally used the view button. This control environment generally produces a higher standard compared to the other environments. I would class the system as second rate with regards to helping me with my sentence construction.

Reference name: student41

The system definitely achieves its main aim of automating sentence construction and dialog display presentation was very clear and easy to follow. I did not need to use the help button. I occasionally used the add button. I frequently used the view button. The system definitely produces a higher standard compared to the other environments. This is mainly due to the reduction of spelling and grammar errors. I would class the system as first rate with regards to helping me with my sentence construction. The evaluation

comments for this environment were encouraging. The system was given two grade 1's and two grade 2's. It will be interesting to see if these will be representational of the final results presented in the next chapter.

8.9 Concluding remarks

This chapter has provided all the information required regarding the testing sample and testing procedure. The test sample common attributes were listed to develop the initial subject profile and to ensure the level of bias was at a minimum. The number of test subjects was fifty, which is greater than the minimum requirement of thirty based on the central limit theorem. Three topics are to be used in the testing process: Who am I; Dyslexia and My life. They were chosen to allow all test subjects to be able to write about topics that they know something about. Prompt notes were provided (for the first two environments) to ensure that all environments gave the same level of support with regards to content (environment 3 uses pre-defined options). This reduced the effects of bias. The selection method was also covered to show again that no bias was given to any individual test subject. It was essential to mix up the environments and topics to ensure it was the environment that was being evaluated not the test subject's ability to write about a particular topic.

An overview of the testing procedure was given detailing the common routine that each test subject followed. In order to reduce bias each test subject followed exactly the same procedure, in terms of environment, equipment used, help offered and testing of the three environments. How the environments are used to qualify the research hypothesis was discussed. This explained that the environments used the same basic word processor but the level of support and control differed. Comparisons would be formed in order to qualify the research hypothesis. A detailed account of the testing procedure for each environment in turn was then given. This included example written work for each environment and a further selection of evaluation comments. This was provided to give a clear account of the testing process, which forms a good foundation for the next chapter.

Chapter 9 Results

9.1 Introduction

This chapter presents the test results using a series of charts. The categories used in the majority of these, are representative of the analysis of the written assignments and not chosen by the author. The data tables are provided in Appendix A.9. For environment 1 and environment 2 the sample were only given prompt notes not offered categories to select from. This method limits the level of bias, as subjects are not confined. Chapter 8 offered a detailed description of the method of testing and the approach that was used. Section 9.2 discusses the test subject's general profile and Section 9.3 gives an analysis of the test subject's difficulties with written English. Section 9.4 offers a detailed analysis of the written text produced by the test subjects and concludes the profile of the test group. Section 9.5 gives the academic and usability grade results. Sections 9.6 - 9.8 provide the evaluation of the three environments. Chapter 10 uses these results to qualify the research hypothesis.

9.2 Test subject's general profile

The test subjects were all adults with dyslexia in the age range eighteen to fifty. Most were formally registered adults with dyslexia and were students from Loughborough University. All test subjects had reached the academic level of higher education (passed A' level standard). In total fifty subjects took part and provided the data which was evaluated. A general profile of the test group is provided in this section. A series of diagrams depict the key areas, which are: gender, academic year, degree subject, preferred academic subject and use of different language structures. It should be noted that very few comparisons with non-dyslexics are provided, as the interest is focused on establishing the test group profile and not in how they differ from the population.

9.2.1 Gender

The test group comprises 31 males and 19 females. This represents a ratio of 5:3 (males to females). The dyslexia association have estimated the ratio of male to female dyslexics as high as 3:1 [BDA02] so the test subject group is quite typical.

9.2.2 Academic year

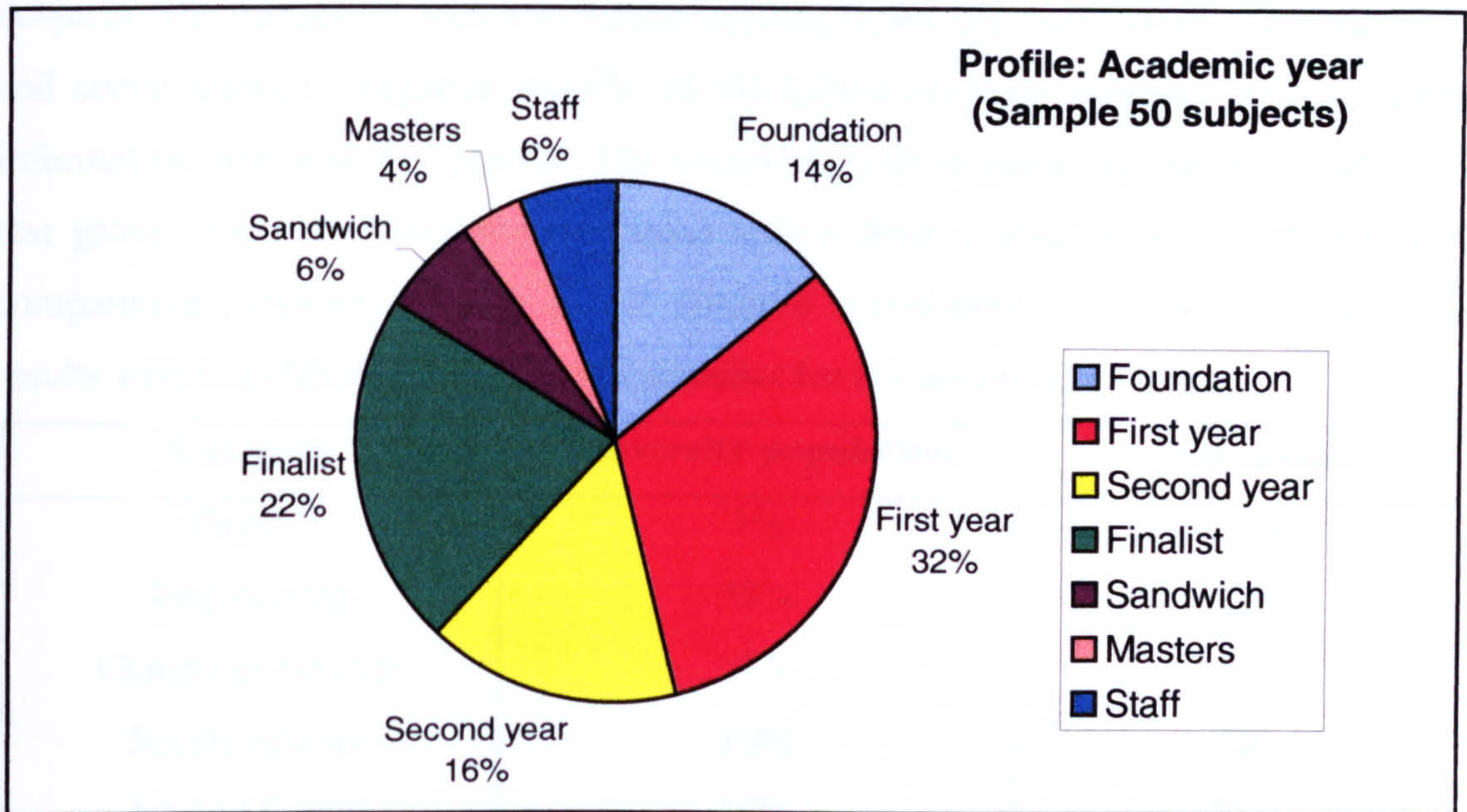


Figure 9.1. Academic year.

Figure 9.1 shows that the test subject group is made up of a varied selection of adults at different stages of the academic system.

9.2.3 Degree subject

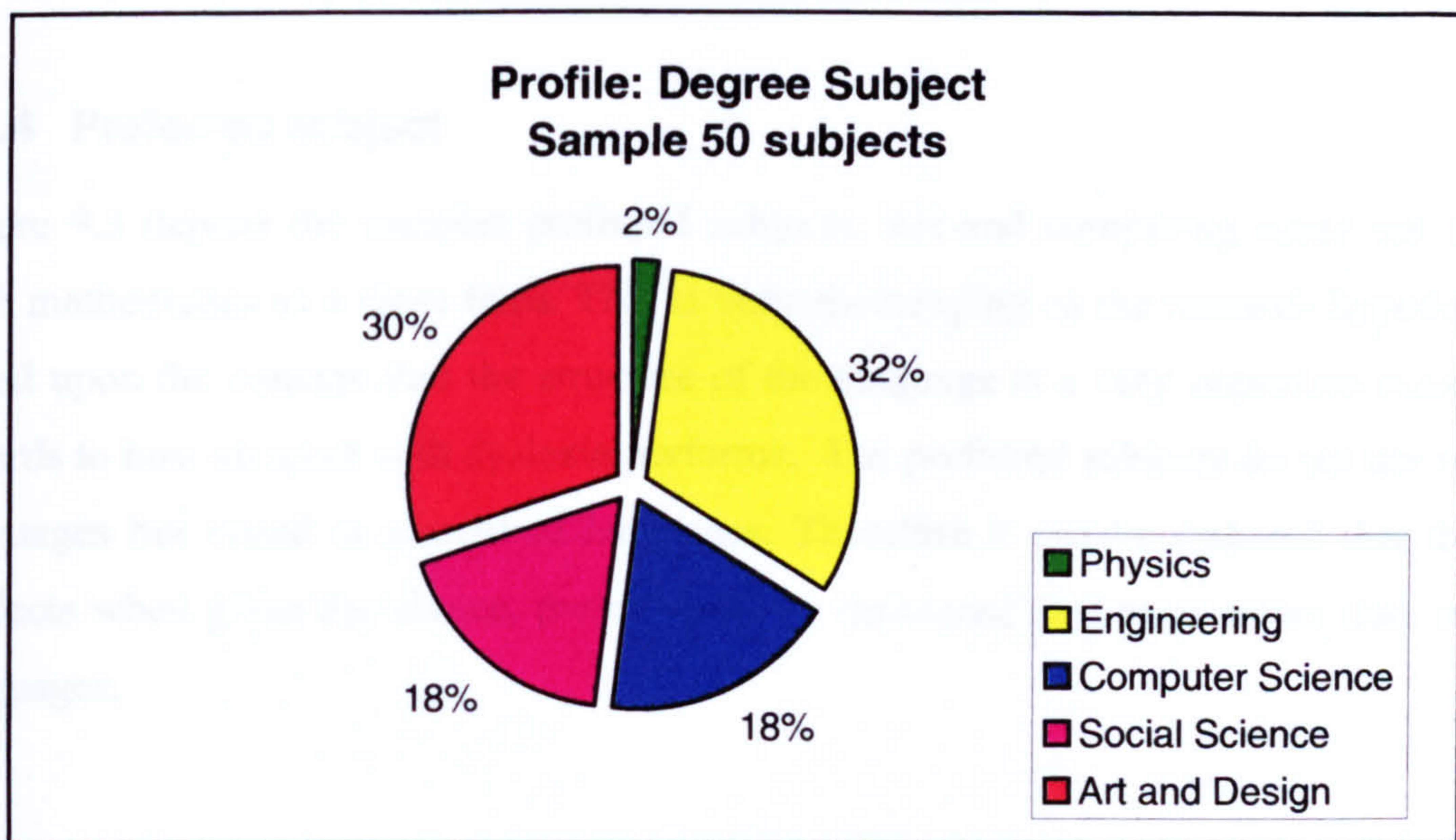


Figure 9.2. Degree subject.

This shows that the test group are studying (have studied) a varied selection of degree subjects. The categories were specified according to the responses given. The engineering and social science categories include all disciplines as many subjects provided general information and were not precise. The computing and engineering students (50% of the test group) will use structured languages within their course, which is of interest for comparative purposes (relating to the research hypothesis). Table 9.1 compares these results with Loughborough University statistics for the general population.

Category	University population	Test sample
Physics	3%	2%
Engineering	58%	32%
Computer Science	14%	18%
Social Science	10%	18%
Art and Design	15%	30%

Table 9.1. Degree subjects for test group and University population

The clear difference is the percentage of students taking Art and Design degrees. This is not surprising, as it is known that dyslexics have a tendency towards this discipline. The Social Science category is quite high because it includes 6 students (12%) from the Sport Faculty.

9.2.4 Preferred subject

Figure 9.3 depicts the samples preferred subjects. Art and computing come out on top with mathematics as a close third. This is very encouraging as the research hypothesis is based upon the concept that the structure of the language is a very important issue with regards to how an adult with dyslexia performs. The preferred subjects do not use natural languages but visual or structured languages. Therefore it can be deduced that the test subjects when given the choice, prefer visual or structured languages rather than natural languages.

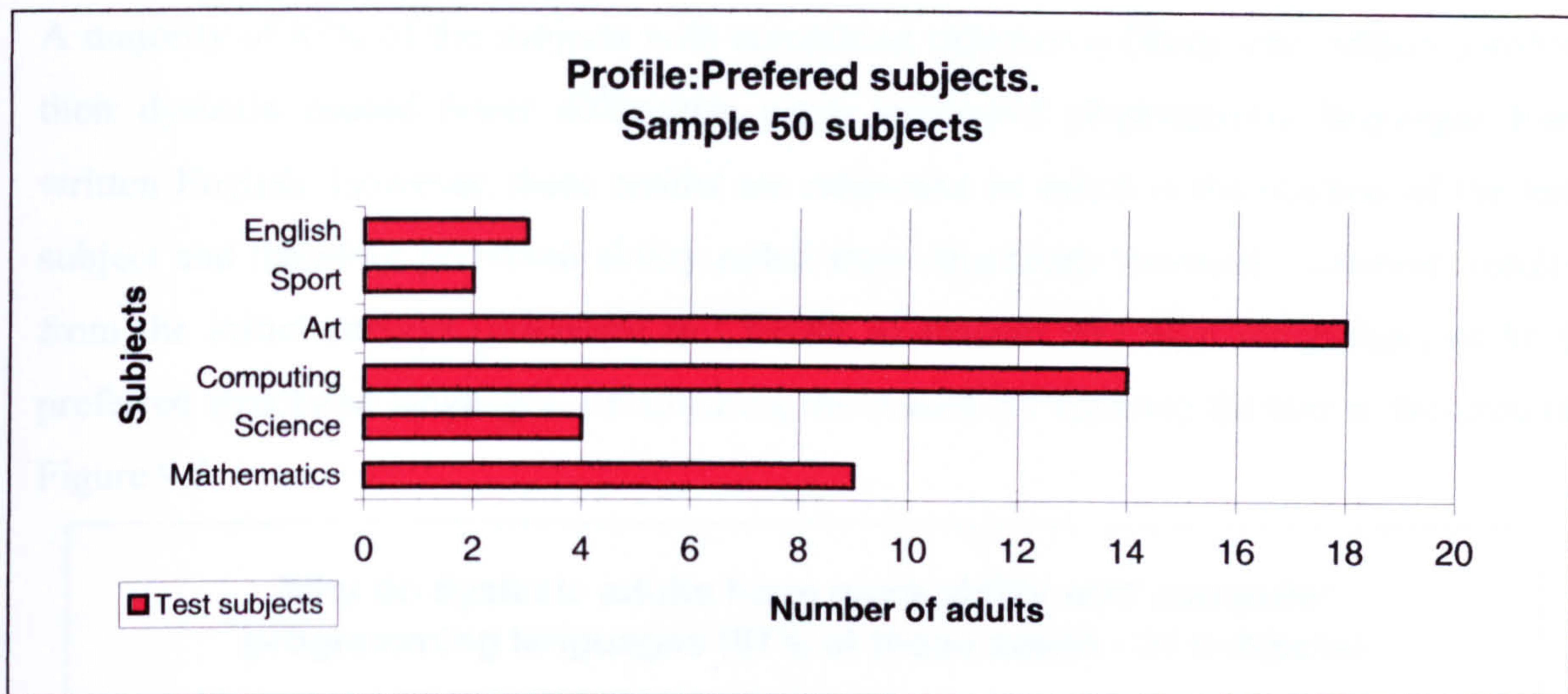


Figure 9.3. Preferred subject.

9.2.5 Experience with different language structures

The following series of charts depict the experience test subjects have with computer programming languages and offers a comparative review with written English. A majority of 62% of the group stated they have used computer programming languages. This is a very encouraging result and when compared with the initial surveys (discussed in Chapter 4), it is 3% higher (59% had experience of computer programming languages). The previous surveys used the Internet (90% from the Internet), which may have increased bias, as they needed to access computers to take part. However, these comparisons reinforce and support the theory that dyslexics are suited to structured languages. Figure 9.4 depicts comparative abilities with different language structures.

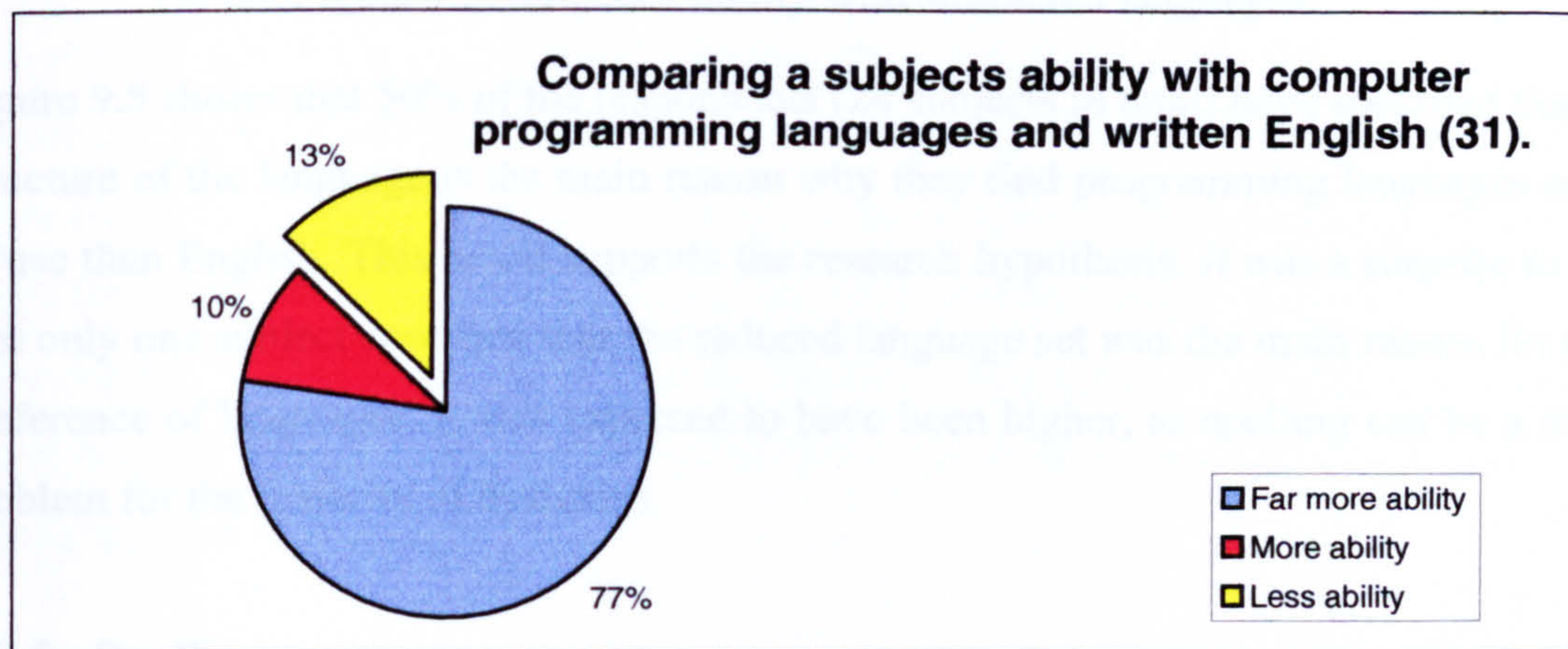


Figure 9.4. Written abilities of subjects with programming experience.

A majority of 87% of the subjects with computing experience (thirty-one subjects) stated their dyslexia caused fewer difficulties using structured programming languages than written English. However, these results are subjective in that it is the opinion of the test subject and therefore perceived ability rather than objectively assessed. However, results from the initial surveys (discussed in Chapter 4) support this high percentage, as 81% preferred structured languages. Establishing the reason (or reasons) for this is depicted in Figure 9.5.

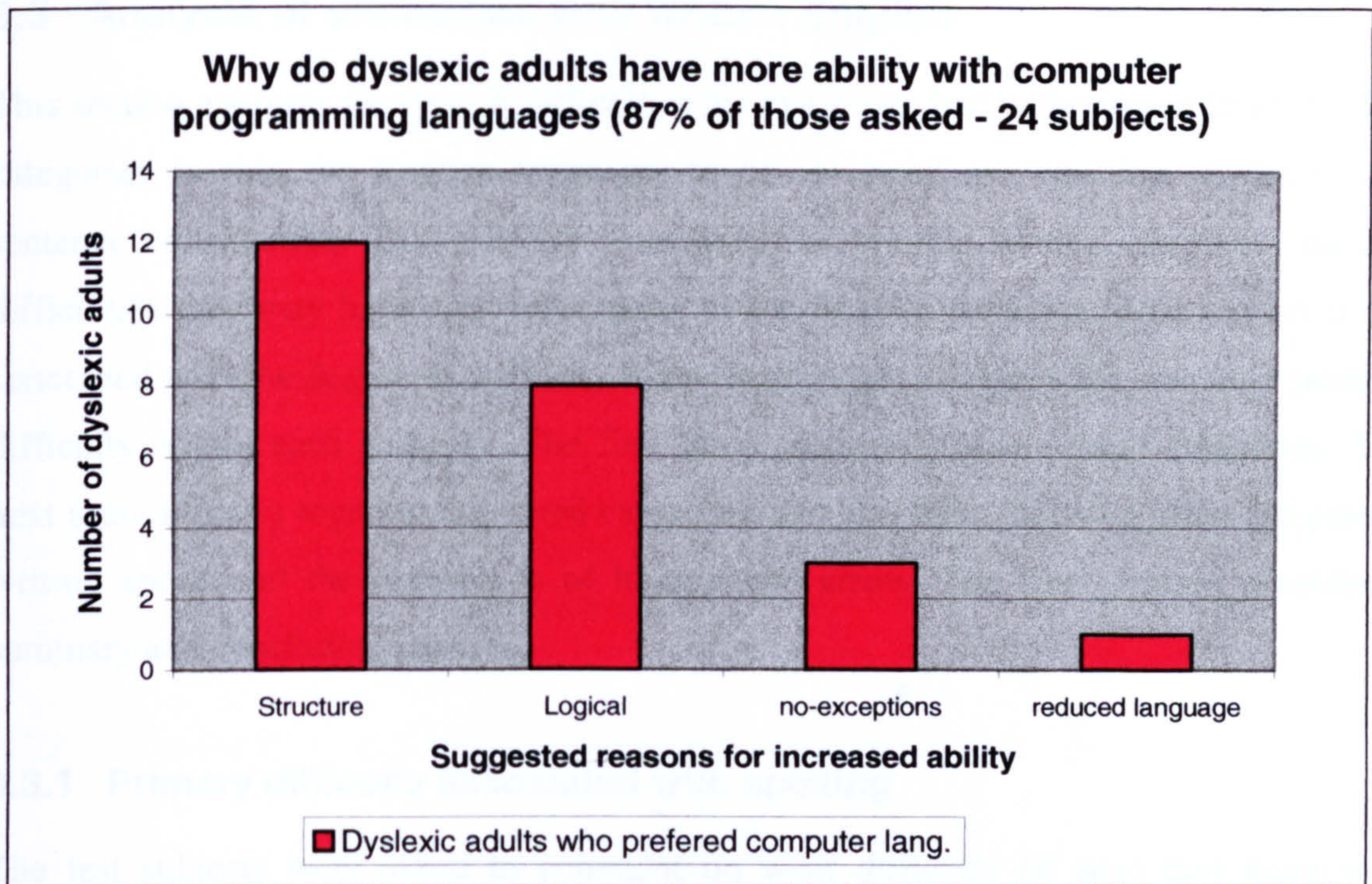


Figure 9.5. Subjects' ability with structured languages.

Figure 9.5 shows that 50% of the respondents (24 subjects in total) have specified that the structure of the language is the main reason why they find programming languages easier to use than English. This result supports the research hypothesis. It was a surprise to find that only one subject specified that the reduced language set was the main reason for their preference of languages. It was expected to have been higher, as spelling can be a major problem for the majority of dyslexics.

9.2.6 Profile summary

In summarising the test group profile, it can be said that the sample is varied in terms of their academic year, preferred subject and degree subject. This is very important to ensure

that a wide range of test subjects evaluate the environments from different disciplines and at different stages of their academic life (in order to limit bias). It is very encouraging that 62% of the test group have experience of using structured languages and of that group 87% find structured languages much easier to use (this represents 54% of the whole test group). This reinforces the initial survey results carried out at the beginning of the research (see Chapter 4).

9.3 Analysis of difficulties with written English

This section analyses the type of difficulties the test group had with written English. The categories (within the English language) to be reviewed are: spelling, grammar and sentence construction. Test subjects were asked to provide written comments on any difficulties they may have with these areas of the English language. This section is not concerned with the degree of difficulty but with what test subject's felt was their primary difficulty within each category. The first three sections evaluate these categories. The next section draws together the stated categories and also includes two further categories: writing speed and the occurrence of homophone errors. The final section provides a summary and concluding remarks.

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9.3.1 Primary difficulty associated with spelling

The test subjects were asked to comment on what difficulty (if any) they have with spelling. Their primary difficulty was recorded and presented in Figure 9.6. It can be seen that 40% of the test group stated the most common difficulty they have with spelling is spelling words phonetically (how they sound). An unexpected result was the fact that 16% of the test group had no problems with spelling, which is rather higher than expected. It should be noted that the test subject's general profile is such that all subjects have reached higher education standards. Therefore it is not unreasonable to assume that some subjects may have found methods to overcome their spelling difficulties, which the results seem to indicate.

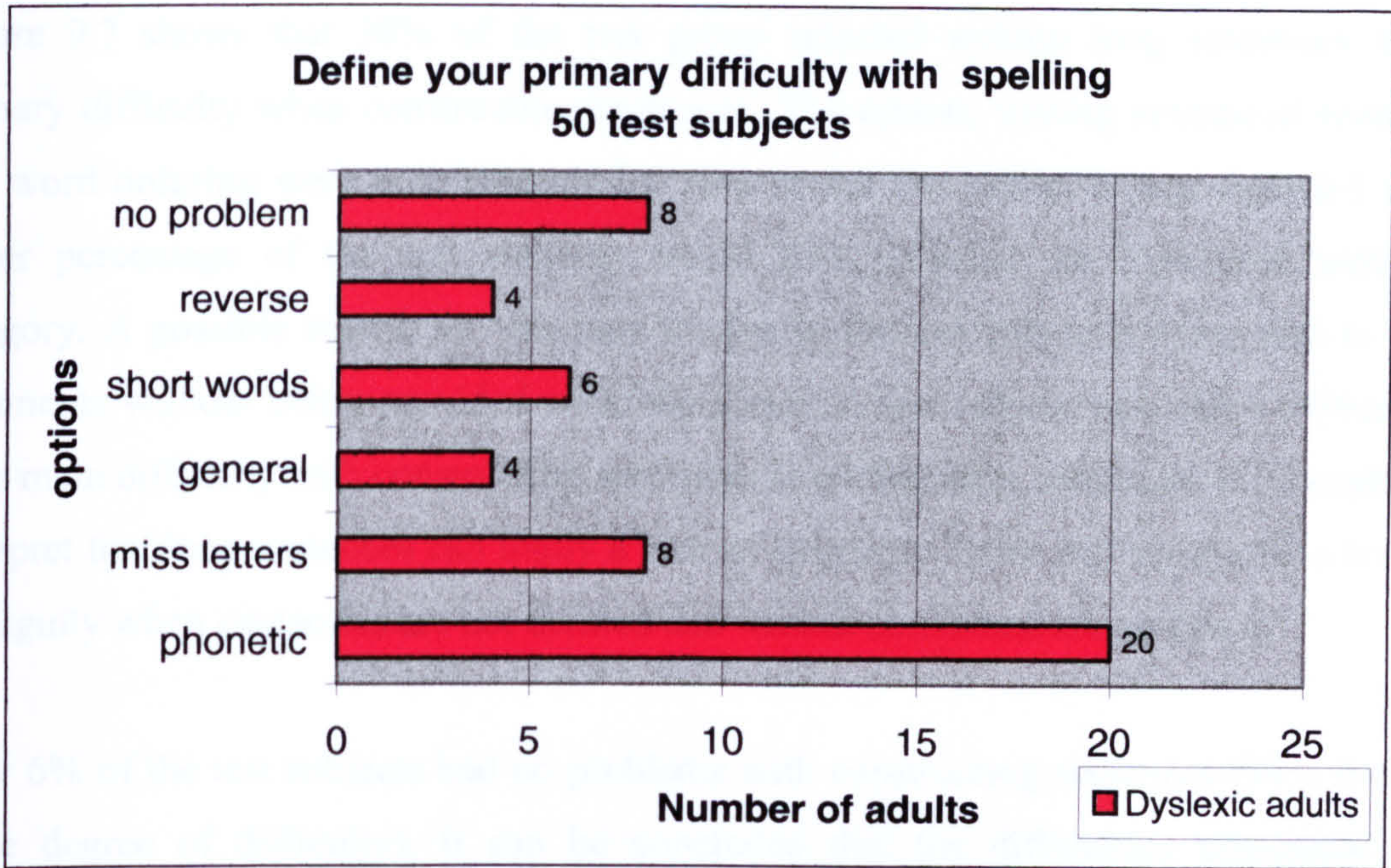


Figure 9.6. Reported primary difficulty in spelling ability.

There was little difference between the values of the other remaining four options. Therefore concluding that the difficulties associated with spelling (for 60%) were varied. 84% had some degree of difficulty with spelling.

9.3.2 Primary Difficulty associated with sentence construction

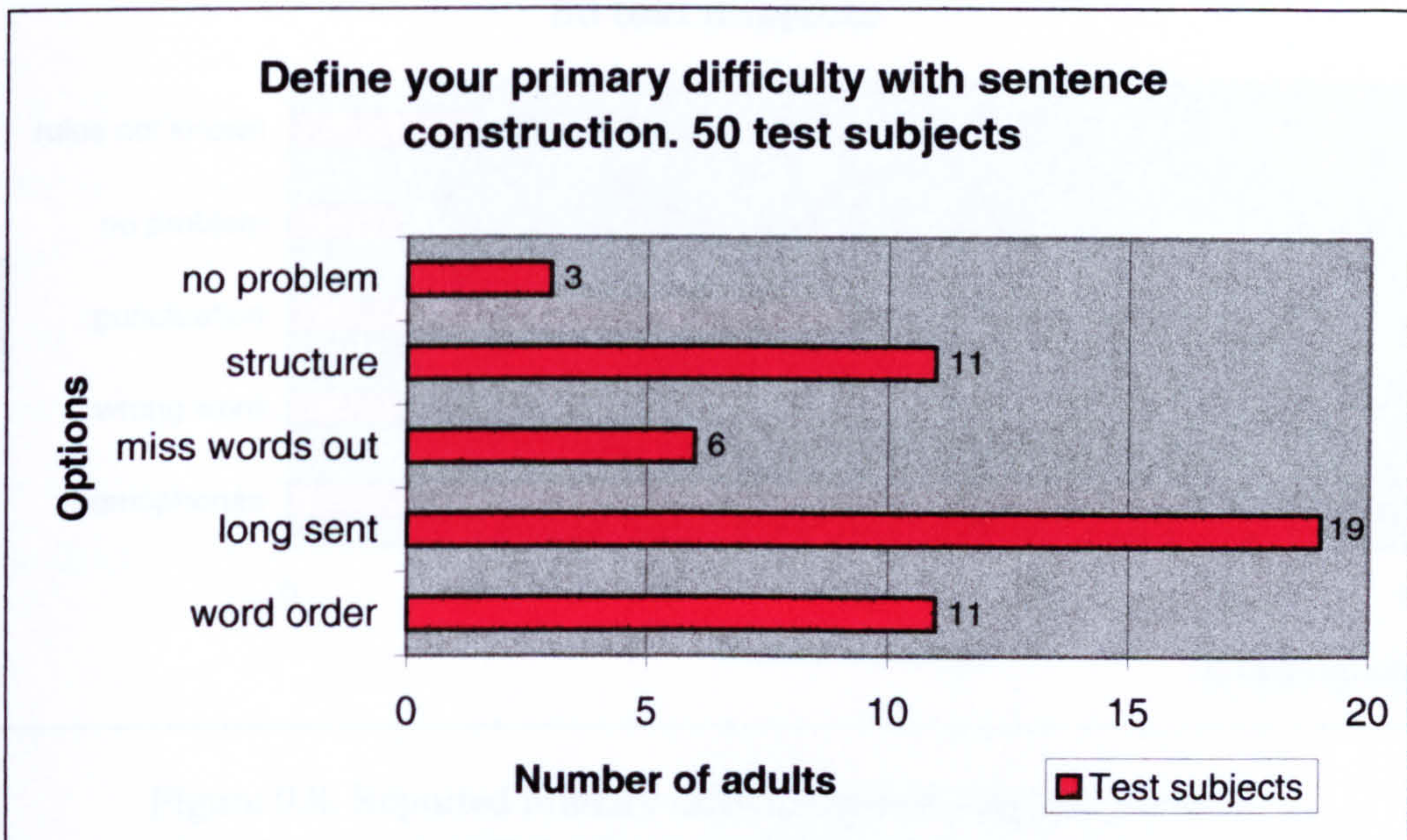


Figure 9.7. Reported primary difficulty in sentence construction.

Figure 9.7 shows that 38% of the test group selected writing long sentences as the primary difficulty when constructing sentences. The option, writing structured sentences and word ordering were both selected by 22% of the test group. It was expected that a larger percentage of the test subjects would have selected the structured sentences category. A possible reason for this may be due to the test subject's being free to write comments without being provided with categories. A test subject may have written that their main difficulty with constructing sentences is writing long sentences. It is possible to interpret that long sentences can imply a lack of structure. There will always be a level of ambiguity when categories are not defined and written comments are analysed.

Only 6% of the test subjects had no problems with constructing sentences (94% do have some degree of difficulty). It can be concluded that the difficulties associated with constructing sentences are varied within the group showing 82% selected from three options.

9.3.3 Primary difficulties with English grammar

Figure 9.8 depicts the primary difficulties associated with English grammar.

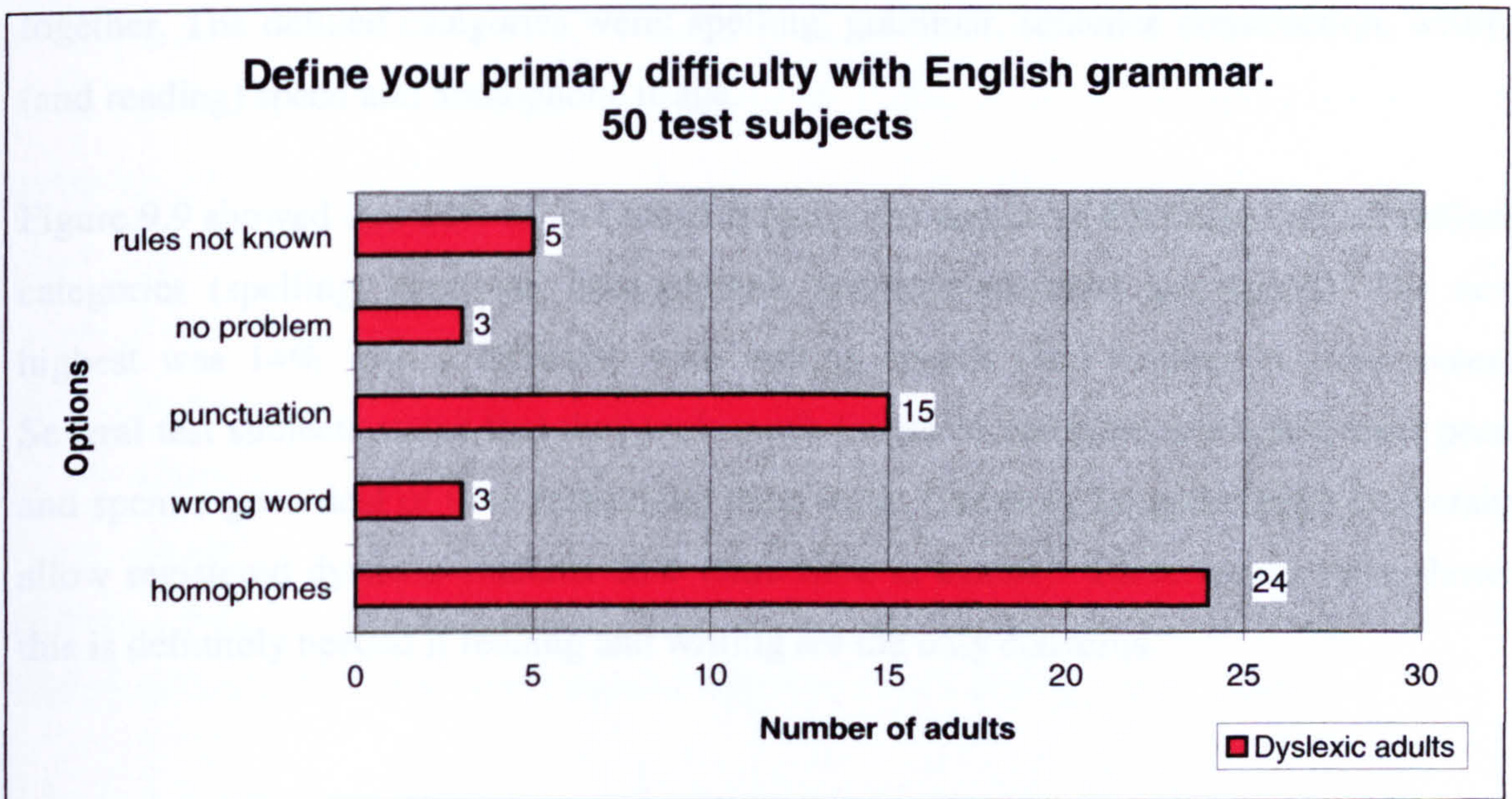


Figure 9.8. Reported primary difficulties with English grammar.

48% of the test group stated that their primary difficulty with English grammar is their inappropriate use of homophones. Being unable to distinguish between two words that sound the same but have different meanings is a problem that can be hard to overcome. Homophones are a lexical category rather than part of English grammar (the subjects denoted the categories). However, categorising them is not the important issue, the test subjects have specified that homophones are a problem for them when constructing sentences.

Difficulty with punctuation also scored quite highly at 30%. A low figure of 6% of the test subjects had no problems with English grammar; therefore a majority of 94% had some degree of difficulty. This was the same as the result for sentence construction. It can be concluded that these results have showed that the difficulties associated with English grammar are not as varied as the two previous written English categories (spelling and sentence construction) as 78% of the test group selected from only two areas.

9.3.4 Subject's general profile associated with written English

Each test subject's written comments were analysed to group their problem categories together. The defined categories were: spelling, grammar, sentence construction, writing (and reading) speed and homophone usage.

Figure 9.9 showed that 22% of test subjects had some degree of difficulty with all defined categories (spelling, grammar, homophones, sentence structure and speed). The next highest was 14% with a difficulty with writing speeds (and reading in some cases). Several test subjects stated that they took much longer to complete work than their peers and spent a great deal of time rechecking their work. Currently Loughborough University allow registered dyslexic students 25% extra time in exams. These results have shown this is definitely needed if reading and writing are the only concerns.

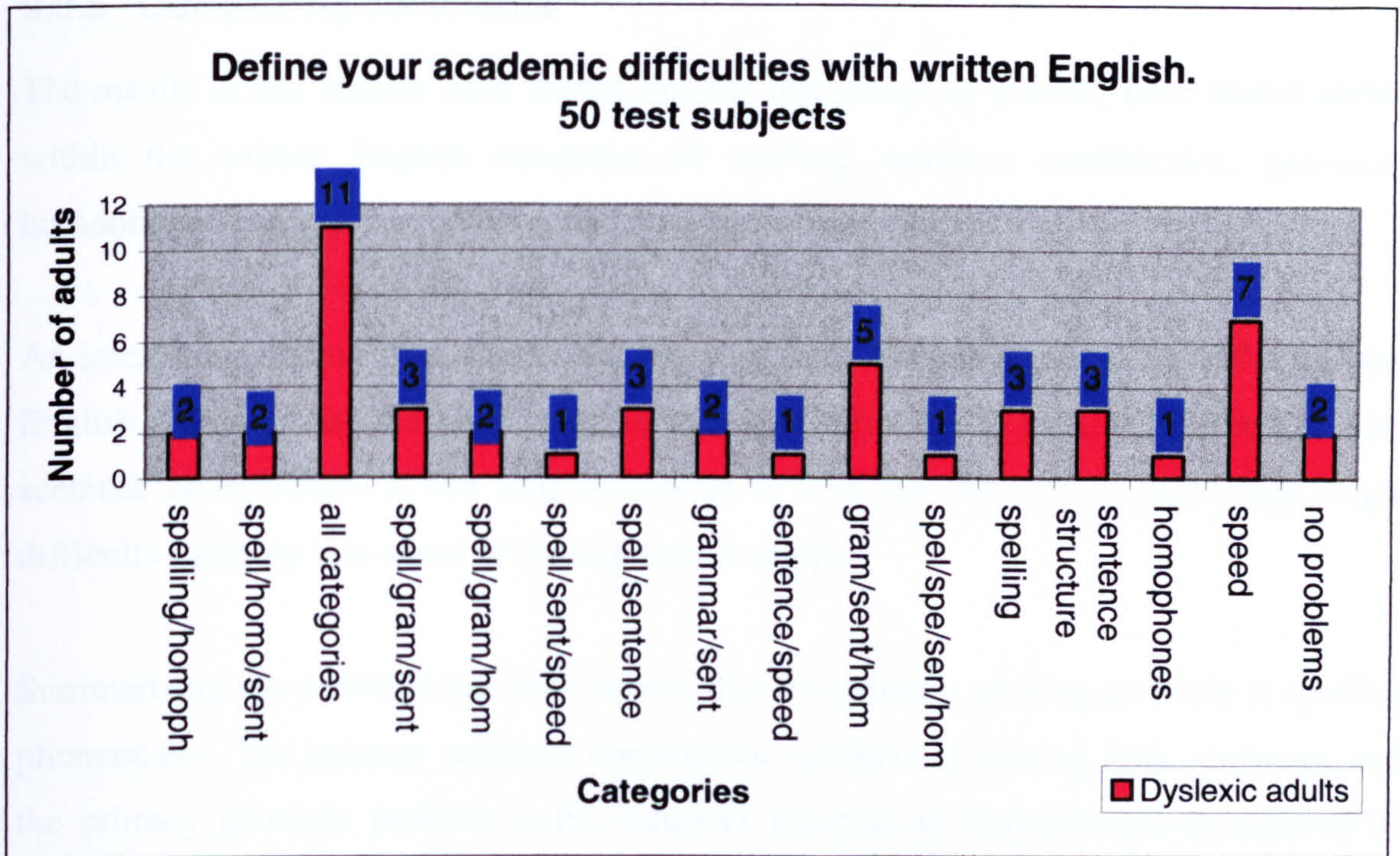


Figure 9.9. Reported academic difficulties with written English.

The next highest mixed category group (with the exception of all) was those test subjects who have difficulties with grammar, sentence construction and homophones. These results indicate that the test group is varied in the combination of difficulties individuals have. An analysis of the frequency of a specific difficulty being present within a mixed category is as follows:

- Spelling - 8 groups
- Sentence construction - 8 groups
- Homophones - 7 groups
- Grammar - 5 groups
- Speed - 5 groups

Grammar was the only difficulty, which was not selected in isolation. A low figure of 4% had no difficulties with written English (majority of 96% having some difficulties).

9.3.5 Concluding comments

The results in this section have shown that the test group, in general, have varied ability within the written English categories of spelling, sentence construction, grammar, homophones and speed of writing (and reading in some cases).

An interesting finding from the results was that three test subjects had no difficulty with English grammar and the same subjects were the only ones to have no difficulties with sentence construction. It was also interesting to find that the highest percentage single difficulty category was speed of writing (and reading).

Summarising the results it has been shown that the primary spelling problem is spelling phonetically. The primary sentence construction problem is writing long sentences and the primary grammar problem is the incorrect selection of homophones. A majority of 94% of the test group have some difficulty with sentence construction and grammar and a substantial majority of 84% have some difficulty with spelling. This category had the highest percentage of test subjects with no difficulties (16%). The next section will look at the degree of difficulty rather than the type.

9.4 Analysis of the written text produced by test subjects

This section attempts to evaluate the test subject's written material produced in terms of the number of errors that were made. It is the final section concluding the test subject's profile. This section follows on from the previous section but looks at the degree of difficulty rather than the type of difficulty. Other considerations are the quantity written and the time taken to complete the task. The written material being evaluated was created using the first environment: basic word processor with no support tools. This represents a subjects true academic ability. The categories are: spelling; grammar; homophones and sentence structuring.

This information is required to allow comparisons to be made with the test subject's academic problems and how useful they found each environment. Initial expectations would be that those subjects who liked environment 1 would have few academic

problems. Those subjects who favoured environment 2 would have problems with spelling but not sentence construction. Finally those that preferred the third environment would have problems with grammar, homophones and sentence construction and possibly spelling. It is also expected that those test subjects who have a slow writing speed would favour environment 3 and those with a slow reading speed will not.

This section also includes a general evaluation of the test group resulting in the accumulation of the most frequently miss-spelt words and incorrect homophone usage. This was provided to complete the test group general profile.

9.4.1 Errors made in the written text

Figure 9.10 depicts the grammar, spelling and homophone errors made by test subjects. The numbers in brackets refer to the total number of spelling errors. Grammar and homophone errors defined in categories: low, few, below average and high.

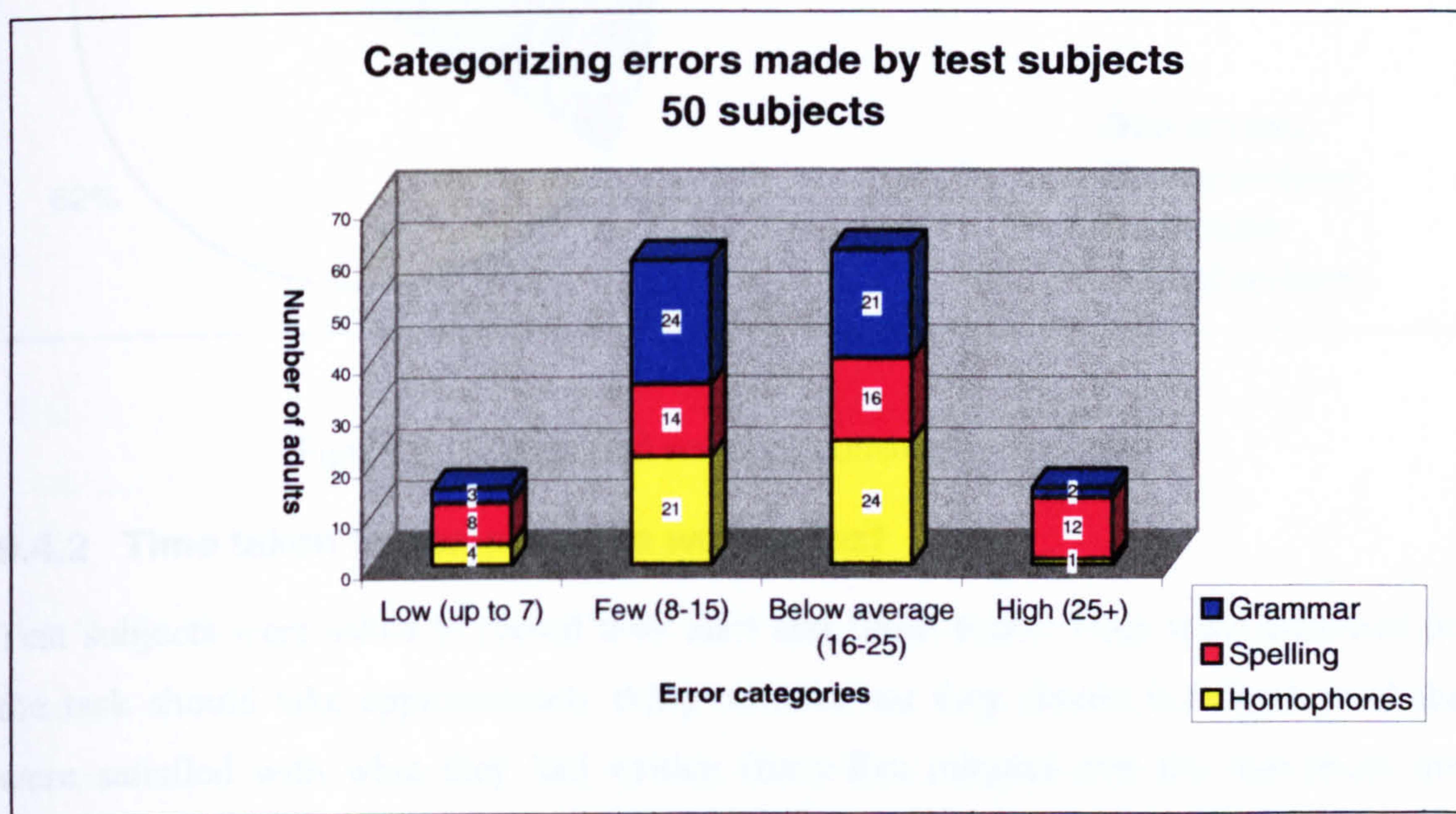


Figure 9.10. Written errors made by subjects.

The spell category shows similar numbers for all ranges, with only a difference of 8 adults between the upper and lower selected categories (8,12,14,16). 44% had under 16 errors and a majority of 56% had 16 errors and above.

The homophone category had highest numbers in the mid ranges. However, 50% of the test group had low or few homophone errors while the other 50% had a definite problem. A similar situation for the grammar category is also shown.

To complete this section the degree of difficulty associated with constructing sentences is included and Figure 9.11 provides a graphical representation of the results for this category. This shows that a very low figure of 6% (discussed in Section 9.3.2) of the test subjects had no difficulty constructing sentences. 66% had a problem (or major problem) in this area. These results reflect expectations.

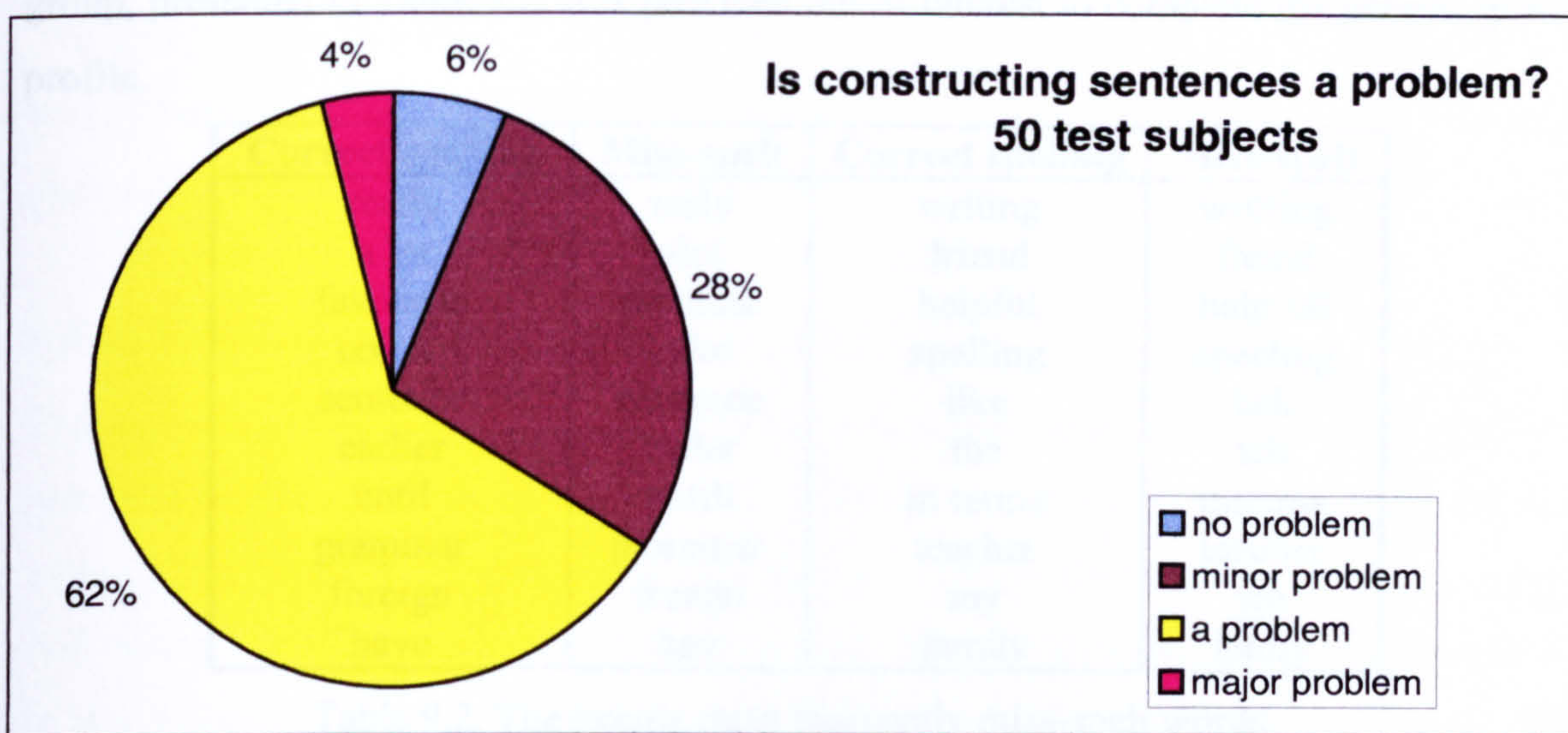


Figure 9.11. Reported sentence construction problems.

9.4.2 Time taken to complete the written text

Test subjects were asked to record their start and finish times. They were informed that the task should take approximately thirty minutes but they should not finish until they were satisfied with what they had written (forty-five minutes was the maximum time permitted). 60% of the test subjects completed the written text within 30 minutes (18% under 25 minutes). However, that also meant that 40% (12% over 40 minutes) of the test group took longer than the set time (recommended by the academic evaluator). This does not determine the subjects writing speed, as the quantity written will vary. This is covered in the next section.

9.4.3 Amount written

The results showed that 40% (16% writing more than 12 lines) of the test group wrote at least nine lines per section and 60% (16% writing under 6 lines) wrote 8 lines and under. A comparison with the time taken data (tables in Appendix A.9) indicates that the group is mixed in its writing speed.

9.4.4 A list of frequently miss-spelt words

This section provides a list of twenty most frequently miss-spelt words made by the test group, presented in Table 9.2. It is provided out of interest to complete the general group profile.

Correct spelling	Miss-spelt	Correct spelling	Miss-spelt
really	realy	writing	writting
a lot	alot	friend	freind
favourite	favorate	helpful	helpfull
colour	color	spelling	speeling
sentence	sentance	like	liek
earlier	earler	the	teh
until	untill	in terms	interms
grammar	grammer	teacher	teecher
foreign	foregn	my	ym
have	hav	family	famly

Table 9.2. The twenty most frequently miss-spelt words.

The miss-spellings are a mixture of phonetic, missing letters, joining words, word reversals and adding extra letters.

9.4.5 A list of words which are used incorrectly

The inability to select the correct word when presented with two words that either 'looks similar' or 'sound similar' is a real problem for made adults with dyslexia. A list of 20 most common misplaced words is shown in Table 9.3.

Word used	Correct word	Word used	Correct word
there	their (vice versa)	ware	wear
were	where	hear	here
to	too	no	know (vice versa)
though	through	as	has (vice versa)
affect	effect	weather	whether
seam	seem	wood	would
wright	right	hare	hair
us	use (vice versa)	gaol	goal
load	loud	being	been
suite	suit	quiet	quite (vice versa)

Table 9.3. The twenty most frequently misused words.

The words presented are in two categories: words that look very similar (suite suit) and words that sound the same (there their). There were many others but these were the most common mistakes made by the test group.

9.4.6 Concluding comments

The aim of Section 9.4 was to complete the test subject profile. The importance of the profile is to reduce bias by showing how varied the group is. The developed environments must be evaluated by a varied group but within a certain academic range. Also the profile will be used to undertake a more detailed analysis to form conclusions (in Chapter 10). It is also essential to be able to combine the results defined so far with results to be drawn from the next four sections. These will be concerned with the environment evaluations.

9.5 Generalised analysis of academic and usability grades

This section is concerned with the evaluation of the three environments in terms of the grades (academic and usability) given. The grade scale was defined in Chapter 8 (Section 8.5) and this knowledge will be assumed. The environments were developed in order to evaluate the research hypothesis by allowing the test subjects to work within three different environments. The test subject's ability (profile) has already been established in previous sections to achieve a true evaluation of the environments.

9.5.1 Environment 1: Basic word processor

Environment 1 (which will be referred to as env1 within this section) is a basic word processing system with no support tools. The layout and default colour scheme used was designed from the requests made by dyslexic adults who took part in the initial surveys (see Chapter 4 and design details in Chapter 5). The system is uncluttered and only includes features that are required to complete the written text. It is very important that the text and background colours are set to the test subject's preferences. As many dyslexics are not aware of what these preferences are the system makes it very easy to change the settings. This will allow them to experiment. This environment will result in written work being produced in its 'raw state' as no support tools are provided. This forms an academic base line. The text produced from this environment was analysed in Section 9.4.

9.5.1.1 Usability and academic grades comparison

The diagram depicted in Figure 9.12 shows all the grades given for this environment.

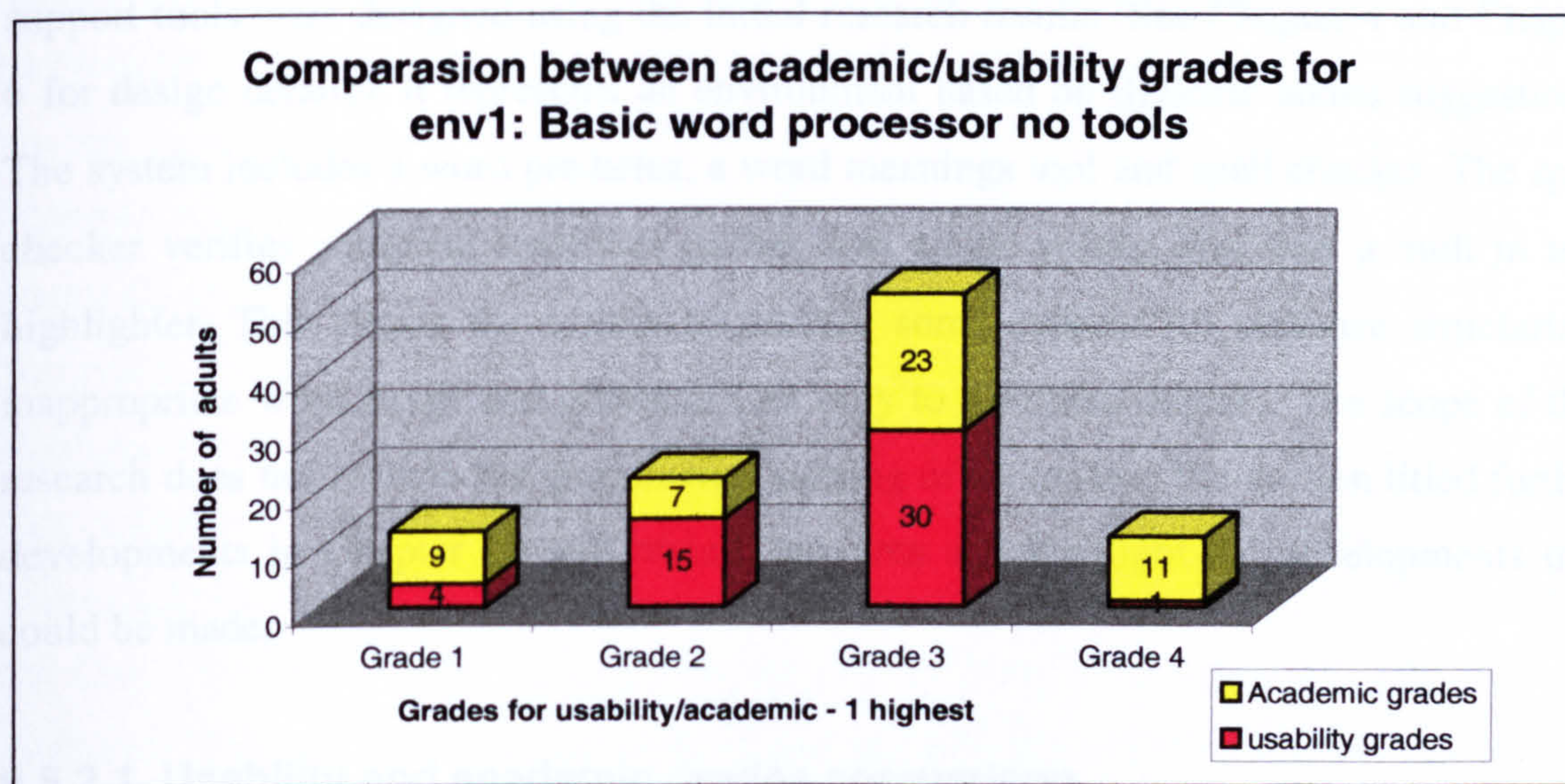


Figure 9.12. Academic and usability grades.

It can be seen that grade 3 is by far the most popular grade. This academic grade level represents below average ability. On a test subject's usability grade level it represents an environment that needs improvements to be of use. The academic grades were more diverse across the grade range compared with the usability grades. This is expected as the

profile indicated a varied sample. 68% of the test group received below average academic grade ratings. It can therefore be assumed that for this percentage of the group (at least) support is required in order for them to achieve acceptable grades. This in some respects mirrors the usability grades at a majority of 62% selecting the highest grades (3 and 4), representing improvements required.

Further evaluation will be undertaken to investigate the profile of the four dyslexic adults who gave this environment a grade 1 (in Section 9.6.3). It would also be interesting to compare their academic grades to see if they would benefit from support. The opinion of the author is that they were comparing this system with Microsoft Word or a similar word processor.

9.5.2 Environment 2: word processor and support tools

This environment provides the same basic system with the addition of spelling support tools to assist the dyslexic adults with their written tasks. The environment and associated support tools were designed using the initial research results (See Chapter 4 and Chapter 6 for design details). It represents an environment based on dyslexic adults suggestions. The system includes a word predictor, a word meanings tool and spell checker. The spell checker verifies complete sentences (rather than single words) and uses a built in text highlighter. This allows the system to provide some support for sentence structuring, inappropriate word usage and grammar (but only to a limited degree). The scope of this research does not include the grammatical parsing of sentences. The section titled further developments in Chapter 10 will review this area and highlight the developments that could be made.

9.5.2.1 Usability and academic grades comparison

The diagram depicted in Figure 9.13 shows all the grades given for this environment. It can be seen that 70% of the test subjects selected the usability grade 2 representing an environment that is liked but requires a few additions to make it ideal. 22% selected the usability grade 1 representing an ideal environment. Only 8% selected the usability grade 3 and no test subjects selected grade 4.

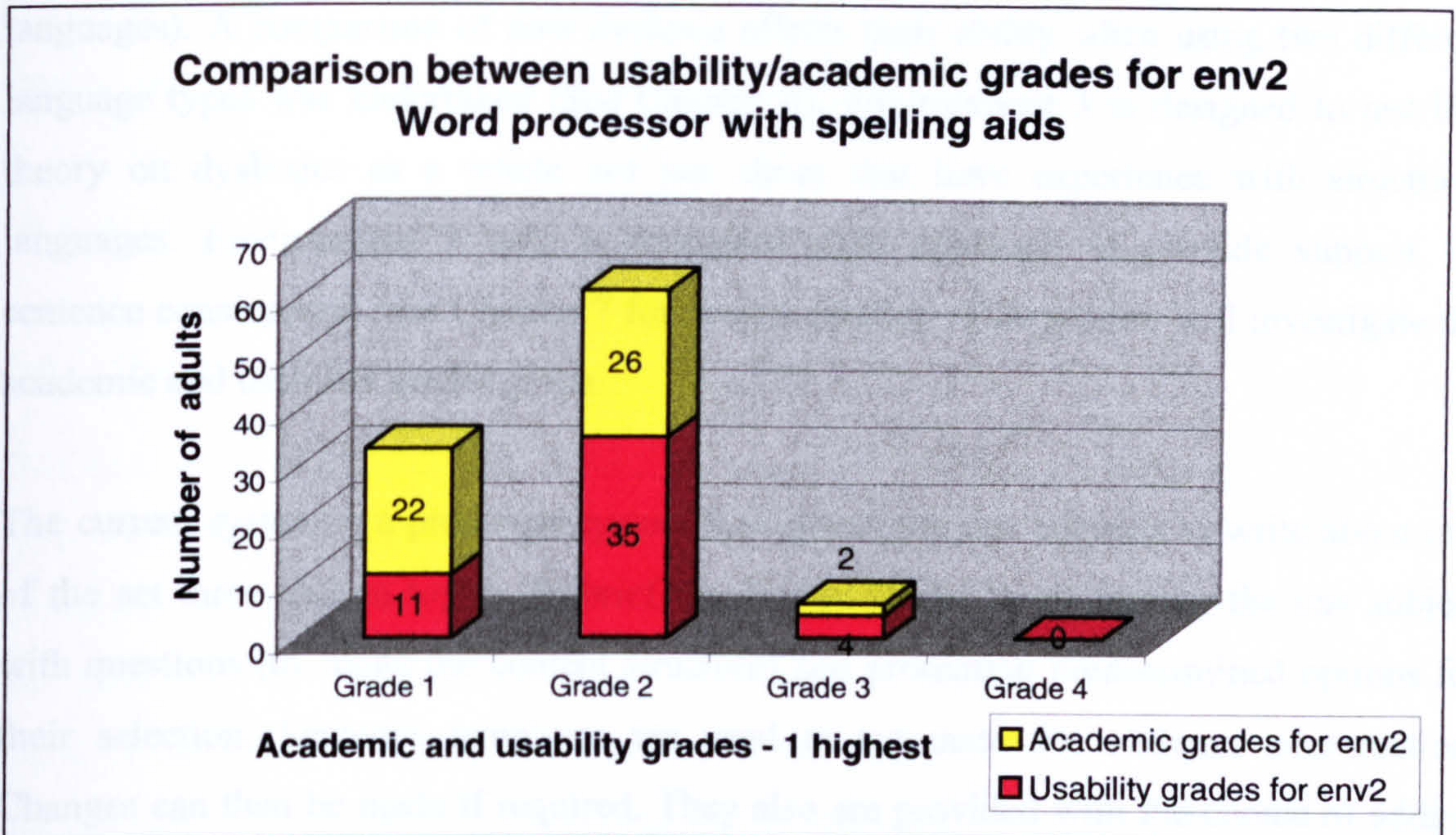


Figure 9.13. Academic and usability comparisons for env2.

The academic grades are very impressive with 44% of the test group achieving the highest grade of 1. 96% of the test group achieved the two highest academic grades. This environment does not provide any direct support for grammatical errors. However, from the test group profile it was shown that the main problem the test group had with grammar was selecting the wrong homophone (although technically this is not a part of grammar, as previously explained). The spell checker provides homophone support and the word meanings support tool also helps with homophone selection. The text highlighter makes subjects aware of the length of sentences, which shall result in fewer long sentences. This was the main problem associated with sentence construction. An interesting result is the number of academic grade 1's is double that of the usability grade 1's. Only five test subjects (out of a possible 11) had grade 1's for academic and usability categories. This indicates that the subjects did not feel they were getting the best support possible although the academic results were high.

9.5.3 Environment 3: sentence constructor

The research hypothesis is based on the concept that the structure of the language and level of rigidity affects dyslexic adults abilities. This has been evaluated using dyslexic adults who have experience with structured languages (computer programming

languages). A comparison of how dyslexia affects their ability when using two different language types was undertaken (See Chapter 4). Environment 3 is designed to test this theory on dyslexics as a whole not just those that have experience with structured languages. Environment 3 uses a structured rigid approach to provide support for sentence construction (see Chapter 7 for design details). This section will investigate the academic and usability grades given.

The current system is a prototype system that allows the test subjects to write about one of the set three chosen topics. In brief the system works by prompting the test subject with questions (to create the content structure) and presenting predetermined options for their selection. Sentence templates are used to automate the sentence construction. Changes can then be made if required. They also are provided with the choice of adding their own option, which would then be validated by the spell checker (used in the previous environment). This system offers the highest level of support and is based on the concepts that order and structure are very important. Full support for grammar, sentence construction and spelling is provided. This environment is also very suited to those who have a slow writing speed. However, this system does require a substantial amount of reading that could be a problem for some test subjects.

9.5.3.1 Usability and academic grades comparison

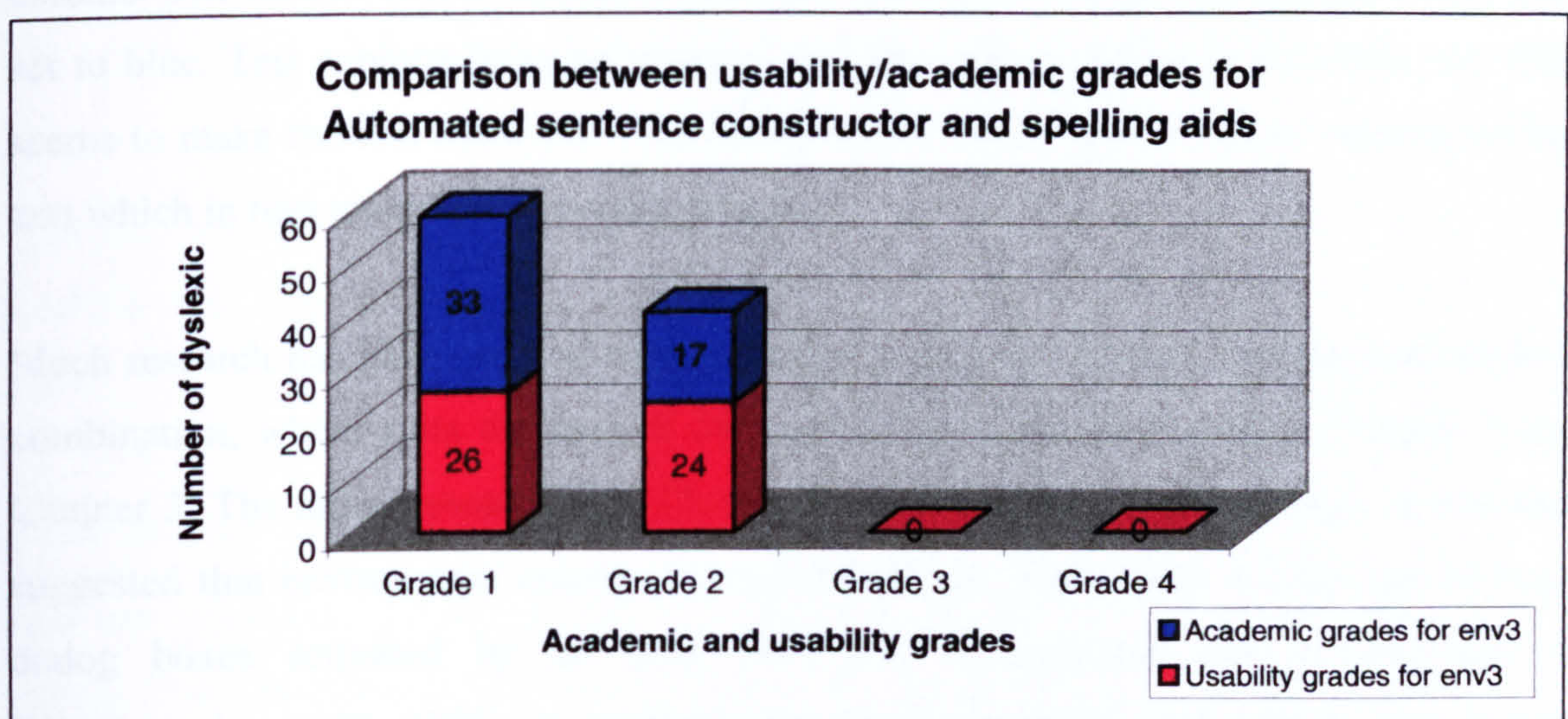


Figure 9.14. Academic and usability comparisons for env3.

Figure 9.14 shows that this environment achieves very high academic and usability grades. 66% of the test subjects achieved the highest academic grade. A majority of 52% of the test subjects graded this environment first rate. 38% of the subjects had grade 1's for both academic and usability categories.

9.6 Detailed evaluation of environment 1

This section is concerned with providing a detailed evaluation of environment 1, taken from the written evaluation comments made by the test subjects. The first section establishes whether the test subjects liked the default environment colours or whether they had their own preferences. The next section establishes whether the test subjects prefer to use icons or menus to make selections. Included in this section is a review of whether they liked the uncluttered layout of this environment.

The final section provides a detailed analysis of the test subjects who gave this an extreme grade of 1 or 4. Their profile will be investigated to see if a pattern exists and the degree to how it affects their ability to work within this environment.

9.6.1 Environment colours

An important feature associated with environment 1 is the setting of the environment colours. The default colour setting for the text was white and the background colour was set to blue. Test subjects have commented that the contrast between the white and blue seems to make the text stand out. This increases the concentration when focusing on the text which in turn makes proof reading easier.

Much research has been done on how effective it is to set the environment colours to a combination, which suits the user of the system. This was discussed in Chapter 2 and Chapter 3. The initial research (see Chapter 4) provided the default settings. It was also suggested that environment colour selection should be made easier by the use of large dialog boxes activated by an icon. This was incorporated into environment 1. Experimenting with different colours can be very worthwhile until the correct combination is found.

Microsoft Word makes it very easy to change the colour of the text but fails to recognise that it is the contrast between the text and background colours, which is important. In order to change the background colour a layered menu system is used. This can be difficult for many dyslexics and the ability to remember where the option is located can also cause a problem. Although the test subjects were not asked directly to comment on changing the environment colours using the developed system, many subjects wrote favourable comments in the user evaluation.

The test subjects were asked to comment on the environment colours in terms of whether they liked the default options or whether they made their own selections. These results are shown in Figure 9.15.

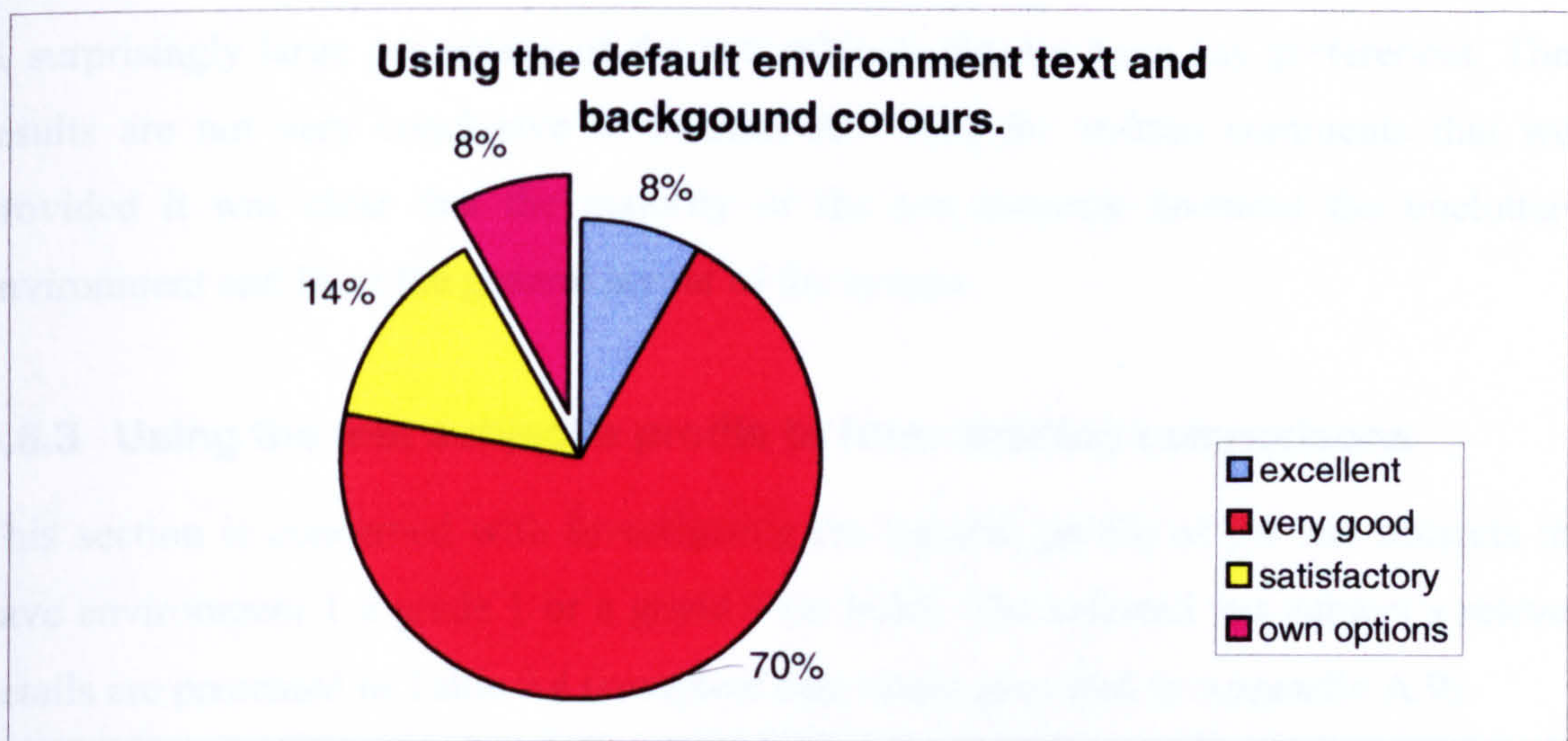


Figure 9.15. Reported colour preferences.

This shows that only 8% of the test group did not like the default colour settings and selected their own options. 78% thought the environment colours were excellent or very good.

9.6.2 Icon and menu selections

The test subjects were asked whether they preferred to make selections via icons or menus. The results depicting the test group preferences are shown in Figure 9.16.

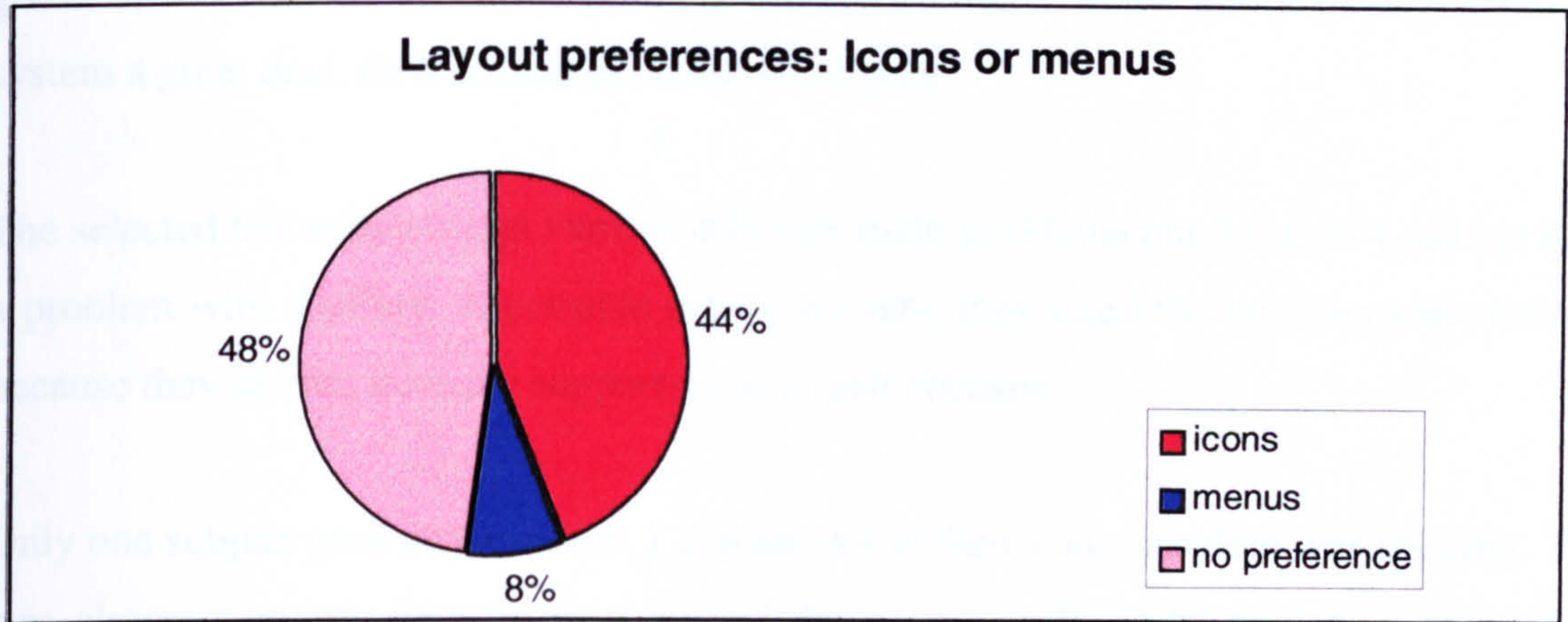


Figure 9.16. Reported icon and menu preferences.

44% of the test group preferred using icons in place of menus. Only 8% preferred menus. A surprisingly large percentage of the test subjects did not have any preferences. These results are not very conclusive in themselves. From the written comments that were provided it was clear that the majority of the test subjects favoured the uncluttered environment and liked the general layout of the system.

9.6.3 Using the test subject's profile to form detailed comparisons

This section is concerned with investigating the general profile of the test subjects that gave environment 1 a grade 1 or a grade 4 (in bold). The selected test subject's relevant details are presented in Table 9.4 (complete data tables provided in Appendix A.9).

Stud Id	Usab. grade	Acad. grade	Spelling	Gram	Sentence structure	Speed	Homo errors	Main Problem
Stud8	1	3	2	3	3	2	2	Gram/sen
Stud23	1	3	3	2	3	2	2	Spell/sen
Stud24	4	3	3	2	2	2	2	Spelling
Stud30	1	3	2	2	2	3	2	Speed
Stud50	1	3	2	2	2	3	2	Speed

Table 9.4. Subjects giving env1 a usability grade 1 or grade 4.

The grading system used for spelling, grammar, sentence structuring, speed and correct homophone usage is 1 no problem and 4 major problem with 2 and 3 mid ranges. It can be seen from the table, that three out of four of the test subjects that gave environment 1 a

grade 1, received an academic grade 3 (below average). Thus, although they liked the system a great deal, their academic results were poor.

The selected test subjects had various different main problems but 3 out of 4 did not have a problem with spelling. A possible reason for why they liked the environment could be because they did not miss the support from a spell checker.

Only one subject gave environment 1 a grade 4 and their main problem was spelling. This was almost certainly because they missed the support offered by a spell checker. This completes the evaluation for environment 1.

9.7 Detailed evaluation of environment 2

The aim of this section is to evaluate environment 2. This environment is similar to environment 1 with the addition of a spell checker (with inbuilt text highlighter), word meanings tool and a word predictor.

The environment design is based on requirements specified by the dyslexic adults who took part in the initial research (discussed in Chapter 4). The test subjects provided written evaluation comments that were used in this section.

9.7.1 General opinion of the spell checker

The spell checker was designed specifically for adults with dyslexia. It includes many reference word files including homophone and phonetic spellings. The test subjects were asked to give their general opinion of the developed spell checker. The results are presented in Figure 9.17.

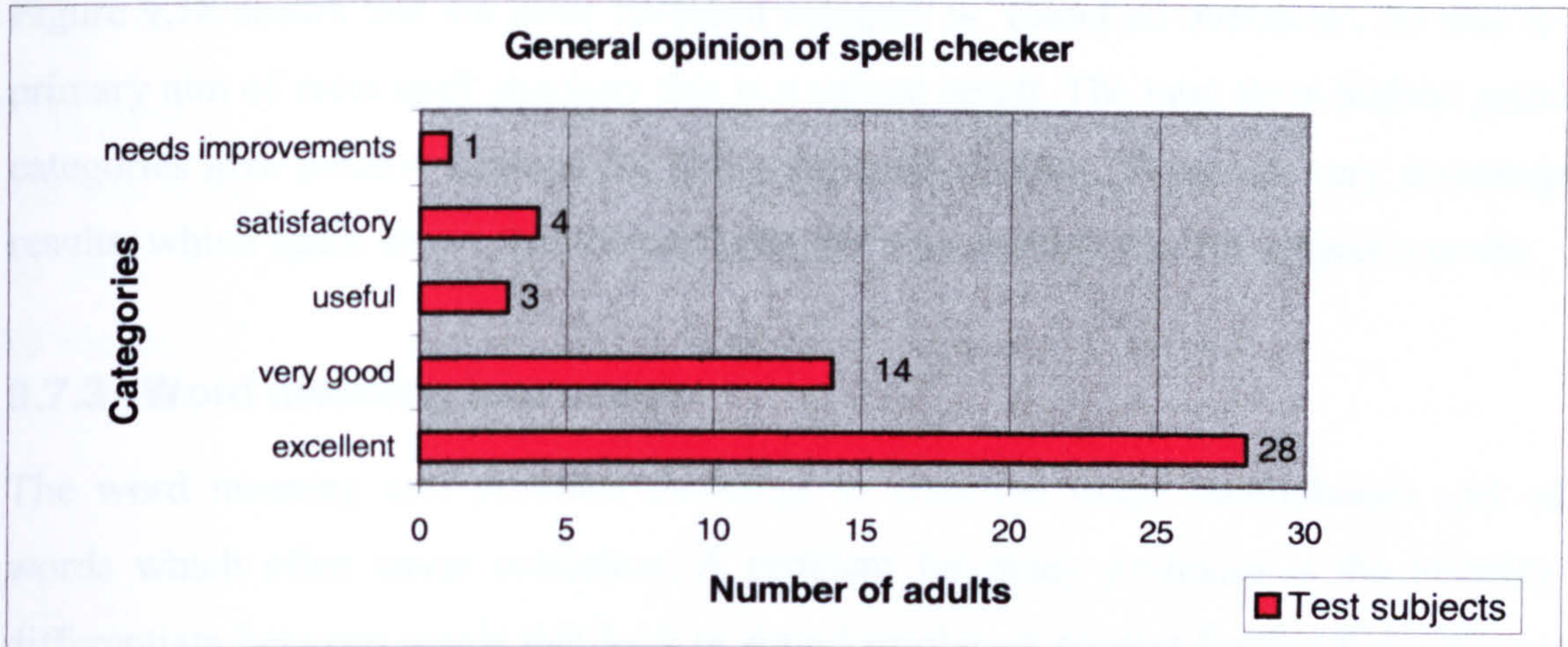


Figure 9.17. Reported opinion of spell checker.

Figure 9.17 shows that 84% of the test group rated the spell checker either very good or excellent. Only 2% thought the spell checker needed improvements. These are very pleasing results, concluding that the design taken from the initial survey results was correct. The test subjects base their opinion on comparisons with systems they have used. This therefore provides a comparison with currently available systems.

9.7.2 Main reason for opinion

The test subjects were asked to give a reason to substantiate their general opinion of the developed spell checker. The results are shown in Figure 9.18.

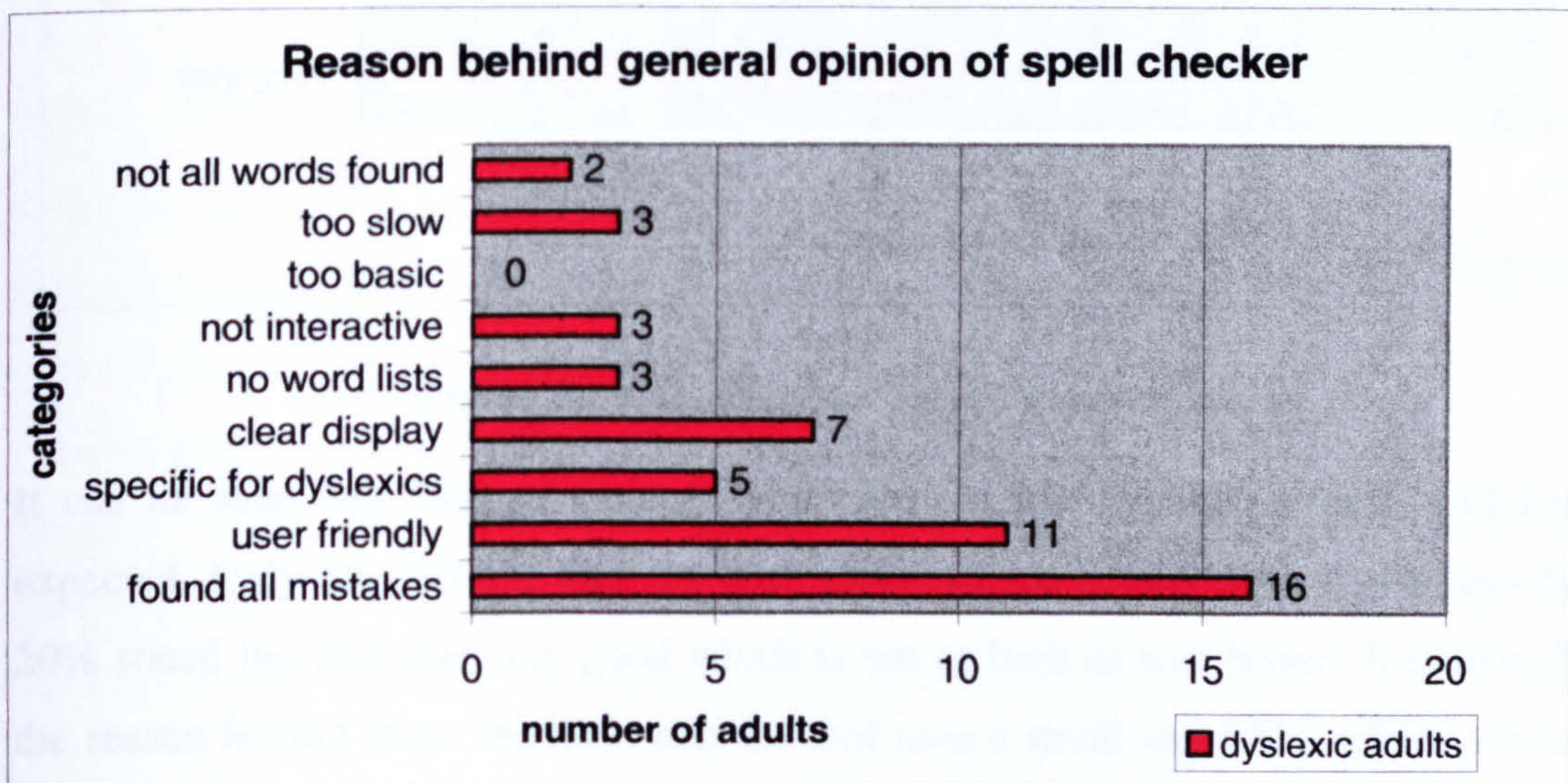


Figure 9.18. Reasons behind opinion of spell checker.

Figure 9.18 shows that the most favoured category is 'found all mistakes'. As this is the primary aim of most spell checkers this is a valued result. The next three highest selected categories give positive reasons for liking the spell checker. These are very encouraging results, which again shows that the spell checker was meeting the test subject's needs.

9.7.3 Word meaning tool usage

The word meaning tool provides meanings to common usage homophones and other words which often cause confusion. A problem for many dyslexics is the inability to differentiate between words that look or sound similar. A request for this type of support was made during the initial research. In an ideal situation the spell checker would provide word meanings when a replacement word was selected. Unfortunately the scope of this research was not able to include this. However, this tool does provide some support if in a minimal way. The test subjects were asked to comment on whether they needed to use the tool and if so was it useful. The results are shown in Figure 9.19.

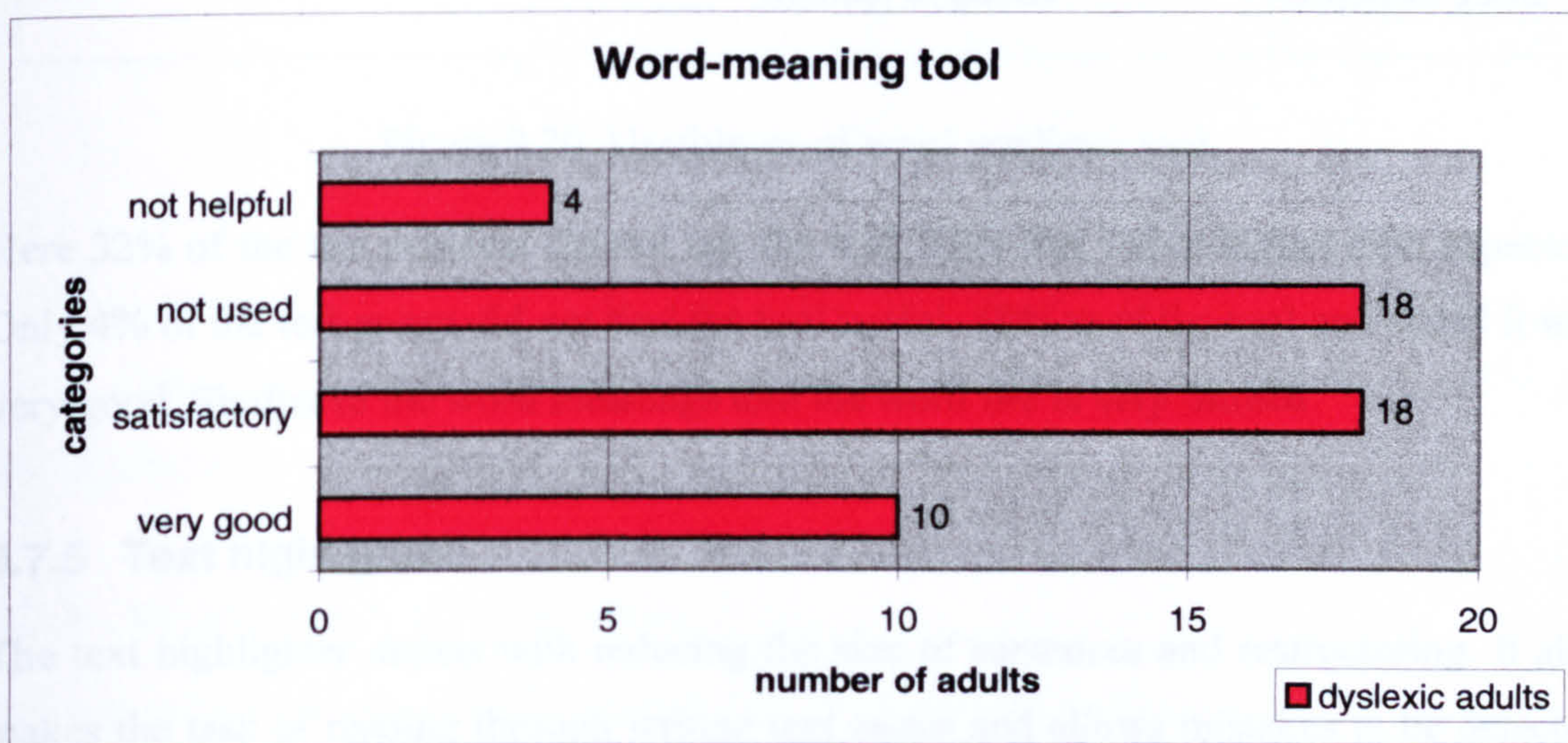


Figure 9.19. Usefulness of word meaning tool.

It can be seen that 36% of the test group did not use the tool, which is higher than expected. Only 8% did not find the tool useful which is very low. Unfortunately only 20% stated the tool was very good which is not as high as was hoped. It is thought that the reason behind these results is that the tool uses a small word file, which needs to be expanded upon to be of any real use. Evidence from this is found in the test subject's comments, where they stated that frequently the word they entered was not found.

9.7.4 Word predictor tool

The word predictor tool attempts to assist with spelling by offering suggestions based on the first letters entered. The initial research indicated this type of support was required in an ideal environment. The test subjects were asked to comment on whether they needed to use the tool and if so was it useful. The results are shown in Figure 9.20.

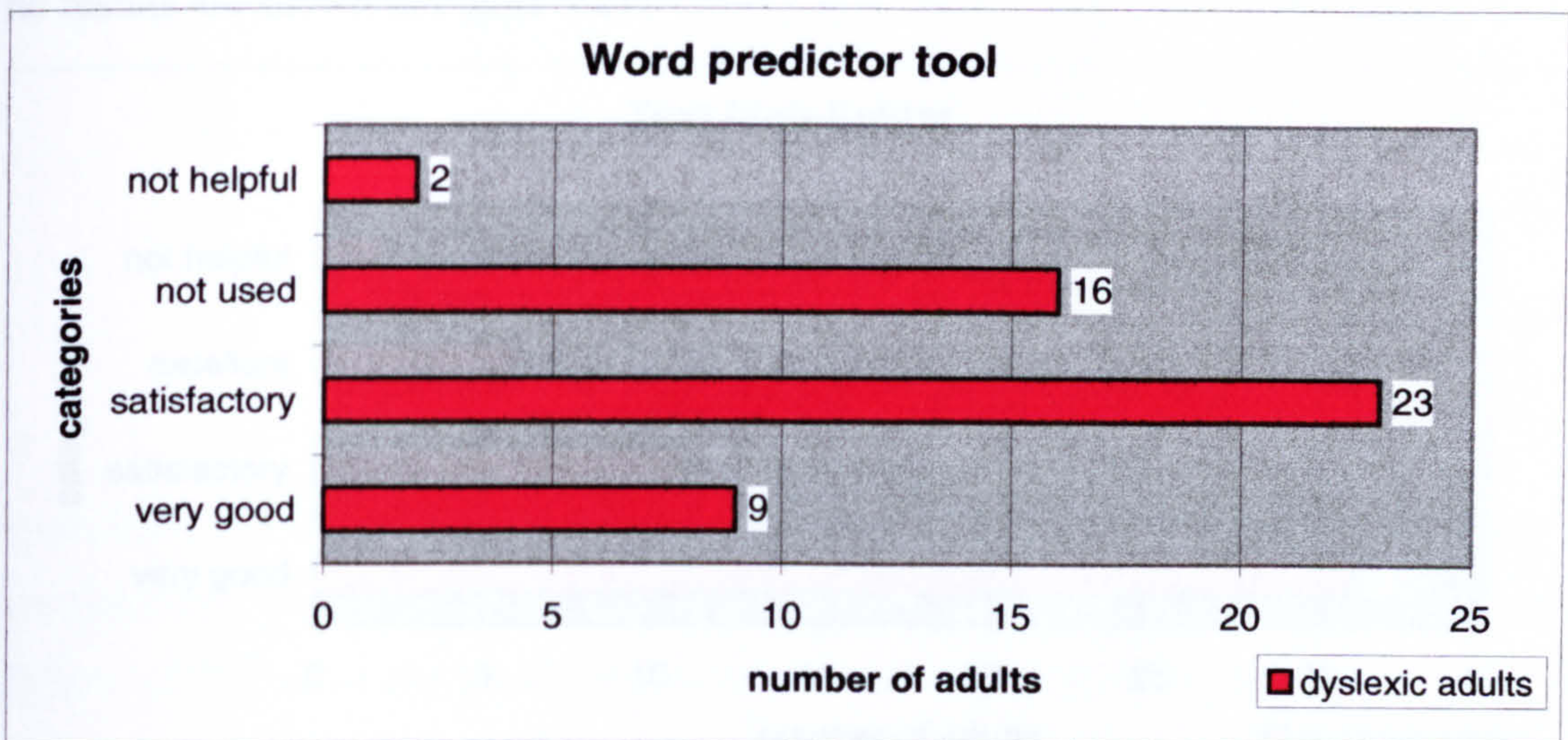


Figure 9.20. Usefulness of word predictor tool.

Here 32% of the test subjects did not use the tool. This was rather higher than expected. Only 4% of the test group did not find the tool useful. 18% used the tool and stated it was very good. Similar to the word meanings tool the word file is very limited.

9.7.5 Text highlighter

The text highlighter assists with reducing the size of sentences and restructuring. It also makes the task of reading through written text easier and allows mistakes to be detected and corrected. This is because the sentence is isolated and this allows them to focus on a relative small number of words. Each sentence is presented in a dialog display box before the spell checker verifies each word and suggests replacements. Changes can be made then the sentence (each word) is verified. The sentence is redisplayed and the test subject is able to modify and split the text into smaller sentences if necessary.

The text highlighter alerts the user to the length of the sentence by presenting it in isolation. Often dyslexics do not notice how long their sentences are as reading text from a computer screen can be a problem. The primary difficulty associated with constructing sentences is writing long sentences, which the text highlighter provides some assistance with. The test subjects were asked to comment on the usefulness of the text highlighter. The results are shown in Figure 9.21.

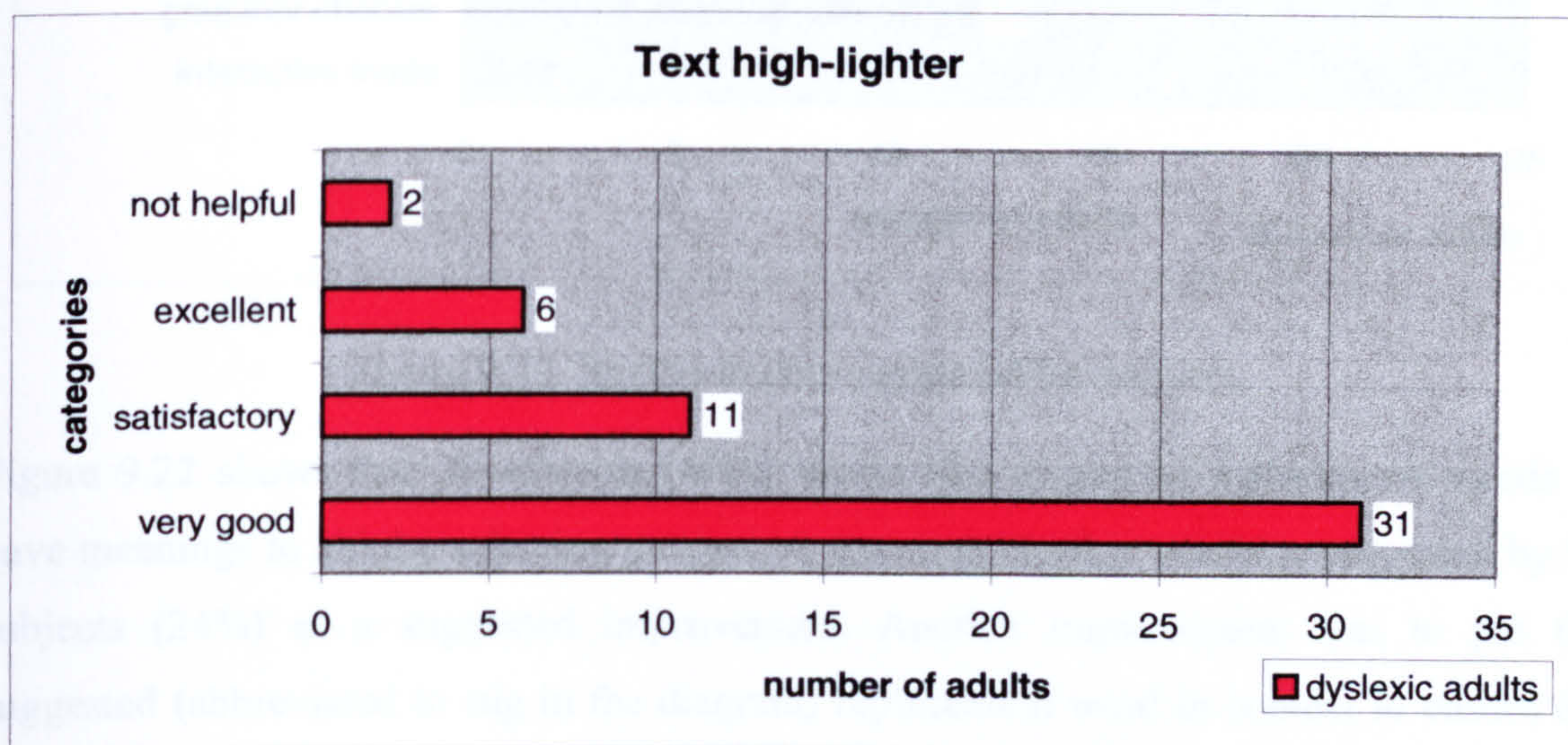


Figure 9.21. Usefulness of text highlighter.

74% stated the text highlighter was very good or excellent. This is a very encouraging result. Only 4% stated the text highlighter was not helpful. It would seem that this is a useful addition to the spell checker.

9.7.6 Suggested improvements

The test subjects were asked to comment on any suggested improvements they felt would be useful. There was a very varied selection of suggestions, which are shown in Figure 9.22.

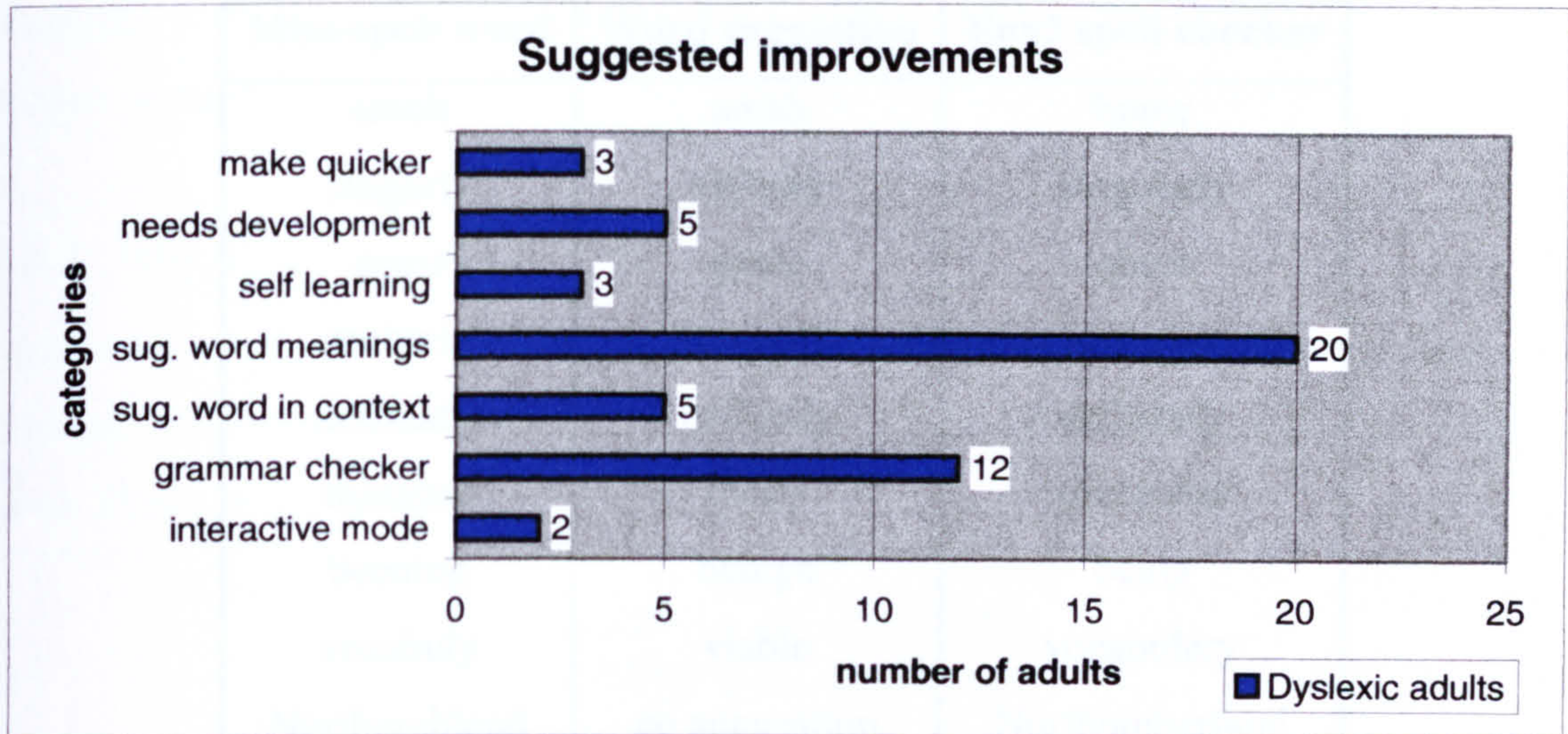


Figure 9.22. Improvements suggested by subjects.

Figure 9.22 shows that 20 subjects (40%) would like suggested replacement words to have meanings to aid the selection process. A grammar checker was also requested by 12 subjects (24%) as a suggested improvement. Another improvement was to put the suggested (abbreviated to sug in the diagram) replacement word in context to ensure the correct use of the words.

9.7.7 Comparison with Microsoft Word spell checker

In order to conclude the evaluation of environment 2 the spell checker in this environment was compared with the Microsoft Word spell checker. A random selection of test subjects written text (before the spell checker was used) was spell checked using the Microsoft spell checker. A comparison was made between the two spell checkers. All words that either the spell checker could not find (or offer the correct suggestion) were noted. A selection of these words is presented in Table 9.5.

8.8 Detailed evaluation of env3

This environment offers a spell checker to write English. The operation of this system is to take a word and offer an example. The system is designed to treat a natural language like a second language. It uses the spell checker to correct the

Miss-spelt word	Word suggestion	Env2 spell checker
emoh	amah	home
singurly	sinfully	singularly
goast	goals	ghost
proberly	property	probably
deffinatly	defiantly	definitely
thasause	thesis	thesaurus
beening	benign	being
vocabuly	viable	vocabulary
Northumbland	no suggestion	Northumberland

Table 9.5. Comparison spell checkers

It can be seen from Table 9.5 that the Microsoft Word spell checker does not offer correct suggestions if the miss-spelt word is reversed (emoh home). Also the correct suggestion was not offered for some words that were spelt phonetically (goast ghost).

The test subjects were not asked directly to compare spell checkers but many of them did while describing the benefits of the environment 2 spell checker. The most frequent positive comparison was that the Word spell checker presents suggested words in a list, which makes the selection a problem. Environment 2 spell checker presents words singularly causing less confusion. Another positive comparison was that the environment 2 spell checker caters for reverse word spellings (common mistake especially for short words) which Microsoft Word spell checker does not. A negative comparison is that the Microsoft Word spell checker works interactive and automatically changes some spellings, whereas the environment 2 spell checker does not. Environment 2 spell checker is also slower because it includes the text highlighter, which cannot be switched off.

9.8 Detailed evaluation of env3

This environment enforces a rigid structure to written English. The components of each sentence are combined in a set order with no exceptions. The environment is designed to treat a natural language as a structured language. It uses the spell checker to verify any

additional text added by the test subjects (accessed via add or view-change buttons). This section presents the results from the test subjects' evaluations of this environment.

9.8.1 Use of dialog function buttons

Function buttons are provided for support (help button) and for flexibility (add and view-change). This section is concerned with the results depicting how useful these functions were. These results are shown in Figure 9.23.

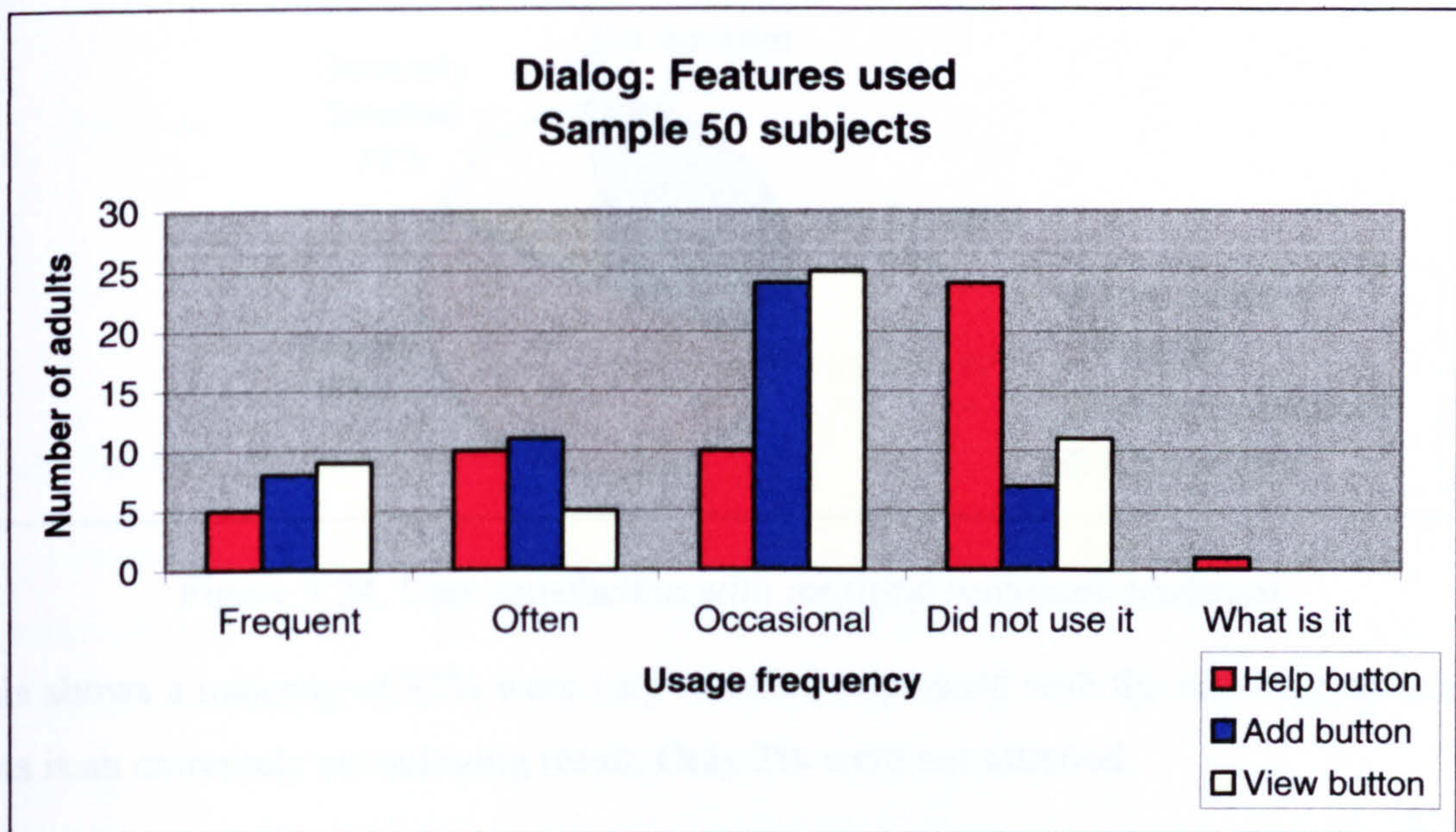


Figure 9.23. Function button usage.

From this, the 'help' function button was used least. This would suggest that this level of support was not required. The 'add' button was the most frequently used function button. However, the view-change button was a very close second. The highest usage category was 'occasional'. This would indicate that in general predefined options were satisfactory. Only occasional use of the add button (to add their own option) or view-change button (to view or change the sentence) was required.

9.8.2 Resulting sentences

This environment takes the selected options (or spell checked text entered using the add button) and forms a sentence using the linked sentence template. The test subjects were asked whether they were satisfied with the sentences produced. The results are shown in Figure 9.24.

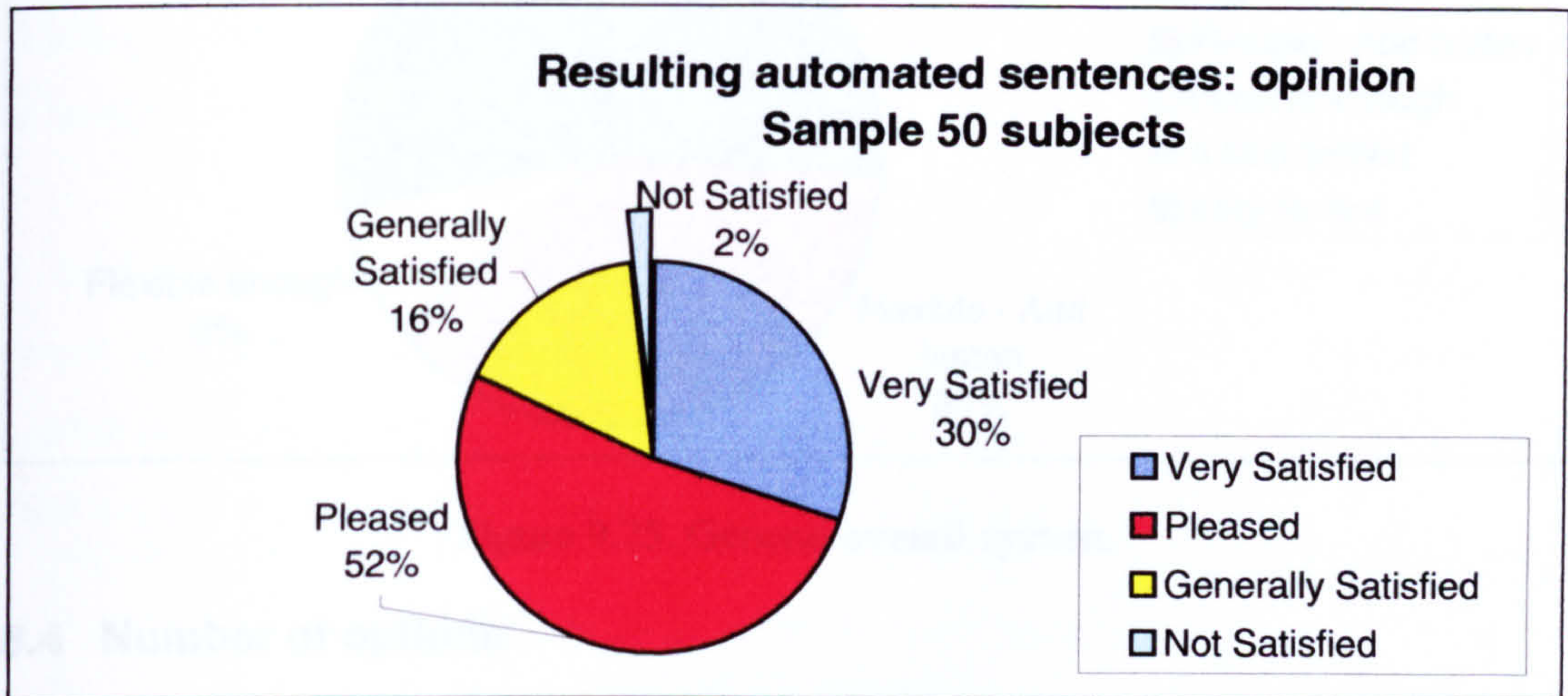


Figure 9.24. User satisfaction with resulting sentences produced.

This shows a majority of 82% were very satisfied or pleased with the resulting sentences. This is an extremely encouraging result. Only 2% were not satisfied.

9.8.3 Level of general overall system

The test subjects were asked whether they felt the overall system was set at the correct level to be useful, in terms of flexibility. The results are presented in Figure 9.25. A majority of 72% of the test subjects stated the system was set at the right level or flexible enough for the task. The largest single group stated that the system was flexible because of the use of the 'add' button. 8% felt it was flexible enough without referring to any particular reason. Only 2% (one subject) stated the system was very limited.

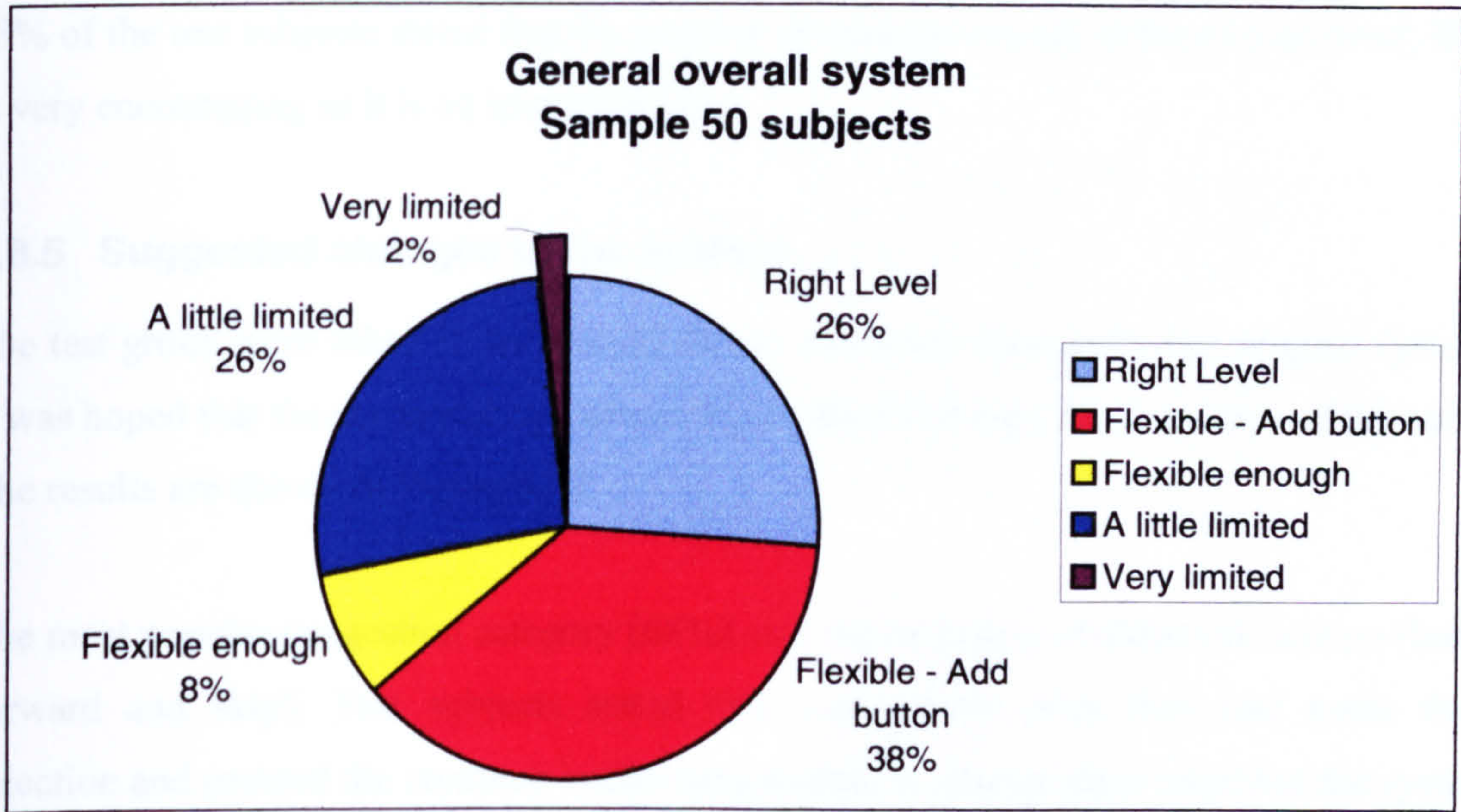
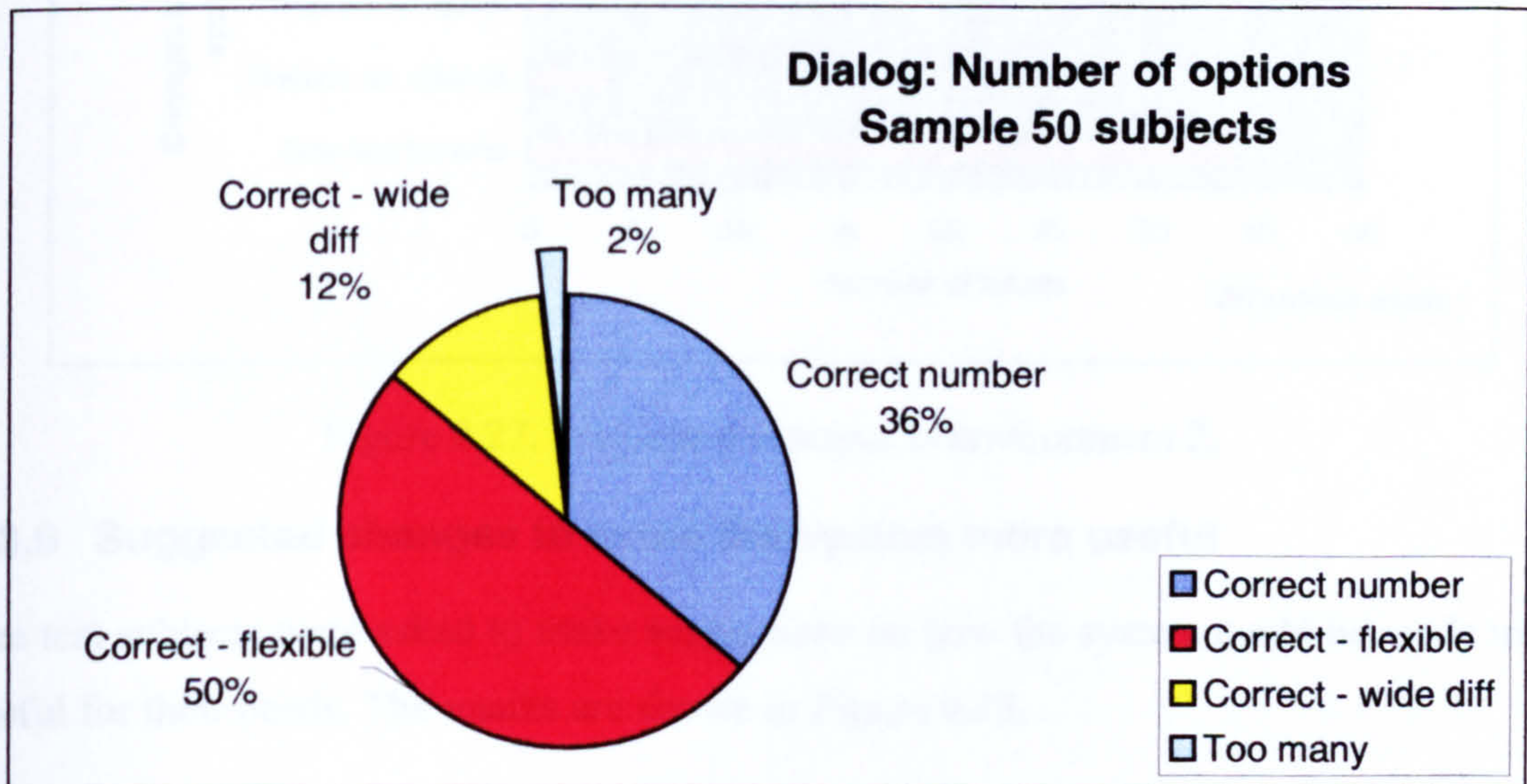


Figure 9.25. General overall system.

9.8.4 Number of options

The number of options provided per question is quite a difficult thing to get right. It is important to offer a wide selection to cater for differences but this must be offset against the amount of reading that is required. The results defining the views of the test subject are in Figure 9.26.



*Figure 9.26. Number of presented options per question.

* Abbreviations: wide diff = wide difference

98% of the test subjects stated that the number of options was set at the correct level. This is very encouraging as it is an important issue.

9.8.5 Suggested changes to the system

The test group were asked if they would like to make any changes to the original system. It was hoped that these suggestions would be included in future developments of the tool. The results are shown in Figure 9.27.

The most popular suggestion category (68%) was the inclusion of direction buttons (back, forward and skip). Test subjects stated that occasionally after they had made their selection and pressed the continue button they wanted to change their mind but the system would not allow this. Also they were not able to choose to skip questions

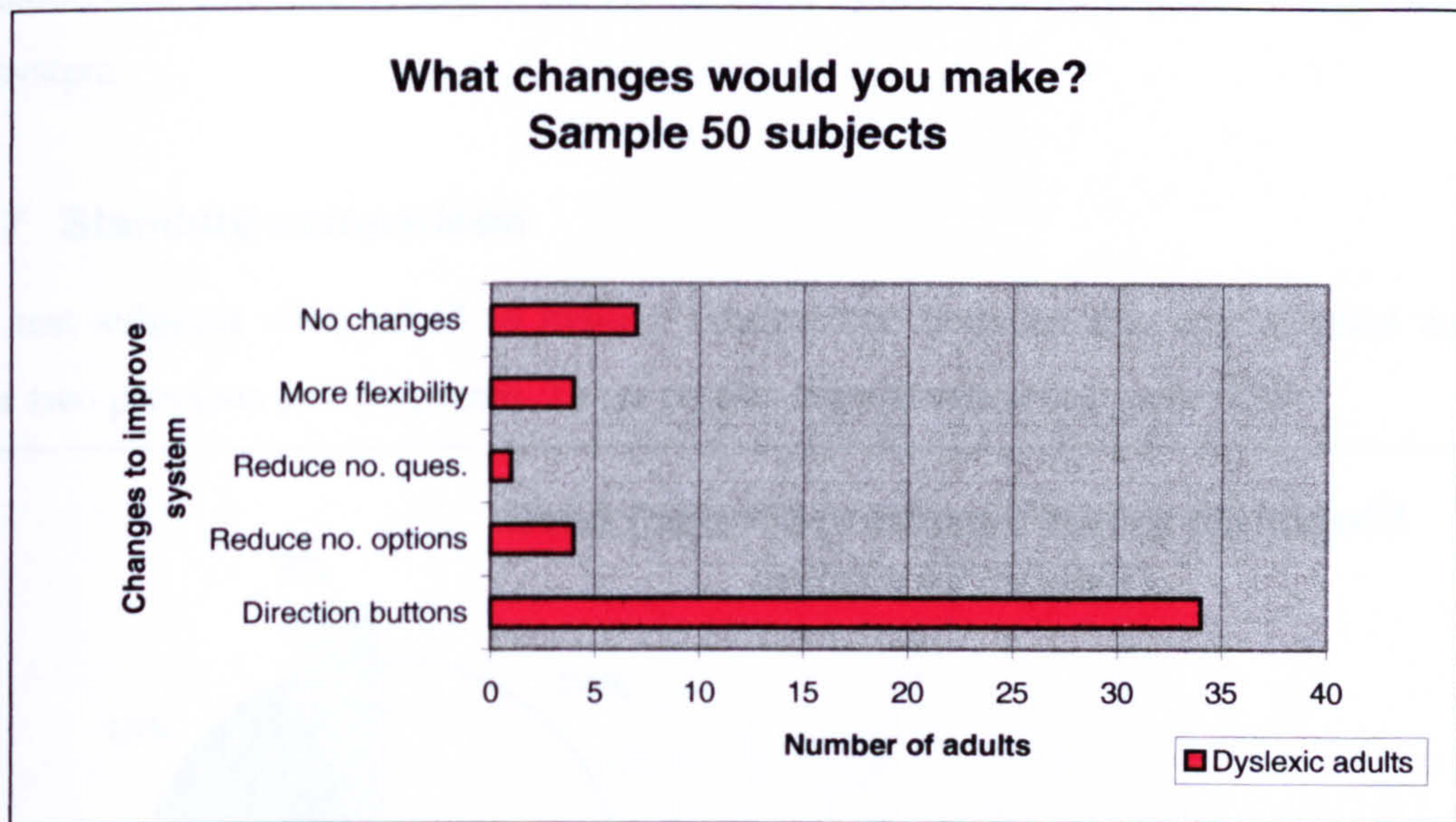


Figure 9.27. Requested changes to environment 2.

9.8.6 Suggested changes to make the system more useful

The test subjects were asked to make suggestions on how the system could be made more useful for their needs. The results are shown in Figure 9.28.

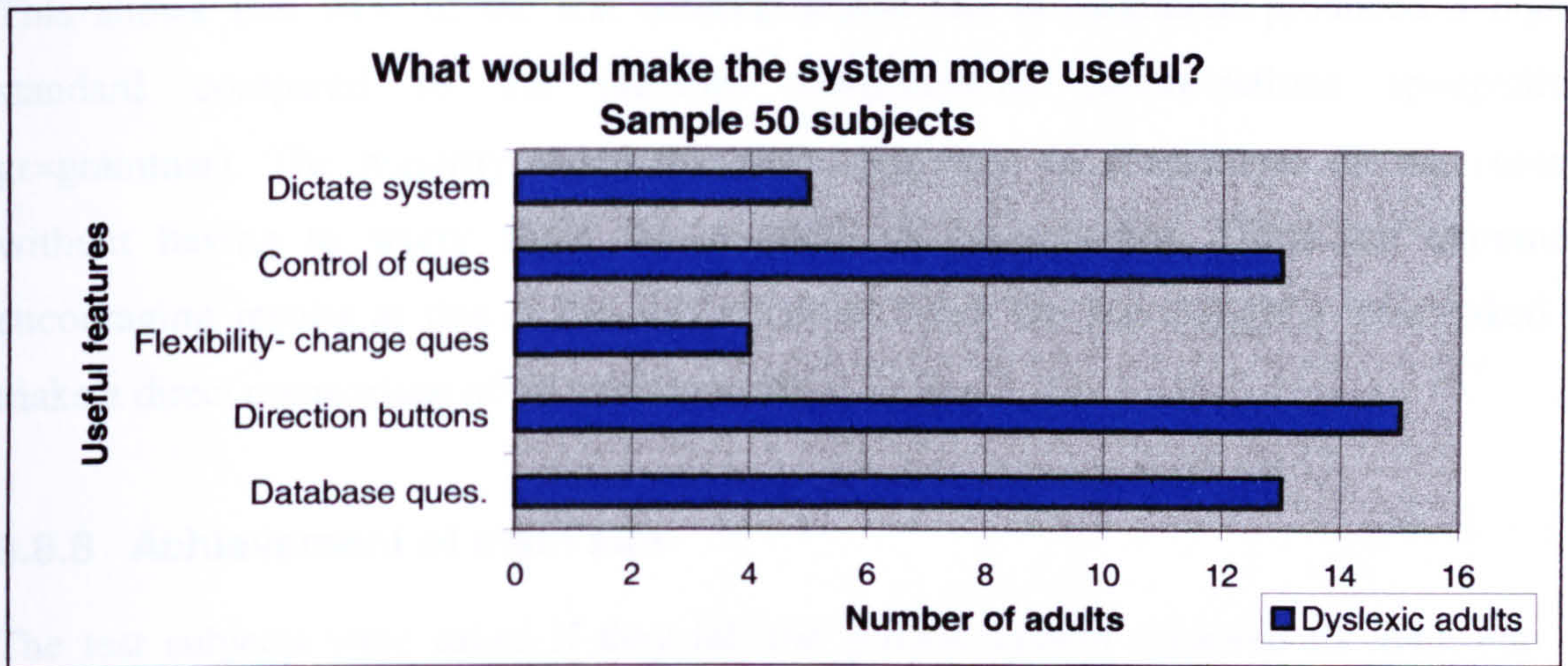


Figure 9.28. Suggested changes to environment 2 to increase usability.

The direction buttons are once again the highest selected category. A close second is the inclusion of a database of questions. All of these options would increase the flexibility of the system.

9.8.7 Standard comparison

The test subjects were asked to make a comparison between this environment and the other two previous environments. These results are presented in Figure 9.29.

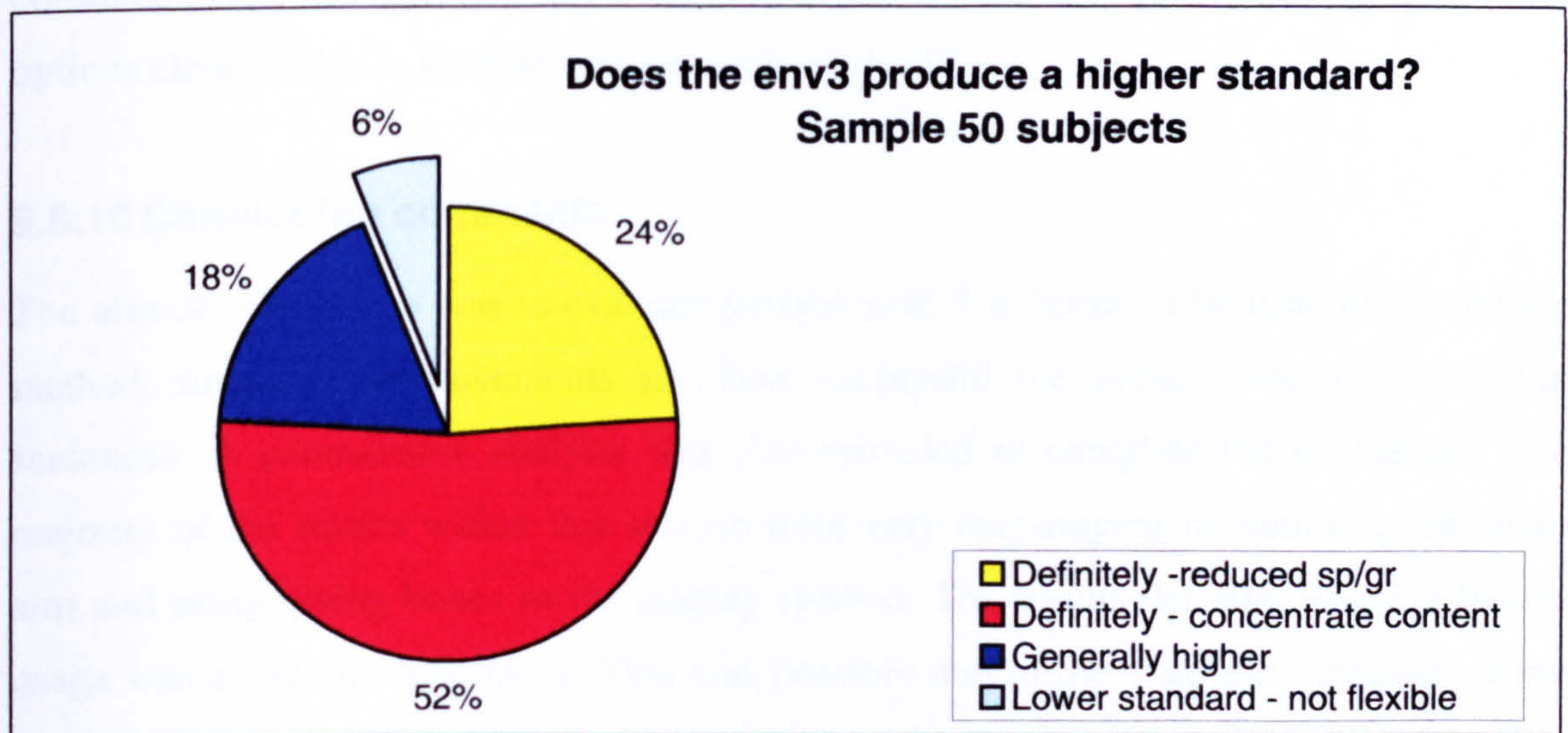


Figure 9.29. Comparison of all environments.

This shows that 94% of the test subjects stated this environment produced a higher standard compared to the previous environments (abbreviations sp=spelling, gr=grammar). The majority stated that they were able to concentrate on the content without having to worry about the structure of the sentence. These are extremely encouraging results as this is the only occasion when the test subject's were asked to make a direct comparison of all environments.

9.8.8 Achievement of main aim

The test subjects were asked if they felt the general system achieved its main aim of automating sentence construction. 100% of the test subjects stated that the system did achieve its main aim of successfully automating sentence construction. It is impossible to get a better result than this.

9.8.9 Dialog display

The test subjects were asked if they liked the chosen method of presenting a list of options and associated question, using dialog boxes. 100% of the test group stated that the dialog boxes were either clear or very clear. These boxes are the sole mode of communication and therefore it is extremely important that they present the questions and options clearly. This is another very encouraging result.

9.8.10 Concluding comments

The aim of this section was to evaluate environment 3 in terms of its usability, interface method, suggested improvements and how successful the system was in automating sentences. A comparative analysis was also provided to complete the evaluation. The majority of the results within this section were very encouraging in achieving the main aim and using dialog boxes as the display method. The results defining function button usage was a little disappointing. This was possibly due to the excellent coverage of the predefined options. The most pleasing result is the comparison section concluding that environment 3 achieved the highest standards compared with the other two environments. The results data tables can be found in Appendix A.7. This chapter has presented the test results. Conclusions will be drawn from these results in Chapter 10.

Chapter 10 Evaluation, conclusions and further work

10.1 Introduction

This chapter evaluates the results from Chapter 9 and provides a statistical proof for the research hypothesis. Conclusions are presented and the research contribution is discussed. A section detailing further work completes this chapter where future developments and further investigations are covered. Enhancements to the current system in order to improve its usability and refinements to the research hypothesis analysis are included.

10.2 Evaluating the test results

The aim of this section is to clearly define the relevant research findings and where necessary provide further analysis. The results are categorised as follows: test subject profile, environment 1: basic word processor, environment 2: word processor/support tools and environment 3: word processor/sentence construction tool. The relevant results are then used to qualify the research hypothesis.

10.2.1 Test subject profile

The test subject profile defines the level of ability and diversity of the test group. It also provides a means of confirming the initial survey results in relation to the research hypothesis. The categories: degree subject, preferred subject and different language structures are particularly important in relation to the research hypothesis. These categories highlight the use of structured languages by the test group. The degree subject category shows Computing and Engineering constitute 50% of the group. These subjects frequently use structured languages as part of their course. The preferred subject category shows Computing and Mathematics constitute 46% of the group. 62% of the test group had used programming languages and 87% of those subjects found programming languages easier to use than written English. The main two reasons (totalling 83%) for finding programming languages easier compared to written English, is the structure of the language and the logical approach used for writing programs. Research was undertaken on non-dyslexic subjects where 21% had programming experience and 44% found programming languages easier to use than written English.

The test group's ability and diversity is defined by analysing the subjects written text and personal evaluations. This information can be used with the associated academic and usability grades to establish why some subjects may not be provided with the appropriate level of support. The spelling category showed the most interesting and unexpected results. 16% of the group claimed to have no spelling problems, which is much higher than expected. This can be verified by looking at the number of test subjects who had less than 7 spelling errors in their written evaluations. 16% were in the low spelling category, which confirms the test subject's personal evaluation. The highest selected problem (associated with spelling) was spelling phonetically at 40%. It was expected that the categories: short words and reverse spelling would have scored quite highly but this is not the case. This could be due to the test subjects being asked what their primary problem was and not to list all of their spelling problems (categories may not have been considered as their primary problem).

The sentence construction category showed that 38% selected writing 'long sentence' as their primary problem. This was considerably the most popular option. 6% had no difficulties with this category. The English grammar category showed that 78% of the test group selected homophone usage and punctuation as the two main problems. Again only 6% had no problems with grammar. Moreover, the same three test subjects had no difficulties with sentence construction and grammar. When asked to group together the written categories which caused problems the 'all categories' option was by far the highest at 22%. Interestingly speed was the next category, which was rather unexpected.

10.2.2 Environment 1: Basic word processor

This environment offers no support but the layout represents the ideal environment as specified in the initial research (survey results). The written text produced using this environment provides a clear indication of the academic standard (with relation to written English) for each test subject. Comparisons with the other two environments will show the improvements, which occur when using the provided support. The categories to be evaluated are: academic grades, usability grades, environment colours and icon/menu selection methods. The results are summarised in Table 10.1.

Category	Value (%)	Value (%)	Value (%)	Value (%)
Acad. Grade	Grade 1: 18	Grade 2: 14	Grade 3: 46	Grade 4: 22
Usability grade	Grade 1: 8	Grade 2: 30	Grade 3: 60	Grade 4: 2
Env. colours	Very good 70	Excellent 8	Satisfactory 14	Own options 8
Icons or menus	Prefer Icons 44	Prefer Menus 8	No preference 48	N/a

*Table 10.1. Results from env1 evaluation.

The combined values for academic grade 3 (below average) and academic grade 4 (poor) represents a not-unexpected 68% of the test group. However, a relatively higher than expected 18% of the group, was given grade 1 (high standard) for the written text. This shows the diversity within the subject group. As expected, a majority of 62% of the test subjects gave usability grade 3 (needs a number of improvements) or grade 4 (not useable) for this environment. 38% gave high usability grades as they favoured the layout in comparison to their usual word processor. This shows that making small changes to the environment can reduce some of the difficulties the user may have and increase their level of satisfaction from using such an environment.

78% of test subjects favoured the default environment colours (white text and blue background) and 44% preferred using icons compared to menus. If the subjects were given more time the percentage of test subjects, which selected their own environment colour combination, may have been higher. It would have been interesting to perform further tests to establish the degree of effects the changes in environment colours has. Unfortunately, this was not possible within the time available. Current research in this field has been discussed in the literature review (Chapter 2 and Chapter 3).

10.2.3 Environment 2: Word processor/support tool

This environment has the same basic design as the previous environment, but includes support tools: spell checker (with inbuilt text highlighter), word meanings and word predictor. This was designed to reflect the requirements suggested by the dyslexic adults who took part in the initial research (surveys). The categories to be evaluated are:

*Abbreviations: Acad=academic, Env=environment

academic grades, usability grades, general opinion and reason, word meaning tool, word predictor, text highlighter and suggested improvements. The [♦]results are summarised in Table 10.2.

Category	Value (%)		Value (%)		Value (%)		Value (%)	
Acad. Grade	Grade 1	44	Grade 2	52	Grade 3	4	Grade 4	0
Usability grade	Grade 1	22	Grade 2	70	Grade 3	8	Grade 4	0
Opinion	Excellent	56	Very good	28	Satis/useful	14	No Change	2
Reason	All mistakes	32	U-friendly	22	Cl-display	14	Sp-dyslexics	10
Word predictor	Very good	18	Satisfactory	46	Not used	32	Not helpful	4
Word meaning	Very good	20	Satisfactory	36	Not used	36	Not helpful	8
Text highlighter	Very good	62	Excellent	12	Satisfactory	22	Not helpful	4
Improvements	W-meanings	40	G-checker	24	W-context	10	N-Develop	10

[†]Table 10.2. Results from env2 evaluation.

The general opinion of environment 2 given by the test group was very positive with 84% stating the environment was excellent or very good. This gives a good indication to how this environment compares to current available word processors, which are used by the test subjects. The main reasons for their opinions were:

- System found all spelling mistakes
- System was user friendly
- Display method used was clear
- System seemed specifically aimed at dyslexics

The word predictor and word meanings tools were not widely used, with 10 subjects not using either tool, 11 subjects not using the word predictor and 13 subjects not using the word meanings tool. The usage of these tools may well have increased if the test subjects were given more time to evaluate the system (using the system several times). However, out of those who did use the tools, only 2 subjects found the word meanings tool

[♦] Only main subcategories displayed in table

[†] Abbreviations used: U=user, Cl=clear, Satis=satisfactory, Acad=academic, Sp=specifically for, W=word in, G=grammar, N-Develop=needs development.

unhelpful, 1 subject found the word predictor unhelpful and 1 subject found both tools were unhelpful.

The majority of subjects who used the tools graded them at a satisfactory level. The reported usefulness of the text highlighter was more encouraging with only 2 subjects stating it was not useful. 74% of the sample thought the text highlighter was either excellent or very good. The written comments indicated that the text highlighter allowed more mistakes to be found (semantic mistakes rather than syntax) and highlighted the length of sentences resulting in a reduction in the number of long sentences. When asked what improvements they would make the most favoured was to give word meanings for all suggested words. There was also a high demand for a grammar checker.

Environment 2 produced much higher academic grades than environment 1, with a majority of 96% of the written work graded either 1 or 2. This environment was also popular with the test subjects, with 92% grading the system 1 or 2. Direct comparisons with environment 1 are shown in Table 10.3.

Category	Value (%)	Value (%)	Value (%)	Value (%)
	Grade 1	Grade 2	Grade 3	Grade 4
Academic Grade Env1	18	14	46	22
Academic Grade Env2	44	52	4	0
Usability Grade Env1	8	30	60	2
Usability Grade Env2	22	70	8	0

◊Table 10.3. Comparisons between env1 and env2 for all grades.

The comparison table shows that 33 (66%) test subjects received poor (3 or 4) academic grades using environment 1 and all but 2 (4%) received high (1 or 2) academic grades when using environment 2. This shows the environment has proven beneficial for adults with dyslexia. Similar results can be seen for usability grades with 31 (62%) test subjects giving environment 1 grades 3 and 4 and only 4 (8%) for environment 2.

◊ Data concerning icons and menus is not provided as there is no change between environment 1 and environment 2.

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The characteristics associated with the two test subjects who still received academic grade 3 when using environment 2 are presented. This is in order to gain an insight into the type of person who does not seem to benefit (to the same degree) when using environment 2.

The characteristics for these two subjects are:

- Spelling problems – levels 3 and 4
- Grammar problems – level 3 for both
- Sentence construction problems – level 3 for both
- Homophone problems – levels 2 and 3
- Main problems selected by both subjects are sentence structuring and spelling
- The changes requested by were: replacement word shown in context (1 subject) and a grammar check (1 subject)
- There were associated problems with punctuation (1 subject) and using the wrong word particularly homophones by both
- Both gave a usability grade level 2

It is clear that these subjects needed support with grammar and sentence structuring which environment 2 does not provide (at an adequate level). It should also be noted that both test subjects received academic grade 4 when using environment 1, which indicates that some improvements were made. The results spreadsheet is provided in Appendix A.9 and the student ids for these two subjects are: student 40 and student 46.

This environment was developed to show that by providing tools which are tailored to the specific needs of a selected group (in this case dyslexia), can result in substantial benefits on an academic level. Also increase satisfaction gained from working in an environment that minimises difficulties, which users may have. This environment is relatively similar in form to other word processors and therefore by allowing the subjects to give usability grades provides an indication of how this environment compares with the current available support for dyslexic adults. The final environment (env3) is unique in its form and if it compares favourably to env2's high standards it will have achieved its aim of maximising ability and satisfaction levels.

10.2.4 Environment 3: Word processor/sentence constructor

This environment uses the same basic word processing system as the previous environments but now incorporates a sentence constructor. No feedback is requested from the test subjects for the components that have already been graded, i.e. icon preference.

The test subjects work within a constrained environment where the framework for both the written assignment generally and for each sentence specifically, is automated. This system was designed to be able to test the research hypothesis by creating a structured and rigid environment that allows the sentence components to be created in a predetermined order. The categories to be evaluated are: academic grades, usability grades, dialog buttons, resulting sentences, overall system, options, changes, increase usability, comparisons, aim and display. The results are summarised in a series of tables. Table 10.4 presents the function button results.

Category	Value (%)	Value (%)	Value (%)	Value (%)
Help button	Frequent 10	Often 20	Occasional 20	Not used 50
Add button	Frequent 16	Often 22	Occasional 48	Not used 14
V-chang button	Frequent 18	Often 10	Occasional 50	Not used 22

^xTable 10.4. Env3: function button results.

The function buttons most popular category was 'occasional use' for the 'Add' and 'View-change' buttons and 'not used' for the 'Help' button. It would seem that the 'Help' button was not really required as the system was user friendly and clearly laid out. The 8 subjects that made frequent use of the 'Add' button achieved 7 academic grade 1's and 1 academic grade 2. This suggests that the 'Add' button when used brings flexibility to the system and does not reduce the academic grades. However, it is not possible from this data to determine whether it increases the academic grade (by using the 'Add' button), this would have required further testing. The 9 subjects that made frequent use of the 'View-change' button gave env3, 8 usability grade 1's and 1 usability grade 2. This would seem to indicate that when the test subjects use the 'View-change' button that

^x Abbreviations: V-chang=view change.

allows a sentence to be viewed and permits changes, the system received a favourable usability grade. Table 10.5 presents further results.

Category	Value (%)	Value (%)	Value (%)	Value (%)
Resulting sent.	Ve-satisfied 30	Pleased 52	G-satisfied 16	N-satisfied 2
Overall system	Right level 26	A-Flexible 38	Flexible 8	Limited 28
Sug. changes	No changes 14	D-buttons 68	More flexible 8	R-Q/options.10
Useful features	Q-Database 26	D-buttons 30	Dictate sys. 10	Q-chang/con 34

[⊖]Table 10.5. Env3: selected results.

A majority of 98% were satisfied with the resulting sentences, of which 82% (of that 98%) selected the 'very satisfied' or 'pleased' options. 72% stated the overall system was flexible enough to be useful. The use of the 'Add button' to ensure flexibility was the most popular option. Although 28% stated the system was limited only 2% of those, used the 'Add' button frequently, whereas 12% (of the 28%) did not use the 'Add' button at all. This suggests some test subjects need longer to be able to use the system in an effective manner. The 'Add' button was provided to ensure flexibility. If subjects did not use this function it is not surprising that they may have found the system a little limited.

Direction buttons were the most favoured suggested improvement with the addition of a database of questions being another popular choice. The system does not allow the subject to change their mind after the sentence is submitted to the word document. The subject must continue and complete the current section then manually edit the word document to make changes. Therefore by including direction buttons the system would become more flexible. A database of questions would again increase flexibility and give more control to the test subject while still constraining the language structure. Table 10.6 presents further results.

[⊖] Abbreviations: R=reduce, Q=questions, Ve=very, D=direction, N=not, G=generally, Sug=suggested, chang=changes, con=control, A=add, Sent=sentence, sys=system.

Category	Value (%)		Value (%)		Value (%)		Value (%)	
Num. options	Correct	36	F-Correct	50	WD-Correct	12	Too many	2
Aim	Definitely	54	Does	46	Does not	0	Def-doesn't	0
Display	Very clear	48	Clear	52	Not clear	0	Not at all clear	0

Table 10.6. Env3: further results.

The results from these three categories were extremely encouraging with 98% of the test sample thought the number of options provided in the dialog boxes was set at the correct level. All the subjects stated the sentence constructor achieved its aim and that the display was clear. Table 10.7 presents the results to be used to qualify the hypothesis.

Category	Value (%)		Value (%)		Value (%)		Value (%)	
Acad. grade	Grade 1	66	Grade 2	34	Grade 3	0	Grade 4	0
Usability grade	Grade 1	52	Grade 2	48	Grade 3	0	Grade 4	0
Comparisons	Def-h(CC)	52	Def-h(sp/gr)	24	G-higher	18	N-flexible	6

*Table 10.7. Env3: results to qualify the hypothesis.

These results will be discussed and used in the next section to qualify the hypothesis. This completes the research findings.

10.2.5 Qualifying the hypothesis

Selected results from the previous section are used to show comparisons between the three environments. The aim of these comparisons is to qualify the research hypothesis. The first two diagrams in this section show the type of grade (academic or usability) taken in isolation, for all environments. Then Figure 10.3 combines both grades and all environments. The abbreviations env1 (basic word processor), env2 (word processor and support tools) and env3 (word processor and sentence constructor) will be used throughout this section. Firstly, Figure 10.1 displays the usability grades for each of the three environments.

Abbreviations: F=flexible, WD=wide difference, Def=definitely Num=number.

* Abbreviations: Acad=academic, Ve=very, chang= change, G=generally, N=not, A=add, D=direction, R=reduce, Q=questions, def=definitely, h=higher, CC=concentrate content, sp=spelling, gr=grammar.

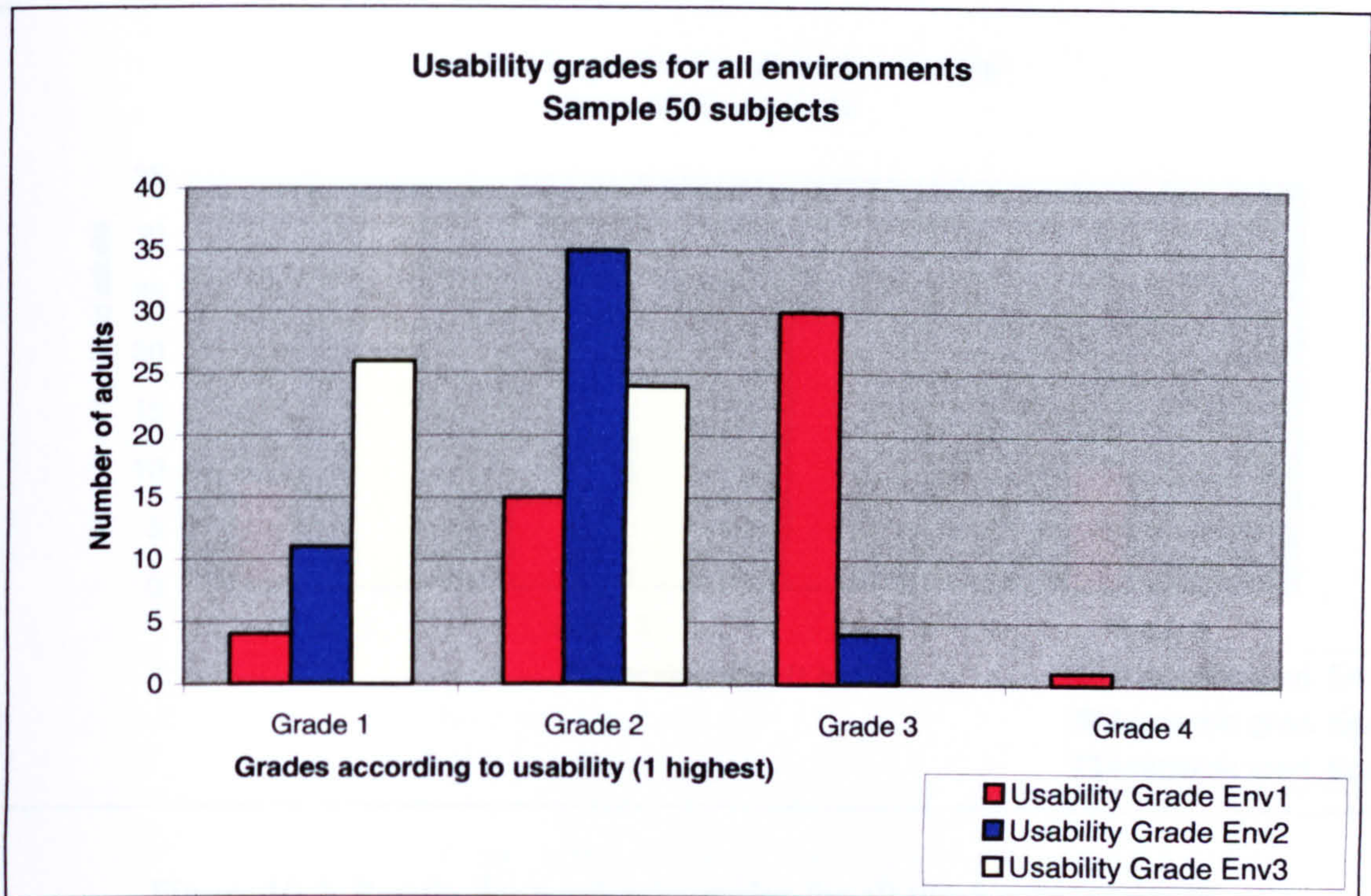


Figure 10.1. Results for usability grades for all environments.

It is clear that env3 received the most grade 1's by a substantial amount. In fact 65% of all usability grade 1's were for env3, 25% for env2 and only 10% for env1. Env2 received the highest number of grade 2's taking 44% of the total. However, env3 was not far behind with 38% of the total and env1 at 18%.

Env1 received the most grade 3's at 88%. The entire test group gave env3 a grade 1 or 2. These results are very pleasing making it clear that the env3 was preferred over the other environments. Statistical analysis of these results is shown in Section 10.2.5.1. The column chart Figure 10.2 displays all the academic grades for all three environments.

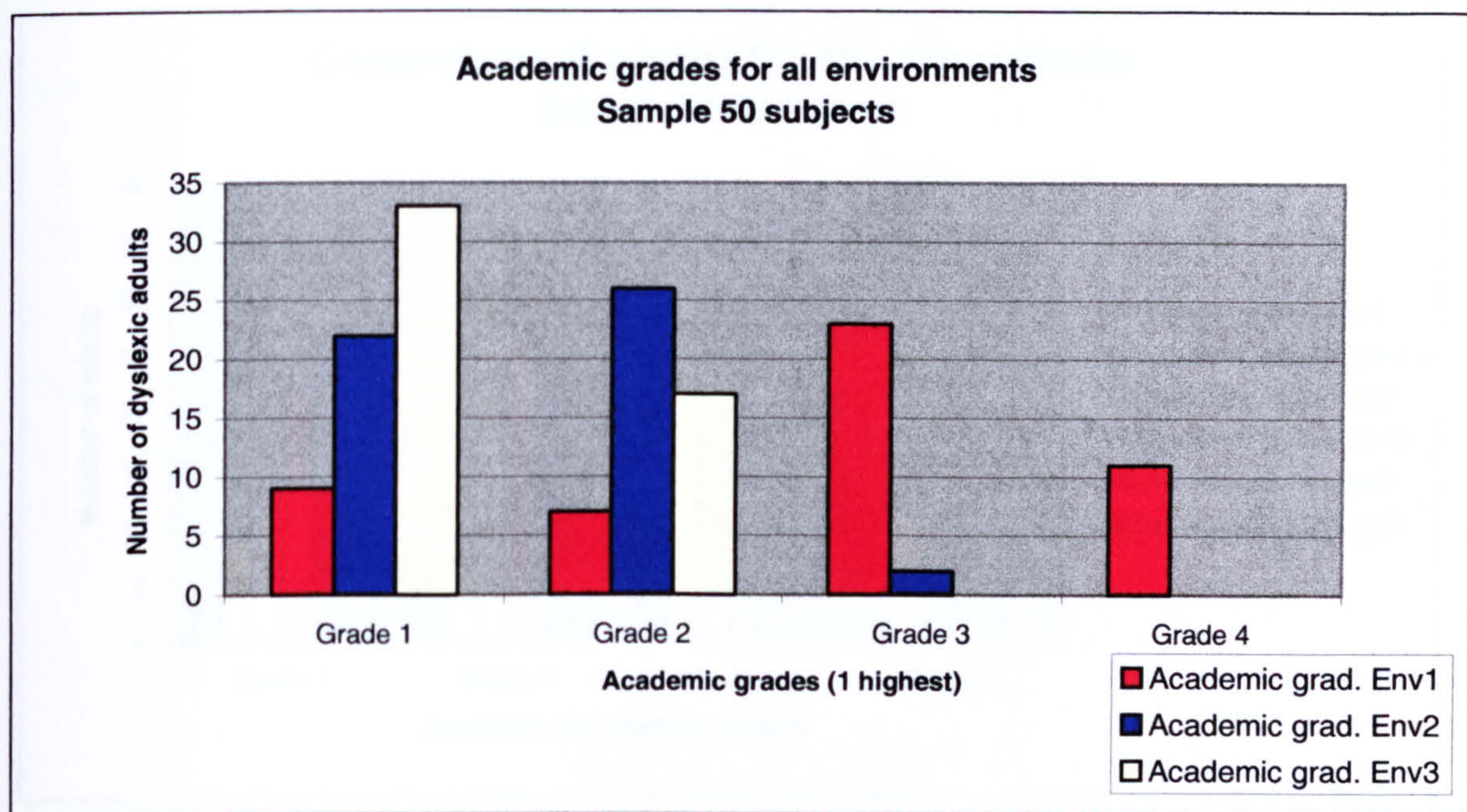


Figure 10.2. Results for academic grades for all three environments.

These results are very similar to the usability grades in that env3 received the most grade 1's at 52% (34% for env2, 14% for env1), env2 received the most grade 2's at 47% (33% for env2, 20% for env1) and env1 received the most grade 3's with a substantial 92% of the total (8% env2). These results are very encouraging and show that env3 produced the highest academic levels. Again all of the test group were given an academic grade 1 (excellent) or 2 (very good). Section 10.2.5.1 gives statistical analysis of these results.

The final diagram in this section combines the two previous diagrams to enable a direct comparison to be made between all three environments and both the academic and usability grades. Figure 10.3 shows the most grade 1's were received for env3, academic level. The second highest was for env3, usability level. The most grade 2's were received for env2, usability level. The second highest being for env2, academic level. The most grade 3's were received for env1, usability level. The second highest was for env1 academic level. The most grade 4's were received for env1, academic level. The second highest was for env1 usability level. This confirms the trend of increasing usefulness and user satisfaction from env1 through env2 to env3.

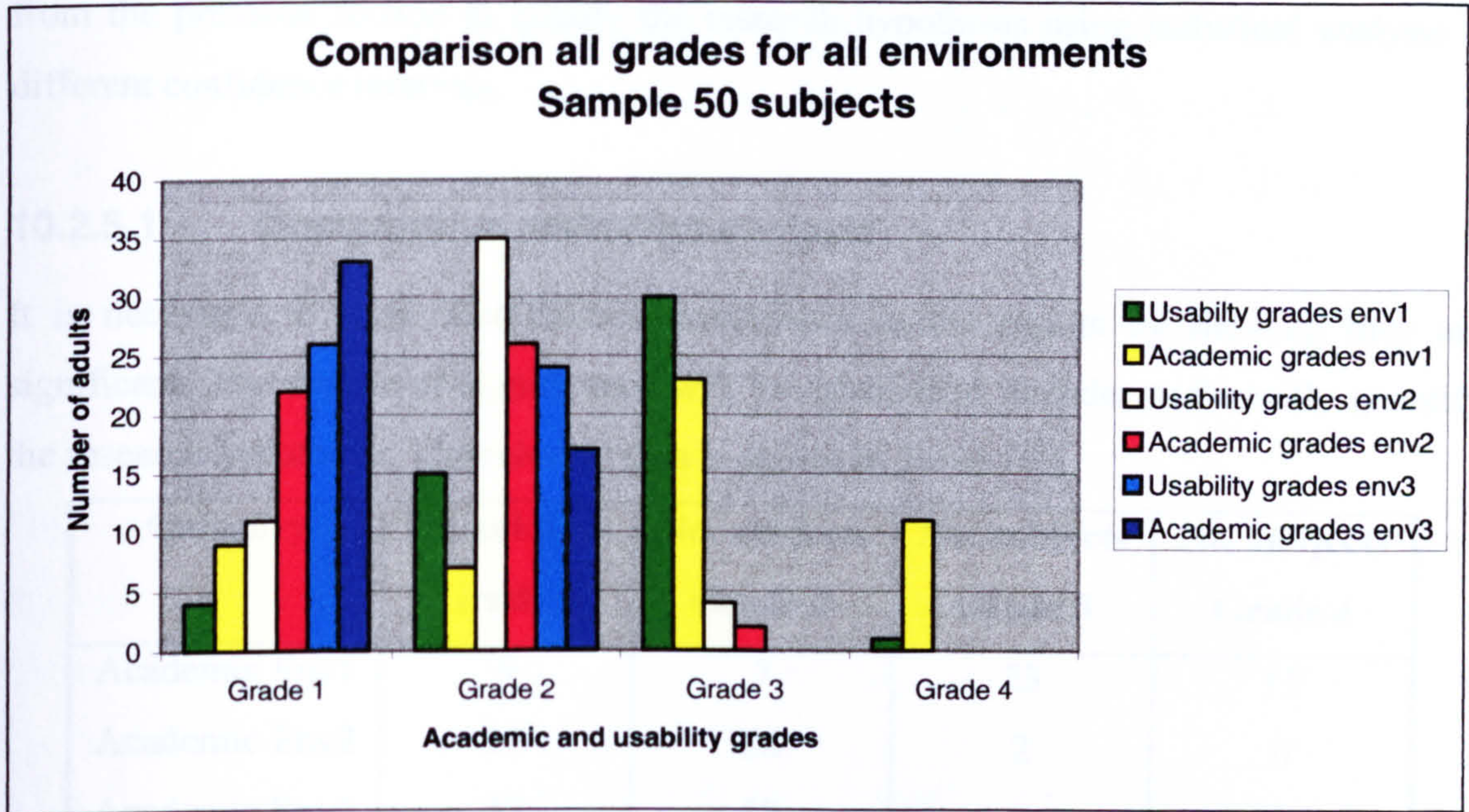


Figure 10.3. Comparisons for all grades in all environments.

What is very clear from these results is the fact that when using the basic word processing environment with no associated tools thirty-three test subjects were given low academic grades (3 or 4). All but two of those subjects were taken out of the low academic achievement categories when using environment 2. This shows that on an academic level the second environment was extremely beneficial. The third environment went one step further and removed all of the test subjects from the low academic grade categories. Thus, proving beyond reasonable doubt that the sentence construction tool achieves its academic objectives. As the academic grades are arrived at independently of the other results and are not subject to the personal opinions of the test sample, their significance gives an impartial measure of the usefulness of the tool.

As well as the independence of the academic grade rating, these results also correlate with the usability grade rating provided by the test sample. 31 subjects gave environment 1 a poor rating in terms of usability. All but four of those subjects gave environment 2 favourable usability ratings. Again the third environment improved upon this further and removed all usability poor ratings. This indicates that the test subjects preferred the third environment overall. These results are most encouraging and are used with the results

from the previous section to qualify the research hypothesis using statistical analysis at different confidence intervals.

10.2.5.1 Comparative statistical analysis

It is necessary to show that there is confidence in the results by showing they are significant. The degree of significance will be established in order to formally quantify the research hypothesis. The relevant data is shown in Table 10.8.

Category	No. subjects	No. subjects	No. subjects	No. subjects
	Grade 1	Grade 2	Grade 3	Grade 4
Academic Env1	9	7	23	11
Academic Env2	22	26	2	0
Academic Env3	33	17	0	0
Usability Env1	4	15	30	1
Usability Env2	11	35	4	0
Usability Env3	26	24	0	0

Table 10.8. Data used in statistical analysis.

The chosen method of analysis is the student t test [Han97]. This is used to compare two sets of data where the sample size is the same. It is particularly useful when there is a natural correspondence between pairs of items and a 'before' and 'after' comparison can be made. This is the case for the research data as the sample size for all environments is the same and each subject tested each environment so they are linked. It will not be possible to compare all three environments together as the chosen method forms comparisons with matched pairs. This method takes two sets of results: base results (referred to as untreated) and 'treated' results and forms a comparison between the two.

The data in Table 10.8 cannot be used for direct evaluations as it represents the frequencies involved. Instead, individual grades for each test subject need to be compared. An example matched pairs comparison would be for each subject's academic grade for environment 1 and each subjects' academic grade for environment 2. The full breakdown of the calculations is shown in tables included in Appendix A.10 to A.15. The tests to be performed are:

- Env1 academic grades (base results) and Env2 academic grades (treated results)
- Env1 academic grades (base results) and Env3 academic grades (treated results)
- Env2 academic grades (base results) and Env3 academic grades (treated results)
- Env1 usability grades (base results) and Env2 usability grades (treated results)
- Env1 usability grades (base results) and Env3 usability grades (treated results)
- Env2 usability grades (base results) and Env3 usability grades (treated results)

The results from the academic grades are important, as these results are independent of the opinions of the test sample. The usability grades are important, as the opinions of the test subjects are based on comparisons with other tools they have used. Table 10.9 shows the *t* test results for all six comparisons.

Comparisons	test t	Accept/reject
Env1, Env2 Academic grades	7.897	test t >> t accept
Env1, Env3 Academic grades	8.835	test t >> t accept
Env2, Env3 Academic grades	2.768	test t > t accept
Env1, Env2 Usability grades	5.735	test t >> t accept
Env1, Env3 Usability grades	8.088	test t >> t accept
Env2, Env3 Usability grades	3.704	test t >> t accept

Table 10.9. Statistical results.

The degree of freedom is 49. Significance levels of 95% (critical value 2) and 99% (critical value 2.7) were chosen for the t^{df} values. In each comparison, the *test t* value is either significant (>) or highly significant (>>) compared to the *t* statistic.

The test subjects were asked to make a direct comparison between all the environments.

Do you think the sentence constructor in environment 3 produces a higher standard compared to the other environments?

The results are shown in Table 10.10.

Category	No. subjects	No. subjects	No. subjects	No. subjects
Comparison	Def-h(CC) 26	Def-h(sp/gr) 12	G-higher 9	N-flexible 3

^oTable 10.10. Subjects' satisfaction with sentence constructor.

94% of the test subjects stated that environment 3 produced higher standards. This correlates with the academic results. In order to establish that the test subjects understood the questions and were not making purely random selections the same question was asked but expressed in a different way. Supplied with the information that the aim of the sentence construction tool was to automate sentence construction in an effective manner, the test subjects were asked:

Does the tool achieve its aim?

Are you satisfied with the resulting sentences?

Both questions were attempting to ask the same question. Table 10.11 shows the results for these two questions. Only one subject gave a negative response, the results were similar for both questions. This completes the proof and conclusions will be presented.

Category	No. subjects	No. subjects	No. subjects	No. subjects
Aim	Definitely 27	Does 23	Does not 0	Def-doesn't 0
Resulting sent.	Ve-satisfied 15	Pleased 26	G-satisfied 8	N-satisfied 1

^{*}Table 10.11. Subjects' satisfaction with resulting sentences produced.

10.2.6 Conclusions

This research has established that there seems to be a link between the number of rules and level of constraints that a language has and the degree of problems that dyslexic subjects encounter (research hypothesis). The test subjects profile confirms this and supports the results from initial research undertaken (discussed in chapter 4). Structured languages, such as computer programming languages, have fixed grammars with rigid

^o Abbreviations: Def-h definitely higher, (CC) can concentrate on content, (sp/gr) reduction in spelling and grammar errors, n not, g generally.

^{*}Definitions are: def definitely, Ve very, G generally, N not.

rules and use a logical approach to constructing statements. There is no ambiguity and the order of sentence components is predetermined and very important.

Investigating dyslexics' comparative ability when using structured and natural languages confirmed the research hypothesis. Devising a method of testing this theory on the general population of dyslexics (regardless of their experience of using structured languages) was undertaken. This was achieved by the development of a specialist word processor whereby three environments (referred to as env1, env2 and env3) were used to provide varying levels of support and control.

Env1 was used to establish a subject's academic ability when no support is given. Devising methods, which would minimise difficulties (visual, short-term memory, hand-eye coordination), commonly associated with dyslexia, was an important concern. These included changes to the methods of presenting lists, setting environment variables and toolbar layouts. Env1 was designed to include these features. Env2 uses support tools devised specifically for dyslexics as requested by them. Developing support tools specifically for dyslexics rather than for the general population or non-specific learning disorders has proven to be beneficial. This environment provided conventional support and formed a basis from which comparisons can be made.

Env3 incorporates concepts from the research hypothesis by using a rigid controlled environment. Environments used to develop computer programs offer support but sometimes enforces a structure that is too strict. Env3 incorporates a degree for flexibility within the constraints and the results show a positive effect. Flexibility was required to ensure individual creativity and originality.

At the onset of the testing process it was expected that env1 would not be popular with the majority of the test subjects as the level of support was deliberately kept to a minimum. However, the majority of the test subjects favoured the layout and contrasting screen and text colours in comparison to their usual word processor environment. For that reason the usability grades for environment 1 were higher than expected, with 38% giving

a usability grade 1 or 2, regardless of the lack of support. This environment provided written text, which showed the true academic ability of the test subjects.

Env2 provided a substantial improvement on env1 on an academic and usability level. The spell checker and associated support tools were designed specifically for dyslexic adults needs. The environment attained high academic and usability grades. The test subjects were grading env2 on its own merit and were initially only comparing it with env1 and their personal experience of other word processors.

The usability grades may have been different if the grade had been sought only after all environments had been used. The test subjects were only asked to provide direct comparisons when they had used env3 (after grading the first two environments). Thus, the comparison question (included in the previous section) was important and reflected the opinions of the test subjects after all environments have been used.

Env3 was designed to provide rigid control and structure the process of constructing sentences. Much research had gone into the visual display and user interface. The results, in particular the comparisons, are very pleasing and form a positive proof for the research hypothesis. Although there is a substantial improvement between env1 and env2, env3 still manages an improvement over env2. Not only does env3 remove all subjects (2 in env2) out of the poor academic grade levels, it also increases the number of academic grade 1's (excellent level) by 11 subjects compared to env2. By reviewing the usability grades it is also clear that env3 makes further improvements on env2 by removing all grade 3's (4 subjects) and increasing the number of grade 1's by 15 subjects.

Although this research is concerned with dyslexic adults, investigations have been undertaken to establish whether the hypothesis may also be true for non-dyslexics. Results have shown that from a general population of non-dyslexics 21% had experience of structured languages. This is in comparison to 59% from the initial survey and 62% from the test subjects. An investigation to establish whether non-dyslexics found structured languages easier in comparison to writing English was undertaken. This was in order to establish how they compared with dyslexic subjects. The sample included 16

programmers, 13 subjects who use structured languages as part of their job and 21 subjects who have experience of using structured languages to varying levels.

The results showed that 44% found programming languages easier than writing English. It was expected that this would be higher in particular from the programmers but this was not the case (data tables provided in A.16). The results from the dyslexic adults were 81% (from the initial survey) and 87% (from the test subjects). There is a substantial difference between dyslexics and non-dyslexics, which would indicate that methods used to support dyslexics, may not be appropriate for non-dyslexics. Further research would need to be undertaken to establish a true comparison.

10.2.6.1 Research contribution

The main research areas covered in this thesis, together with a brief review, is as follows:

- Preferred interfacing modes for adults with dyslexia (computer – based support)
- The design and development of associated support tools (spell checker etc)
- An analysis of written difficulties experienced by adults with dyslexia
- An analysis of how dyslexia affects abilities when using different language structures (written English and computer programming languages)
- The development of a research hypothesis
- The development of a specialist word processor to provide support for adults with dyslexia and test the hypothesis
- Comparison study with non-dyslexic subjects

When developing software it is imperative to ensure the interface between the computer and the user is correct. This is particularly important for dyslexics, as reading can be a problem. Through this research it has been shown that the contrasting colours: blue (screen) and white (font) enable the test subjects to concentrate for longer and make fewer mistakes. These were comments made by the test subjects although they were not investigated further. This research also shows that icons are preferred to menus as layered menus can cause confusion. An uncluttered layout with choices made by selecting icons linked to large dialog boxes, was very popular with the test subjects, many of whom

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provided favourable comments when comparing this research word processor with their usual system. This has been covered in various chapters of the thesis.

This research shows that standard spell checkers are not providing the correct level of support required by many adults with dyslexia. The underlying interface is also not suited to their needs. The spell checker provided in Microsoft Word (the most popular word processor used by the test sample) presents suggestions in a list of very similar 'looking' words for the user to choose from. This is definitely a problem for many dyslexic adults. This research spell checker presents words separately in a large text font. Also homophone support is available to aid word selection.

To help reduce the number of long sentences, the spell checker includes a text highlighter, which lets the user step through the text, highlighting a sentence at a time. Changes can be made and the spell checker will verify each word. Although the spell checker is not directly linked to the research hypothesis it forms a valuable part of the sentence constructor as it validates text entered by the test subjects.

Using the concepts behind the research hypothesis allowed the development of the sentence constructor (used in env3) to take place. This has provided a supportive environment, which has proven benefits at an academic and usability level. There is a definite need for support tools to aid dyslexic adults with their written work and this research has made a contribution to it. The usability grades have provided the means to establish the usefulness of the research software in comparison to current alternatives. From the literature review contained in Chapter 3, it seems that little research has been conducted in the specific area addressed in this thesis. In particular, the concept of enforcing constraints on natural languages (to a limited degree) gives beneficial results. Therefore this thesis represents a substantial contribution within this area. The underlying concepts can be used when designing support software to aid dyslexic adults with their written tasks.

Although the specialist word processor was designed primarily to qualify the hypothesis it has proven beneficial to dyslexic adults. Therefore further developments of this software

could provide this group of people with the kind of support they need to compensate for the limitations that their disability brings.

10.3 Further work

This section is concerned with developments resulting from the current research. It consists of two main parts: future developments and issues for further investigation. The section entitled 'Future developments' is concerned with developing the current environments. This is in order to provide the required support for adults with dyslexia based upon the concepts developed throughout this research. The section entitled 'Issues for further investigation' is concerned with further evaluations of the research hypothesis and possible uses that can be made of it.

10.3.1 Future developments

Throughout the evaluation process, the test subjects were asked to comment on the usefulness of each environment. They also provided comments on improvements they would like to make to the environments. This section will discuss these improvements. Some of the suggested improvements were considered in the early stages of the research but, due to time constraints, were deemed to be outside the scope of the current research.

The suggested enhancements to the spell checking unit are presented in order of popular demand:

1. Word meanings for all suggested words
2. A grammar checker that offers solutions and communicates in simple English
3. Present the suggested words in-context to define the usage and meaning
4. Self-learning options whereby the system learns from the user and records spelling mistakes with the selected corrected word
5. Use of more graphical concepts to aid poor
6. Word meanings for all homophones to aid the selection process
7. Increase the usefulness of the word predictor by increasing its lexicon (word file)

The suggested improvements (additions) to the sentence constructor are presented in order of popular demand:

1. Dialog direction buttons such as skip, back, forward. This would allow changes to be made to the constructed sentences or allow questions to be skipped. This would give more control to the user of the system
2. The addition of a database of questions linked to selected topics. This would make the system more useful and flexible
3. Allow the user to control which questions are answered and consequent sentences constructed
4. The inclusion of a voice text reader system to speed up the process and help poor readers
5. Increased flexibility for changing constructed sentences by including a grammar checker to verify text changed or added by the user

The suggested enhancements would make the specialist word processor more useful and meet the demands of dyslexic adults. The suggestions did not alter the constraints of the system but increased the level of support.

Two papers have been published (provided in Appendix A.17 and A.18) which present the initial survey results. The inclusion of a teaching environment (for dyslexic adults) is discussed which provides support and aids the learning process. This enhancement could prove useful for those dyslexics whose standard of English is at a level where they require more than just support.

The next section reviews the research hypothesis in terms of any changes or refinements that could be made. Suggestions are made for alternative methods of hypothesis evaluation and possible linked benefits.

10.3.2 Issues for further investigation

The research hypothesis is quite broad based and could be interpreted in several ways. The chosen method was to compare a natural language such as English with a structured language such as a computer programming language. These language types (natural and

structured) differ in many ways. The implication of increasing a person's ability within one language type, by creating an environment to use the benefits from another type, is a powerful concept.

An alternative language comparison would be to see how dyslexia affects a person's ability with pictorial languages such as Chinese or Japanese. The question concerning whether the number of rules and level of constraints within such a language affects a dyslexics ability would be an interesting area to investigate. The current research in this area has been covered in the literature review (Chapter 3).

During this research some information that has been gathered, related to the test subjects experience of using other natural languages (and in one case a pictorial language). The results were not very interesting, as it would seem that the second language was even harder to use than English because of the limited length of time of study and the age at which learning began. Latin languages, such as Italian and Spanish, did cause fewer spelling problems, which may be due to them being more phonetically based. The single Chinese student that took part, claimed to have equal difficulties using Chinese, as poor memory was his biggest problem. Subjects with experience of German and French had major problems mainly due to the complicated grammar. As stated, this information was not very conclusive and the time constraints prevented further evaluation. This is an obvious area for further research, although as stated in the introduction chapter, the specific research area of linguistics is outside the scope of this thesis.

The creation of the sentence constructor to alter the language constraints was a valid solution to provide an effective method of testing the research hypothesis. The concepts were designed to mirror an environment used to develop computer code. Within a computing environment tools such as debuggers and compilers are used. Also the use of wizards in Microsoft products can be (but not always) useful and provide support. This research has found that those subjects with programming experience find these tools useful and make detecting and correcting errors (syntax errors rather than semantic errors) relatively easy. The programmer is allowed to concentrate on the content rather than the structure as the correct support is given.

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Another area of future research would be to incorporate more concepts from general programming languages to enhance environment 3. More specifically, one such idea would be to develop a grammar checker that provides the same support as a debugger. The current system allows the user to modify the sentences but does not provide a grammar checking service (only spelling verified). The spell checker has been developed to allow for the inclusion of a grammar checker at a later date. This has been made possible by using a dictionary, which includes a grammar field and the functionality of the spell checker, is such that a complete sentence is verified rather than a single word.

This research has included an initial investigation to relate the research hypothesis to non-dyslexics. Indications are that language structure has a far lower effect on non-dyslexics in comparisons to dyslexics. Thus, the methods used to develop support tools to assist dyslexic adults would not benefit non-dyslexics to the same degree. However, this is based on a very limited investigation, further research is required to achieve a true evaluation.

The concepts behind the research hypothesis can be used to develop support software for adults with dyslexia. Designing the software to meet the needs of one specific group (in this case dyslexic adults) rather than for people with general non-specific learning disorders has proven to be beneficial. The benefits of working in a controlled rigid environment, where structure is enforced and constraints are made, could be developed further. The inclusion of a grammar checker based on programming support tools would be a very useful addition.

This thesis has covered many areas and was both challenging and very rewarding. It is hoped that the development and the consequent qualifying of the research hypothesis, provide the basis of the unique knowledge required, to justify this thesis.

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Appendix

A.1 Initial survey data

Key

Contact	Unique number allocated to each subject – order
Sex	Gender of subject
Age	Age of subject
Usage	Computer usage BA: below average, AVE: average, ABA: Above average
GE	Grammar effects
CT	Usage of current tools
WO	How dyslexia affects word ordering in sentences
NT	Demand for new grammatical tool
LT	Demand for learning interface to grammatical tool
PE	Computer programming effects
COM	Comparison of English grammar and computer programming effects
CO	Constructing programming statements
CE	Understanding compiler errors
DT	Using debugging tools
GROUPS	Available grade options 1 to 4
GPGE	Total number in grammar effects groupings
GPCT	Total number in current tool usage groupings
GPWO	Total number in word ordering groupings
GPNT	Total number in new grammatical tool groupings
GPLT	Total number in learning environment groupings
GPPA	Total number in computer programming groupings
GPCO	Total number in constructing programming statements
GPCOM	Total number in comparison effects groupings
GPCE	Total number in compiler error groupings
GPDT	Total number in debugging tools groupings
GPOUP2	Computer usage groups
GPUSAGE	Total number in each computer usage group
GROUP3	Gender groups
GPSEX	Total number in gender groups
GROUP4	Age groups
GPAGE	Total number in age groups
GROUP5	Computer programming/non-computer programming
TOTAL	Total in each computer programming category

Appendix A1

Contact	Sex	Age	Usage	GE	CT	WO
1	M	21	AVE	3	4	2
2	M	21	AVE	3	2	
3	M	21	AVE	3	1	3
4	F	21	ABA	3	1	2
5	F	21	AVE	4	4	3
6	F	21	AVE	4		3
7	M	20	ABA	3	4	2
8	M	20	AVE	3	2	3
9	M	21	ABA	4	1	3
10	M	20	ABA	4	2	3
11	F	21	ABA	4	3	3
12	M	21	ABA	3	4	2
13	M	20	AVE	3	1	1
14	M	20	ABA	4	1	3
15	F	21	ABA	3	2	4
16	F	21	AVE	4	3	4
17	M	21	AVE	4	2	3
18	M	21	AVE	2	2	3
19	F	21	AVE	3	2	3
20	M	21	AVE	3	2	2
21	F	40	AVE	1	1	2
22	M	21	ABA	4	3	2
23	F	21	ABA	2	1	1
24	M	21	ABA	1	1	1
25	F	20	ABA	2	1	1
26	M	21	ABA	3	4	1
27	M	20	ABA	4	2	2
28	M	21	ABA	3	2	2
29	M	20	ABA	2	2	1
30	F	21	ABA	1	4	1
31	M	40	ABA	3	3	4
32	M	21	ABA	4	1	1
33	M	21	ABA	2	3	3
34	F	21	ABA	4	2	4
35	M	21	ABA	3	4	2
36	M	40	BA	3	3	1
37	M	21	ABA	4	1	3
38	M	21	ABA	2	4	1
39	F	21	ABA	1	4	1
40	M	40	ABA	3	3	4
41	M	21	ABA	4	1	1
42	M	21	ABA	2	3	3
43	F	21	ABA	4		1
44	M	40	AVE	4	3	2
45	F	20	AVE	2	2	2
46	F	21	AVE	3	1	1
47	F	21	AVE	3	1	4
48	M	21	ABA	4	1	2
49	M	20	ABA	4	3	4
50	M	21	ABA	4	2	3
51	M	21	ABA	4	2	3
52	M	20	ABA	4	3	3
53	M	20	ABA	2	2	1

Appendix A1

Contact	Sex	Age	Usage	GE	CT	WO
54	M	21	ABA	3	3	3
55	F	20	ABA	3	2	2
56	F	21	ABA	2	2	2
57	M	21	ABA	4	4	3
58	M	20	AVE	3	1	2
59	F	21	ABA	4	3	4
60	F	20	ABA	4	1	1
61	M	21	ABA	1		
62	M	21	ABA	4		1
63	F	21	ABA	3	3	2
64	M	21	AVE	4	1	4
65	F	21	ABA	2	2	3
66	M	20	ABA	4	4	1
67	M	21	ABA	4	1	3
68	F	21	ABA	4	4	4
69	M	20	ABA	4	3	3
70	M	40	AVE	4	3	3
71	F	20	ABA	3	2	2
72	M	21	ABA	3	2	3
73	M	21	ABA	4	3	4
74	M	21	ABA	4	1	1
75	M	21	AVE	3		2
76	M	20	ABA	3	3	2
77	F	21	ABA	2	3	3
78	F	21	ABA	4	3	4
79	F	20	ABA	4	2	4
80	M	20	ABA	3	2	4
81	F	21	AVE	4	1	4
82	F	21	ABA	4	2	4
83	F	40	ABA	1	1	2
84	F	21	ABA	4	3	4
85	F	21	AVE	3	3	3
86	F	21	AVE	3	3	4
87	M	21	ABA	2	2	1
88	M	21	AVE	3	3	3
89	F	40	ABA	4	4	4
90	F	20	ABA	4	4	1
91	F	21	AVE	3	3	4
92	M	21	ABA	4	4	3
93	M	21	ABA	3	3	4
94	F	21	ABA	4	4	4
95	M	20	AVE	4	4	4
96	M	21	ABA	3	3	3
97	M	21	ABA	3	3	3
98	M	21	ABA	3	3	1
99	F	21	ABA	3	3	2
100	F	20	ABA	3	3	4
101	F	21	ABA	1	1	2
102	F	40	AVE	2	2	1
103	M	40	ABA	1	1	1
104	F	21	ABA	2	2	3
105	M	21	ABA	1	1	1
106	F	20	AVE	4	4	4

Appendix A1

Contact	Sex	Age	Usage	GE	CT	WO
107	M	40	ABA	3	1	2
108	F	21	AVE	3	2	2
109	M	21	AVE	4	2	3
110	M	40	ABA	1		4
111	F	40	ABA	2	4	1
112	M	21	ABA	4	4	3
113	F	20	AVE	4	3	3
114	F	21	AVE	1	1	2
115	M	21	ABA	3	3	1
116	F	21	ABA	3	2	2
117	F	21	AVE	3	2	4
118	F	21	AVE	2	3	1
119	M	21	AVE	4	1	2
120	M	21	ABA	4	3	2
121	F	21	AVE	2	2	3
122	F	21	ABA	3	4	1
123	F	40	AVE	4	1	1
124	F	20	AVE	2	2	2
125	M	21	ABA	3	2	1
126	F	21	ABA	3	4	2
127	M	21	ABA	3	2	1
128	F	21	ABA	4	1	3
129	M	40	AVE	3	2	1
130	F	21	ABA	3	1	1
131	M	21	ABA	1	1	1
132	M	21	ABA	4	1	1
133	F	20	ABA	4	1	3
134	F	20	AVE	4	1	3
135	M	21	AVE	4	1	3
136	M	40	ABA	4	1	3
137	M	20	ABA	3	2	2
138	F	40	AVE	3	1	4
139	F	40	ABA	4	4	3
140	M	21	ABA	4	3	2
141	M	20	AVE	4	1	4
142	M	21	ABA	4	3	4
143	F	21	ABA	4	2	1
144	F	21	ABA	4	2	4
145	M	21	ABA	3	2	4
146	F	21	BA	3	3	1
147	M	21	ABA	3	3	3
148	F	21	AVE	3	3	4
149	M	21	ABA	3	2	2
150	M	21	AVE	4	1	2
151	F	21	ABA	4	1	4
152	F	21	ABA	3		
153	F	21	AVE	2	1	3
154	F	21	AVE	4	1	3
155	M	21	AVE	4	3	2
156	M	21	ABA	3	2	2
157	M	21	AVE	4	2	2
158	M	21	AVE	2	2	2
159	M	21	ABA	3	1	2

Appendix A1

Contact	Sex	Age	Usage	GE	CT	WO
160	M	21	ABA	2	2	1
161	F	21	ABA	4	1	3
162	M	20	ABA	3	1	1
163	F	20	BA	4	1	3
164	F	21	AVE	3	3	2
165	F	40	ABA	2	2	1
166	M	21	ABA	4	2	3
167	M	21	ABA	3	3	4
168	M	21	ABA	1	1	1
169	M	21	ABA	3	4	2
170	F	21	ABA	3	2	1
171	M	21	ABA	4	3	1
172	M	21	ABA	2	2	3
173	M	21	ABA	2	4	1
174	F	40	AVE	3	2	3
175	F	21	ABA	3	3	1
176	F	40	ABA	3	2	2
177	M	21	ABA	4	3	4
178	F	21	ABA	3	2	3
179	F	21	ABA	2	3	3
180	M	21	ABA	1	4	1
181	M	21	ABA	4	2	1
182	M	21	BA	4	4	4
183	M	21	ABA	2	1	2
184	M	21	ABA	4	2	1
185	M	20	ABA	2	2	3
186	F	40	ABA	2	2	2
187	M	21	ABA	2	4	3
188	M	21	ABA	4	2	3
189	M	21	AVE	3	2	1
190	M	21	ABA	3	1	1
191	F	21	ABA	4	2	4
192	M	21	ABA	4	1	4
193	F	21	ABA	4	2	3
194	M	20	AVE	2	2	2
195	M	20	ABA	4	3	4
196	M	21	ABA	3	2	2
197	M	21	AVE	2	1	3
198	F	21	ABA	3	3	3
199	F	21	ABA	1	1	2
200	F	21	ABA	4	4	3
201	F	40	ABA	1	1	1
202	M	20	AVE	2	2	3
203	F	40	ABA	4	4	1
204	F	21	ABA	4	4	3
205	M	21	ABA	4	4	1
206	F	21	AVE	3	3	4
207	F	20	AVE	3	3	1
208	F	20	AVE	3	3	2
209	M	21	AVE	4	4	1
210	M	21	AVE	3	3	2
211	F	20	AVE	3	3	1

Appendix A1

Contact	Sex	Age	Usage	GE	CT	WO
212	M	21	ABA	4	4	4
213	F	21	ABA	4	2	3
214	F	40	ABA	3	1	3
215	F	40	ABA	1	1	1
216	M	20	AVE	3	1	3
217	F	40	ABA	3	1	2
218	M	21	ABA	4	1	3
219	F	21	AVE	4	2	4
220	F	21	AVE	3	2	4
221	F	21	AVE	4	2	1
222	F	20	AVE	3	2	3
223	F	21	AVE	4	3	2
224	F	21	ABA	3	4	3
225	M	20	AVE	3	1	2
226	M	21	AVE	4	3	3
227	F	20	ABA	4	1	2
228	F	21	ABA	4	2	3
229	M	21	ABA	3	3	4
230	M	21	ABA	2	1	3
231	F	21	AVE	3	1	2
232	M	21	ABA	3	1	4
233	F	21	ABA	4	3	4
234	M	21	ABA	3	1	2
235	M	21	ABA	2	1	4
236	M	21	ABA	4	1	4
237	M	21	ABA	3	3	4
238	F	21	ABA	3	1	2
239	M	21	AVE	1	1	2
240	F	21	ABA	4	3	4
241	M	21	ABA	4	2	3
242	M	21	ABA	3	1	1
243	M	21	AVE	2	3	1
244	M	40	ABA	3	4	2
245	M	21	ABA	3	1	1
246	M	21	ABA	2	3	2
247	M	21	ABA	2	4	2
248	F	21	ABA	4	1	2
249	F	21	ABA	2	4	3
250	M	21	ABA	3	2	3
251	M	21	ABA	3	2	3
252	M	21	ABA	2	3	3
253	M	21	ABA	4	2	1
254	M	21	ABA	2	2	3
255	M	21	ABA	3	1	2
256	M	21	ABA	4	1	3
257	M	21	ABA	3	1	2
258	M	21	ABA	2	1	2
259	M	21	ABA	3	3	3
260	M	21	ABA	3	4	3
261	M	20	ABA	3	2	1
262	M	20	ABA	4	4	2
263	M	21	ABA	3	3	2
264	F	21	ABA	4	1	3

Appendix A1

Contact	NT	LT	PE	COM	CO	CE	DT
1	4	4	3	2	4	3	4
2	4	2	2	4	2	3	3
3	4	3	4		4	4	2
4	3	2					
5	4	4					
6	4	3					
7	2	3	1	4	1	4	1
8	2	3					
9	3	3					
10	4	4	4	3	3	4	4
11	4	4					
12	3	2	3	1	4	4	3
13	4	2					
14	4	2					
15	4	4	4	1	4	4	1
16	4	3	1	4	2	3	1
17	4	2					
18	3	1					
19	2	1	2	2		1	
20	4	2					
21	1	1	1	2	1	1	2
22	4	3	2	4	4	1	1
23	1	1	4	1	4	4	4
24	3	1					
25	1	1	1	4	1	1	2
26	1	1	1	4	1	1	4
27	4	3					
28	3	3					
29	2	2	1	1	1	1	1
30	2	2	1	1	1	1	4
31	4	3	1	4	1	4	1
32	2	1					
33	3	3					
34	4	4					
35	4	4					
36	2	1					
37	4	4	1	4	2	2	2
38	1	1					
39	2	2	1	1	1	1	4
40	4	3	1	4	1	4	1
41	2	1					
42	3	3					
43			1	4	1	1	1
44	3	1	1	4	1	1	3
45	3	2	3	1	2	3	3
46	2	2					
47	4	4					
48	3	2	3	4	1	1	4
49	4	4	3	3	4	3	3
50	4	4	2	4	4	3	2
51	3	1	2	4	1	1	4
52	3	3	2	4	2	2	4
53	2	1	1	4	1	2	3

Appendix A1

Contact	NT	LT	PE	COM	CO	CE	DT
54	4	4	2	3	3	4	1
55	2	2					
56	4	4					
57	4	4					
58	3	3	2	1	1	3	2
59	4	4	4	3	1	2	1
60	4	4	4	1	4	4	1
61	3	3					
62	4	4					
63	3	3					
64	4	4					
65	3	3					
66	1	1	2	2	2	1	2
67	4	4					
68	4	4					
69	3	3					
70	4	4	4	2	3	3	4
71	3	3	2	2	1	4	1
72	4	3	2	2	3	2	2
73	3	3	2	4	2	3	4
74	1	1	3	3	4	1	4
75	2	2					
76	4	3	2	3	1	1	1
77	2	1	4	3	3	2	2
78	4	2					
79	4	4					
80	3	3					
81	4	3					
82	4	4	3	4	3	3	4
83	1	1					
84	4	3					
85	3	4					
86	4	3					
87	2	1	1	2	1	1	4
88	3						
89	4	4					
90	4	3	1	4	1	1	1
91	4	2					
92	4	4					
93	4	4	4	2	4	2	3
94	4	4	3	4	1	2	4
95	4	4					
96	4	3					
97	3	4	1	4	1	2	4
98	2	2	2	3	2	3	4
99	2	2	1	4	1	1	2
100	3	3	1	4	1	1	4
101	2	1					
102	1	1					
103	1	1	1	3	2	1	3
104	2	4					
105	4	1	1	3	1	1	1
106	4	4					

Appendix A1

Contact	NT	LT	PE	COM	CO	CE	DT
107	4	3					
108	3	3					
109	3	1					
110	1	1	1	2	2	3	2
111	2	2					
112	4	3	4	4	4	4	3
113	4	3					
114	1	1	1	1	1	1	1
115	4	4	1	1	1	2	4
116	4	3	3	3	2	2	1
117	4	1	2	3	4	2	1
118	1	3	1	2	1	1	3
119	2	3					
120	2	2	1	4	1	1	1
121	4	4					
122	1	3					
123	1	1					
124	4	4					
125	4	4	4	3	4	4	2
126	4	4	1	4	1	3	4
127	2	3	1	4	3	3	1
128	4	4	3	1			
129	2	3					
130	4	2	1	3	1	1	1
131	4	4	1	4	1	1	3
132	1	2	1	2	1	1	3
133	4	3					
134	4	3					
135	4	4					
136	4	4					
137	3	3	1	4	1	2	1
138	3	4	3	1	3	3	1
139	3	2					
140	4	2	1	4	1	2	3
141	4	4					
142	3	2	4	1	2	2	1
143	1	3	1	4	1	4	3
144	4	4	3	3	3	2	4
145	4	4	2	1	3	3	4
146	3	3					
147	2	2	2	1	2	3	3
148	3	3					
149	2	2	3	4	3	2	1
150	4	4					
151	4	3					
152	4	4					
153	1	3	1	3	4	3	1
154	4	4					
155	3	3					
156	4	3	2	2	3	3	1
157	4	2	1	4	1	2	1
158	3	1					
159	4	2					

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Contact	NT	LT	PE	COM	CO	CE	DT
160	1	4	2	2	2	2	1
161	4	4	1	4	1	1	1
162	1	1	1	3	1	1	2
163	3	4	2	2	2	1	1
164	4	4	1	4	1	2	4
165	2	3					
166	4	3	3	3	3	4	4
167	2	4	1	4	3	1	4
168	3						
169	3	3	1	4	1	1	4
170	3	4					
171	4	3	4	1	4	4	2
172	1	1	4	4	4	4	4
173	1	1	1	4	1	1	3
174	3	2					
175	3	2	1	4	1	3	1
176	4	4	3	2	3	3	3
177	4	3	2	4	2	1	3
178	4	3					
179	3	3	1	1	3	3	4
180	1	1	1	4	1	1	
181	4	3					
182	1	4	1	4	4	1	
183	4	4	4		4	4	3
184	4	2	1	1	1	2	2
185	3	3	1	3	1	3	1
186	1	1					
187	3	2	2	3	2	1	4
188	4	3	3	3	2	2	2
189	3	3	2	2	2	2	1
190	2	1	2	3	1	2	1
191	3	4	2	4	3	4	1
192	4	4	2	3	2	1	4
193	4	4	4	3	3	4	2
194	2	1	2	2	2	3	2
195	4	4	3	4	3	4	4
196	3	2	2	1	3	1	2
197	4	2					
198	4	3	3	4	3	3	1
199							
200	2	3	2	1	3	3	1
201	1	3					
202	3	2	3	3	3	4	3
203	3	4	3	2	1	1	1
204	4	4					
205	2	2					
206	4	4	2	1	2	2	1
207	1	3					
208	2	3	2	3	2	2	2
209	1	3	1	1	3		
210	4	4	2	4	4		
211	3	4	1	3	4		

Appendix A1

Contact	NT	LT	PA	COM	CO	CE	DT
212	4	3					
213	3	2					
214	3	3	1	4	1	1	3
215	1	2	1	4	4	4	4
216	4	4					
217	3	2	4	1	2	4	1
218	4	3	3	3	3	1	1
219	3	4	4	4	2	2	3
220	3	2	4	4	4	4	2
221	2	1	4	1	3	2	3
222	3	3					
223	4	4	2	3	4	2	4
224	3	3					
225	4	1					
226	2	2					
227	4	4					
228	4	4	1	4	1	1	4
229	2	2	1	4	4	1	4
230	4	3					
231	4	4					
232	4	3					
233	4	3					
234	4	3	2	4	4	2	3
235	3	2	1	4	3	2	4
236	3	3	1	4	2	1	3
237	3	3	1	3	2	2	3
238	3	3					
239	3	3	1	4	3	2	4
240	3	4	3	3	1	1	3
241	3	3	2	1	3	2	1
242	2	1	1	3	1	1	3
243	1	1	2	4	1	2	1
244	2	1	4	2	3	2	2
245	3	4	1	4	1	2	2
246	4	1	1	4	1	2	2
247	3	2	1	4	3	2	3
248	4	4	3	2	2	4	1
249	3	3	2	1	2	2	3
250	4	4	2	1	3	2	4
251	4	1	1	4	1	2	4
252	4	3	1	4	2	2	3
253	4	4	3	3	1	1	2
254	3	2	1	3	1	1	1
255	4	3	1	4	2	2	4
256	4	3	1	4	4	2	3
257	3	3	4	1	4	4	1
258	2	2	2	2	3	3	3
259	3	1	2	1	1	1	1
260	4	1	1	4	1	2	2
261	1	1	2	4	1	3	4
262	3	2	1	4	2	1	3
263	1	2	1	4	1	1	3
264	4	4	2	3	3	3	1

Appendix A1

Results Tables

GROUPS	GPGE	GPCT	GPWO	GPNT	GPLT	GPPA
1	18	87	64	32	46	68
2	43	86	67	40	53	40
3	101	53	79	70	85	25
4	102	30	51	121	77	22

GPCO	GPCOM	GPCE	GPDT	GROUP2	GUSAGE
62	29	52	49	Little/no use	4
32	23	46	26	Average use	74
33	34	29	35	Above average use	186
26	67	27	42		

GROUP3	GPSEX	GROUP4	GPAGE	GROUPS	TOTAL
Male	153	0-20 years	51	No programming	109
Female	111	21-45 years	184	Programming	155
		Over 45 years	29		

A.2 Follow-up survey data

This survey used the dyslexia-mailing forum to request information from those subjects who had already taken part in the initial survey. The subjects were asked to provide comments, which were then analysed. Email addresses and names were given which will not be disclosed. The follow up survey form is also provided to show which categories comments were requested. The comments have not been included but the results were shown in Chapter 4.

Survey form

General details

Occupation:

Country of residence:

First language spoken:

Any other spoken languages:

Do you have the same written problems as your first language?

(Give details):

Has the effects of your dyslexia changed over time?

(If yes give details):

Have been able to overcome any of the language problems?

(If yes give details):

Please supply any further information related to how dyslexia affects your written language abilities:

Grammar and spelling abilities

Sequencing of: Letters/words/numbers

Comments:

Spelling: Reversing the word/ exchanging letters e.g. p for b

Comments:

Reading: Reading sentences or words

Comments:

Memory: need repetition, short-term memory

Comments:

Grammar: Not knowing or understanding the rules

Comments:

Constructing sentences

Comments:

Other, give details:

Please supply any further information related to your grammar or spelling problems:

Current methods used to help with written English

Word processing packages

Comments:

Spell checkers

Comments:

Appendix A2

Grammatical tools

Comments:

Friends and family

Comments:

Others, give details:

Please supply any further information:

Name any software packages you use to assist with written English

Type: Name:

Type: Name

Were any of these packages specifically designed for adults with dyslexia?
If so which features did you find useful:

Grade features if used (Scale 1 (not helpful) to 4 (very helpful))

Interactive help:

Comments:

Phonetic spell checker:

Comments:

Text to speech:

Comments:

Speech to text:

Comments:

Easy to understand guidance:

Comments:

Using pictures or diagrams:

Comments:

Sentence construction:

Comments:

List any other useful features:

Comments:

Have you used any software that teaches written English?

Name

Name

Comments:

Please give details about the teaching method used and how useful you found it. Also list any features, which were liked

Comments:

General comments

Comments:

The results table provides details concerning: occupation, country of residence and linked contact number used in initial survey.

Appendix A2

Contact	Country	Occupation
180	USA	Software engineering
262	GB	
2	GB -Derby	Computer technician
71	GB	
41	USA	Owner of music store
99	USA	Computer programming
27	GB	
97	USA	Software developer
190	GB - Bradford	
16	GB	Computer co-ordinator
157	USA	Sales person
245	USA	Computer programmer
259	GB	Final BA student
230	USA	
110	USA	Retired lorry driver
26	GB	PhD in Astrophysics
81	USA	Gaming executive
121	USA	Home maker
67	USA	Insurance
165	GB	Executive secretary
142	USA	Computer field engineer
79	GB	Student teacher
225	GB - Dublin	Graphics designer
238	USA	Research
143	GB	
247	USA	Student
109	AUSTRALIA	
260		
198	GB	
112	AUSTRALIA	PhD student lives of dyslexics
159		
145	GB	
248	GB - London	Computing student
210	GB - Leicester	Senior marketing lecturer
148	USA	Student
48	GB - Leeds	Research fellow
176	GB	
24	GB - Leicester	Research associate
244	USA	Electronics engineer
251	GB - Teesside	PhD software engineering

Appendix A2

Contact	Country	Occupation
101	GB	Research assistant
66	USA	Student
135	GB	Machine operator
215	BRAZIL	Dr in psychology
58	GB	Unemployed
94	USA	Insurance
175	GB	
51	GB	PhD research assistant
212	GB	
128	CANADA	Research assistant
242	GB – Leeds	PhD student CBL
196	GB	Technical support
241	GB	Data entry
192	GB	
76	GB	Student
129	USA	Literacy recruiter
224	GB	
65	USA	Nursing assistant
147	GB	Physics student
264	USA	Executive director
79	GB – Bradford	Phd student
123	GB – Derby	
151	GB	
139	USA	Educational evaluator
New contact	GB – Loughborough	Group leader
137	GB - Loughborough	Student at Loughborough
169	USA	College English teacher
233	GB - Newcastle	Psychology student
204	USA	Sales
258	USA	
102	USA	
131	GERMANY	PhD student
214	USA	Software developer
1	GB	Teachers aide for disabled
149	GB – Canterbury	
72	GB	3 rd year law student
171	GB – Leicester	Student
193	GB	
250	USA	Accounts manager
166	GB – Bradford	Computing student
240	USA	
249	USA	Technical support
177	USA	Computer consultant
203	GB	
99	AUSTRALIA	
185	GB	

Key

Contact: linked to initial survey.

A.3 Implementing default settings for env1

Implementing the default document and environment variables

Visual C++ code extracts are provided to give a basic understanding for the chosen implementation language. In order to change the default settings, code needed to be added to a file called *wordpvw.cpp*. This file creates the view seen by the user of the system. In technical terms it represents the implementation of the *CWordPadView* class. It is also one of the main programs to which alterations were made. The file was too long to include within the thesis (two hundred pages).

Background colour

The background colour needed to be changed to blue and the text to white, as indicated in the design specifications. The class *CRichEditCtrl* (underlining class used for word processing) has a member function *SetBackgroundColor*, which was ideal for changing the background colour. Since these colours are to be the default colours for the environment, this function call was placed immediately after the creation of the control in the *OnCreate* function of *CWordPadView*. The code for changing the background colour to blue is:

```
GetRichEditCtrl().SetBackgroundColor (FALSE, RGB(0, 0, 255))  
M_CurrentBackgroundColour = RGB(0,0,255);
```

The first parameter is a Boolean, used to indicate whether the background colour should be set to the system value. If this is *TRUE*, the second parameter is ignored. The second parameter gives the colour for the background. (*RGB* is a macro used to set the red, green and blue values of the colour. In this case, the colour is pure blue, at maximum intensity.)

Text colour and font size

The code for changing the text colours and setting the font size to 14 (font style not changed) was added after the `GetDefaultFont` function. The code is:

```
cf.dwEffects = 0;
cf.yHeight = 280; // 14 pt
cf.yOffset = 0;
cf.crTextColor = RGB(255, 255, 255); //white
m_CurrentTextColour = RGB(255, 255, 255);
m_CurrentHighlightColour = RGB(200, 200, 200); //Grey
```

The member *yHeight* is the height of the characters (divided by 20 to give the font size, i.e. if the *yHeight* is 280, font size is 14). The member *yOffset* is the distance of the characters above the baseline. This value is 0 for normal characters. A positive value indicates superscript a negative value indicates subscript. The member *crTextColor* is the colour of the text. (A RGB value like that used for the background colour.) When a user document is first opened, there should be no unusual character formatting effects active. Hence, the *dwEffects* member was set to 0. The default text colour was to be white, so the *crTextColor* member was set to white. The highlight colour was set to grey.

A.4 Implementing a question dialog box

The aim is to show how an example question dialog box used in environment 3 is implemented. It will then be possible to explain how data is passed to and from the control function. Figure A.1 shows a default dialog box and an example question box, which uses radio buttons. The controls toolbar, which was used to create the dialog box features, is also shown. A step-by-step guide to how the dialog box on the right is formed from the dialog box on the left will be provided.

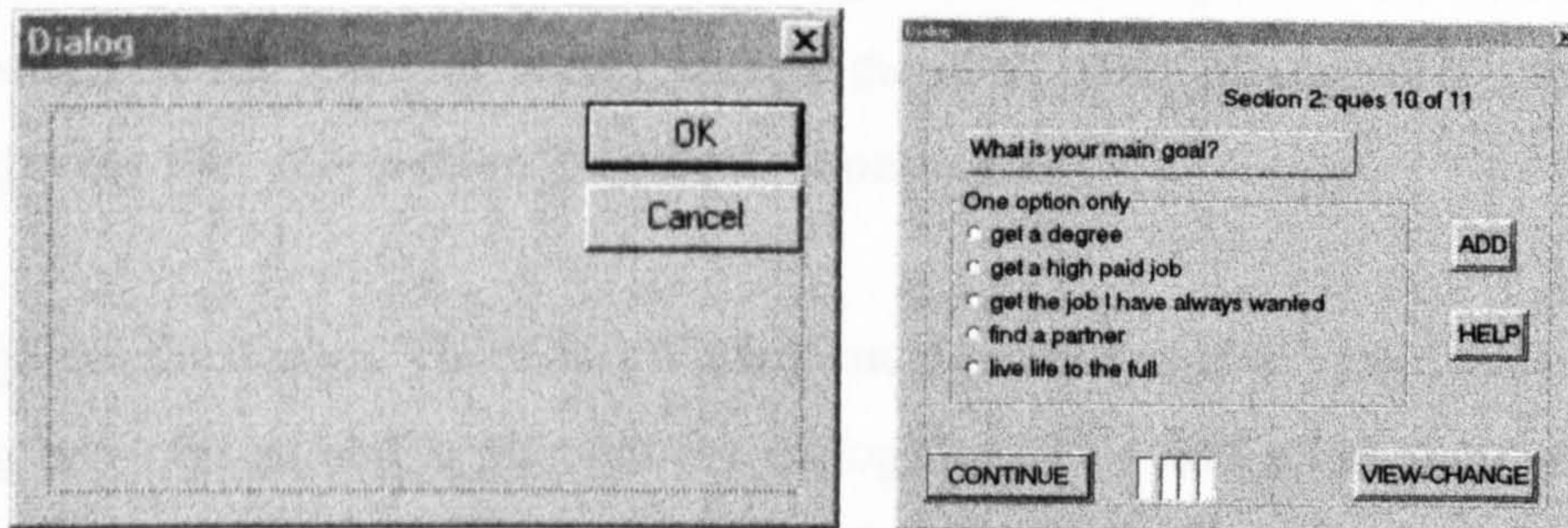

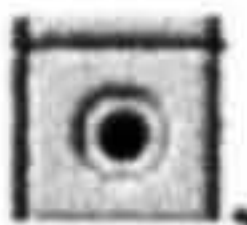





Figure A.1. Example depicting default and question dialog box.

Implementing the design

The programmer when creating a dialog box is initially presented with a dialog box with only an OK and CANCEL button. The controls toolbar is used to select the required feature by clicking on the button and using the pointer to place it in the correct position in the dialog box. The example dialog box design is as follows:

- Select the static text button  and add the text 'Section 2: ques 10 of 11'
- Repeat process for 'One option only'
- Repeat for 'What is your main goal?' Use the mouse and right click over the static box and select properties. Select 'border' option in 'Styles' menu and 'Modal frame' in 'Extended styles' menu
- Select the radio button , select properties as above. Change the caption to 'get a degree' in 'General' menu. Repeat this process for the remaining four options
- Select the group button , and position it around the options as shown
- Right click on the OK button, select properties, in 'General' menu change caption to 'CONTINUE', select 'Modal Frame' in 'Extended styles' menu
- Right click on 'CANCEL' button and select 'cut' to remove it

- Select the button , select properties (as above) change the caption to 'ADD', and change from 'ID_button' to 'ID_ADD', set 'Modal Frame' (as above)
- Repeat the process for VIEW_CHANGE giving it an id of 'ID_VIEW', and 'HELP' giving it an id of 'ID_HELP'
- Select the edit button , select properties, 'General' menu remove the visible option by clicking the associated box. Repeat the process three more times
- The final task is to rename the dialog box. Click right button while not on a feature, select 'General' menu, change the id to 'IDD_mls2ques10. (name format ml = my life, s2 = section 2, ques10 = question 10)

This completes the design. The 'ClassWizard' must now be used to create a class to group the dialog box objects and implement the dialog box. This will allow data values to be linked to the created features and also send data to the calling function.

Using the ClassWizard

Using the mouse right click method can be used to access the ClassWizard. As it is a new dialog box you will be asked to create a new class. Select yes, the class name will be suggested, (removes the IDD from the dialog box name and adds a capital 'C') Cmls2ques10. The ClassWizard creates a file (.cpp) and a header file (.h) named similar to the class with the removal of capital 'C'.

It is now necessary to enable the buttons so some action is taken when the user selects them. Figure A.2 shows the option identifiers's (ID's) and the available actions.

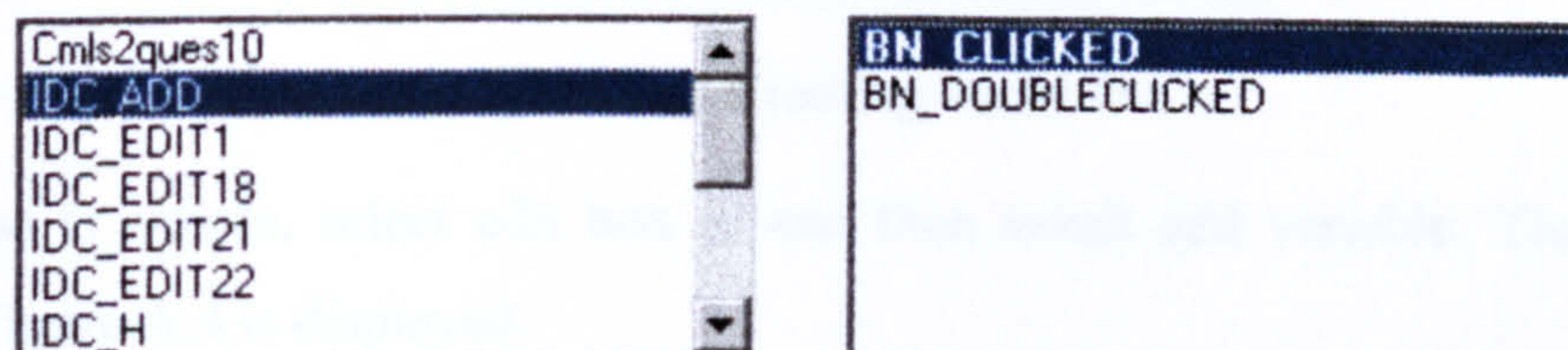


Figure A.2. Linking identifier's to actions.

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OK needs to be selected and a function template will be created for the Add function. This function will be activated when the user selects the Add function. At a later stage code will be added to this function. This process needs to be repeated for the remaining buttons (HELP, VIEW_CHANGE and radio buttons).

The edit box is a special case. To enable values to be passed back to the control function variables need to be used. Only edit boxes allow the programmer to create variables, which can pass data to the calling program (and data can be sent back). The edit boxes in this case are not visible to the user they are simply there to allow variables to be created. One variable is required for the radio buttons to hold the data from the selected button and one variable for each of the feature buttons: HELP, ADD, VIEW-CHANGE. These variables are required so the control function will know which selections have been made, i.e. did the user select the Help function. If check boxes were used they would require one variable for each option as the user could choose to select all of the options and the control program must be made aware of this. Figure A.3 shows how variables are created (1 per edit box).

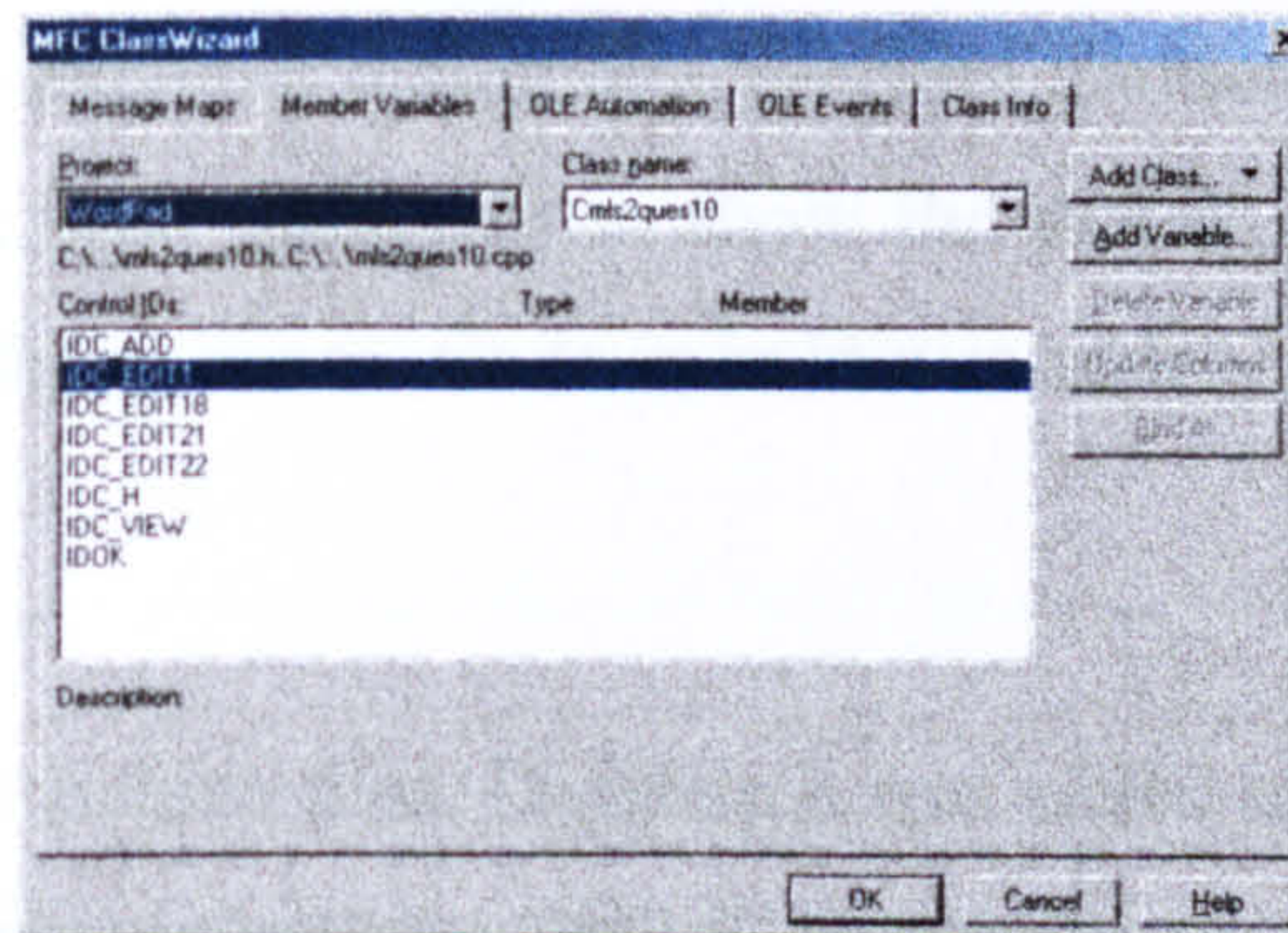


Figure A.3. Creating variables.

The process is simple, select edit box id and then select add variable. The dialog box shown in Figure A.4 is displayed.

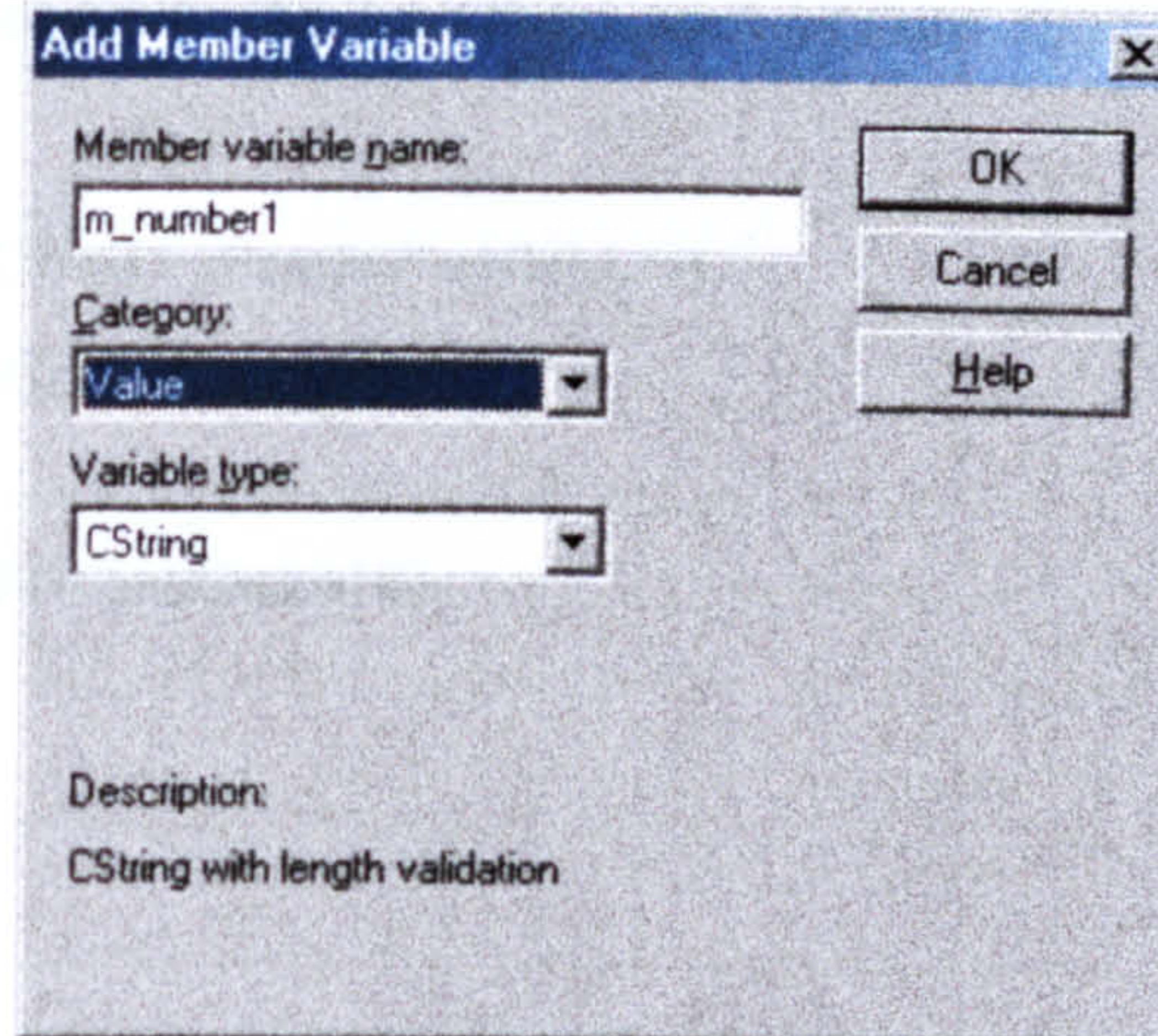


Figure A.4. Add member variable.

The member variable name needs to be entered, example shown. The variable type should be left as 'CString'. Select OK and repeat the process for the remaining three edit boxes. The ClassWizard will insert these variable into the associated '.cpp' and '.h' files so they can be used. It is now necessary to view the dialog file and add values to the variables.

Example dialog box code

This section will use an example dialog box program, (which is used to implement the dialog box that has just been designed) to show the dialog implementation procedure, which is similar for all dialog boxes. Code in bold was added, remaining text was created by the ClassWizard.

This section contains the include files. DysHelp.h was added to allow the help dialog box to be accessed when the user selects the 'HELP' button.

Program name: // mls2ques10.cpp : implementation file

```
#include "stdafx.h"
```

```
#include "wordpad.h"
```

```
#include "mls2ques10.h"
```

```
#include "DysHelp.h"
```

```
#ifdef _DEBUG
```

```
#define new DEBUG_NEW
```

```
#undef THIS_FILE
```

```
static char THIS_FILE[] = __FILE__;
```

```
#endif
```


Appendix A4

This section is used to declare the variables and ensure they have no initial value. No code was added.

```
CmIs2ques10::CmIs2ques10(CWnd* pParent /*=NULL*/)
    : CDialog(CmIs2ques10::IDD, pParent)
{
   //{{AFX_DATA_INIT(CmIs2ques10)
    m_help = _T("");
    m_add = _T("");
    m_view = _T("");
    m_number = _T("");
    //}}AFX_DATA_INIT
}
```

This section is used to allow data to be sent back to the calling program via variables: m_help, m_add, m_view and m_number. No code was added.

```
void CmIs2ques10::DoDataExchange(CDataExchange* pDX)
{
    CDialog::DoDataExchange(pDX);
   //{{AFX_DATA_MAP(CmIs2ques10)
    // DDX_Text(pDX, IDC_EDIT1, m_help);
    // DDX_Text(pDX, IDC_EDIT18, m_add);
    // DDX_Text(pDX, IDC_EDIT21, m_view);
    // DDX_Text(pDX, IDC_EDIT22, m_number);
    //}}AFX_DATA_MAP }
}
```

This section is to enable some action (button function) to be taken when the buttons are selected. No code was added.

```
BEGIN_MESSAGE_MAP(CmIs2ques10, CDialog)
   //{{AFX_MSG_MAP(CmIs2ques10)
    ON_BN_CLICKED(IDC_ADD, OnAdd)
    ON_BN_CLICKED(IDC_H, OnH)
    ON_BN_CLICKED(IDC_RADIO1, OnRadio1)
    ON_BN_CLICKED(IDC_RADIO2, OnRadio2)
    ON_BN_CLICKED(IDC_RADIO3, OnRadio3)
    ON_BN_CLICKED(IDC_RADIO4, OnRadio4)
    ON_BN_CLICKED(IDC_RADIO5, OnRadio5)
    ON_BN_CLICKED(IDC_VIEW, OnView)
    //}}AFX_MSG_MAP
END_MESSAGE_MAP()
```


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```
//}}AFX_MSG_MAP
END_MESSAGE_MAP()
```

```
*****
```

If the Add function is pressed a value is given to the variable `m_add`. This will be sent back to the calling program, which will then know that ADD has been selected. The 'OnOK' function closes the current dialog box.

```
void Cmls2ques10::OnAdd()
{
    // TODO: Add your control notification handler code here
    m_add="*";
    OnOK();
}
```

```
*****
```

If the Help function is pressed the help dialog box is called. The help dialog box is the default box used by all question dialog boxes thus, values need to be sent to it to provide help linked to specific questions. This will differ for each question dialog box. The variable `m_help` will be given a value to inform the calling program that help has been given. The calling program will then have to redisplay this question dialog box.

```
void Cmls2ques10::OnH()
{
    // TODO: Add your control notification handler code here
    CDysHelp DysHelp;
    DysHelp.m_word2meaning="What is your main goal in your life. Select ADD to form your own option.";
    DysHelp.m_word1="-----";
    DysHelp.m_word1meaning="-----";
    DysHelp.DoModal(); // this displays the help dialog box
    m_help="*";
}
```

```
*****
```

If the first radio button is selected the variable `m_number` will hold the text string "get a degree. " This will be passed to the calling program. This process is the same for the remaining radio buttons. The value of `m_number` will equal the users selection. If the add function is selected the `m_number` value will be ignored as only one selection is allowed (add has higher preference).

```
void Cmls2ques10::OnRadio1()
```


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```
{  
    // TODO: Add your control notification handler code here  
    m_number=" get a degree. ";  
}
```

```
void Cmls2ques10::OnRadio2()
```

```
{  
    // TODO: Add your control notification handler code here  
    m_number=" get a high paid job. ";  
}
```

```
void Cmls2ques10::OnRadio3()
```

```
{  
    // TODO: Add your control notification handler code here  
    m_number=" get the job I have always wanted. ";  
}
```

```
void Cmls2ques10::OnRadio4()
```

```
{  
    // TODO: Add your control notification handler code here  
    m_number=" find a partner. ";  
}
```

```
void Cmls2ques10::OnRadio5()
```

```
{  
    // TODO: Add your control notification handler code here  
    m_number=" live life to the full. ";  
}
```

```
*****
```

If the user selects the View-change function the variable m_view will be given a value and the calling program will take the appropriate action.

```
void Cmls2ques10::OnView()
```

```
{  
    // TODO: Add your control notification handler code here  
    m_view="*";  
    OnOK();  
}
```


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This example code will vary for each question dialog box. When check boxes are used the task is more complicated as many selections can be made. It also a far more complicated issue for the programming of the control function. However, the example used defines the concepts used and it is not necessary to provide a more complicated example, which would cause confusion to a non-programmer.

Example control function code

This section will review the code from the control function, which is used to accept data from the example question dialog box and create a sentence, which will then be stored in the document. The majority of the sample code is written in C++ and is relatively easy to follow. Added comments will be presented in bold.

These variables will be used to store the values passed from the question dialog box.

```
mls2ques10.m_view="";  
mls2ques10.m_help="";  
mls2ques10.m_add="";  
AddOption.m_option = "";
```

This displays the question dialog box and initialises the array, which will hold the sentence.

```
mls2ques10.DoModal(); // my life question 10 section 2  
nextsen[0]='\0';
```

This loop will continue to redisplay the question dialog box until a radio button is selected (mls2ques10.m_number) or the Add function is selected (mls2ques10.m_add)

```
while ((mls2ques10.m_number == "")&&(mls2ques10.m_add == ""))
```

```
{  
    if (mls2ques10.m_help == "") MessageBox("No option selected, Dialog box re-displayed", "Warning");  
    mls2ques10.m_view="";  
    mls2ques10.m_add="";  
    mls2ques10.DoModal();  
}
```

If the Add function has been selected the add dialog box will be displayed. A default add dialog box is used (similar to the help dialog box), thus values need to be sent, such as the question and sentence template.

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```
if (mls2ques10.m_add != "") //display add dialog box
{
    AddOption.m_ques="What is your main goal?";
    AddOption.m_format="My main goal is to *****.";
    AddOption.m_option="";
    AddOption.DoModal(); This displays the add dialog box.
```

This loop will continue until the user enters the option text.

```
while (AddOption.m_option=="")
{
    MessageBox("Error you must enter an option");
    AddOption.DoModal(); Redisplays add dialog box.
}
}
```

This copies the sentence template to the array, which holds the created sentence.

```
strcpy(nextsen,"My main goal is to");
```

If the add option was not used the radio button text is copied to the created sentence.

```
if (AddOption.m_option == "")
strcat(nextsen,mls2ques10.m_number);
```

If the add function was used a space is added, followed by the add text, a full stop and a further space (used to space the created sentences when stored in environment 1).

```
else
{
    strcat(nextsen," ");
    strcat(nextsen,AddOption.m_option);
    strcat(nextsen,". ");
```

This activates the spell checker and sends the created sentence. Any changes made will be updated.

```
//new bit to run spell checker
p=strlen(nextsen);
nword[0]=nextsen[p-1];
nextsen[p-1]='\0'; //remove sentence terminator
Sentence=nextsen;
Parser.OriginalSentence=Sentence;
NewSentence = Parser.ParseSentence();
strcpy(nextsen,NewSentence);
p=strlen(nextsen);
```


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```
nextsen[p]=nword[0];
nextsen[p+1]='\0';
//end
}
```

This displays the sentence to allow the user to make any changes before it is sent to the document. This is performed if the VIEW-CHANGE or Add function was selected.

```
if ((AddOption.m_number1!="")||(mIs2ques10.m_view!=""))
{
    VSENTENCE.m_sentence=nextsen;
    VSENTENCE.DoModal();
    strcpy(nextsen,VSENTENCE.m_sentence);
}
```

This writes the created sentence to the document.

```
GetRichEditCtrl().ReplaceSel(nextsen);
AddOption.m_number1="";
```

This was a relatively simple example. More complicated examples are briefly discussed:

- User can select a number of options (check boxes used)
The system must use the correct punctuation and modify the sentence. For example inserting 'and' between two options, or using commas when more than two options are selected. It may be necessary to alter components of the sentence, for example, using 'are' instead of 'is'
- Special case options are frequently used
Several options may require a completely different sentence template to be used. For example, when asked the question, 'Does anyone else in your family have dyslexia?' If the option 'no one' is selected the resulting sentence would be, 'There is no one else in my family who has dyslexia.' Other options would list the family members
- Checking option if add feature was used
The user may not have used the correct format for the add option. Removal of misplaced spaces and punctuation must be done

The implementation of these occurrences will not be covered, as the code is too complicated to follow. The example used shows the general procedure, which is the same for all question dialog boxes, it is purely the level of complexity that changes.

A.5 Example of written text using env1

Two assignments selected to show extremes in terms of difficulties with written English.

Reference name: student49	Pre-selected topic: Topic My life
Time taken: 30 minutes.	Status: female member of staff at Loughborough University

My childhood

I always had pets around me at home. I think that had a **lsting affect** as the first thing I bought when I left home was a cat. I still have two cats and two dogs. I also have some of the same **freinds**. I loved bagpuss and **latr_on** the young ones. I think it is really funny to see people wearing bagpuss bags and phone covers. A **fraind** and I recently watched her son's bagpus video. I don't think it would have been as funny to us then as it was that night. All my **freinds** and I were big , and I mean **BIG bog** George fans. Two **fo** them nearly had a **fallong** out over who would dress as Boy for our 30th **pary**. You would be surprised how difficult it is to hire a boy costume unless you make your own. But then, he had so many looks to **chose** from.

The present

I am pleased with my **liveing accomodation** as I own it mself, well, the **bulfign** society does technically. It is perfect for dogs and cats as there is a **perk** at the back of the house, **nad** not too far for me to nip **outto** the shops. There is even a iron mongers so when decorating I don't have to **trapse** to a **gib** superstore. Firstly I would like to finish my **devores**, but **inorder** to do this I will need to find another **paying** job. Stamping books woud be good as there is a library at the end of the road. I **hav** had enough of **universit ylife** at the moment. If you are **polical** animal then you can **sufrvive** better ,but I am fed up with having to have **za** translation of **he** subtext. E-mail is a bad thing to let academics **loos** on when it is summer holiday for the students. There **seams** little else to do but **critiices** others. Well the Open Univsoty takes me away from all of that. I like the course I am studying. It is a bit **frusrtatng** when I take time to learn the correct term for something, and then have to explain what I mean to **peple** who are more senior with more **qualfications** than me.

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University life

I **njoyed** being able to study a **verietiy** of subjects within my degree. The heavy text based English **litery** criticism **anoyed** me from the point of view that I wanted to take longer to read a book than the time **allow**. It removed **th efun** from it. I **droppd** English after the first **tow** years, as third year you carry on with double of one subject as a major subject. My art **freinds** used to say of me, **ahh** , shame she **tires** hard. I really enjoyed having my own desk to retreat to, other **undersgrads** **do't** have that luxury. I could **stopp** reading and **writting** and play with pens, paints, cut outs or what ever. I did not like being broke though. I don't know how students cope now there is no grant system at all. I felt a bit sad that at the end of it probably had less job **opportunities**. I **soo realis** I was applying for the wrong kind of jobs, drama and art graduates don't get creative jobs. Still **hav** some **freinds** from that time. It is good to have **freinds** in other parts of the country.

Future

I **ned** to travel I must travel. I would love to be a volunteer **someware** like Madagascar. **THE** fact that there are species of **animalswhich** only have ever existed on the island **faccinates** me. I have some **freinds** who are **traveling** at the moment., one is going to Spain to study for three months and then try and get a job over there. I

Thik it is about my turn. Well, I would also **like** to carry **one** upgrading my living **acomodation**. At last I have colour and pattern on the walls, that makes every thing feel much better. Still could dump some junk though. I am going to have a go at the car booting again. I can get rid of stuff if I can see **ditrect benefit**, and not just because I need space. Good job I only have three bedrooms worth of house. Well, see how the **divrce** thing goes and then think about **donig** something for me, and the dogs and cats. I think I have found a nice chap. Well, as Rusty dog **approves**, he can't be that bad. He **dosen't** mind coming over to pick me up and ending up with dog hairs on his clothes. Any **mand** who **loeves** shopping and does not object to second hand shops is on the **rithg** lines.

User evaluation

I found the blue back ground makes it easier to read. I noticed that the **highliter** is in yellow, so had a go at typing with that. It **seamed** to help I can distinguish the letters better, and I can see all sorts of daft **mistakes**. Black was too dull a text on the

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background. But this is a massive improvement on glaring white. Like being able to change colour this way. It is too much effort in word so haven't bothered before. Like big icons at the top. Would like something to check my **spellings** against, I **sue** the **thesurus** **inword** a lot. Too lazy to look up a word in a book, as takes too long. I automatically clicked the right button on the mouse when I saw a mistake, but of course there is no spell checker. I did not have a problem with finding **thinys** to **typee**, of with **sentance** **tructure**. However, still think there are plenty of mistakes I have not spotted, spelling wise. I think the notes were **helpfull** , **couldn** ot have written on each of the notes in the time allowed though. Grade 3.

Comment: This student made a very large number of spelling errors, in the region of 90. She had the classic trait of being able to spell quite difficult words correctly like, Madagascar and criticism but not able to spell the word 'friend'. Homophone errors and punctuation errors were also a problem. Her writing speed was very quick indeed. She gave the system a grade 3 because the level of support was not what she required. She was given a grade 4 on the academic level.

Reference name: student1	Pre-selected topic: Topic Who am I
Time taken: 28 minutes.	Status: male 2 nd year student at Loughborough University

General details about you

My name is Lee I am 31 years old and am male. I am a Scorpio, I was born in November/ Winter, I am Left handed, my favourite colour is Red, my lucky number is 10, I am in the second year of study. I think my main problems to be my slow reading and writing speed. In exams I am allowed 25% extra time, which though helping **considerabley** I feel that I am often still at a disadvantage.

About your family

I come from a fairly large family. I have two brothers and one sister. My brothers names are Shane and Glenn am my sisters name is Amber. My Mum and Dad's names are Susan and William. My mother works as a care assistant in a school and my father has retired. I am the first person in my family to go university, all my brothers and sisters work full-time. I live in Derby and commute to Loughborough to study.

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Describe your physical self

I am 6 feet tall and have a slim build. My hair colour is Red and I have Brown eyes. I like to keep fit and also try to maintain my ideal body weight. My skin is fair and I seem to have fairly sensitive skin; this is probably due to my hair colouring. My best feature is my brain. It would be nice to have good eyesight.

Describe your inner self

I think I have a fairly quiet personality but if I feel strongly about something I will make it known. Nowerdays I try to accept people for who they are and think that everyone has a good and a bad side. Due to the fact that I have lived alone for a long time I feel that I have become slightly inconsiderate but I try not to let it show.

User evaluation

I found the task fairly easy to perform. I use Word alot and am therefore fairly comfortable in this kind of environment. I think that I spell words quite well but still have to make alot of corrections due to not typing what I meant to type. I feel that I should have been able to write more in the time. Grade 3.

Comment: This student did not have a spelling problem, only 4 mistakes. His main problem was the inappropriate use of capital letters and writing very long sentences. His writing speed was also very slow. This student also gave the system a grade 3. He was given a grade 1 at academic level.

These two examples have shown the various degrees of difficulties test subjects have. Interestingly enough although their support needs were very different each gave the same usability grade.

A.6 Example of written text using env2

Two assignments selected to show extremes in terms of difficulties with written English.

Reference name: student49	Pre-selected topic: Topic Who am I
Time taken: 30 minutes.	Status: female member of staff at Loughborough University

General details about you

My name is Ursula as *pronunciation* (ponunciation) is easy in *German* (German) and English. I am thirty years old, which I think is a good age to be, but then again thirty one will be a good age next year. My birth sign is *Sagittarius* (sagitarious). This *is* (was i corrected by student when using text highlighter) the sign of the senator. It is an nice lively sign to be, half horse half man. I sometimes feel like that, that one half of me looks all calm on top, and underneath there are lots of *legs* (leggs) working away. I reckon my best number is nine, as that is *thy* (meant the not corrected) star sign, the ninth house. Don't know much about numerology though. I needed to use a computer for spell checking when I sat exams at *university* (Univstiy), But I think it hindered me, it took so long to spell check I could *only* (knly) *spen* (spend) 20 *mind* (meant minutes) per essay question. I was bad a (meant at) typing too, I still do mix up letters did it just then typed leet instead of lett. I would have been better helped if they could have given me tips on how to write clearer and extra time so I could *for* (meant form) *letter* (meant letters) better. Still, passed in the end.

About your family

I am an only child. My parents had me late in their lives. I have two cousins who I *grew* (grwe) up with seeing a lot of. They are *brothers* (borothers) so we sort of adopted each other. I had no brother, and they had no sister. *Unfortunately* (unfortunately) one of them has "sided" with my soon to be ex husband. He does not speak to me, well neither of them do. I was *the* (th) first to do a degree form Dad's side of the family. My dad *went* (whent) to Leicester poly. He was funded by the RAF when he left them. He did all sorts of diplomas *and* (ans) stuff, had a lot of letter he could put *after* (aftr) his name. I never found out what they meant. My mum was the oldest of three children. She said it was either that or become a nurse. I would have made a great university lecturer, but she

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trained t teach little ones. *This* (ths) was a disaster. She is deaf in one ear so any class she taught (tought) took about five *minutes* (minuets) to realise she can not tell who is making the noise, and can't hear all the comments muttered. She has some funny stories to tell, like the time she asked about them to bring in a pet. You can imagine. Yep the children ended up jumping out of the window *after* (aftr) the cat.

Describe your physical self

I *think* (thik) I look different *depending* (depeniing) on how I am felling. I look like a *wreck* (reck) when I have been rushing *somewhere* (somewhere), and I feel I look it too. Hair plastered to face, red in the face sweaty. Some people manage to keep looking cool whatever, I'm not one of them. One person said I had a nice "infectious *powerful* (powerfull) smile", I think he was creeping. I feel I look better when I smile. As a kid I always had a red nose for half the year, thank fully grown out of that, only happens when I have a really bad cold. My opinion of my best feature is changing. I used to feel very much that *me* (meant my) best feature was my shape, but I don't think *such* (shuch) things matter so much. I like to now think is smilinh, as I manage to smile a lot of the time. That makes you feel better about anything. I always worried *about* (baout) my *ability* (ability) to wear clothes, but I was always told I had no dress sense so *often* (oftern) I *believed* (blieved) it. I still have no concept of *size* (sixe). I just rely on *friends* (freinds) I trust to tell me if a colour does not suit me. I buy *things* (trhings) I either like the colour of, *or* (of, change after text highlighter used) the fell of. A *friend* (freind) *did* (di) say I bought this for *your* (meant you) as you are the only person I know who can wear such an *awful* (awfull) colour. She added that was meant as a compliment.

Describe your inner self

My *inner* (innser) self is *something* (sometwthing) I am *learning* (learnign) about. Perhaps it comes of being 30, or more *likely* (liekly) from going **though** (through) a *divorce* (devorce). I am gaining confidence. I *seam* (meant seem) to have held onto *friends* (freinds) for a long time, and always have a list of *people* (peopl) to call can catch up with. Making *friends* (freinds) is easy for me. I wish there were more free hours in the day to talk to them all more *often* (oftern). I think that sort of thing is a *strength* (stength). I can't always see the long term effects of something, some action, but can *usually* (usally) concider the wider effects. I dislike people who don't like animals. I don't mean

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people who don't have pats, but those who can be cruel to animals, cause them pain, tend to capable of *doingthat* (meant doing that, text highlight used) to humans too. I often get sad *listening* (listening) to the *news* (newd). In the last ten year, I think there have been a *lot* (alot) of bad things in the news.

User evaluation

I did not use the meaning tool very much. The spell checker picked up *nearly* (nealy) all of my mistakes, I was impressed. The text box helped *to* (remove one to) instantly see most of the mistakes, not always what the correct word should look like, but I could see that it was wrong. I used the predictor tool it *seamed* (meant seemed) quicker than most spell checkers would be. I did not write long *sentences* (sentances) this time. When I have written essays I have used long *sentences* (sentances). This would *certainly* (certsinly) help a lot with recognising *where* (meant whether) they are long and being able to *thin* (meant think) about just the text in that long *sentence* (sentence). I think it will make essay *Writing* (writting) much better. RATE: 2.

The spell checker certainly helped this test subject. The remaining errors were of the type of inappropriate use. The words were spelled correctly but used in the wrong context. There were still a large number of grammar errors in particular punctuation errors. This student requires support with sentence construction and grammar. The test subject was given an academic grade of 2 for this written work.

Reference name: student1	Pre-selected topic: Topic Dyslexia
Time taken: 29 minutes.	Status: male 2 nd year student at Loughborough University

How did dyslexia affect you as a child

At primary school I found English very difficult indeed. My main problem was my ability to keep up with the other students in my class. The English that we did was in the form of cards, the idea being that you completed one card before moving on to the next. I did not find the tasks contained in the cards difficult to complete, the problem was that because it took me so long to complete a card I never managed to work up to the higher more difficult levels. I can remember being tested at school by a *psychologist* (psychologist) but my mother told me that the outcome of that test mainly blamed my poor eyesight.

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Coping with dyslexia as an adult

On leaving school I got a job as a mechanic which mainly involved me performing physically rather than *academically* (accodemically). I did attend college one day a week but managed to succeed in the subjects I took. I can remember whilst at college I used to find note taking very difficult, this results in my notes becoming almost unreadable.

Dyslexia and different language structures

I think that it is *much* (mush) harder for me to understand any foreign languages. I have tried to learn languages before but don't seem to remember them very well. I seem to like things that have a **definite** (definate) structure to them, I like hard rules with no *grey* (gray) areas. I used to be very bad at sentence structuring, I think this was mainly due to lack of practice. I hated English whilst at school but since leaving have come to like it, although it still takes me a long time to read or write anything.

Using computers to help with written English

I think computers have helped *a lot* (alot) with my problem. Being able to easily correct mistakes is of great benefit. I would ideally like a fairly dark screen colour with yellow text, this is mainly to cut out eye strain. This is often difficult to achieve because a colour scheme set up in one application is often unusable in another.

User evaluation

I think the word predictor is a very good feature, but may benefit by being able to list possible word configurations so that the user can choose the required one. A self learning predictor that completed words as you typed might be *advantageous* (advantagous). The spell checker managed to find several words I had spelt wrongly. It should be very useful with a couple of improvements. Grade 2.

Comment: This student had less than 10 spelling mistakes, which were all corrected by the spell checker. This environment was set at the right level of support for him. His main problem is his writing and reading speed. Student was given an academic grade 1 for this written text.

A.7 Example of written text using env3

Two assignments selected to show extremes in terms of difficulties with written English.

Reference name: student49	Pre-selected topic: Topic Dyslexia
Time taken: 14 minutes.	Status: female member of staff at Loughborough University

How did dyslexia affect you as a child

As a child my dyslexia caused some problems for me. In general I just managed to overcome most of my dyslexia related problems. The main physical problems dyslexia caused me as a child was: not being able to estimate time, (should be comma) a short concentration span, (should be comma) a sight problem when reading and **coordination of hand eye**. The main academic problems dyslexia caused me as a child was: learning basic mathematical principles; learning English grammar rules; my untidy handwriting; my spelling. Dyslexia also caused social problems for me, the greatest problem was forgetting peoples names. My cousin is the only other member of my family who is also dyslexic. The benefits associated with having dyslexia as a child were: the ability to see complicated concepts as a series of pictures; being more visually aware than others; being more imaginative than others; seeing things differently to others. At school I was given no support due to a lack of knowledge. The main support I received at home was: extra teaching from parents; extra books. I tried to overcome my academic problems by doing extra work at home to catch up. As a child I lacked confidence and thought I was stupid.

Coping with dyslexia as an adult

As an adult my dyslexia causes some problems for me. In general I just managed to overcome most of my dyslexia related problems. The main physical problem dyslexia causes me as an adult is spelling and writing and typing. In my adult life the main academic problems dyslexia causes are: spelling; untidy handwriting; reading slowly; getting confused with mathematical problems. The main social problems dyslexia causes are: forgetting peoples names; not knowing left from right; being clumsy; being forgetful. There are also benefits to having dyslexia, the main ones being: seeing concepts as pictures; more imaginative than most; more visually aware than most; seeing things differently to most. The subject area I feel I need more help with is English mainly

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spelling and sentence structuring. The subject area I enjoy the most and feel I achieve high standards is English: creative writing. I try to overcome some of my academic problems by: avoiding handwriting by using word processors; using spell checkers whenever possible; using grammar checkers whenever possible; using memory mapping techniques. My dyslexia makes me think that I am stupid because I think differently and lack confidence in myself. A very common problem for many dyslexics is the inability to spell. I do not know the spelling rules and regularly interchange letters and frequently miss out letters. Writing concise grammatically correct sentences in English also causes many dyslexics problems. I do not know the grammar rules and use the wrong homophone words for example, there for their and tend to write long unstructured sentences.

Dyslexia and different language structures

I am able to write in one other foreign language, which is German. I find from my experience that English is no different to other foreign languages with respect to grammar and spelling. I have no experience of writing computer programming languages.

Using computers to help with written English

I frequently use word processors to perform written tasks. The word processing package I mainly use is Word and Cannon Strat Writer 75 and it has no specific features designed to help people with dyslexia. My preferred settings are: screen colour blue, character font colour yellow, font type Times New Roman and font size 14. When selecting options I prefer menus to icons. The main thing I like most about word processors is that it allows me to make changes easily. The thing I least like is that I find making selections from the spell check difficult. The improvements I would make to standard word processors are: spell checkers designed to detect dyslexic type errors; spell checkers which include word meanings for homophones; grammar checkers which give clear advise and help me; the inclusion of word predictors for words commonly spelled wrong. There is an increasing number of specialist or support packages now available. I have never used any. Word predictors allow you to type only the first few letters of a word and offer suggestions. I have used them and found it extremely useful. I have used Nokia mobile phone which includes a word predictor.

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User evaluation

In my opinion the system definitely achieves its main aim of automating sentence construction. The dialog display presentation was clear and easy to follow. The help button was provided to offer extra guidance when needed. I did not need to use it. The add button was provided to allow me to define my own options. I occasionally used it. The view button was provided to allow the user to view the sentences and make minor changes if required. I occasionally used it. I was pleased with the resulting sentences. I felt that the system was set at the right level, allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. One change I would like to see made is the inclusion of a back and forward button to allow changes to be made. In order to increase the usefulness of the control environment I think the inclusion of direction buttons (such as: back, forward, skip) to allow the user to make changes. In my opinion this control environment produces a higher standard compared to the other environments. This is mainly due to being allowed to concentrate on the content rather than the sentence syntax. I would class the system as first rate with regards to helping me with my sentence construction.

Comment: This written work was given an academic grade 2. The test subject was given the support she needed for grammar and sentence structuring. She completed two pages of text in only 14 minutes. She did use the add button to enter her own text and the spell checker corrected any mistakes she made.

Reference name: student1	Pre-selected topic: Topic My life
Time taken: 25 minutes.	Status: male 2 nd year student at Loughborough University

Your childhood

In general my childhood was happy. Looking back I feel I had the happiest time when I was in the age range nine to eleven. The saddest time was in the age range nine to eleven. My favourite subject at school was Science. My worst subject at school was English. My best friends Christian name was Roxette. When I was growing up I wanted to be a scientist. I have got 6 GCSE's. Subjects include English, Mathematics, Science, Information Technology. I have 0 A' levels but I do have equivalents.

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The present

I would describe my life at present to be a mixture of ups and downs. This is mainly due to my studies. I am interested in keeping fit and my main hobby is Internet surfing and computers. During term time I live at home and have been there for over three years. The lack of money is not a problem because I budget. I do not have a part time job. I definitely do make plans for my future and feel it is very important. My main goal is to live life to the full. Ideally, I would like to work in the research industry.

University life

I am studying Computer Science BSc in the Computer Science department. I spend on average over twenty five hours per week attending lectures and fifteen to twenty hours outside of lectures. My favourite subject area within my course is operating systems and my worst area is AI systems. I get limited support to help with my problems caused by dyslexia. My main academic strength is a logical mind. My main academic weakness is a poor short term memory. The university campus could do with some improvements. If I could change the campus I would provide more meeting places. The best thing about being a student is having a great social life. The worst thing about being a student is the pressure of work.

Future

My main ambition for the future is to be happy. In the future, ideally, I would live in America. I would like at least one child in the future. The main qualities I look for in a partner is their similar outlook. My chosen career for the future is to be a information technology consultant. The reason for my career choice is because it will be an exciting challenge. I do to a degree set goals but they are changeable. I am a little scared and apprehensive about the future. I feel fortunate about how my life as gone so far.

User evaluation

In my opinion the system does achieve its main aim of automating sentence construction. The dialog display presentation was very clear and easy to follow. The help button was provided to offer extra guidance when needed. I used it and it sometimes helped. The add button was provided to allow me to define my own options. I occasionally used it. The view button was provided to allow the user to view the sentences and make minor

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changes if required. I occasionally used it. I was generally satisfied with the resulting sentences. I felt that the system was a little limited in allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. One change I would like to see made is the reduction of the number of options because it result in less reading. In order to increase the usefulness of the control environment I think the inclusion of a dictate system to avoid reading options. In my opinion this control environment did not really produce a higher standard compared to the other environments. This is mainly due to the system not being flexible enough. I would class the system as second rate with regards to helping me with my sentence construction.

Comment: This student did not have a problem with spelling or sentence structuring. His main problem was writing and reading speed. He therefore did not require the level of support this system offered and graded the system a 2. He had poor eyesight and found reading from the screen a problem; a dictate and reader would make this tool more useful for him.

A.8 Evaluation comments for env3

Selections of evaluation comments for environment 3 are presented (using environment 3).

Reference name: student50

In my opinion the system does achieve its main aim of automating sentence construction. The dialog display presentation was clear and easy to follow. The help button was provided to offer extra guidance when needed. I did not need to use it. The add button was provided to allow me to define my own options. I used it often in order to define my views. The view button was provided to allow the user to view the sentences and make minor changes if required. I occasionally used it. I was pleased with the resulting sentences. I felt that the system was set at the right level, allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. One change I would like to see made is the inclusion of a back and forward button to allow changes to be made. In order to increase the usefulness of the control environment I think the user should be given control of which questions to include. In my opinion this control environment produces a higher standard compared to the other environments. This is mainly due to being allowed to concentrate on the content rather than the sentence syntax. I would class the system as second rate with regards to helping me with my sentence construction.

Reference name: student47

In my opinion the system definitely achieve its main aim of automating sentence construction. The dialog display presentation was very clear and easy to follow. The help button was provided to offer extra guidance when needed. I frequently used it and it was helpful. The add button was provided to allow me to define my own options. I frequently used it and it made the system flexible. The view button was provided to allow the user to view the sentences and make minor changes if required. I frequently used it. I was very satisfied with the resulting sentences. I felt that the system was set at the right level, allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. I do not think the system needs to be changes in order to achieve its aims. In order to increase the usefulness of the control environment I think, the user should be given control of which questions to include. In

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my opinion this control environment definitely produces a higher standard compared to the other environments. This is mainly due to the reduction of spelling and grammar errors. I would class the system as first rate with regards to helping me with my sentence construction.

Reference name: student45

In my opinion the system does achieve its main aim of automating sentence construction. The dialog display presentation was clear and easy to follow. The help button was provided to offer extra guidance when needed. I frequently used it and it was helpful. The add button was provided to allow me to define my own options. I occasionally used it. The view button was provided to allow the user to view the sentences and make minor changes if required. I occasionally used it. I was pleased with the resulting sentences. I felt that the system was a little limited in allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. One change I would like to see made is the inclusion of a back and forward button to allow changes to be made. In order to increase the usefulness of the control environment I think the inclusion of direction buttons (such as: back, forward, skip) to allow the user to make changes. In my opinion this control environment generally produces a higher standard compared to the other environments. This is mainly due to the system not being flexible enough. I would class the system as second rate with regards to helping me with my sentence construction.

Reference name: student41

In my opinion the system definitely achieves its main aim of automating sentence construction. The dialog display presentation was very clear and easy to follow. The help button was provided to offer extra guidance when needed. I did not need to use it. The add button was provided to allow me to define my own options. I occasionally used it. The view button was provided to allow the user to view the sentences and make minor changes if required. I frequently used it. I was very satisfied with the resulting sentences. I felt that the system was set at the right level, allowing me to write about the chosen topic. In general, thought the correct number of options was provided. One change I would like to see made is the inclusion of a back forward button to allow changes to be made. In order to increase the usefulness of the control environment I think the inclusion

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of a dictate system to avoid reading options. In my opinion definitely produces a higher standard compared to the other environments. This is mainly due to the reduction of spelling and grammar errors. I would class the system as first rate with regards to helping me with my sentence construction.

Reference name: student12

In my opinion the system does achieve its main aim of automating sentence construction. The dialog display presentation was very clear and easy to follow. The help button was provided to offer extra guidance when needed. I occasionally used it. The add button was provided to allow me to define my own options. I occasionally used it. The view button was provided to allow the user to view the sentences and make minor changes if required. I occasionally used it. I was pleased with the resulting sentences. I felt that the system was flexible due to the use of the add button, allowing me to write about the chosen topic. In general, I thought the correct number of options was provided which made the system flexible. One change I would like to see made is the inclusion of a back and forward button to allow changes to be made. In order to increase the usefulness of the control environment I think the inclusion of a database of questions and options. In my opinion this control environment generally produces a higher standard compared to the other environments. This is mainly due to the system not being flexible enough. I would class the system as second rate with regards to helping me with my sentence construction.

A.9 Testing data tables

Abbreviations Used in Survey Results Tables

Table: Grades

Abbreviations used are:

- **Titles**
Ac = Academic grade, Us = Usability grade
- **Grades**
1 = Excellent, 2 = Very good, 3 = Below average, 4 = Poor

Table: General profile

Abbreviations used are:

- **Titles**
Cp lang = computer programming language, Com = comparing ability,
P sub = preferred subject
- **Status**
0 = foundation, 1 = 1st year, 2 = 2nd year, 3 = 3rd year, 4 = sandwich course,
5 = MSc, S = staff.
- **Degree**
CS = Computer Science, EG = Engineering, SS = Social Science, AD = Art,
PH = Physics
- **Cp lang**
FMA = far more ability, MA = more ability, LA = less ability,
NA = not applicable
- **Why**
ST = structure, LOG = logical, NA not applicable, RD = reduced language,
NEX = no exceptions
- **P sub**
Ma=Mathematics, CS =Computer Science, ART =Art, SCI =Science,
SP =Sport, ENG =English

Table: Evaluations of Written Text

Abbreviations used are:

- **Grades**

1 = excellent, 2 = very good, 3 = a problem, 4 = major problem

Table: Categorizing Written English Difficulties

Abbreviations used are:

- **Spell problem**

SS = short words, SG = general spelling, SP = spell phonetically,

ML = missing letters, RW = reversing letters in words, NP = no problem

- **Sent problem**

MWO = missing words out, LS = Long sentences, WO = Wrong word order,

ST = structure

- **Grammar problem**

H = homophone, RN = rules not known, WW = Wrong word used,

PP = punctuation

- **Main problem**

NP = no problems, E = sentence structure, P = speed, S = spelling,

G = grammar, H = homophone, ALL = all categories

Table: Features included in Environment 2

Abbreviations used are:

- **Titles**

Spell C = spell checker, Word M = meanings tool, Word P = predictor,

Text R = text reader, Cols = env colours, Ic/Me = icons/menus,

Imp = suggested improvements

- **Common abbreviations**

EX = excellent, VG = very good, S = satisfactory, NU = not useful,

NH = not helpful

- **Spell C**

NI = needs improvements, UF=useful

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- **Why**
FAM = found all words, CD = clear display, UF = user friendly, NL = no list,
NF = not all words found, TS = too slow, NI = not interactive,
SD = for dyslexics
- **Cols**
OP=own preference
- **Ic/Me**
NP=no preference, M=menu, I=icon
- **Imp**
SL = self learning, WM = word meanings, IT = interactive mode,
RW = replacement word in context, ND = needs developments,
MQ = make quicker, GC = grammar checker

Table: Evaluation of Environment 3: Part 1

Abbreviations used are:

- **Aim**
DO = does, DE = definitely does
- **Display**
VC = very clear, C = clear
- **Help**
O = occasional, OU = often used, F = frequent, DN = did not use it,
WH = what is it
- **Add**
O = occasional, OU = often used, F = frequent, DN = did not use it
- **View**
O = occasional, OU = often used, F = frequent, DN = did not use it

Table: Evaluation of Environment 3: Part 2

Abbreviations used are:

- **Result sent**
GS = generally satisfied, VS = very satisfied, PL = pleased, NS = not satisfied

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- **Level**

FA = flexible add button, RL = right level, LL = a little limited, FE = flexible

- **Options**

CF = correct number for flexibility, C = correct number, TM = too many,

CD = correct number for wide differences

- **Changes**

BFB = direction buttons, NC = no changes, MF = make system faster, RQ = reduce number questions, RO = reduce number of options

- **Useful**

DB = database of questions, BFB = direction buttons, CQ = control questions, DS = dictate system, FQ = increase flexibility

- **Standard**

GH = Env3 generally higher, DC = Env3 definitely higher – concentrate on content, DS = Env3 definitely higher – no spelling or grammar errors, NF = not flexible enough

Grades

Identifier	Us env1	Ac env1	Us env2	Ac env2	Us env3	Ac env3
Student 1	3	1	2	1	2	1
Student 2	3	3	1	1	1	1
Student 3	3	3	2	1	2	2
Student 4	3	4	1	1	1	1
Student 5	3	2	2	2	1	2
Student 6	3	2	1	1	1	2
Student 7	2	3	2	1	2	1
Student 8	1	2	2	1	2	2
Student 9	3	4	1	2	2	2
Student 10	3	1	2	1	2	1
Student 11	2	3	2	1	2	1
Student 12	3	1	2	1	2	2
Student 13	3	3	2	2	2	1
Student 14	3	1	2	2	1	1
Student 15	2	4	2	2	2	1
Student 16	3	2	2	2	2	1
Student 17	3	4	2	1	1	1
Student 18	3	3	3	1	1	1
Student 19	3	3	1	1	1	2
Student 20	3	3	3	2	1	1
Student 21	2	2	2	2	1	2
Student 22	2	1	2	1	1	1
Student 23	1	3	3	2	2	1
Student 24	4	3	2	2	2	1
Student 25	2	3	2	1	2	1
Student 26	2	2	2	1	2	1
Student 27	2	1	2	1	2	1
Student 28	2	3	1	1	2	1
Student 29	2	3	2	1	1	1
Student 30	1	3	1	2	1	1
Student 31	2	3	2	1	1	1
Student 32	3	3	2	2	1	1
Student 33	2	3	1	2	2	2
Student 34	3	4	2	2	1	1
Student 35	3	3	2	2	1	1
Student 36	3	3	2	2	1	2
Student 37	2	1	1	2	2	2
Student 38	3	4	2	2	1	1
Student 39	3	3	2	2	1	1
Student 40	3	4	2	3	1	1
Student 41	3	1	1	2	1	1
Student 42	3	1	2	1	1	1
Student 43	2	4	2	1	1	1
Student 44	3	2	2	2	2	1
Student 45	2	3	2	2	2	2
Student 46	3	4	2	3	2	2
Student 47	3	3	1	2	1	2
Student 48	3	4	2	2	2	2
Student 49	3	4	3	2	1	2
Student 50	1	3	2	2	2	2

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General Profile

Identifier	Gender	Status	Degree	Cp lang	Com	Why	P sub
Student 1	M	2	CS	Y	MA	ST	MA
Student 2	F	3	CS	Y	FMA	LOG	CS
Student 3	M	1	CS	Y	FMA	LOG	CS
Student 4	M	0	EG	Y	FMA	LOG	ART
Student 5	M	2	CS	Y	FMA	ST	CS
Student 6	M	1	EG	N	NA	NA	MA
Student 7	F	2	SS	N	NA	NA	ART
Student 8	M	0	EG	Y	FMA	NEX	CS
Student 9	M	1	CS	Y	FMA	ST	CS
Student 10	M	4	CS	Y	FMA	NEX	CS
Student 11	M	5	EG	Y	LA	NA	SCI
Student 12	M	5	EG	Y	FMA	ST	CS
Student 13	M	2	EG	Y	MA	ST	ART
Student 14	M	1	SS	N	NA	NA	SP
Student 15	F	2	AD	N	NA	NA	ART
Student 16	M	0	AD	Y	FMA	ST	ART
Student 17	M	1	EG	Y	FMA	ST	CS
Student 18	M	2	EG	Y	FMA	LOG	MA
Student 19	F	1	AD	N	NA	NA	ART
Student 20	M	3	EG	Y	FMA	LOG	MA
Student 21	M	1	SS	N	NA	NA	SCI
Student 22	M	0	EG	Y	LA	NA	ART
Student 23	M	4	EG	Y	FMA	ST	CS
Student 24	M	1	EG	Y	FMA	ST	CS
Student 25	F	1	SS	N	NA	NA	ENG
Student 26	M	3	CS	Y	FMA	ST	CS
Student 27	M	3	EG	N	NA	NA	SCI
Student 28	M	1	AD	Y	FMA	LOG	ART
Student 29	F	1	AD	N	NA	NA	ART
Student 30	F	3	AD	N	NA	NA	ART
Student 31	M	3	EG	Y	LA	NA	MA
Student 32	M	0	AD	N	NA	NA	ART
Student 33	F	1	AD	N	NA	NA	ART
Student 34	M	0	EG	Y	FMA	RL	MA
Student 35	M	2	AD	Y	FMA	ST	ART
Student 36	M	3	SS	Y	MA	LOG	SP
Student 37	F	1	SS	N	NA	NA	ENG
Student 38	F	3	SS	N	NA	NA	MA
Student 39	F	1	AD	Y	FMA	LOG	ART
Student 40	F	S	CS	Y	FMA	ST	CS
Student 41	F	2	AD	Y	FMA	NEX	CS
Student 42	M	4	EG	Y	LA	NA	MA
Student 43	F	3	AD	Y	FMA	LOG	ART
Student 44	M	1	AD	N	NA	NA	ART
Student 45	M	0	AD	N	NA	NA	ART
Student 46	F	S	AD	N	NA	NA	ART
Student 47	M	3	SS	Y	FMA	LOG	SCI
Student 48	M	3	CS	Y	FMA	ST	CS
Student 49	F	S	SS	N	NA	NA	ENG
Student 50	M	1	PH	N	NA	NA	MA

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Evaluation of Written Text

Identifier	Spelling	Grammar	SentenceStruct	Speed	Quantity	Homophones
Student 1	1	1	1	2	3	1
Student 2	3	3	2	1	3	3
Student 3	3	3	3	4	4	3
Student 4	4	2	3	4	3	2
Student 5	3	2	3	2	4	1
Student 6	2	2	3	1	3	2
Student 7	2	2	2	2	3	2
Student 8	2	3	3	2	3	2
Student 9	4	3	3	3	1	3
Student 10	2	3	3	2	3	2
Student 11	4	3	3	3	2	3
Student 12	1	2	2	3	2	2
Student 13	1	2	3	4	4	2
Student 14	2	3	3	1	3	3
Student 15	4	4	4	4	4	3
Student 16	1	1	1	2	3	1
Student 17	4	2	2	2	3	2
Student 18	3	3	2	2	3	3
Student 19	3	3	4	2	1	3
Student 20	3	2	3	3	4	3
Student 21	2	3	3	1	2	3
Student 22	1	1	1	1	2	1
Student 23	3	2	3	4	2	2
Student 24	3	2	2	2	3	2
Student 25	2	3	3	3	3	3
Student 26	2	2	2	3	1	2
Student 27	1	2	3	2	1	2
Student 28	4	3	3	3	1	3
Student 29	3	3	3	2	3	3
Student 30	2	2	2	3	3	2
Student 31	4	2	3	1	2	3
Student 32	3	2	2	2	2	2
Student 33	3	3	3	2	2	3
Student 34	4	3	3	4	3	3
Student 35	4	3	3	2	3	3
Student 36	2	3	3	3	1	4
Student 37	2	2	2	3	3	3
Student 38	2	2	3	3	1	2
Student 39	3	2	2	3	4	3
Student 40	4	3	3	3	2	2
Student 41	3	2	3	1	2	2
Student 42	1	2	2	1	3	2
Student 43	4	3	3	3	3	2
Student 44	3	2	2	2	4	3
Student 45	2	3	3	2	2	3
Student 46	3	3	3	2	2	3
Student 47	2	2	3	2	3	3
Student 48	3	2	3	2	3	3
Student 49	4	4	3	2	1	2
Student 50	2	2	2	3	4	2

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Categorizing Written English Difficulties

Identifier	Spell problem	Sent problem	Gram problem	Main problem
Student 1	NP	NP	NP	NP
Student 2	SP	LS	H	SGH
Student 3	SP	LS	H	ALL
Student 4	SG	MWO	PP	SEP
Student 5	SP	LS	PP	SE
Student 6	RW	LS	PP	E
Student 7	SP	MWO	PP	P
Student 8	SP	MWO	PP	GE
Student 9	SP	WO	H	ALL
Student 10	SP	ST	WW	GE
Student 11	SG	WO	H	ALL
Student 12	NP	ST	PP	P
Student 13	NP	WO	WW	EP
Student 14	SP	MWO	H	GEH
Student 15	SG	LS	H	ALL
Student 16	NP	NP	NP	P
Student 17	SP	ST	PP	S
Student 18	SS	WO	H	SGH
Student 19	SP	LS	H	ALL
Student 20	SS	LS	H	SEPH
Student 21	SS	WO	H	GEH
Student 22	NP	NP	NP	NP
Student 23	SP	ST	PP	SE
Student 24	SP	WO	H	S
Student 25	ML	LS	H	GEH
Student 26	RW	LS	PP	P
Student 27	NP	ST	PP	E
Student 28	ML	ST	PP	ALL
Student 29	SP	LS	H	ALL
Student 30	ML	WO	H	P
Student 31	ML	LS	PP	SHE
Student 32	RW	LS	RN	S
Student 33	SP	MWO	RN	ALL
Student 34	SP	LS	H	ALL
Student 35	SS	LS	H	ALL
Student 36	ML	ST	RN	GEH
Student 37	ML	WO	H	H
Student 38	SP	LS	PP	E
Student 39	SP	ST	H	SH
Student 40	SP	ST	PP	SGE
Student 41	ML	LS	PP	SE
Student 42	NP	LS	H	P
Student 43	SP	WO	H	SGE
Student 44	SS	LS	H	SH
Student 45	SS	MWO	RN	GEH
Student 46	RW	ST	WW	ALL
Student 47	ML	WO	H	EH
Student 48	SP	ST	H	SHE
Student 49	SG	LS	H	SGE
Student 50	NP	WO	RN	P

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Features included in Environment 2

Identifier	Spell C	Why	Word M	Word P	Text R	Cols	Ic/Me	Imp
Student 1	NI	TS	NU	VG	NU	S	NP	SL
Student 2	EX	NI	VG	NU	S	S	I	WM
Student 3	S	NF	S	S	S	OP	NP	ND
Student 4	EX	SD	S	S	S	OP	I	WM
Student 5	EX	FAM	S	S	S	VG	NP	SL
Student 6	EX	CD	VG	NU	VG	VG	NP	GC
Student 7	S	TS	NU	NU	VG	VG	I	ND
Student 8	VG	NL	NU	NU	S	VG	NP	ND
Student 9	S	TS	NU	NH	NH	S	NP	GC
Student 10	VG	FAM	NU	NU	S	S	I	WM
Student 11	VG	NL	NH	NU	S	VG	I	RW
Student 12	EX	NL	VG	VG	VG	VG	I	WM
Student 13	VG	UF	S	S	S	VG	I	SL
Student 14	VG	UF	NU	NU	VG	VG	I	WM
Student 15	VG	FAM	S	S	S	VG	I	IT
Student 16	VG	FAM	S	S	S	VG	NP	MQ
Student 17	EX	FAM	VG	VG	VG	VG	I	WM
Student 18	VG	UF	S	S	VG	VG	NP	WM
Student 19	EX	SD	NU	NU	VG	S	I	RW
Student 20	S	NI	NU	NU	S	VG	NP	GC
Student 21	EX	CD	NU	S	VG	VG	NP	WM
Student 22	EX	UF	NU	NU	VG	VG	I	ND
Student 23	VG	SD	S	S	VG	VG	NP	WM
Student 24	EX	FAM	VG	S	VG	VG	I	WM
Student 25	UF	NF	S	S	VG	VG	NP	ND
Student 26	UF	CD	NU	NU	VG	OP	NP	RW
Student 27	EX	NI	NH	NU	VG	VG	I	MQ
Student 28	EX	FAM	S	S	VG	VG	I	WM
Student 29	EX	UF	VG	VG	VG	VG	NP	GC
Student 30	EX	SD	NU	S	EX	EX	I	RW
Student 31	EX	CD	NU	S	VG	VG	NP	WM
Student 32	EX	FAM	S	S	VG	VG	NP	WM
Student 33	EX	CD	S	S	VG	VG	I	WM
Student 34	EX	FAM	VG	VG	VG	VG	M	GC
Student 35	EX	UF	NU	VG	VG	EX	I	GC
Student 36	VG	FAM	NU	NU	VG	OP	I	WM
Student 37	EX	UF	VG	S	EX	VG	M	WM
Student 38	EX	SD	S	S	VG	VG	NP	GC
Student 39	VG	FAM	NH	S	VG	VG	I	WM
Student 40	EX	UF	S	S	EX	EX	I	RW
Student 41	EX	FAM	S	NU	EX	VG	NP	GC
Student 42	UF	CD	NU	NU	VG	S	NP	MQ
Student 43	EX	FAM	S	S	EX	EX	M	GC
Student 44	EX	FAM	VG	VG	VG	VG	NP	GC
Student 45	EX	FAM	S	S	VG	VG	NP	WM
Student 46	VG	UF	NH	NH	VG	VG	NP	GC
Student 47	EX	UF	VG	VG	VG	VG	I	GC
Student 48	VG	CD	S	S	VG	S	NP	WM
Student 49	EX	FAM	NU	VG	EX	VG	M	WM
Student 50	VG	UF	NU	NU	VG	VG	NP	IT

Appendix A9

Evaluation of Environment 3: Part 1

Identifier	Aim	Display	Help	Add	View
Student 1	DO	VC	OU	O	O
Student 2	DE	VC	DN	DN	O
Student 3	DO	C	OU	DN	DN
Student 4	DE	C	DN	O	O
Student 5	DE	C	DN	O	O
Student 6	DO	C	OU	DN	O
Student 7	DE	C	WH	O	O
Student 8	DO	C	DN	O	DN
Student 9	DO	C	O	O	O
Student 10	DE	C	O	O	O
Student 11	DE	VC	DN	O	DN
Student 12	DO	VC	O	O	O
Student 13	DO	C	O	O	O
Student 14	DO	VC	DN	O	O
Student 15	DO	C	DN	DN	DN
Student 16	DE	VC	F	O	O
Student 17	DE	VC	OU	F	F
Student 18	DE	C	OU	OU	O
Student 19	DO	C	OU	F	F
Student 20	DO	C	OU	F	F
Student 21	DE	VC	DN	OU	DN
Student 22	DO	C	DN	O	DN
Student 23	DE	C	O	F	O
Student 24	DO	C	O	O	O
Student 25	DE	VC	O	F	O
Student 26	DO	C	DN	OU	O
Student 27	DE	C	O	O	DN
Student 28	DO	VC	DN	O	DN
Student 29	DO	VC	DN	OU	DN
Student 30	DE	C	O	O	OU
Student 31	DO	VC	DN	DN	DN
Student 32	DE	VC	DN	F	OU
Student 33	DO	VC	DN	DN	O
Student 34	DE	VC	DN	O	O
Student 35	DE	VC	F	DN	F
Student 36	DE	VC	DN	O	F
Student 37	DO	VC	DN	OU	OU
Student 38	DE	VC	DN	OU	DN
Student 39	DE	C	O	O	O
Student 40	DE	C	OU	OU	O
Student 41	DE	VC	DN	O	F
Student 42	DE	VC	DN	O	OU
Student 43	DE	VC	OU	OU	F
Student 44	DE	VC	F	F	F
Student 45	DO	C	F	O	O
Student 46	DO	C	DN	OU	O
Student 47	DE	VC	F	F	F
Student 48	DO	C	OU	OU	OU
Student 49	DE	C	DN	O	O
Student 50	DO	C	DN	OU	O

Appendix A9

Evaluation of Environment 3: Part 2

Identifier	Result sent	Level	Options	Changes	Useful	Standard
Student 1	GS	LL	CF	RO	DS	NF
Student 2	VS	RL	C	NC	BFB	DSG
Student 3	PL	LL	C	MF	CQ	DC
Student 4	PL	FA	C	BFB	CQ	DC
Student 5	PL	LL	CF	BFB	CQ	GH
Student 6	GS	FE	CF	BFB	BFB	GH
Student 7	PL	LL	C	RQ	BFB	DC
Student 8	GS	LL	CF	BFB	FQ	GH
Student 9	PL	LL	C	NC	CQ	NF
Student 10	PL	FA	CF	BFB	CQ	DC
Student 11	PL	LL	TM	MF	CQ	DC
Student 12	PL	FA	CF	BFB	DB	GH
Student 13	PL	LL	C	NC	DB	DC
Student 14	GS	FA	CF	BFB	BFB	DC
Student 15	GS	LL	C	BFB	BFB	GH
Student 16	VS	FA	CD	BFB	DB	DSG
Student 17	VS	RL	CD	MF	DB	DSG
Student 18	PL	FE	CF	BFB	DB	DSG
Student 19	PL	FA	CF	BFB	DB	GH
Student 20	VS	RL	CF	NC	DB	DSG
Student 21	VS	FA	C	BFB	FQ	GH
Student 22	VS	FA	CF	BFB	BFB	DC
Student 23	GS	RL	C	BFB	BFB	DC
Student 24	PL	FA	C	BFB	DB	DC
Student 25	VS	FA	CF	BFB	BFB	DC
Student 26	GS	FA	C	BFB	BFB	GH
Student 27	PL	LL	CF	BFB	CQ	DC
Student 28	NS	FA	CF	BFB	DS	DC
Student 29	PL	FE	C	BFB	CQ	DC
Student 30	PL	FA	CF	BFB	CQ	DC
Student 31	PL	LL	C	BFB	FQ	DC
Student 32	PL	LL	CF	BFB	BFB	DC
Student 33	PL	FA	CF	BFB	BFB	DC
Student 34	VS	FA	CF	BFB	BFB	DC
Student 35	VS	RL	CD	NC	DB	DSG
Student 36	VS	FA	CD	BFB	DS	DSG
Student 37	PL	LL	C	NC	CQ	DC
Student 38	PL	FA	CF	BFB	BFB	DC
Student 39	PL	RL	CF	RO	DB	DSG
Student 40	VS	RL	CF	MF	DB	DC
Student 41	VS	RL	C	BFB	DS	DSG
Student 42	PL	FA	C	BFB	CQ	DC
Student 43	VS	FE	CF	BFB	DB	DSG
Student 44	VS	RL	CD	RO	DB	DSG
Student 45	PL	LL	C	BFB	BFB	GH
Student 46	GS	VL	CF	BFB	FQ	NF
Student 47	VS	RL	CD	NC	CQ	DSG
Student 48	PL	FA	C	RO	DS	DC
Student 49	PL	RL	CF	BFB	BFB	DC
Student 50	PL	RL	CF	BFB	CQ	DC

A.10 Usability grade stats – env1 and env2

Student	Env 1 (1)	Env 2 (2)	1-2 (d)	d-d̄ (s)	s ²	
#1	3	2	1	0.3	0.0900	
#2	3	1	2	1.3	1.6900	
#3	3	2	1	0.3	0.0900	
#4	3	1	2	1.3	1.6900	
#5	3	2	1	0.3	0.0900	
#6	3	1	2	1.3	1.6900	
#7	2	2	0	-0.7	0.4900	
#8	1	2	-1	-1.7	2.8900	
#9	3	1	2	1.3	1.6900	
#10	3	2	1	0.3	0.0900	
#11	2	2	0	-0.7	0.4900	
#12	3	2	1	0.3	0.0900	
#13	3	2	1	0.3	0.0900	
#14	3	2	1	0.3	0.0900	
#15	2	2	0	-0.7	0.4900	
#16	3	2	1	0.3	0.0900	
#17	3	2	1	0.3	0.0900	
#18	3	3	0	-0.7	0.4900	
#19	3	1	2	1.3	1.6900	
#20	3	3	0	-0.7	0.4900	
#21	2	2	0	-0.7	0.4900	
#22	2	2	0	-0.7	0.4900	
#23	1	3	-2	-2.7	7.2900	
#24	4	2	2	1.3	1.6900	
#25	2	2	0	-0.7	0.4900	
#26	2	2	0	-0.7	0.4900	
#27	2	2	0	-0.7	0.4900	
#28	2	1	1	0.3	0.0900	
#29	2	2	0	-0.7	0.4900	
#30	1	1	0	-0.7	0.4900	
#31	2	2	0	-0.7	0.4900	
#32	3	2	1	0.3	0.0900	
#33	2	1	1	0.3	0.0900	
#34	3	2	1	0.3	0.0900	
#35	3	2	1	0.3	0.0900	
#36	3	2	1	0.3	0.0900	
#37	2	1	1	0.3	0.0900	
#38	3	2	1	0.3	0.0900	
#39	3	2	1	0.3	0.0900	
#40	3	2	1	0.3	0.0900	
#41	3	1	2	1.3	1.6900	
#42	3	2	1	0.3	0.0900	
#43	2	2	0	-0.7	0.4900	
#44	3	2	1	0.3	0.0900	
#45	2	2	0	-0.7	0.4900	
#46	3	2	1	0.3	0.0900	
#47	3	1	2	1.3	1.6900	
#48	3	2	1	0.3	0.0900	
#49	3	3	0	-0.7	0.4900	
#50	1	2	-1	-1.7	2.8900	
n = 50			Σ d = 35		Σ s ² = 36.5	
df = 49			d = 0.7		s ² / df = 0.744898	
					√ above = 0.86307	
			t _{0.05} ⁽⁴⁹⁾ = 2	t _{0.01} ⁽⁴⁹⁾ = 2.7	test t = 5.735	∴ test t >> t so accept H ₁

A.11 Usability grade stats – env1 and env3

Student	Env 1 (1)	Env 3 (2)	1-2 (d)	d-d (s)	s ²
#1	3	2	1	-0.08	0.0064
#2	3	1	2	0.92	0.8464
#3	3	2	1	-0.08	0.0064
#4	3	1	2	0.92	0.8464
#5	3	1	2	0.92	0.8464
#6	3	1	2	0.92	0.8464
#7	2	2	0	-1.08	1.1664
#8	1	2	-1	-2.08	4.3264
#9	3	2	1	-0.08	0.0064
#10	3	2	1	-0.08	0.0064
#11	2	2	0	-1.08	1.1664
#12	3	2	1	-0.08	0.0064
#13	3	2	1	-0.08	0.0064
#14	3	1	2	0.92	0.8464
#15	2	2	0	-1.08	1.1664
#16	3	2	1	-0.08	0.0064
#17	3	1	2	0.92	0.8464
#18	3	1	2	0.92	0.8464
#19	3	1	2	0.92	0.8464
#20	3	1	2	0.92	0.8464
#21	2	1	1	-0.08	0.0064
#22	2	1	1	-0.08	0.0064
#23	1	2	-1	-2.08	4.3264
#24	4	2	2	0.92	0.8464
#25	2	2	0	-1.08	1.1664
#26	2	2	0	-1.08	1.1664
#27	2	2	0	-1.08	1.1664
#28	2	2	0	-1.08	1.1664
#29	2	1	1	-0.08	0.0064
#30	1	1	0	-1.08	1.1664
#31	2	1	1	-0.08	0.0064
#32	3	1	2	0.92	0.8464
#33	2	2	0	-1.08	1.1664
#34	3	1	2	0.92	0.8464
#35	3	1	2	0.92	0.8464
#36	3	1	2	0.92	0.8464
#37	2	2	0	-1.08	1.1664
#38	3	1	2	0.92	0.8464
#39	3	1	2	0.92	0.8464
#40	3	1	2	0.92	0.8464
#41	3	1	2	0.92	0.8464
#42	3	1	2	0.92	0.8464
#43	2	1	1	-0.08	0.0064
#44	3	2	1	-0.08	0.0064
#45	2	2	0	-1.08	1.1664
#46	3	2	1	-0.08	0.0064
#47	3	1	2	0.92	0.8464
#48	3	2	1	-0.08	0.0064
#49	3	1	2	0.92	0.8464
#50	1	2	-1	-2.08	4.3264
n = 50			Σ d = 54		Σ s ² = 43.68
df = 49			d̄ = 1.08		s ² / df = 0.891429
					√ above = 0.94416
			t _{0.05} ⁽⁴⁹⁾ = 2	t _{0.01} ⁽⁴⁹⁾ = 2.7	test t = 8.088
					∴ test t >> t so accept H ₁

A.12 Usability grade stats – env2 and env3

Student	Env 1 (1)	Env 2 (2)	1 - 2 (d)	d - \bar{d} (s)	s^2
#1	2	2	0	-0.38	0.1444
#2	1	1	0	-0.38	0.1444
#3	2	2	0	-0.38	0.1444
#4	1	1	0	-0.38	0.1444
#5	2	1	1	0.62	0.3844
#6	1	1	0	-0.38	0.1444
#7	2	2	0	-0.38	0.1444
#8	2	2	0	-0.38	0.1444
#9	1	2	-1	-1.38	1.9044
#10	2	2	0	-0.38	0.1444
#11	2	2	0	-0.38	0.1444
#12	2	2	0	-0.38	0.1444
#13	2	2	0	-0.38	0.1444
#14	2	1	1	0.62	0.3844
#15	2	2	0	-0.38	0.1444
#16	2	2	0	-0.38	0.1444
#17	2	1	1	0.62	0.3844
#18	3	1	2	1.62	2.6244
#19	1	1	0	-0.38	0.1444
#20	3	1	2	1.62	2.6244
#21	2	1	1	0.62	0.3844
#22	2	1	1	0.62	0.3844
#23	3	2	1	0.62	0.3844
#24	2	2	0	-0.38	0.1444
#25	2	2	0	-0.38	0.1444
#26	2	2	0	-0.38	0.1444
#27	2	2	0	-0.38	0.1444
#28	1	2	-1	-1.38	1.9044
#29	2	1	1	0.62	0.3844
#30	1	1	0	-0.38	0.1444
#31	2	1	1	0.62	0.3844
#32	2	1	1	0.62	0.3844
#33	1	2	-1	-1.38	1.9044
#34	2	1	1	0.62	0.3844
#35	2	1	1	0.62	0.3844
#36	2	1	1	0.62	0.3844
#37	1	2	-1	-1.38	1.9044
#38	2	1	1	0.62	0.3844
#39	2	1	1	0.62	0.3844
#40	2	1	1	0.62	0.3844
#41	1	1	0	-0.38	0.1444
#42	2	1	1	0.62	0.3844
#43	2	1	1	0.62	0.3844
#44	2	2	0	-0.38	0.1444
#45	2	2	0	-0.38	0.1444
#46	2	2	0	-0.38	0.1444
#47	1	1	0	-0.38	0.1444
#48	2	2	0	-0.38	0.1444
#49	3	1	2	1.62	2.6244
#50	2	2	0	-0.38	0.1444
n = 50			$\Sigma d = 19$		$\Sigma s^2 = 25.78$
df = 49			$\bar{d} = 0.38$		$s^2 / df = 0.526122$
					$\sqrt{\text{above}} = 0.72534$
			$t_{0.05}^{(49)} \approx 2$	$t_{0.01}^{(49)} \approx 2.7$	test t = 3.704
					$\therefore \text{test } t \gg t \text{ so accept } H_1$

A.13 Academic grade stats – env1 and env2

Student	Env 1 (1)	Env 2 (2)	1 - 2 (d)	d - \bar{d} (s)	s^2	
#1	1	1	0	-1.12	1.2544	
#2	3	1	2	0.88	0.7744	
#3	3	1	2	0.88	0.7744	
#4	4	1	3	1.88	3.5344	
#5	2	2	0	-1.12	1.2544	
#6	2	1	1	-0.12	0.0144	
#7	3	1	2	0.88	0.7744	
#8	2	1	1	-0.12	0.0144	
#9	4	2	2	0.88	0.7744	
#10	1	1	0	-1.12	1.2544	
#11	3	1	2	0.88	0.7744	
#12	1	1	0	-1.12	1.2544	
#13	3	2	1	-0.12	0.0144	
#14	1	2	-1	-2.12	4.4944	
#15	4	2	2	0.88	0.7744	
#16	2	2	0	-1.12	1.2544	
#17	4	1	3	1.88	3.5344	
#18	3	1	2	0.88	0.7744	
#19	3	1	2	0.88	0.7744	
#20	3	2	1	-0.12	0.0144	
#21	2	2	0	-1.12	1.2544	
#22	1	1	0	-1.12	1.2544	
#23	3	2	1	-0.12	0.0144	
#24	3	2	1	-0.12	0.0144	
#25	3	1	2	0.88	0.7744	
#26	2	1	1	-0.12	0.0144	
#27	1	1	0	-1.12	1.2544	
#28	3	1	2	0.88	0.7744	
#29	3	1	2	0.88	0.7744	
#30	3	2	1	-0.12	0.0144	
#31	3	1	2	0.88	0.7744	
#32	3	2	1	-0.12	0.0144	
#33	3	2	1	-0.12	0.0144	
#34	4	2	2	0.88	0.7744	
#35	3	2	1	-0.12	0.0144	
#36	3	2	1	-0.12	0.0144	
#37	1	2	-1	-2.12	4.4944	
#38	4	2	2	0.88	0.7744	
#39	3	2	1	-0.12	0.0144	
#40	4	3	1	-0.12	0.0144	
#41	1	2	-1	-2.12	4.4944	
#42	1	1	0	-1.12	1.2544	
#43	4	1	3	1.88	3.5344	
#44	2	2	0	-1.12	1.2544	
#45	3	2	1	-0.12	0.0144	
#46	4	3	1	-0.12	0.0144	
#47	3	2	1	-0.12	0.0144	
#48	4	2	2	0.88	0.7744	
#49	4	2	2	0.88	0.7744	
#50	3	2	1	-0.12	0.0144	
n = 50			$\Sigma d = 56$		$\Sigma s^2 = 49.28$	
df = 49			$\bar{d} = 1.12$		$s^2 / df = 1.005714$	
					$\sqrt{\text{above}} = 1.00285$	
			$t_{0.05}^{(49)} \approx 2$	$t_{0.01}^{(49)} \approx 2.7$	test t = 7.897	$\therefore \text{test } t \gg t \text{ so accept } H_1$

A.14 Academic grade stats – env1 and env3

Student	Env 1 (1)	Env 3 (2)	1-2 (d)	d - \bar{d} (s)	s^2
#1	1	1	0	-1.38	1.9044
#2	3	1	2	0.62	0.3844
#3	3	2	1	-0.38	0.1444
#4	4	1	3	1.62	2.6244
#5	2	2	0	-1.38	1.9044
#6	2	2	0	-1.38	1.9044
#7	3	1	2	0.62	0.3844
#8	2	2	0	-1.38	1.9044
#9	4	2	2	0.62	0.3844
#10	1	1	0	-1.38	1.9044
#11	3	1	2	0.62	0.3844
#12	1	2	-1	-2.38	5.6644
#13	3	1	2	0.62	0.3844
#14	1	1	0	-1.38	1.9044
#15	4	1	3	1.62	2.6244
#16	2	1	1	-0.38	0.1444
#17	4	1	3	1.62	2.6244
#18	3	1	2	0.62	0.3844
#19	3	2	1	-0.38	0.1444
#20	3	1	2	0.62	0.3844
#21	2	2	0	-1.38	1.9044
#22	1	1	0	-1.38	1.9044
#23	3	1	2	0.62	0.3844
#24	3	1	2	0.62	0.3844
#25	3	1	2	0.62	0.3844
#26	2	1	1	-0.38	0.1444
#27	1	1	0	-1.38	1.9044
#28	3	1	2	0.62	0.3844
#29	3	1	2	0.62	0.3844
#30	3	1	2	0.62	0.3844
#31	3	1	2	0.62	0.3844
#32	3	1	2	0.62	0.3844
#33	3	2	1	-0.38	0.1444
#34	4	1	3	1.62	2.6244
#35	3	1	2	0.62	0.3844
#36	3	2	1	-0.38	0.1444
#37	1	2	-1	-2.38	5.6644
#38	4	1	3	1.62	2.6244
#39	3	1	2	0.62	0.3844
#40	4	1	3	1.62	2.6244
#41	1	1	0	-1.38	1.9044
#42	1	1	0	-1.38	1.9044
#43	4	1	3	1.62	2.6244
#44	2	1	1	-0.38	0.1444
#45	3	2	1	-0.38	0.1444
#46	4	2	2	0.62	0.3844
#47	3	2	1	-0.38	0.1444
#48	4	2	2	0.62	0.3844
#49	4	2	2	0.62	0.3844
#50	3	2	1	-0.38	0.1444
n = 50			$\Sigma d = 69$		$\Sigma s^2 = 59.78$
df = 49			$\bar{d} = 1.38$		$s^2 / df = 1.22000$
					$\sqrt{\text{above}} = 1.10454$
			$t_{005}^{(49)} \approx 2$	$t_{001}^{(49)} \approx 2.7$	test t = 8.835
					$\therefore \text{test } t \gg t \text{ so accept } H_1$

A.15 Academic grade stats – env2 and env3

Student	Env 1 (1)	Env 3 (2)	1 – 2 (d)	d – \bar{d} (s)	s^2
#1	1	1	0	-0.26	0.0676
#2	1	1	0	-0.26	0.0676
#3	1	2	-1	-1.26	1.5876
#4	1	1	0	-0.26	0.0676
#5	2	2	0	-0.26	0.0676
#6	1	2	-1	-1.26	1.5876
#7	1	1	0	-0.26	0.0676
#8	1	2	-1	-1.26	1.5876
#9	2	2	0	-0.26	0.0676
#10	1	1	0	-0.26	0.0676
#11	1	1	0	-0.26	0.0676
#12	1	2	-1	-1.26	1.5876
#13	2	1	1	0.74	0.5476
#14	2	1	1	0.74	0.5476
#15	2	1	1	0.74	0.5476
#16	2	1	1	0.74	0.5476
#17	1	1	0	-0.26	0.0676
#18	1	1	0	-0.26	0.0676
#19	1	2	-1	-1.26	1.5876
#20	2	1	1	0.74	0.5476
#21	2	2	0	-0.26	0.0676
#22	1	1	0	-0.26	0.0676
#23	2	1	1	0.74	0.5476
#24	2	1	1	0.74	0.5476
#25	1	1	0	-0.26	0.0676
#26	1	1	0	-0.26	0.0676
#27	1	1	0	-0.26	0.0676
#28	1	1	0	-0.26	0.0676
#29	1	1	0	-0.26	0.0676
#30	2	1	1	0.74	0.5476
#31	1	1	0	-0.26	0.0676
#32	2	1	1	0.74	0.5476
#33	2	2	0	-0.26	0.0676
#34	2	1	1	0.74	0.5476
#35	2	1	1	0.74	0.5476
#36	2	2	0	-0.26	0.0676
#37	2	2	0	-0.26	0.0676
#38	2	1	1	0.74	0.5476
#39	2	1	1	0.74	0.5476
#40	3	1	2	1.74	3.0276
#41	2	1	1	0.74	0.5476
#42	1	1	0	-0.26	0.0676
#43	1	1	0	-0.26	0.0676
#44	2	1	1	0.74	0.5476
#45	2	2	0	-0.26	0.0676
#46	3	2	1	0.74	0.5476
#47	2	2	0	-0.26	0.0676
#48	2	2	0	-0.26	0.0676
#49	2	2	0	-0.26	0.0676
#50	2	2	0	-0.26	0.0676
n = 50			$\Sigma d = 13$		$\Sigma s^2 = 21.62$
df = 49			$\bar{d} = 0.26$		$s^2 / df = 0.441224$
					$\sqrt{\text{above}} = 0.66425$
			$t_{0.05}^{(49)} = 2$	$t_{0.01}^{(49)} = 2.7$	test t = 2.768
					$\therefore \text{test } t > t \text{ so accept } H_1$

A.16 The use of structured languages by non-dyslexic subjects

A survey was undertaken within Loughborough University campus to establish the percentage of subjects, within a sample, who have experience of using programming languages. Dyslexic subjects were not included. This information was required to ascertain whether the percentage of subjects with programming experience in the general population is similar to the dyslexic population. In total 100 subjects took part and were selected at random. The results are presented in Table A.1 and Table A.2.

A second survey was undertaken to establish whether the results from non-dyslexics were similar to dyslexics when asked about their ability with structured and natural (English) languages. Those subjects, which took part in the previous survey (referred to as 'random contact' abbreviated to RC) and had programming experience (21 in total) were asked a very general question and provided with a scale from which to make their choice.

Do you find programming easier than writing English?

Scale

- 1 (no)
- 2 (similar)
- 3 (programming easier)
- 4 (programming much easier)
- 5 (programming a great deal easier)

A further 16 programmers (non-dyslexics) from a company called EDS (in Milton Keynes) and 13 subjects within the Computer Science department (referred to as CSD) at Loughborough University took part in the survey. In total 50 subjects with programming experience contributed. The results are presented in Table A.3.

Appendix A16

Subject number	Non-programmer	Programmer
1	YES	NO
2	YES	NO
3	YES	NO
4	YES	NO
5	YES	NO
6	NO	YES
7	YES	NO
8	YES	NO
9	YES	NO
10	YES	NO
11	YES	NO
12	NO	YES
13	NO	YES
14	YES	NO
15	YES	NO
16	NO	YES
17	YES	NO
18	NO	YES
19	YES	NO
20	YES	NO
21	YES	NO
22	YES	NO
23	YES	NO
24	YES	NO
25	NO	YES
26	YES	NO
27	NO	YES
28	NO	YES
29	YES	NO
30	NO	YES
31	YES	NO
32	YES	NO
33	YES	NO
34	NO	YES
35	YES	NO
36	YES	NO
37	YES	NO
38	YES	NO
39	YES	NO
40	YES	NO
41	NO	YES
42	NO	YES
43	YES	NO
44	YES	NO
45	YES	NO
46	YES	NO
47	NO	YES
48	YES	NO
49	YES	NO
50	YES	NO

Table A.1. Programming experience within the general population part 1.

Appendix A16

Subject number	Non-programmer	Programmer
51	YES	NO
52	YES	NO
53	YES	NO
54	YES	NO
55	YES	NO
56	YES	NO
57	YES	NO
58	YES	NO
59	NO	YES
60	YES	NO
61	YES	NO
62	YES	NO
63	YES	NO
64	YES	NO
65	YES	NO
66	YES	NO
67	NO	YES
68	YES	NO
69	YES	NO
70	YES	NO
71	YES	NO
72	YES	NO
73	NO	YES
74	NO	YES
75	YES	NO
76	YES	NO
77	YES	NO
78	YES	NO
79	YES	NO
80	YES	NO
81	YES	NO
82	YES	NO
83	YES	NO
84	YES	NO
85	YES	NO
86	YES	NO
87	NO	YES
88	YES	NO
89	YES	NO
90	YES	NO
91	YES	NO
92	NO	YES
93	YES	NO
94	NO	YES
95	YES	NO
96	YES	NO
97	YES	NO
98	NO	YES
99	YES	NO
100	YES	NO

Table A.2. Programming experience within the general population part 2.

Appendix A16

Subject number	Contact	Comparison
1	RC	1
2	RC	3
3	RC	4
4	RC	4
5	RC	1
6	RC	1
7	RC	2
8	RC	5
9	RC	3
10	RC	1
11	RC	1
12	RC	5
13	RC	2
14	RC	1
15	RC	5
16	RC	1
17	RC	5
18	RC	2
19	RC	5
20	RC	2
21	RC	4
22	EDS	2
23	EDS	4
24	EDS	2
25	EDS	1
26	EDS	1
27	EDS	1
28	EDS	5
29	EDS	3
30	EDS	1
31	EDS	2
32	EDS	1
33	EDS	5
34	EDS	3
35	EDS	1
36	EDS	2
37	EDS	3
38	CSD	1
39	CSD	3
40	CSD	1
41	CSD	2
42	CSD	4
43	CSD	4
44	CSD	5
45	CSD	1
46	CSD	1
47	CSD	2
48	CSD	3
49	CSD	3
50	CSD	1

Table A.3. Non-dyslexic subjects with programming experience.

A.17 Paper presented in Totnes 11-13th November 1996**An Evaluation of the Requirements for a New English Language Grammatical Tool and Teaching Environment.**

Marina Carter and Janet Edwards.

Loughborough University, Computer Studies Department, Loughborough.

Published in Dyslexia in Higher Education 2nd International Conference

Abstract

The paper reports on the conclusions drawn from firstly, an initial survey of approximately two hundred and fifty dyslexic adults using the Internet and secondly a detailed questionnaire sent directly to over eighty adults with dyslexia. The initial survey was designed to gain information about dyslexic adult's English grammar abilities, use of current grammatical tools (using a computer) and the requirements for a new grammatical tool. The survey was also used to establish whether there exists a link between the number of rules (and level of constraints) that a language has and the degree of problems that dyslexic subjects encounter. Computer programming languages use a relatively small set of rules and are correspondingly rigid in construction when compared to written English. The detailed questionnaire was designed to gain more information regarding preferred teaching methods, useful features to include, interface preferences and to establish a list of common written English errors that dyslexics tended to make. The paper concludes by reviewing how such information could be used to direct the design and implementation of a grammar tool for assisting dyslexic adults with natural language. A teaching environment will also be designed showing how enforced language structure can be used to aid the teaching of adults with dyslexia.

1 Introduction

The paper represents one year of research, which establishes detailed information regarding the English grammatical problems dyslexic adults have.

The research began by investigating how useful computers were for helping dyslexic adults with their written English. The use of computers has been revolutionary for many dyslexics allowing them access to word processing packages (Singleton, 1994). However, the need to establish whether current grammatical tools and spell checkers (incorporated in word processors) actually provide the type of support dyslexic adults require, needs to be evaluated.

It is hoped that this research will lead to the development of a grammatical tool designed to aid dyslexic adults. The research is also concerned with providing the adult with a controlled environment designed to generally improve their English grammar abilities. This idea was developed from looking at how dyslexia effects an adult's ability with different language structures. While carrying out an initial literature study of dyslexia it seemed that dyslexic adults in general tended to be more proficient at advanced mathematics than basic mathematics (Miles, 1992). Further studies indicated that a rigid structure, fixed limited rules and the use of symbols seemed to have a positive effect and go some way to explaining their abilities with advanced mathematics. It would be interesting to investigate the comparative effects of how dyslexia affects a subject's

abilities with natural language (written English) and highly structured languages such as computer programming languages.

The decision was made to undertake a survey and a follow up detailed questionnaire, initially using the Internet to evaluate the research ideas. The following hypothesis was developed which would be used to design the controlled environment if the survey results showed a positive effect.

To establish whether there exists a link between the number of rules and level of constraints that a language has and the degree of problems that dyslexic subjects encounter.

The main research areas of interest are as follows:-

English Grammar

Common grammatical errors made,
Current computer packages used to aid written English,
Problems with using current packages,
Requirements for a grammatical tool,
Interface preferences,
Preferred teaching methods.

Dyslexics use of computer programming languages.

How dyslexia effects their use,
Reasons why they find programming easier than written English.

Spell checkers

Problems with current spell checkers,
Features they would like to have available,
Requirements for an in-context spell checker,
List of common spelling errors.

Controlled teaching environment

Using limited set of sentence templates to increase language rigidity,
Sentence construction tool to enforce structure,
Using flowcharts.

In order to evaluate the hypothesis subjects were asked to comment on how dyslexia affects their abilities when using computer programming languages and natural languages such as English (in the written form). Computer programming languages use a relatively small set of rules and are correspondingly rigid in construction when compared to written English.

2 Initial Survey Using the Internet

The survey was designed to reflect and gain information to support the research ideas. It took approximately 6 months to gather sufficient returned questionnaires (260) that were then subsequently analysed to produce the results presented in this paper.

The survey requested information from dyslexics. The questions are contained in three separate sections:-

- General background.
- English grammar.
- Computer programming languages.

Comment boxes were provided at the end of each section.

In order to collect a broad range of survey data, two methods of data collection was used. Localised collection using paper survey forms were given to adults with dyslexia in both Loughborough and Leicester Universities. This represented approximately 10% of the sample.

A computerised form was made available on the Internet. Electronic mail was used to send the data back for analysis. Links to the form were established from other key dyslexic sources of information web sites, for example Dyslexia Archive. This resulted in dyslexic adults from all over the world (e.g. UK, America, Canada and Australia), replying to a request for information. The subjects tended to be technologically proficient as they required computer access to use the Internet and gain access to the survey form. Therefore it was hoped that some of the subjects would have experience of using computer programming languages and enable the testing of the hypothesis to be undertaken.

2.1 General Information

General information was requested from each person who responded to the survey. The subjects were also encouraged to use the general comment box at the end of the section.

Age group categories: under 21, 21- 45 and over 45.
The majority of 70% of subjects were aged 21-45.

Gender: 58% male 42% female.

Computer usage categories: Little/no use (under 1 hour per week).
Average use (1-5 hours per week).
Above average use (above 5 hours per week).
The majority of 70% selected the Above average category.

The results show that the largest group are Males with above average computer usage in the age range 21-45. This is due to the fact that only adults were asked to respond to the survey and this is the age group in which you would expect to see the majority of computer expertise. The British Dyslexia Association give a ratio of 3:1 male to female ratio for dyslexia so it would be expected that there would be more male subjects than female.

General Comments

From the general background comments it was possible to establish a list of general problems encountered by dyslexic adults, which are as follows:-

- Reading:** Reading sentences right to left, reading books upside down or reading down the centre of the page commonly occur.
- Memory:** Short term memory is a problem for most dyslexics and frequently they do not remember work that has just been read. Many dyslexics have poor visual sequential memory and often need to use repetition in order to remember something.
- Physical:** Many subjects stated they were left handed and a large number of subjects also stated they have inner ear imbalances. When under stress stuttering and slurring frequently occurs. Dyslexia also tends to be hereditary.
- Handwriting:** A major problem for most dyslexics is untidy or 'child like' handwriting making it difficult to read.

2.2 English Grammar

Subjects were asked specific questions related to English and provided with a comment box at the end of the section. In this section (except where stated) subjects were asked to select from a scale 1 (low) to 4 (high) effects.

To what extent does your dyslexia affect your written work?

This was a very generalised question and because of the nature of dyslexia it was to be expected that the majority of subjects would select the higher effect options. This was indeed the case and 77% of the sample selected those options.

Do the current available grammar tools help you?

The results show that 33% did not use any grammatical tools and 34% found the tools to be of little help. Only 12% found them very useful. This is a positive result for the research objectives.

The subjects were provided with some general details about the development of a new grammatical tool designed to detect common dyslexic type errors offering solutions in plain English.

Do you have a need for a new grammatical tool?

Scale 1 (little/no demand) to 4 (great demand). A significant majority of 73% selected the higher levels of demand options for a new grammatical tool. This was again a very encouraging result.

The subjects were given information about the teaching environment within which a grammatical tool will be used. "The teaching environment for the grammatical tool aims to reinforce basic grammar rules using a relatively small set of allowable sentence structure templates. The tool will provide both practical and learning environment through step by step guidance and comprehensive help."

Would a teaching environment be of use to you?

Scale 1 (little/no demand) to 4 (great demand). The results show that a majority of 62% selected the higher demand options for a new grammatical learning environment tool.

Comments Evaluation

The comments made in this section have been categorised into two separate groups:-

Written English problems and
Requirements for the new grammatical tool.

The most common problems associated with written English according to the grammar comments made in the survey, are as follows:-

Sequencing: Sequencing of letters within words or words within sentences commonly cause problems for dyslexics. Many also have a problem with sequences of numbers, such as telephone numbers. Consistently leaving out words or writing the sentence in reverse were also commonly mentioned problems.

Spelling: A unique dyslexic tendency to reverse the spelling of a word for example was for saw and interchanging letters e.g. p for d are common problems. Another problem is the tendency to consistently spell difficult words correctly and easy words incorrectly. Dyslexics tend to spell phonetically and need a spell checker that takes this into account.

Grammar: Subjects found English grammar rules hard to follow. Many subjects stated that different teachers seem to use a different set of grammar rules that lead to confusion. Some subjects experience problems applying grammar rules when given examples to follow. The majority of the subjects felt that English grammar was too flexible and they required more rigid rules to follow. A small number of subjects did not know what grammar rules were.

Writing Style: Identifying tenses is a common problem for many subjects.

Punctuation: Sentence punctuation is a major problem for many dyslexics. There is a tendency to incorrectly use commas and apostrophes.

Homophones: The mixing of Homophones: such as 'there' place for 'their' belonging is a real problem that causes embarrassment for many dyslexics.

English: Dyslexics tend to use only words they are familiar with which results in a very limited vocabulary. Words that look alike can cause confusion, such as because, became, become. Also words that sound alike such as effect and affect.

The following is a list of requirements for the grammatical tool from the grammar comments made in the survey:-

Current Tools: The tools are not designed to detect unique dyslexic errors such as word reversal. When using grammatical tools the explanation of errors is hard to understand and assume greater knowledge than many subjects have.

Rules: Many subjects stated they wanted the grammar rules described using English they can understand. They want to be able to write in personal or impersonal styles without the grammatical tool complaining. Subjects also stated it would be useful to give meanings to words or sentences using speech and pictures. A multi-sensory approach has proven benefits.

- Predictor:** There was a demand for a word predictor that guesses what the word is after the first few letters are input. It must use a large vocabulary and offer a large picking list.
- Help:** Dyslexics require help and advise which helps them to conform, preferably interactively, using plain English.
- Errors:** They want a tool to be able to tell the difference between a spelling error and grammatical error.
- Teach:** The tool should teach different grammatical structure in an interactive way
- Spelling:** A spelling device to verify each word is required.
- Interface:** A multi-level interface is required allowing a subject to select an ability level suitable to their needs. The interface should be user friendly and graphical based.
- Punctuation:** Help with English sentence punctuation was commonly requested.

2.3 Computer Programming Details

Subjects were asked to answer questions related to computer programming experience for that subject that used these languages. A comment box was again provided at the end of the section.

Do you use computer programming languages?

From the sample 59% used computer programming languages in their everyday lives. This percentage is very encouraging and shows that the majority of the subjects, regardless of their dyslexia, were able to learn and use computer programming languages. This was essential in order to use the survey results to investigate comparative effects

Does your dyslexia effect your programming abilities?

A significant majority of 70% selected the lower effect options. This is a very encouraging result with regards to the research hypothesis.

Do you find programming easier than written English?

Scale 1 (similar effects) to 4 (great deal easier). A significant majority of 66% of the sample selected options 3 or 4 indicating computer programming was substantially easier than written English. Only 19% selected option 1 representing similar effects.

A comparison of a subject's English grammar and computer programming abilities (where applicable) were combined. This was in order to illustrate the responses in terms of the level to which dyslexia affects both grammar and computer programming skills. Combined Groupings compared the individual subjects' responses to grammar and programming abilities previously reviewed. If options 1 or 2 was selected category low value was assigned and if options 3 or 4 was selected category high was assigned for both grammar and programming abilities. 47% of the sample have significantly high English grammar affects and low computer programming affects. This represented a positive result for the hypothesis Only 5% of the sample have low English grammar affects and high computer programming affects. This represented a negative result for the hypothesis.

Is understanding errors generated by the compiler a problem?

A compiler reports on the syntax of the program statements as they are converted to a machine readable form. Scale 1(Little or no effect) to 4(Great effect). A significant majority 63% selected the lower effect options indicating their dyslexia caused a relatively low affect on their ability to understand compiler errors.

If you use debugging tools are they helpful?

A debugger is a tool used to detect errors in the programming code and offers solutions. Scale 1(Not used) to 4(High use). 51% selected options 3 or 4 indicating they found debugging tools were very useful.

Is the construction of programming instructions a problem?

A program instruction can be compared to a sentence in written English. Scale 1 (Little or no effect) to 4(Great effect). A majority of 61% of the sample selected the lower effect options on their ability to construct programming statements

Comments Evaluation

The comments made in this section have been categorised into two separate groups:-

Problems using programming languages,
Reasons why programming languages cause fewer problems.

The most common problems faced by dyslexic adults who frequently use computer programming languages from comments in the survey are as follows:-

Program size: The larger the program the more difficult the process is. This is overcome by using program modules whenever possible.

Memory: The problem of poor visual sequential memory still remains. Problems remembering variable names and what they are used for was frequently mentioned.

Spelling: The spelling of commands, variable names, comment statements and noticeably input/output dialogue cause problems.

Reading: Reading hard copy is sometimes difficult and can be very time consuming.

There are many features that make computer programming languages easier to use than written English for sufferers of dyslexia. Listed are the most common comments made:-

Computer code: Many subjects stated that computer code seemed to make much more sense to them than written English.

Vocabulary: A limited spelling vocabulary in terms of programming commands limits the spelling problems associated with dyslexics.

Structure: Programming languages have a strict deterministic structure and the syntax of a command is rigid.

- Logic:** Programming languages have a high degree of logic and precision built into them and the ability to split a programming task into modules following logical steps is also beneficial.
- Flowcharts:** Flowcharts can be used to design structure and work well for visual thinking people.
- Rules:** Programming languages use clearly defined ridged rules.
- Tools** Debuggers and compilers that detect errors are helpful.
- Memory:** The use of short distinct variables can aid memory using names that have meanings that responds to the dyslexic visual thinking process. Also programming languages use a relatively small set of commands to remember

2.4 Results Summary and Conclusions

This survey consisted of very generalised questions to attempt to establish how dyslexia affects a subject's English grammar and computer programming skills and a review of grammatical tools. A vast amount of information was also provided from the comment boxes and has resulted in providing a great deal of extra information.

In summary the results of the initial survey results are:

Background

The results show that the majority of the sample have an above average use of computers (70%) and use computer programming languages in their every day working lives (59%).

Grammar and Grammatical Tools

The majority of the subjects (77%) indicated that their dyslexia has a significant affect on their abilities with English grammar. A significant 77% of the subjects stated current tools are unsuitable or not used and 73% required a new grammatical tool. The majority of 62% stated that a teaching environment would be of use to them.

Computer programming

From the adults that responded to the survey the majority of 59% used computer programming languages. Evidence from this survey suggests that (70%) of the subjects stated that dyslexia does not impinge on their computer programming abilities. A significant 63% of the subjects stated they did not have problems understanding compiler errors. The results showed that 51% found debugging tools useful and 61% selected lower effects options when constructing programming instructions.

The survey results have been used to evaluate the hypothesis. The results have established there is a demand for a new learning environment grammatical tool. It has also provided information about the requirements for the new tool. Useful information about the grammatical problems faced by dyslexic adults has been obtained. It has also been possible to make contact with a large number of dyslexic adults willing to help further with the research.

From the survey it could be concluded that, in adults, dyslexia has a markedly lower affect on the grammar of computer programming languages than on their ability to deal with English grammar. This information will be used to design the controlled teaching environment in which the subjects use a limited number of sentence templates. Some of the teaching approaches to be used will be based on computer programming logic and will be expanded on shortly.

3 Detailed Questionnaire

The initial survey provided a great deal of information, however, further information is required to aid the design of a grammatical tool. A mailing forum that was set up to aid the research, was used to distribute the computerised questionnaire and 80 subjects responded.

3.1 Objectives

The main objectives of the (detailed) questionnaire were as follows:-

- To establish the most common written English errors made by adults with dyslexia.
- To find out which computing packages are used.
- To establish what current techniques and tools are useful.

3.2 Questionnaire Results

The use of computers and software (particularly word processing packages) have been a tremendous help to the majority of dyslexic adults.

The most common written English errors (both grammatical and spelling) made by the subjects were as follows:-

- Upper and lower case letters used in the wrong place.
- Plurals and non-plurals used in the wrong place.
- Incorrect use of full stops, commas, apostrophise and semicolons.
- Mixing homophones, i.e. 'there' for 'their'
- Words used in the wrong context due to problems with letter reversals, for example 'how' instead of 'who' or 'saw' instead of 'was'.
- Mistakes made when using the spell checker, for example selecting the word 'modal' instead of 'model'.
- Words which by themselves are correct but when used next to one another, they should be combined, for example 'in to' instead of 'into'.
- Word reversals within a sentence, for example 'The cat on sat the chair' instead of 'The cat sat on the chair'.
- Leaving the last letter off the end of a word or missing off 'ed' and 's'
- Missing out preposition (a, the, in, are) and repeating words in sentences
- Interchanging letters: b/d p/q s/c c/k i/e f/ph wh/we ai/ia ou/uo
- Interchanging verb tenses: its/it's loose/lose
- Spelling phonetically, i.e. 'shure' for 'sure'
- Words with double consonants spelt incorrectly, i.e. 'necessary' spelt 'neccessary'
- Writing in passive tense

Difficulties constructing sentences, i.e. subject - verb - object
Not knowing general grammatical rules

The subjects provided the names of the tools they currently use to aid them with their written English. The most popular tool in each category is listed. The subjects were also asked to grade from 1 to 4 (1:low 4:high) how useful they found the tools to be.

Word processors: TextHelp was the most popular special purpose word processor used. It includes a text reader, spell checker and word predictor. 85% found word processors extremely useful.

Spell checkers: Franklin Word master was the most popular used spell checker. 83% found spell checkers very useful.

Grammatical Tool: grammatik part of word perfect word processor was the most popular grammar checker used. 70% found then of no or little use.

Voice dictation: Dragon dictate, type as you talk was the most popular used voice dictation system. The use of these tools is increasing but currently too few subjects commented on their usefulness to be recorded.

Subjects were asked to comment on why word processors were useful and these comments have been summarised.

One of the most common features of a dyslexic adult is a poor standard of hand writing. The use of the keyboard has been very beneficial in overcoming the problem of producing written text (Singleton, 1992). Computers allow the user to select large fonts and change the letter type and background colours. Many dyslexics have a problem when reading black letters on a white background so these colours can be changed. The cut and paste feature allows the restructuring of text.

The spell checkers were also widely used, however, many subjects find it very difficult to choose from the picking list as many of the words look alike. Outliners allow the subject to concentrate on the section headings and sub headings and expanding them when required. These are useful to allow the person to concentrate on the structure of the text.

The results from the (detailed) questionnaire show that grammatical tools are seldom used. Most dyslexic adults do not understand the responses given by current standard grammatical tools. They find them to be very confusing and of little help.

4 Design Outline for the Grammatical Tool

The grammatical tool comprises a natural language parser, spell checker and a teaching environment. The parser must be designed to look for common dyslexic written errors and be able to offer solutions to them. A list of the most frequently made errors has been compiled and will be used in the design rules for the natural language parser

From the responses there was a high demand for a tool to assist in sentence construction. Many subjects stated that they knew what they wanted to write but found it very hard to construct sentences. Word processing packages were extremely useful for layout and presentation but did not help with content or structure. This will be incorporated into the teaching environment

Spell checkers were widely used, however, selecting from the picking list caused problems as the chosen words look very similar. An in-context spell checker would be a useful tool and will be discussed shortly.

The controlled teaching environment will use a reduced set of allowable sentence structures, a small set of clearly defined grammar rules and incorporate a logical design approach to structuring of sentences.

The grammatical tool will have a two phase function allowing the user to decide how they want to use the tool. The tool can be used purely as a grammatical checker to check word processed documents for grammatical errors and make no use of the teaching environment. In this case the tool would be used as an 'add on' to the users existing word processor. Alternatively the user can select to work within the teaching environment and develop the document from within the controlled environment. The tool will be developed for a PC platform and interface with current windows packages. The tool components consist of four main parts.

User interface

The user Interface will be a graphical interface whereby the mouse is used to select the required icon. Related text will be in large font and presented in a user friendly manner. Menus and lists will be avoided where possible. Dyslexics are visual thinkers and the use of pictures in the place of words has benefits.

Natural language parser

The natural language parser takes a sentence breaks it down into its smallest components and checks to see if it is structured according to the in built grammar rules. This parser will be designed to look for specific dyslexic type errors. Current grammar checkers are not designed to interpret the unique dyslexic tendencies of reversing sentences and words. Also many dyslexics do not understand the feedback they are given from grammatical checkers and thus prefer not to use them. The parser must primarily check for English grammar rules, secondly respond to dyslexic type errors and offer useful advice and feedback in plain English. From the research a list of common mistakes made by dyslexic adults have been produced (see section 3.2).

The parser will either be used as an 'add on' to the users current word processing package (as previously described) or used within the teaching environment. For both cases the parser will function in a similar way. The parser will read each sentence and pause when a grammatical error has been detected. The sentence containing the error will be highlighted. An explanation of the error will be given and the suggested remedy. Feedback will then be requested from the user. On detection of a spelling error the spell checker will be activated.

Teaching environment

The teaching environment can be used to provide step by step guidance, to reinforce basic grammar rules and aid sentence construction. The users will work within

an interactive controlled teaching environment. The system will function like a word processing package allowing users to produce written documents. Within the environment the rigidity of the English language construct allowed will be increased. This will be achieved by only allowing the user to select from a small set of sentence structure templates. No other sentence structures will be allowed. The spell checker will work interactively checking each word as it is input. If a spelling error is detected the spell checker will offer a picking list. After a full stop is detected the grammatical checker will check the structure of the sentence and immediately report on any errors that have been made. Within the environment the number of rules will be reduced. Only basic grammar rules will be enforced.

At present the investigation into various possible teaching approaches to be used is still in its infancy. However, from the detailed questionnaire the subjects provided a potential list of features that they think would be useful. Further research needs to be undertaken to ascertain the feasibility of these methods. Only the viable ones will be incorporated in the tool. The user will make a selection according to their requirements. At this stage of the research an initial interpretation of these methods are as follows:-

The use of diagrams has always been beneficial for visual thinkers. The idea of using a flow chart to design the structure of text either overall, for a paragraph or individual sentence was a very popular request from the detailed questionnaire. This would work similar to an outliner.

Using modular sentence structuring to split up the sentence into its smallest components for example noun phrase and applying this to different sentence structures. This would be used to teach the basic grammar rules.

Constructing sentences can be a problem and knowing which template to chose can also be difficult. Many subjects stated they knew what to write but found it difficult constructing sentences. A feature that requests the key words from the user and automatically generates a suitable sentence may be useful.

Spell checker

The spell checker will be designed specifically to aid dyslexic adults who tend to spell phonetically. The resulting picking list will include the word meanings to aid the selection.

Spell checkers are imperative to many dyslexics and widely used as this research has shown. Unfortunately several difficulties still occur. When a spell checker has found a word that is spelled incorrectly, it provides the user with a list of suggestions. These suggestions are usually similar in shape but very different in meaning. It is very difficult for a dyslexic to distinguish between the words when the true meaning (of the words) may not be understood. Reading abilities vary tremendously and some subjects may be unable to even read the suggested words correctly. It is hoped that the development of an in-context spell checker whereby the offered picking list will include the meaning of each word will be undertaken. This should help dyslexic adults make their selection.

The picking list will be presented in large font and the arrow keys can be used to highlight each option and make the selection. The spell checker is designed to be used by subjects who spell phonetically. The system will have the ability to store information about commonly incorrectly spelled words and learn from the subject's mistakes.

The information presented in this paper will now be used to design the grammatical tool and produce a working prototype for testing in the near future.

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A.18 Paper presented in York 1-4th April 1997**Evaluation of the Requirements for a Grammar and In-context Spell Checker for Dyslexic Adults.**

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Abstract published in Dyslexia British Dyslexia Association 25th Anniversary Conference

Abstract

The paper reports on the conclusions drawn from a series of surveys carried out using the Internet, that requested information from adults with dyslexia. The research was concerned with how dyslexia affects a person's abilities with different language structures. An in-depth evaluation of common spelling and grammatical errors made by dyslexic adults, was also undertaken. Finally information related to the effectiveness of current grammatical tools was requested and evaluated. Adults with dyslexia need a grammar and spell checker designed specifically for their needs to help them enhance their potential. The paper concludes by showing how the survey information can be used to design a grammatical tool, in-context spell checker and an optional teaching environment for adults with dyslexia.

1 Introduction

This paper reports on survey results compiled from (approximately 260) adults with dyslexia. Computerised forms were made available on the Internet and electronic mail was used to send the data back for analysis. Links to the forms were established from key dyslexic sources of information web sites, for example Dyslexia Archive. This resulted in dyslexic adults from all over the world (i.e. UK, America, Canada and Australia), replying to a request for information. The subjects tended to be technologically proficient as they required computer access to use the Internet and gain access to the survey form. The main areas under investigation in this paper are as follows:-

How language structure effects adults with dyslexia.

Computer programming languages and natural languages such as the English language were used to review how dyslexia affects a subject's ability when using different language structures. The research aims to establish whether there exists a link between the number of rules (and level of constraints) that a language has and the degree of problems that dyslexic subjects encounter.

Evaluation of current grammar tools.

An evaluation of current grammatical tools available when using a computer was undertaken. A list of the problems associated with current grammatical tools and spell checkers along with a review of the features found most useful by the subjects are presented. This was performed to ascertain whether dyslexic adults were provided with the type of support they need to aid them with their written English problems.

A review of English grammar and spelling problems

A list of common English grammar and spelling problems that dyslexic adults encounter are presented. A detailed list of the type of written English errors that are made along with examples is also included.

Development of the grammatical tool.

The requirements and initial design of the grammatical tool, phonetically based in-context spell checker and controlled teaching environment are presented.

2 How language structure effects adults with dyslexia.

While undertaking an initial literature study of dyslexia it seemed that dyslexic adults in general tended to be more proficient at advanced mathematics than basic mathematics (Miles, 1992). Further studies indicated that a rigid structure, fixed limited rules and the use of symbols seemed to have a positive effect and go some way to explaining their abilities with advanced mathematics. This research investigates how dyslexia affects a subject's abilities with different language structures. The languages to be used for comparative purposes are written English (natural language) and highly structured languages such as computer programming languages. From this the following hypothesis was devised.

To establish whether there exists a link between the number of rules and level of constraints that a language has and the degree of problems that dyslexic subjects encounter.

A survey was designed to identify how dyslexia affects the subject's ability with written English and their use of computer programming languages. Computer programming languages use a relatively small set of rules and are correspondingly rigid in construction when compared to written English.

2.1 General background

General background information was requested from each person who responded to the survey. The subjects were also encouraged to use the general comment box at the end of the section (Sample size 260).

Age group categories: under 21, 21- 45 and over 45.
The majority of 70% of subjects were aged 21-45.

Gender: 58% male 42% female.

Computer usage categories: Little/no use (under 1 hour per week).
Average use (1-5 hours per week).
Above average use (above 5 hours per week).
70% selected the Above average category.

2.2 English grammar

Subjects were asked specific questions related to written English and provided with a comment box at the end of the section. In this section (except where stated) subjects were asked to select from a scale 1 (low) to 4 (high) effects. (Sample size 260).

To what extent does your dyslexia effect your written work?

This was a very generalised question and because of the nature of dyslexia it was to be expected that the majority of subjects would select the higher effect options. This was indeed the case and 77% of the sample selected those options.

Do the current available grammar tools help you?

The results show that 33% did not use any grammatical tools and 34% found the tools to be of little help. Only 12% found them very useful. This is a positive result for the research objectives.

The subjects were provided with some general details about the development of a new grammatical tool designed to detect common dyslexic type errors offering solutions in plain English.

Do you have a need for a new grammatical tool?

Scale 1 (little/no demand) to 4 (great demand). A significant majority of 73% selected the higher levels of demand options for a new grammatical tool. This was again a very encouraging result.

The subjects were given information about the teaching environment within which a grammatical tool will be used. "The teaching environment for the grammatical tool aims to reinforce basic grammar rules using a relatively small set of allowable sentence structure templates. The tool will provide both practical and learning environment through step by step guidance and comprehensive help."

Would a teaching environment be of use to you?

Scale 1 (little/no demand) to 4 (great demand). The results show that a majority of 62% selected the higher demand options for a new grammatical learning environment tool.

2.3 Computer programming languages

Subjects were asked to answer questions related to computer programming experience for those subjects that used these languages. A comment box was again provided at the end of the section.

Do you use computer programming languages?

From the sample 59% used computer programming languages in their everyday lives. This percentage is very encouraging and shows that the majority of the subjects, regardless of their dyslexia, were able to learn and use computer programming languages. This was essential in order to use the survey results to investigate comparative affects

Does your dyslexia effect your programming abilities?

A significant majority of 70% selected the lower effect options. This is a very encouraging result with regards to the research hypothesis.

Do you find programming easier than written English?

Scale 1 (similar affects) to 4 (great deal easier). A significant majority of 66% of the sample selected options 3 or 4 indicating computer programming was substantially easier than written English. Only 19% selected option 1 representing similar affects.

A comparison of a subject's English grammar and computer programming abilities (where applicable) were combined. This was in order to illustrate the responses in terms of the level to which dyslexia affects both grammar and computer programming skills. Combined Groupings compared the individual subjects' responses to grammar and programming abilities previously reviewed. If options 1 or 2 was selected category low value was assigned and if options 3 or 4 was selected category high was assigned for both grammar and programming abilities. 47% of the sample have significantly high English grammar effects and low computer programming affects. This represented a positive result for the hypothesis Only 5% of the sample have low English grammar effects and high computer programming affects. This represented a negative result for the hypothesis.

Is understanding errors generated by the compiler a problem?

A compiler reports on the syntax of the program statements as they are converted to a machine readable form. Scale 1(Little or no effect) to 4(Great effect). A significant majority 63% selected the lower effect options indicating their dyslexia caused a relatively low affect on their ability to understand compiler errors.

If you use debugging tools are they helpful?

A debugger is a tool used to detect errors in the programming code and offers correction advise. Scale 1 (Not used) to 4 (High use). 51% selected options 3 or 4 indicating they found debugging tools were very useful.

Is the construction of programming instructions a problem?

A program instruction can be compared to a sentence in written English. Scale 1 (Little or no effect) to 4(Great effect). A majority of 61% of the sample selected the lower effect options on their ability to construct programming statements

2.3.1 Comment evaluation

The most common problems faced by dyslexic adults who frequently use computer programming languages from comments made in the survey are as follows:-

Program size:The larger the program the more difficult the process is. This is overcome by using program modules whenever possible.

Memory: The problem of poor visual sequential memory still remains. Problem remembering variable names and what they are used for was frequently mentioned.

Spelling: The spelling of commands, variable names, comment statements and noticeably input/output dialogue cause problems.

Reading: Reading the hard copy is sometimes difficult and can be very time consuming.

There are many features that make computer programming languages easier to use than written English for sufferers of dyslexia. Listed are the most common comments made:-

- Computer code:** Many subjects stated that computer code seemed to make much more sense to them than written English.
- Vocabulary:** A limited spelling vocabulary in terms of programming commands limits the spelling problems associated with dyslexics.
- Structure:** Programming languages have a strict deterministic structure and the syntax of a command is rigid.
- Logic:** Programming languages have a high degree of logic and precision built into them and the ability to split a programming task into modules following logical steps is also beneficial.
- Flowcharts:** Flowcharts can be used to design structure and work well for visual thinking people.
- Rules:** Programming languages use clearly defined ridged rules.
- Tools** Debuggers and compilers that detect errors are helpful.
- Memory:** The use of short distinct variables can aid memory using names that have meanings that responds to the dyslexic visual thinking process. Also programming languages use a relatively small set of commands making it easier to remember.

2.4 Section summary

This section consisted of very generalised questions to attempt to establish how dyslexia affects a subject's English grammar and computer programming skills and a review of grammatical tools. In summary the results are:-

Background

The results show that the majority of the sample have an above average use of computers (70%) and use computer programming languages in their every day working lives (59%).

Grammar and Grammatical Tools

The majority of the subjects (77%) indicated that their dyslexia has a significant effect on their abilities with English grammar. A significant 77% of the subjects stated current tools are unsuitable or not used and 73% required a new grammatical tool. The majority of 62% stated that a teaching environment would be of use to them.

Computer programming

From the adults that responded to the survey the majority of 59% used computer programming languages. Evidence from this survey suggests that (70%) of the subjects stated that dyslexia does not impinge on their computer programming abilities. A significant 63% of the subjects stated they did not have problems understanding compiler errors. The results showed that 51% found debugging tools useful and 61% selected lower effects options when constructing programming instructions.

3 Evaluate how useful current grammar tools are.

A second survey was carried out again using the Internet and eighty dyslexic adults responded by completing the survey form. The survey was designed to evaluate current packages and to ascertain the type of problems dyslexic adults have with written English. The results are summarised in sections 3 and 4.

The subjects stated the names of the tools they currently use to aid them with their written English. The most popular tool in each category is listed. The subjects were also asked to grade from 1 to 4 (1: Low - 4: high) how useful they found the tools to be.

Word processors: TextHelp was the most popular special purpose word processor used. It includes a text reader, spell checker and word predictor. 85% found word processors extremely useful.

Spell checkers: Franklin Word master was the most popular used spell checker. 83% found spell checkers very useful.

Grammatical Tool: grammatik part of word perfect word processor was the most popular grammar checker used. 30% found current grammatical checkers useful.

Voice dictation: Dragon dictate, type as you talk was the most popular used voice dictation system. The use of these tools is increasing but currently too few subjects commented on their usefulness to be recorded.

Subjects were asked to comment on why word processors were useful and these comments are now summarised.

One of the most common features of a dyslexic adult is a poor standard of hand writing. The use of the keyboard has been very beneficial in overcoming the problem of producing written text. Computers allow the user to select large fonts and change the letter type and background colours. Many dyslexics have a problem when reading black letters on a white background so these colours can be changed. The cut and paste feature allows the restructuring of text. These results agree with Dr. Singleton's research and evaluation (Singleton, 1992).

Spell checkers are imperative to many dyslexics and widely used as this research has shown. Unfortunately several difficulties still occur. When a spell checker has found a word that is spelled incorrectly, it provides the user with a list of suggestions. These suggestions are usually similar in shape but very different in meaning. It is very difficult for a dyslexic to distinguish between the words when the true meaning (of the words) may not be understood. Reading abilities vary tremendously and some subjects may be unable to even read the suggested words correctly. It is hoped that the development of an in-context spell checker, whereby the offered picking list will include the meaning of each word, will be undertaken. An improved system would present the words in context (give example use of the word in a sentence) with the option of a further example (word usage) if required. This should aid the selection process for dyslexic adults.

Outliners allow the subject to concentrate on the section headings and sub-headings and expand them when required. This allows dyslexics to focus on the structure of the text.

The subjects were asked to comment on their use of grammatical tools. The results indicated that grammatical tools were seldom used. Most dyslexic adults do not understand the responses given by current standard grammatical tools and find them to be very confusing and of little help.

4 A review of English grammar and spelling problems

The most common problems associated with written English according to the grammar comments made in the survey, are as follows:-

Sequencing: Sequencing of letters within words or words within sentences commonly cause problems for dyslexics. Many also have a problem with sequences of numbers, such as telephone numbers. Consistently leaving out words or writing the sentence in reverse were also commonly mentioned problems.

Spelling: A unique dyslexic tendency to reverse the spelling of a word for example 'was' for 'saw' and interchanging letters i.e. p for q are common problems. Another problem is the tendency to consistently spell difficult words correctly and easy words incorrectly. Dyslexics tend to spell phonetically and need a spell checker that takes this into account.

Grammar: Subjects found English grammar rules hard to follow. Many subjects stated that different teachers seem to use a different set of grammar rules that lead to confusion. Some subjects experience problems applying grammar rules when given examples to follow. The majority of the subjects felt that English grammar was too flexible and they required more rigid rules to follow. A small number of subjects did not know what grammar rules were.

Writing Style: Identifying tenses is a common problem for many subjects.

Punctuation: Sentence punctuation is a major problem for many dyslexics. There is a tendency to incorrectly use commas and apostrophes.

Homophones: The mixing of Homophones: such as 'there' place for 'their' belonging is a real problem that causes embarrassment for many dyslexics.

English: Dyslexics tend to use only words they are familiar with which results in a very limited vocabulary. Words that look alike can cause confusion, such as because, became, become. Also words that sound alike such as effect and affect.

The most common written English errors (both grammatical and spelling) made by the subjects were as follows:-

Upper and lower case letters used in the wrong place.
 Plurals and non-plurals used in the wrong place.
 Incorrect use of full stops, commas, apostrophise and semicolons.
 Mixing homophones, e.g. 'there' for 'their'
 Words used in the wrong context due to problems with letter reversals, for example 'how' instead of 'who' or 'saw' instead of 'was'.
 Mistakes made when using the spell checker, for example selecting the word 'modal' instead of 'model'.
 Words which by themselves are correct but when used next to one another, they should be combined, for example 'in to' instead of 'into'.
 Word reversals within a sentence, for example 'The cat on sat the chair' instead of 'The cat sat on the chair'.
 Leaving the last letter off the end of a word or missing off 'ed' and 's'
 Missing out preposition (a, the, in, are) and repeating words in sentences.
 Interchanging letters: b/d p/q s/c c/k i/e f/ph wh/we ai/ia ou/uo
 Interchanging verb tenses: its/it's loose/lose
 Spelling phonetically, i.e. 'shure' for 'sure'
 Words with double consonants spelt incorrectly, i.e. 'necessary' spelt 'neccessary'
 Writing in passive tense
 Difficulties constructing sentences, i.e. subject - verb - object
 Not knowing general grammatical rules

5 Development of the grammatical tool and teaching environment.

This section is concerned with the general requires for a grammatical tool and presents the outline.

5.1 Grammatical tool requirements

The following is a list of requirements for the grammatical tool from the grammar comments made in the survey:-

- Current Tools:*** The tools are not designed to detect unique dyslexic errors such as word reversal. When using grammatical tools the explanation of errors is hard to understand and assumes greater knowledge than many subjects have.
- Rules:*** Many subjects stated they wanted the grammar rules described using English they can understand. They want to be able to write in personal or impersonal styles without the grammatical tool complaining. Subjects also stated it would be useful to give meanings to words or sentences using speech and pictures. A multi-sensory approach has proven benefits (Singleton,1994).
- Predictor:*** There was a demand for a word predictor that guesses what the word is after the first few letters are input. It must use a large vocabulary and offer a large picking list.

- Help:** Dyslexics require help and advise which helps them to conform, preferably interactively, using plain English.
- Errors:** They want a tool to be able to tell the difference between a spelling error and grammatical error.
- Teach:** The tool should teach different grammatical structures in an interactive way
- Spelling:** A spelling device to verify each word is required.
- Interface:** A multi-level interface is required allowing a subject to select an ability level suitable to their needs. The interface should be user friendly and graphical based.
- Punctuation:** Help with English sentence punctuation was commonly requested.

5.2 Grammatical tool design features

The grammatical tool comprises a natural language parser, spell checker and a teaching environment. The grammatical tool will have a two phase function allowing the user to select how they want to use the tool. The tool can be used purely as a grammatical checker to check word processed documents for grammatical errors and make no use of the teaching environment. In this case the tool would be used as an 'add on' to the user's existing word processor. Alternatively the user can select to develop the document within the controlled teaching environment. The tool will be developed for a PC platform and interface with current windows packages. The tool components consist of four main parts.

User interface

The user interface will be a graphical interface whereby the mouse is used to select the required icon. Related text will be in large font and presented in a user friendly manner. Menus and lists will be avoided where possible. Dyslexics are visual thinkers and the use of pictures in the place of words has benefits.

Natural language parser

The natural language parser will take a sentence, break it down into its smallest components and check to see if it is structured according to the in built grammar rules. This parser will be designed to look for specific dyslexic type errors. Current grammar checkers are not designed to interpret the unique dyslexic tendencies of reversing sentences and words. Also many dyslexics do not understand the feedback they are given from grammatical checkers and thus prefer not to use them. The parser must primarily check for English grammar rules, secondly respond to dyslexic type errors and offer useful advice and feedback in plain English. From the research, a list of common mistakes made by dyslexic adults, have been produced (see section 4).

The parser will either be used as an 'add on' to the users current word processing package (as previously described) or used within the teaching environment. In both cases the parser will function in a similar way. The parser will read each sentence and pause when a grammatical error has been detected. The sentence containing the error will be highlighted. An explanation of the error will be given and the suggested remedy. The

user must then respond by either accepting the suggested remedy or requesting an alternative solution. On detection of a spelling error the spell checker will be activated.

Spell checker

The spell checker will be designed specifically to aid dyslexic adults who tend to spell phonetically. The resulting picking list will include the word meanings to aid the selection. The picking list will be presented in large font and the arrow keys can be used to highlight each option and make the selection. The system will have the ability to store information about commonly incorrectly spelled words and learn from the subject's mistakes. From this research and other sources (Davis, 1995) a list of potentially problematic words which dyslexic adults have a tendency to spell incorrectly will be stored in the system aiding the correction process. Examples of such words are as follows:-

almost, always, also.	Commonly add an extra 'l', i.e. allmost.
taking, making, coming.	Commonly add an 'e' before the 'ing', i.e. makeing.
putting, running, getting.	Commonly forget the double constant, i.e. geting.
knit, knelt, knight.	Commonly miss off the silent 'k', i.e. nit.
it, is, if.	Commonly reverse spelling, i.e. fi.
saw for was	Commonly confuse these words.
effect, affect, there, their	Mixing homophones

Teaching environment

The teaching environment can be used to provide step by step guidance, to reinforce basic grammar rules and aid sentence construction. The users will work within an interactive controlled teaching environment. The system will function like a word processing package allowing users to produce written documents. Within the environment the rigidity of the English language construct allowed will be increased. This will be achieved by only allowing the user to select from a small set of sentence structure templates. No other sentence structures will be allowed. Within the environment the number of grammar rules will be reduced depending on the type of document, for example formal or informal.

At present the investigation into various possible teaching approaches to be used is still in its infancy. However, an initial interpretation of these methods will now be covered.

The use of diagrams has always been beneficial for visual thinkers. The idea of using a flow chart to design the structure of text either overall, for a paragraph or individual sentence may be considered. This would work similar to an outliner.

Using modular sentence structuring to split up the sentence into its smallest components, for example noun phrase and applying this to different sentence structures. This would be used to teach the basic grammar rules.

Constructing sentences can be a problem and knowing which template to chose can also be difficult. Many subjects stated they knew what to write but found it difficult constructing sentences. A feature that requests the key words from the user and automatically generates a suitable sentence may be useful.

This paper represents a summary of the research carried out. The development of the grammatical tool is now under way and a working prototype should be available in the near future.