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A comparison of the rate and accuracy of symbol location on visual displays using colour-coded alphabetic and categorisation strategies in Grade 1 to 3 children

by

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Abstract

The ability to locate symbols on a visual display forms an integral part of the effective use of AAC systems. Characteristics of display design and perceptual features of symbols have been shown to influence rate and accuracy of symbol location (Thistle & Wilkinson, 2009; Wilkinson, Carlin, & Jagaroo, 2006). The current study endeavoured to compare the use of two colour-coded organisational strategies (alphabetical order and categorisation) for their effectiveness in symbol location and to investigate if some bottom-up features influenced the performance of the participants in these tasks.

114 learners in Grade 1 to 3 in a mainstream school were randomly divided into two groups. Both of the groups were exposed to two visual search tests in alternating order. The tests involved searching for 36 visual targets amongst 81 coloured Picture Communication Symbols on a computer screen in one of two colour-coded organizational methods, namely alphabetical order or categorisation. The data from the research task was collected through computer logging of all mouse selections.

Findings showed that locating symbols on a computer screen with a categorisation strategy was significantly faster and more accurate than with an alphabetical strategy for the Grade 1 to 3 participants. The rate and accuracy of target symbol location in both the strategies decreased significantly as grade increased, as did the differences between rate and accuracy of target location when using the two strategies.

It was also found that although the tests in this study placed heavy top-down processing demands on the participants, there was still evidence of bottom-up factors influencing their performance.

Implications for display design in AAC clinical practice were discussed.

Key words: Visual search; Rate; Accuracy; Location; Alphabetical order; Categorisation; Top-down processing; Bottom-up processing; AAC display design

Opsomming

Die vermoë om simbole op 'n visuele vertoon te lokaliseer vorm 'n integrale deel van AAK-sisteme. Daar is gevind dat die kenmerkende eienskappe van die vertoonontwerp en die perseptuele kenmerke van simbole die spoed en akkuraatheid van simboollokalisering beïnvloed (Thistle & Wilkinson, 2009; Wilkinson, Carlin, & Jagaroo, 2006). Die huidige studie het gepoog om 'n vergelyking te tref tussen die gebruik van twee kleur-gekodeerde organisasiestrategieë (alfabeties en kategorisering) in terme van hul doeltreffendheid ten opsigte van simboollokalisering en om te ondersoek of sommige onder-na-bo kenmerke die prestasie van deelnemers aan hierdie take beïnvloed het.

114 van Graad 1 tot 3 in 'n hoofstroomskool is lukraak in twee groepe verdeel. Albei die groepe is blootgestel aan twee visuele soektoetse in alternerende orde. Die toetse het die soek na 36 visuele teikens tussen 81 gekleurde "Picture Communication Symbols" op 'n rekenaarskerm in twee kleur-gekodeerde organisasiemetodes, naamlik alfabeties en kategorisering behels. Die data van die navorsingstaak is versamel deur rekenaar-invoering van alle muis-keuses.

Bevindinge het getoon dat die lokalisering van simbole op 'n rekenaarskerm met 'n kategoriseringstrategie beduidend vinniger en meer akkuraat as 'n alfabetiese strategie vir die Graad 1 tot 3 deelnemers was. Die verskil tussen die spoed van die lokalisering en die akkuraatheid van die lokalisering van teikensimbole met gebruik van die twee strategieë het beduidend afgeneem na mate graad toegeneem het.

Daar is ook gevind dat, alhoewel die toetse in hierdie studie 'n hoë bo-na-onder eis aan die deelnemers gestel het, daar steeds bewyse van onder-na-bo faktore was wat hulle prestasies beïnvloed het.

Implikasies vir vertoonontwerp in AAK is bespreek.

Sleutelwoorde: Visuele soek; Spoed; Akkuraatheid; Lokalisering; Alfabetiese orde; Kategorisering; Bo-na-onder prosessering; Onder-na-bo prosessering; AAK-vertoonontwerp

Chapter 1

Introduction

1.1 Problem statement

The use of visual-graphic displays forms the core of most low and high tech AAC interventions. Their importance necessitates a research-based consideration of the design factors impacting on their use. Of interest in this study is the use of large displays. Large displays are sometimes used in preference to a greater number of linked, smaller displays, due to the decreased memory demands and navigational steps required to find vocabulary. Large displays are also frequently used in the developing world context, where electronic dynamic systems are not readily available. However, large displays may place high cognitive demands on users with resultant high visual search times and increased error selections, especially for young users.

Methods that have been used in AAC practice to reduce cognitive demands and increase visual search rates in large displays are the organizational strategies of presenting vocabulary in the display grid, the symbol colour, the background colour and instruction in the use of the system.

Although there are different organizational strategies used by AAC users and interventionists, the most common are alphabetical order and categorization of the symbols. However, the comparative effectiveness of these organizational strategies has not been well researched (Wilkinson, Carlin, & Jagaroo, 2006).

In particular, there is little research to guide interventionists as to the most appropriate organizational strategy to present to young AAC users. Young children in their early educational years are only beginning to master the alphabet and are simultaneously developing in a taxonomic method of categorization (Fallon, Light, & Achenbach, 2003). The question arises whether young children can use these two strategies efficiently, and how their performance differs when using them.

In addition to the organizational strategies, foreground colour (colour in symbols) has been used extensively in AAC display design. A growing body of AAC research has supported the use of foreground colour, showing its effectiveness to enhance the rate of symbol location (Alant, Kolatsis, & Lilienfeld, 2010; Thistle & Wilkinson, 2009; Wilkinson, Carlin, & Jagaroo, 2006; Wilkinson & Jagaroo, 2004). However, the symbol location tasks in the above research studies were visually and cognitively undemanding. It is not clear whether the influence of foreground colour would extend to AAC tasks that require significant cognitive processing, such as when young users attempt to locate symbols in alphabetical and/or categorized displays.

Research into the impact of colour in AAC displays has stimulated research interest as to which other perceptual features of symbols influence location rate, and has included studies in the impact of motion (Jagaroo & Wilkinson, 2008) and background colour (Thistle & Wilkinson, 2009). No AAC research has been found on the impact of the perceptual features of size and visual complexity of symbols on visual search.

The background colour against which symbols in grid cells appear is another method used to facilitate visual search and has been used extensively in AAC displays. The systems of FitzGerald and Goosens' colour-code grammatical information in displays, primarily for language support (Beukelman & Mirenda, 1998). Many interventionists use colour-coding in idiosyncratic ways, intuitively knowing its value in display design, but their decisions have, until recently, not been supported by systematic research. Preliminary research has found background colour to be not as effective as foreground colour in increasing rate of symbol location (Thistle & Wilkinson, 2009). However, Thistle and Wilkinson used small displays and did not specifically instruct their participants to utilize the colour-coding cues strategically.

It is considered that symbol location in large displays will be facilitated by the addition of background colour if the area that is cued through top-down processing of alphabetic and categorization information is at the same time supported by bottom-up visual cues. This positive influence of background colour-coding will be most effective if supported by best practice factors such as foreground symbol colour, inclusion of a gloss and instruction in the use of the two search strategies mentioned above.

The focus of this study is a comparison of the rate and accuracy of symbol location in two visual displays, using either colour-coded alphabetical order or categorisation strategies for children in Grade 1 to 3.

The outcome of this study would be to inform AAC practice as to the most efficient organizational strategy with respect to rate and accuracy of symbol location to offer young AAC users. It would also inform AAC practice concerning the possible influence of some perceptual features of symbols during a visual search task.

1.2 Outline of chapters

This research study is presented in six chapters. Chapter 1 provides the basic introduction and motivation for the research. Research into visual search, an integral part of the AAC message selection process, is required to compare the performance of young children when searching while using two common but different search strategies – alphabetical order and categorisation. Chapter 2 provides a literature review of the three major elements of the rationale for this study - an investigation into the current status of methods for enhancing symbol location rate enhancing methods in AAC design, as well as an overview of visual search theory and relevant factors in the development of alphabetical order and categorization skill in Grade 1 to 3 children. Chapter 3 describes the methodology of the research that was designed to compare the use of the two visual search strategies and includes a description of the design, sampling method, participants of the study, materials used, data collection and data analysis procedures. Chapter 4 presents the results of the research. In Chapter 5 the main issues arising out of the results are discussed, including clinical implications. In Chapter 6, the study is critically evaluated in terms of its strengths and limitations, and recommendations for further research are made.

1.3 Abbreviations

AAC	Augmentative and Alternative Communication
ALP	Alphabetical Order test and/or Alphabetical Order visual display
PCS	Picture Communication Symbols
SUB	Subcategorisation test and/or Subcategorisation visual display

1.4 Definition of terms

Attention	The act or state of selective concentration on a particular aspect of the environment (Olivers, Peters, Houtkamp, & Roelfsema, 2011)
Bottom-up processing	Stimulus-driven processing (Wolfe, 2003)
Cognitive science	The interdisciplinary study of the mind (Light & Lindsay, 1991)

Cognitive neuroscience	The field of science that seeks to understand cognition and behaviour in relation to underlying neural systems (Wilkinson & Jagaroo, 2004)
Distractor	Any symbol or visual stimulus that occurs together with the target symbol in a visual field (Wolfe, 1998)
Parallel search	Processing all items at once (Wolfe, 1998)
Pop-out	The summoning of attention to an unusual item (Wolfe, 1998)
Salience	The target's ability to attract attention (Meyer, 2004)
Set size	The total number of items in the visual display (Wolfe, 1998)
Serial search	Visual field processed in small regions at a time
Top-down processing	User-driven or goal-driven processing (Wolfe, 2003)
Vigilance	The ability of an observer to maintain a high level of detection performance in visual search tasks over long periods (Uttal, 1998)
Visual cognitive neuroscience	The cognitive discipline interested in visual cognition (Wilkinson & Jagaroo, 2004)
Visual search	The process during which a predefined target needs to be found within a visual field in terms of specific task requirements and reacted to (Meyer, 2004)

Working memory	Storage and manipulation of a limited amount of information for cognitive tasks (Olivers, Peters, Houtkamp, & Roelfsema, 2011)

1.5 Summary

Visual search research is required to inform AAC practice concerning the provision of the more suitable of two display designs (alphabetical order or categorisation) for young children. A research study to investigate this issue is presented in this thesis.

Chapter 2

Literature review

2.1 Introduction

There are three key theoretical issues which form the basis for the current study: firstly, the principles and strategies used in AAC display design for enhancing symbol location rate; secondly, visual search theory; and thirdly, the development of children in Grade 1 to 3, especially with respect to the development of taxonomic categorization and alphabetical order. Figure 1 provides an overview of the chapter.

2.1	Introduction
2.2	AAC strategies for enhancing symbol location *Consideration of: display design, symbol characteristics, user skills, and instruction and experience*
2.3	Visual search theory Visual processing *Bottom-up and top-down, parallel and serial, pre-attentive and attentive* Factors influencing visual search Bottom-up factors *Symbol factors, display factors and user factors* Top-down factors *Symbol semantic factors, working memory, task demands and user factors* Differences between visual search research and AAC
2.4	Developmental issues in children in Grade 1 to 3 *Categorisation and alphabetical order development*
2.5	Concluding remarks
2.6	Summary

Figure 1. Overview of Chapter 2

2.2 AAC strategies for enhancing symbol location

Most AAC systems rely on a visual representation of vocabulary from which a user has to systematically access symbols to form messages (Wilkinson et al., 2006). To access those messages users have to visually scan, locate and select a symbol in a visual field. Symbol location is thus an integral part of AAC use, a skill that needs to be applied in its' everyday use.

Symbol location rate is an important factor in maximizing the efficiency and effectiveness of an AAC system. However, the current status on strategies for enhancing rate of location in AAC is supported by best practice rather than by scientific research. AAC practice addresses the challenge of maximizing rate of location through consideration of aspects such as: (1) display design; (2) symbol characteristics; (3) consideration of user skills; and (4) instruction and experience.

2.2.1 Display design

The grid structure of rows and columns has been used extensively as an efficient method to both store and access the vocabulary required for a visually presented AAC system, from fixed low-tech boards through to pre-programmed dynamic computerized systems. In the case of very young users of about 2.5 years old the use of a grid system for displays has been challenged and natural scenes shown to be an alternative (Drager, Light, Speltz, Fallon, & Jeffries, 2003).

There are, however, physical constraints to the external representation of language in terms of the number of symbols that can be displayed at any one time, device capabilities and the visual and cognitive capabilities of the user. As the number of symbols on a board is increased, so are the cognitive, visual and motor demands to locate those symbols, with subsequent decreases in symbol location rates. The two primary methods of reducing these cognitive and visual demands in AAC are physical organization (layout) of the symbols within the display and visual organization of the content of the display (McFadd & Wilkinson, 2010; Wilkinson et al., 2006).

Physical organisation within a display influences symbol location because it provides a cueing system to guide visual search. Basic strategies that have been used to organise symbols when grid structures are used in AAC are semantic categorisation (where concepts are in taxonomic relationships to one another), grammatical relationships (such as grouping nouns, verbs and other parts of speech), alphabetical order, specific contextual or thematic relationships and idiosyncratic (personalized) relationships (Beukelman, 1991; Simpson, Hux, Beukelman, Lutt, & Gaeblar, 1996). Two methods of display organization commonly used with graphic symbols are taxonomic categorization and alphabetical order.

Colour-coding has been used extensively as a method of visual organization in AAC displays, to minimize operational, attentional, and/or cognitive demands (McFadd & Wilkinson, 2010). FitzGerald and Goosens' used coding of the background symbols in a grammatical encoding system to provide users with a reference to help locate the symbols (Beukelman & Mirenda, 1998). Their work has, however, never been researched. Thistle and Wilkinson (2009) explored the use of colour in the background of line drawings in a visual display to ease visual processing demands. They found that foreground colour had a stronger impact on rate of location than background colour and that there were no statistical differences between the use of white backgrounds or coloured backgrounds. However, they suggested research into the use of colour backgrounds as an organizational tool to enhance AAC performance.

What is common throughout AAC display design is the principle of organization in the visual field, whether it be markers, clustering, sorting, categorization or elaboration (Oxley & Norris, 2000). However, display design has not enjoyed the research attention it deserves. Besides, the most efficient grid for any set of symbols is probably not an absolute one, but may be impacted by a set of viewing conditions (Wilkinson & Jagaroo, 2004) and user characteristics.

2.2.2 Symbol characteristics

The symbols themselves can attract attention during a search for a symbol, resulting in a faster location rate. The attraction is due to the perceptual features of the symbols. The feature which has received the greatest amount of research attention in AAC is colour.

Wilkinson et al. (2006) conducted a study which specifically investigated the role of symbol colour in visual search. They found that grouping symbols by colour facilitated the rate of symbol location in a display, and in similar ways for both non-referential stimuli and iconic symbols. Stephenson (2007) investigated the effect of colour in the recognition and use of line drawings and found that coloured pictures are more salient than black and white ones. Thistle and Wilkinson (2009) found that foreground colour influenced rate of location of symbols in an array, irrespective of the presence of background colour and that this impact of colour was stronger for younger children than it was for older children. Alant et al. (2010)

extended Wilkinson et al.'s 2006 study and investigated the effect of sequential exposure of colour conditions. The study confirmed the complexities of visual search processing, and that the variation in the distractors had an effect on performance only when the perceptual features were relevant to the search task.

Another symbol perceptual feature was investigated when Jagarooo and Wilkinson (2008) conducted a study on the role of motion in symbols in display design. It was shown that motion can enhance symbol location rate. It may be that there are symbol features other than colour and motion that impact on symbol location rate too. Symbol features that are already frequently manipulated in AAC intervention are the size of the symbols and their visual complexity, but their impact on visual search location rates in AAC practice are largely unknown.

The linguistic label in written form (gloss) which is usually included in AAC displays may serve to enhance symbol location rate. For literate users, the written word positioned above or below the graphic serves to specify the actual word associated with that graphic. It appears that the gloss associated with a picture aids in the category perception of that picture (Callanan, 1985). Where images are semantically labelled and recognized, there is better recall than when they are not (Brady, Konkle, & Alvarez, 2011). In displays where the symbols are arranged categorically, category labels provided along with picture stimuli influence categorisation performance (Schlosser, 1997b). It is probable that the gloss added to a display organized alphabetically would impact symbol location rate, as search may rely on the information in the ordered labels.

2.2.3 User skills

In AAC intervention, not only are the users' current skills and challenges considered in display design, but their developmental requirements as well. Language organisation for children should be age appropriate to facilitate their learning as well as a fast and effortless retrieval of the language concepts from their AAC systems (Strauss, Uys, & Alant, 2007).

When considering the user's current skills and challenges, the factors to consider are extensive, as they include a wide range of issues – the specific strengths and challenges in motor, sensory, cognitive, educational and communicative areas of human functioning (Beukelman & Mirenda, 1998). Of particular interest to this study are the cognitive and educational skills of the user with respect to categorization and alphabetical order. Higher-level AAC systems utilize both the former skills, mostly using a combination of grammatical, taxonomic and alphabetical arrangements. Where grammatical or taxonomic categories are used in these systems, symbols are often arranged alphabetically within those categories. However, for young users and for pre-literate users categorisation is primarily used.

Developmental considerations are important to consider in display design. Fallon et al (2003) investigated the difficulty of using a taxonomic organization with young typically developing children, finding that children of 4-5 years used a schematic organizational system rather than a taxonomic one (but also drew attention to the variability and instability between the participants and between sessions). They stressed the importance of guided instruction and support for a developmental progression in the semantic organization skills of children. They suggested including features such as having small groups of schematically arranged symbols within a broader organizational structure to provide support for current needs as well as for developmental progression (Fallon et al., 2003). It may be that the introduction of alphabetically ordered symbols within the context of categorized groups of symbols is also a good developmental principle to consider for young children.

AAC display design for the purpose of enhancing symbol location has also been investigated within specific non-typical populations. Visual search efficiency in people with mental retardation was improved by guiding attention through manipulating perceptual variables. They found no difference between the performance of people with and without mental retardation for the perceptual dimensions of colour, but they did find intelligence-related differences for form and size (Carlin, Soraci, Goldman, & McIlvane, 1995). Visual search efficiency was increased for people with mental retardation when colour was used to guide search tasks (Carlin, Soraci, Dennis, Strawbridge, & Chechile, 2002). Search rate and accuracy was facilitated when grouping same colour symbols for both typically developing pre-school children and children with Down syndrome (Wilkinson, Carlin, & Thistle, 2008). These preliminary studies suggest that the principles of visual search found to operate in people without disabilities may also be found to operate in populations with disabilities.

2.2.4 Instruction and experience

Although instruction in and experience with a display organisational search strategy is not in the scope of this study, a literature review on the impact of instruction and experience in mastering an AAC display indicates that initial user performance should not be a decisive factor when choosing the most appropriate AAC system for a user (Hocstein, McDaniel & Nettleton, 2004; Mizuko, Reichle, Ratcliff, & Esser, 1994; Oxley & Norris, 2000).

Mizuko, Reichle, Ratcliff, & Esser (1994) highlighted the impact of cognitive demands in the use of an AAC communication system. To the extent that a task is attention demanding, time to execute the task will increase and accuracy of performance will decrease. However, they also pointed out how attention-demanding processes can become automated with the acquisition of skill when using a consistent system. Their study investigated selection techniques and sizes of arrays. Oxley and Norris (2000) investigated children's use of memory strategies. They proposed that children can learn even complex strategies with instruction and practice in the application of meta-memory. Children are universal novices, and even although a task may demand much mental effort initially, learned strategies can become faster and less effortful over time, until they are considered routine by adults (Oxley & Norris, 2000). Hochstein, McDaniel and Nettleton (2004) compared two speech coding schemes (static versus dynamic) for efficiency of use with speaking children and adolescents with cerebral palsy. An important finding was that a strategy that was initially less efficient (the dynamic display) than another one (the static display), rapidly became more efficient with use and instruction. Quach and Beukelman (2010) highlighted the necessity for research on the efficacy of instruction to facilitate learning of an AAC system or strategy.

An AAC strategy is a specific way of using a technique more effectively for enhanced communication (Oxley & Norris, 2000). Instruction in the use of strategies to maximize visual search efficiencies is expected to be highly adaptable to the influences of experience.

2.3 Visual search theory

In this study, visual search is defined as the process during which a predefined target needs to be found within a visual field in terms of specific task requirements and reacted to (Meyer, 2004).

Visual search is an integral part of AAC use. Every component of every message must be selected before it (and its idea) can be transmitted. For every selection, there is a process of visual search that must occur before a selection is made (Jagaroo & Wilkinson, 2008). The study of visual processing in general and visual search in particular, is therefore very important in AAC intervention. Wilkinson and Jagaroo (2004) suggested that the application of the contributions of visual cognitive neuroscience may reduce some of the perceptual processing cost of AAC symbol use and that research into the design properties that enhance or inhibit visual symbol use is essential to the success of AAC interventions.

The following section summarises some important concepts in visual search theory, presents some specific factors enhancing visual search and concludes with a discussion on the major differences between AAC visual search and experimental visual search. It is important to note that visual search theory has been developed primarily out of research using typical populations (especially adult populations). The extent to which this theory can be applied to the atypical populations (especially children) who are users of AAC is at this stage unclear.

2.3.1 Visual processing

Some important concepts used to describe visual processing in visual search theory are bottom-up and top-down processing, serial and parallel processing and pre-attentive and attentive processing (Wolfe, 2003). A description of the basic issues involved in each of these concepts is presented in Table 1, providing a framework for understanding the factors which may impact on this study. Although researchers tend to focus their scientific enquiry towards one extreme of the theoretical debate on these issues, and although they differ in their positions as to the relative influence of the factors involved, most agree that there is a continuum of influence between the two extremes (Itti, 2005; Uttal, 1998; Wright & Ward, 1998).

Table 1

Visual Processing

Bottom-up and top-down processing			
Bottom-up processing	Top-down processing	References	Implications for study
Bottom-up processing is stimulus-driven, involuntary processing and is associated with neural activity. Examples of features that are primarily processed bottom-up are size, colour, orientation and motion.	Top-down processing is user driven processing under intentional control and is associated with higher level cognitive function. Features that are primarily processed top-down are task requirements, verbal instructions, memory, training search strategies and expertise such as category knowledge, alphabetical order knowledge.	Chen & Zelinsky, 2006 Lany & Egeth, 2003 Itti, 2005 Meyer, 2004 Wolfe, 2003	Will the perceptual features of the symbols still be able to exert a bottom-up influence in a visual search task that has strong, top-down processing requirements?
There is a continuum between bottom-up and top-down processing. Sensory information is initially processed from the bottom-up, but influenced by top-down processes.			

Parallel and serial processing			
Parallel processing	**Serial processing**	**References**	**Implications for study**
Search is directed to targets which 'pop-out', summoning attention without any effort from the viewer. The entire visual field is processed at once (in parallel), gathering enough information to distinguish the target from the distractors.	Search is conducted randomly through all the items in the field. A region in the visual field is selected for specialized analysis by an attentional (cognitively driven) spotlight.	Chikkerur, Tan, Serre, & Poggio, 2009 Lamy & Egeth, 2003 Uttal, 1998 Wolfe, 1998	Will some target symbols in the display have a relative pop-out effect compared to others? Will cognitive processing be able to direct attention to specific regions in the visual field?
Parallel strategies are used where basic features in the symbols guide attention to interesting objects in the visual field.	Serial strategies are employed where targets have features other than basic features, or a combination of features, or where basic features in the targets are not sufficiently different from the distractors.		Will parallel processing occur more frequently in a visual search task that is less cognitively demanding than another?
There is a continuum between parallel and serial processing. Various processing events happen simultaneously, simulating parallel and serial processing at their extremes.			

Pre-attentive and attentive processing			
Pre-attentive processing	**Attentive processing**	**References**	**Implications for study**
Perceptual processing occurs automatically without effortful attention, segregating perceptual input into functionally independent information channels of primitive properties such as form, colour and motion.	Attentive processing occurs as complex higher level cognitive processes integrate perceptual processes, forming a single, coherent representation of the attended object.	Betz, Kietzmann, Wilming, & König, 2010 Pratt & Hommel, 2003 Uttal, 1998 Wright & Ward, 1998	Will increased working demands impact on perceptual processing? Will the cues from cognitive processing efficiently guide attention to specific areas in the display and will the colour-coded areas serve as pull influences that draw attention to the targets?
Direct cues (or pull cues or stimulus cues) are visual features that draw attention to the target.	Symbolic cues (or push cues or information cues) are cues that guide attention to the target. Experience and practice guide attention to locations of high probability and attention is inhibited to areas already processed.		Will search times increase during the task due to experience and the repeated exposure to the visual displays?
There is a continuum between pre-attentive and attentive processing. There is a constant amount of mental processing available (working memory), distributed according to the number and type of items in the visual field and visual search task demands. However, it is cognitive factors which predominantly guide attention, not the influence of low-level features.			

Because this study investigates the impact of bottom-up features in visual search, the literature is reviewed within a framework of the bottom-up and top-down processing concepts.

2.3.2 Factors influencing visual search

In real-life visual search, in picture visual search, or in AAC use, the visual search task of the laboratory goes far beyond distinguishing between a set of features. Usually stimuli also have numerous semantic and context factors associated with them (Wolfe, Vo, Evans, & Greene, 2011) and the many components interact with each other in complex ways. How the visual neural system integrates all the information it receives on initial perception, together with all the top-down influences, is still largely unknown (Chikkerur et al., 2009) and is in fact incomputable (Uttal, 1998). A brief overview of the most significant factors influencing visual search which were identified in the literature follows. It is important to note that neither bottom-up and top-down processing, nor the factors described within each of them, are independent of each other. They are largely interdependent.

2.3.2.1 Bottom-up factors

The bottom-up factors impacting on symbol saliency (the 'ability' of a target to attract attention (Meyer, 2004)) reviewed are: (1) the perceptual features of the symbols themselves; (2) the visual field in which the symbols are found; and (3) the observer's interaction with the symbols. In AAC terms, it would be symbol factors, display factors and user factors.

2.3.2.1.1 Symbol perceptual features

The perceptual features of a symbol and its distractors collectively contribute to symbol salience in any given visual field, but in a non-linear manner, because the individual components are interdependent (Meyer, 2004). Itti (2005) was able to isolate the influence of some basic features but found that the greatest correlations were with all the features combined. Although many perceptual features have been identified as having bottom-up influence, the specific features considered in this study are colour, size and visual complexity.

Visual cognitive science research has shown that colour and contrast are two dimensions influencing visual processing (Wilkinson & Jagaroo, 2004), both in bottom-up processing as well as in top-down processing tasks. Colour facilitates many aspects of the process of visual perception and search. Colour information segments the visual scene at the initial stages of processing and aids symbol contrast, increases perceptual salience of symbols and impacts on perceptual discrimination. Colour has been noted to be ideal for breaking up a coherent display and for marking areas of a display in which items should be seen as connected (Davidoff, 1991). It also aids symbol recognition through the use of colour shading and details, facilitates symbol retrieval, aids object classification and facilitates both short-term and long-term visual memory. Long-term visual memory is especially facilitated through the mental representation that is built up by the association of colour and form (Wilkinson & Jagaroo, 2004) although colour and form information is not bound together in memory representations (Hanna & Remington, 1996). In addition, colour has been found to directly support efficient visual search, but only if the differences between the targets and distractors are not too small (Wolfe, 1998).

If colour is part of the stored memory representation of an object, it will provide additional information to assist in matching to a target in a visual field. Recognition is more accurate for coloured than for black and white stimuli. Recognition is also faster if the colour represents the real-life colour of the object and if sufficient processing time is allowed for the perceptual and conceptual processing of the object (Hanna & Remington, 1996). Warmer colours have been found to be more salient than cool colours (Bruce & Tsotsos, 2009).

However, it is important to note that the information above refers to the role of colour *within* symbols, not colour in cell backgrounds. Coloured backgrounds play a different role to foreground colours in visual search, and will be discussed later.

If the size difference is sufficient, a target of one size will be found efficiently among distractors of another size. Looking for the medium sized item among larger and smaller items is inefficient unless the size differences are very large (Wolfe, 1998).

Visual complexity reflects the superficial visual characteristics of the pictorial representation of an object (Snodgrass & Vanderwart, 1980), or the amount of lines and details in a picture (Alario & Ferrand, 1999). Visual complexity may impact on visual processing at the earliest stages of vision. Reaction times for naming pictures tend to be slower for more complex pictures (Szekely & Bates, 2000). Would visual complexity also impact on search location rates? Wilkinson and Jagaroo (2004) suggested that message preparation in AAC usage may be enhanced if the symbols are simpler to locate visually.

Although the perceptual features of a symbol contribute to its salience, symbol salience is a relative term, since it is based on the relationship of all the items in a visual field. The features of the item as well as those of the neighbouring items contribute to the overall salience of a target. Therefore perceptual salience of symbols may not only facilitate visual search, but also distract the observer when those symbols are not targets, but distractors.

Visual search skills require the ability to focus attention on task-relevant features in a visual field, while simultaneously limiting attention to irrelevant elements (Carlin et al., 2002).

If colour does indeed impact on perception of symbols in numerous ways, as was indicated above, a question arises as to the influence of colour from all the distractors within the visual field. The positive effects of a highly coloured visual field may be offset by the confounding effects of distractors. However, it appears that maximising the physical differences among symbols in a visual field reduces inter-stimulus confusions, increasing the speed of location of targets (Wilkinson et al., 2006).

2.3.2.1.2 Display factors

Not only do the perceptual features of the symbols and distractors influence symbol salience, but also factors related to the visual display in which the symbols are found. Display factors reviewed are: (1) structure; (2) set-size or information density; (3) visual cueing; and (4) position in display.

Firstly, any structure in a visual field can be exploited in visual search (Chun & Yuhong, 1998). In particular, it appears that symbols arranged in a grid structure facilitate visual processing. The neural saliency map (Itti, 2005) which is created on any visual sensory reception of a stimulus could be facilitated by the organization which is already found in a grid-structured visual field. For each point in the grid, and for each stimulus occupying that space, the brain assigns an internal coordinate, thus transposing the external space from the visual field to an internal representational system (Wilkinson & Jagaroo, 2004). The more predictable (organized) a visual field is, the more redundancy there is in the visual field. To the degree that an image contains redundancy, it can be represented in the brain with a more efficient code. Repetition in a visual field is encoded by a repetitive pattern rather than individually (Rosenholtz, Li, & Nakano, 2007). Not only does repetition within a visual field facilitate visual processing, but also repetition across visual fields. Repetition of identical visual fields leads to predictability which facilitates memory. It has been found that targets presented within identically arranged (repeated, predictable) displays were located faster and more accurately than targets in novel or random displays (Geyer, Zehetleitner, & Muller, 2010).

Secondly, set-size is an important factor to consider in visual search, as set-size accounts for a significant proportion of the variance in simple search experiments (Rosenholtz et al., 2007). Generally, reaction time to locate a target increases as set-size increases, or, the efficiency of processing of any one item decreases as the number of items in the display increases (Wolfe, et at., 2011). However, set-size interacts with target-distractor discriminability to determine search difficulty (Rosenholtz et al., 2007). For example, in visual fields where parallel processing occurs, *pop-out* is independent of set-size. In theoretical terms, the measure of visual information in a visual field is called *information density*. A measure of clutter (or information density) is less a measure of the number of items in a visual field, than a measure of the number of features (Rosenholtz et al., 2007). This implies that items with higher visual complexity contribute more to visual clutter than items with lower visual complexity. Knowledge of information density could facilitate decisions as to the optimal level of information to present in a display where a trade is made between giving the user more information to recognise symbols against making it more difficult for the user to quickly and efficiently extract the required information from the display (Rosenholtz et al., 2007). An excess of items and disorganized items can cause crowding (visual clutter) and with it a degradation of performance (Rosenholtz et al., 2007). Crowding may result in the tendency for the observer to select a flanker (a nearby distractor) rather than the target (Whitney & Levi, 2011), especially if the inter-element distance is small (Meyer, 2004). Objects that can be easily identified in isolation seem indistinct and jumbled in clutter because crowding negatively influences the visual discrimination of features and contours, and the ability to recognize and respond appropriately to objects (Whitney & Levi, 2011).

A third aspect of display design to consider is the visual organization of the symbols in the display. The effects of visual clutter or crowding can be reduced by colour-coding the items into groups, maximizing differences in shape, size and colour between targets and flankers and cueing target location (Rosenholtz et al., 2007). Visual cues are referred to as direct (pull or stimulus) cues and are usually associated with stimulus-driven control, or bottom-up processing (Wright & Ward, 1998). Direct cues take the form of visual features at or near the probable location of the target, such as boxes or other markers (Wright & Ward, 1998) and include coloured backgrounds. Colour is useful in cueing locations and segregating targets from distractors (Nagy & Thomas, 2003). Cues which themselves contain the target (such as the backgrounds of cell containing symbols) may be particularly efficient because they are directly associated with the features of the target (Nothdurft, 2002). Cues which direct attention to a specific area in the visual field also facilitate faster visual search (Nothdurft, 2002). Cues which are spatially distributed do not improve performance (Nothdurft, 2002). The function of cueing is that it serves to reduce the functional set size

(Wolfe et al., 2011), and therefore the search area. Search time in a cued search is related more to the size of the cued area than the display size (Rosenholtz et al., 2007).

Fourthly, the position of the symbols in the display may influence the rate at which they are located. Perceptual biases may reflect a hemifield dominance, with a bias to one half of the visual field. In most individuals there appears to be a generalized rightward bias, with a right visual field advantage in reaction time tasks where stimulus discrimination is required (Reuter-Lorenz & Moscovitch, 1990). Another perceptual bias may be a central-peripheral one with symbols centrally located being easier to locate than symbols which are positioned peripherally (Wilkinson & Jagaroo, 2004).

2.3.2.1.3 User factors

Not only do the perceptual features of the symbols and distractors, and the visual display in which the symbols are found, influence symbol salience, and therefore visual search efficiency, but also factors related to the observer, or user. The following user-related factors are discussed: (1) vigilance; (2) other neural factors; (3) personal symbol salience; and (4) gender.

Firstly, vigilance is the ability of an observer to maintain a high level of detection performance in visual search tasks over long periods (Uttal, 1998). The ability to perform in a repetitive visual search task generally declines as time goes by. Vigilance is therefore seen as closely related to fatigue, but represents fatigue at a neural level.

Secondly, the ability of the user to retain sensory information is influenced by other neural factors such as the sensory information store, the process of inhibition, peripheral processing and neural memory.

Visual processing of information begins when sensory information is encoded in the neurons that receive the incoming stimulus. In this sensory information store of activated neurons is an unprocessed, relatively complete version of the stimulus. The neurons remain activated for only the briefest period of time, in which a process of selective recoding of the information is done, so as to pass the information forward to the next stage of processing (Light & Lindsay, 1991). Differences in visual processing between people may be more related to sensory processing efficiencies than to cognitive processing capabilities (Carlin et al., 2002).

Once a search begins, bottom-up memory influences appear to be more related to the influence of inhibition of return strategies than to the direct influence of memory of location (Gilchrist & Harvey, 2000). Inhibition of return is a mechanism that prevents re-examination of a location already attended (Meyer, 2004) because observers are able to tag items in a visual field that have already been searched (Kristjansson, 2000). However, although memory of locations that have already been visited plays a part in determining the scan path of eye movements, it is only a small part (Gilchrist & Harvey, 2000).

There is an indication that during each fixation there is some peripheral processing of items adjacent to the current fixation, as well as saccadic guidance to items in the display that are similar to the target (Gilchrist & Harvey, 2000). Recent research has suggested that the visual system integrates and averages information over stimuli if those stimuli are presented close together. Memory of a target stimulus may be influenced by the presence of another non-target, task-irrelevant stimulus and the effect depends on the perceptual similarity of target and non-target stimuli to one another (Huang & Sekuler, 2010).

The role of memory at a neural level has been a controversial one in visual search research. Some researchers have suggested that visual search has no memory (Horowitz & Wolfe, 1998) or that visual search requires minimal or no working memory resources (Woodman, Vogel, & Luck, 2001). However, there is strong evidence regarding the role of memory for locations in a visual search task (Kristjansson, 2000). It has been shown that performing a working memory task influences the efficiency of visual search (Han & Kim, 2004). Wolfe (2002), despite his argument that visual search has no memory, acknowledged that some research results indicate learning of *something*, but this *something* has so far remained unidentified. Can observers learn to become more efficient at the same visual task within a session or over time? In these cases, is the observer building a new parallel process or is he isolating an attention guiding signal from amongst all the existing pre-attentive processes, or are serial mechanisms beginning to imitate parallel behaviour due to increased experience (Uttal, 1998)? It has been found that targets presented within identical repeated displays are located faster and more accurately than targets in novel or random displays (Geyer et al., 2010).

Thirdly, personal symbol salience can also influence the mental representation of symbols and shift the attention focus in a visual display. Personal symbol salience is dependent on the individual who is viewing the display; it is influenced by personal characteristics such as interests (Wilkinson & Jagaroo, 2004) and experiences. Some symbols may be more evocative of an emotional response than others may. However, individual differences in the visual salience of symbols should remain constant within viewers in any given study (Wilkinson & Jagaroo, 2004).

Fourthly, it appears that females may have an advantage in visual search location rates, since research studies have shown that females generally have faster processing speeds than males (Roivainen, 2011). This difference has been noted in research across the lifespan and in many of the specific cognitive and motor subtests of intelligence tests. However, no significant differences have been found in general intelligence (Camarata & Woodcock, 2006). A consistent female advantage has been found on processing speed subtests in general intellectual ability tests. Males perform worse than females when there is pressure to maintain attention and concentration. However, processing speed is only one measure of the different speed abilities in intelligence tests, some of which are faster in females and some in males. Females have been found to have greater rapid naming speeds, phonological coding tasks, matching tasks, reading and writing fluency. Males are faster in reaction time tests, some verbal skills, mental rotation tasks and academic knowledge (Roivainen, 2011). The cognitive factors which underlie gender differences in processing speeds are largely unknown (Roivainen, 2011). Discussions as to the reasons for slower processing speeds in males often involve the nature-nurture debate (Roivainen, 2011).

2.3.2.2 Top-down factors

Symbol salience is not a purely bottom-up process (Yantis, 1998). Top-down processes also impact on a symbol's salience in a visual display by interpreting bottom-up information and guiding attention through the visual field. It appears that it is cognitive factors which predominantly guide attention, not the influence of low-level features (Betz et al., 2010; Itti, 2005). When top-down and bottom-up guidance are placed in competition, top-down guidance prevails (Chen & Zelinsky, 2006). However, it would seem that when search tasks are demanding, top-down context cueing guidance predominates, but when tasks are more efficient, bottom-up guidance can capture attention more readily (Geyer et al., 2010).

The items used in experimental visual search are usually non-symbolic and they are perceived and interacted with almost exclusively as visual representations. However, in AAC use the graphic images are not only perceived visually, but symbolically too. The symbolic, or semantic, content of the symbols contribute in profound ways to the visual search task and includes picture recognition as well as the meaning and naming associated with the pictures.

The top-down factors influencing visual search reviewed are: (1) the semantic properties of the symbols; (2) working memory demands; (3) task demands; and (4) user factors.

2.3.2.2.1 Symbol semantic factors

After a picture has been translated into a visual sensory code in the form of a neural activation map, it has to be processed for recognition and use. During the processing, the visual code soon becomes imbued with semantic associations and information. This information is important to understand in a visual search task, as in its coded form, a mental representation may lead to an observer making error selections.

In language, it appears that there are stored, or pre-existing, mental representations that underlie our ability to perceive and recognize visual input (Brady et al., 2011). Picture recognition requires accessing these stored mental representations, which are built up through world knowledge and experience. Once a picture has been recognized (perceived), the visual sensory code has become more than a neural activation map of feature stimuli. It is now linked with the stored mental representation that led to its recognition.

Also linked to the visual sensory code are the semantic codes of the mental name that was assigned to the picture on recognition as well as category information. As Schlosser (1997b) pointed out, whenever something is named, it is also categorized. This categorization is a language-based categorization reflecting meaning (Stephenson, 2009a), not specific taxonomic information. Meaning is particularly associated with the pictures used in AAC, since they have specific linguistic associations and are called symbols in AAC terminology because they symbolize something else.

It is thought that both sensory (visual) and semantic codes are used to store mental representations of objects and pictures (Snodgrass & Vanderwart, 1980; Uttal, 1998). Of interest is the relative weighting of the visual and semantic codes of the mental image of the target symbol that is held in working memory during a visual search. It may be that the more heavily loaded the semantic component of the task requirement is, the more the mental image will be coded semantically. In visual search with meaningless symbols the mental image is probably mostly in a visual code format. In AAC, with its meaningful and named symbols, there is probably a significant semantic component to the mental code (if the symbols do in fact have meaning to the user, which sometimes is not the case).

Picture naming inefficiencies in young children are linked to developing category knowledge, since picture naming errors are often related to category issues (Cycowicz, Friedman, & Rothstein, 1997). Research using pictures needs to take into account the familiarity of the pictures being used because familiarity significantly influences a number of cognitive processing tasks (Alario & Ferrand, 1999). Children's abilities to draw category-based inferences have been correlated with the absence or presence of receptive understanding of the referent (Schlosser, 1997b).

Visual search target selection errors may result from inaccuracies in the visual sensory code at the beginning stages of perception (such as too short a time of exposure to the target or only partial attention applied to target), in the visual code formed after recognition (such as undeveloped picture recognition) or in the semantic code associated with it after naming and categorisation (such as weak world knowledge or category concepts).

2.3.2.2.2 Working memory

The demands on working memory (or short-term memory) are considered integral to understanding the impact of cognitively demanding search strategies on visual search efficiencies. Memory demands in most simple visual search experiments are minimal (Horowitz & Wolfe, 1998). However, in more complex search tasks memory can place significant demands on working memory.

Working memory temporarily holds information received from the sensory information store while it is processed to find a solution to a given task, or used for memory retrieval, or encoded into a more durable form for long-term storage or discarded (Light & Lindsay, 1991). Working memory may be closely linked to processing speed (also called cognitive speed or mental speed). Cognitive speed not only impacts on the duration of processing, but also on the quality of processing. In complex tasks, information is required at each stage of processing but may only be available for a limited time (Roivainen, 2011), because working memory is limited in size and duration (Light & Lindsay, 1991).

With respect to size, there is a limit to the total amount of information that can be stored at any one time and working memory is shared among all the items vying for attention (Brady et al., 2011). A fixed amount of resource can be flexibly allocated to represent either a small number of objects with high precision or a large number of objects with lower precision (Huang, 2011). Visual working memory is impacted by the feature-load of objects (visual complexity) with loss of precision of representations where multiple features have to be maintained during processing.

With respect to duration, information is known to dissipate rather quickly from working memory without constant rehearsal (Light & Lindsay, 1991) or active maintenance (Brady et al., 2011). In visual search it is a known occurrence to forget the target symbol before the search is completed.

Attention is highly flexible (Tipper & Weaver, 1998) and selective in its operation. Instead of simultaneous processing of all the information in a visual field, attention selects which aspects of the visual field will be processed, as our visual systems have a limited capacity and cannot process all aspects at once (Benjamins, Hooge, van Elst, Wertheim, & Verstraten, 2009). Working memory allows for the processing of active mental representations (that which is being directly attended to at that moment) as well as for information that is temporarily peripheral to the current processing (but which is being held in working memory for later use) (Olivers et al., 2011). The processing that is required in a visual search task necessitates this multiple processing because the mental representation of the target symbol has to be held in some kind of storage system while the available targets are processed to find a match.

In visual search, top-down attention is divided between tasks such as the mental representation of the target, the mental representations of all the symbols in the visual display as they are attended to and processed, inhibition to return to already processed areas, decision processes of what to do when the target cannot be found, the application of task requirements and cued information; and in studies with meaningful symbols the accessing of stored knowledge. Figure 2 diagrammatically presents the multiplicity of active attention switches required in visual search. Attention devoted to this top-down processing is in addition to the attention which is being allocated to the bottom-up processing of the perceptual features of the symbols.

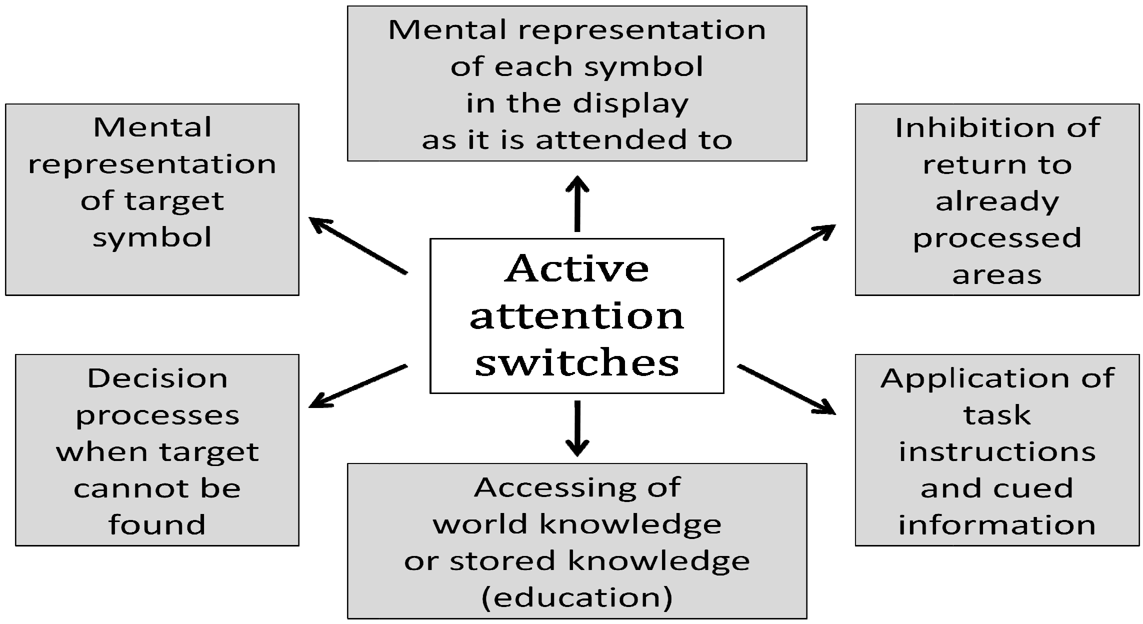


Figure 2. Active attention switches

In addition to the ability to focus attention on task-relevant features in a visual field, the ability to simultaneously limit attention to irrelevant elements is also required (Carlin et al., 2002). Younger children show little ability to display selective attention. They are not able to adjust their focus of attention till the age of 6-7 years (Ford, 2003). Older children are much better than younger ones at concentrating on relevant information and filtering out extraneous input that may interfere with task performance (Shaffer, 2002). The ability to focus and maintain attention is therefore a developmental process and may impact on the results in important ways.

Working memory processing can improve with instruction and experience, the ultimate outcome of which can be automaticity, "the great conserver of cognitive resources and working memory space" (Light & Lindsay, 1991, p. 190).

2.3.2.2.3 Task demands

The visual search task requirements include the search strategy and any cueing which supports it. The search task impacts on the relative weight of bottom-up and top-down influences (Meyer, 2004) and therefore a symbol's salience within that task. That is, a task requiring top-down cognitive controls can bias attention deployment variably between the target symbol and the distractors. Symbols are more likely to attract attention if they have the task-relevant features of an expected target and attention can be volitionally allocated to specific locations in the visual field that have a high probability of yielding important information (Pratt & Hommel, 2003).

The task demands of taxonomic categorization and alphabetical order both require further mental coding of the symbol to occur than that which occurs after picture recognition, picture naming and the association of picture meaning. The task requirement necessitates the addition of taxonomic or linguistic information to the mental representation of the target symbol. If the mental representations of the symbols have the taxonomic or linguistic information coded onto them, the symbols will be more salient during a visual search.

Symbolic cues (also called push or information cues) direct attention to probable locations of the target (Wright & Ward, 1998) through top-down guidance (application of the search task). Cueing reduces the functional set size (Wolfe et al., 2011), and therefore the search area. However, the cost of invalid cueing is a reduction in speed and accuracy (Wright & Ward, 1998), should the observer search in the wrong area of the display or among the wrong symbols.

2.3.2.2.4 User factors

Factors related to the user which can influence visual search efficiencies are world knowledge, education, instruction and experience (practice).

World knowledge influences visual search from the earliest stages of the search. Picture recognition is related to world knowledge and experience, as is the naming and categorization that occurs on picture recognition (Schlosser, 1997b).

Knowledge is power – the more one knows about a topic, the more one can learn and remember (Shaffer, 2002). Prior knowledge can assist in the interpretation of new information and facilitate the integration of this new information into existing knowledge structures (Light & Lindsay, 1991). Learning and retaining information about an unfamiliar topic is much more effortful where prior knowledge is limited because there is no existing conceptual peg to hang the information on. The capacity of visual memory, both long-term and working memory, is dependent upon stored knowledge (Brady et al., 2011).

Search tasks can sometimes involve formal education such as literacy or category knowledge. Performance in a visual search task is clearly dependent both on the level of knowledge required to perform the search task and the level of knowledge already attained.

Instruction is an important factor in the acquisition of a skill in cognitively demanding tasks. Visual search performance in a task can improve with practice - there is strong evidence regarding the role of memory for locations in a visual search task (Kristjansson, 2000). Perception of visual stimuli improves with experience (Baeck & Op de Beeck, 2010) and experience and practice guide attention to locations of high probability (Pratt & Hommel, 2003).

2.3.3 Visual search research and its application to AAC

Although there are many similarities between AAC and experimental visual search research, there are important differences too, the most significant of which are: (1) the dual coding of symbols in AAC; (2) the use of meaningful symbols in AAC; and (3) the use of typical participants.

Firstly, visual search in AAC is clearly a visual task. Accessing vocabulary requires perception (seeing that a symbol is present in the display), identification (knowing what that symbol represents) and discrimination (distinguishing between symbols) (Wilkinson & Jagaroo, 2004). Not only are symbols represented visually, they are also accessed visually. However, visual search in AAC use is also a language task. Accessing vocabulary is for the purpose of message production. Symbols are searched for and located on the basis of the meaning they hold and the part they play in message formulation. AAC introduces a visual component to language processing and a semantic component to visual processing.

For people who use speech, vocabulary is internally organized and internally stored. For AAC users, vocabulary is graphically represented, visually organized by other people (mostly) and stored on a two dimensional external system (Wilkinson & Jagaroo, 2004). This holds true whether symbols are in the form of traditional orthography or in the form of picture symbols. The processing between linguistic symbols and visual-graphic symbols is a complex issue, one that is not yet fully understood, but both systems clearly need to be taken into account in language processing when a visual mode is used (Wilkinson & Jagaroo, 2004).

Secondly, a significant difference between the items used in laboratory settings and the symbols used in AAC is their meaningfulness. Experimental items (generally) are intentionally non-referential, having no symbolic component to them and are designed to minimize all higher cognitive function. AAC symbols, however, are explicitly intended to convey meaning (Wilkinson et al., 2006). It is not only the iconicity or lack of iconicity of the symbols that is the issue in the difference between experimental and functional use of these visual stimuli, but the semantic component associated with it (Wilkinson et al., 2006).

Of importance is the question of whether there are differences in the visual processing of non-referential items and meaningful symbols or not. A study on typical adults, in which reaction times to locating referential as compared to non-meaningful symbols was investigated, and it was found that visual search factors were similar, but enhanced, across both symbol types (Remington & Williams, 1986, cited in Wilkinson et al., 2006). In addition, Wilkinson et al. (2006) compared children's reaction times in a visual search task between meaningful, iconic symbols (PCS) and non-referential symbols and found that both accuracy and response times were virtually identical. The stimulus-driven visual processes that have been shown to affect visual search efficiency in non-referential stimuli in experimental laboratories appeared to generalize to the commonly-used, meaningful symbols of AAC practice (Wilkinson et al., 2006). These findings justify the application of factors influencing visual search in experimental conditions to those in more realistic AAC settings.

Thirdly, participants in research on visual search are usually people with no clinical disabilities. The use of typical participants is acknowledged as a limitation to the applicability of the findings to the AAC population. Very little is known about the effects of neuropathology on visual cognition, and many AAC users, by definition, have some neuropathology causing an inability to rely on speech as their primary mode of communication (Wilkinson et al., 2006). To what degree can the principles of visual cognitive science be applied to these users without compromising external validity (Bedrosian, 1995)? Even if a study has high internal validity, it does not necessarily follow that it can be generalised outside the study context (Onwuegbuzie, 2000). The argument that findings from a typical population cannot be generalized to the heterogeneous AAC population (Bedrosian, 1995) has some validity in general (Alant et al., 2006) and specifically where the research is on principles of visual cognition within language-based constraints.

Even within typically developing children conclusions cannot be drawn about an individual, based on larger group characteristics (Wilkinson & Rosenquist, 2006). Inferences from the group are even more limited where children differ significantly from the larger group (Wilkinson & Rosenquist, 2006). There are also significant difficulties with applying research on semantic organization from people without communication difficulties to people with communication disabilities, because it cannot be assumed that people with communication difficulties have comparable semantic organization to those who do not (Wilkinson & Rosenquist, 2006). The linguistic association in a symbol is debatable with respect to some AAC users who may have developed concepts without linguistic associations. It may even be that differences in the performance on cognitive processing tasks of people with cognitive challenges lie more in differences in the sensory information they receive than in cognitive mediation differences (Carlin et al., 2002).

However, using participants without disabilities is not uncommon in AAC research (Bedrosian, 1995) and is generally accepted as a means to evaluate processes in children who do not have potentially interfering sensorineural, cognitive, social, motor, or emotional issues, prior to studying individuals who use AAC (Wilkinson, Carlin, & Jagaroo, 2006). As Higginbotham (1995, p. 4) stated, “there are many situations in which nondisabled individuals can serve as viable and, sometimes, preferential subjects for research. Ultimately, the decision should be based on what subject characteristics best address the research problem at hand”. Sometimes a sound understanding of the topic is required before it can be tested and analysed within an atypical population (Alant et al., 2006).

2.4 Developmental issues in children in Grade 1 to 3

The children represented by the age-group Grade 1 to 3 are in transition, both with respect to their taxonomic development and alphabetical order learning. A discussion on the development of categorization and alphabetic skills in children will follow.

2.4.1 Categorisation development

Categorisation is defined as the treatment of a group of entities as equivalent, while categories are distinct classes to which entities or concepts belong (Jaimes & Chang, 2000). A more active definition of categorisation is the ability to assign items to categories for the purpose of accessing knowledge (Schlosser, 1997b). Taxonomic organization is a hierarchical system of categories (Fallon et al., 2003). There are three taxonomic category levels: basic, superordinate and subordinate (Deneault & Ricard, 2005; Schlosser, 1997a). In categorization of symbols, prototypicality is a measure of how good a representation of an exemplar the picture of the concept is (Snodgrass & Vanderwart, 1980). A new image is classified according to similarity to the category's prototype (Jaimes & Chang, 2000). The use of strong prototypes is required in a study involving taxonomic categorization.

Researchers agree that categorization in language is dependent on cognitive development, but disagree on the nature of that development.

With respect to age, many researchers have referred to the developmental milestone that occurs in categorization around 6-7 years of age (Krackow & Gordon, 1998; Wilkinson & Rosenquist, 2006). Younger children (4-5 year olds) tend to use primarily narrow, slot-filler classes (event based) or schematic organization systems for organizing their information (Fallon et al., 2003; Lucariello, Kyratzis, & Nelson, 1992). Young children move towards categorical/taxonomic structures during their early school years at the age of 6 or 7 (Fallon et al., 2003). Children over the age of 7 understand taxonomical relations (Lucariello et al., 1992) and can sort pictures into categories, but children younger than 7, who are able to sort objects into categories and label those objects, find it difficult to sort pictures by categories (Stephenson & Linfoot, 1996). Adults and children over the age of 7 years use a taxonomic system for organizing items in their lexicons (Wilkinson & Rosenquist, 2006).

However, some researchers have questioned the principle that categorisation development matures from a thematic form to a taxonomic from. Most research in categorisation behaviour among young children is based on a matching-to-sample methodology, but powerful independent variables appear to override the apparent developmental preference of thematic categorisation (Osborne & Calhoun, 1998). Blaye and Bonthoux (2001) propose that the bias towards thematic organization of semantic knowledge may not be as strong as previously suggested, and that both thematic and taxonomic relations are available at an early age, even as young as one or two years old. Piaget argued that young children were not able to categorise at different levels but later research indicated that pre-school children were able to show understanding of superordinate category principles (Callanan, 1985). Typically developing young children may have access to both thematic and taxonomic organization patterns, although they may tend to use a preferred slot-filler method of taxonomic knowledge (Lucariello et al., 1992). Others suggest that the use of slot-filler or taxonomic methods may depend on factors such as context, personal preference and task design (Krackow & Gordon, 1998; Wilkinson & Rosenquist, 2006). Independent methodological variables such as modelling, reward and instructions (Osborne & Calhoun, 1998), may also have an influence on which organizational pattern is favoured. Consistent use of instructions across all participants is cautioned in any categorisation task.

Irrespective of what age taxonomic categorization skill is available from, it seems clear that it is a developmental skill that matures over many years. Taxonomic categorisation continues to develop through young childhood and into many years of school (Scott & Greenfield, 1985). From 5-10 years there is an increase in both the efficiency with which children encode new information and the sensitivity to feature matches within categories (Hayes & Younger, 2004). An updating of category membership through the inclusion of new exemplars develops from early childhood. Category properties are dynamic and evolve over time (Hayes & Younger, 2004).

It has been shown that the development of concept organization (or taxonomic organization) in typically developing children is related to the level of adult language input, the child's overall language mastery and formal school instruction (Fallon et al., 2003). For children to learn the compositional structure of categories, they have to be exposed to the categorization and organisation of linguistic concepts by adult models. It has been noted, however, that it is seldom from parents that children receive explicit instruction in category discrimination (Hayes & Younger, 2004). Learning to operate within a given categorization structure is an important functional skill. Conventional or common organizational structures form the foundation of much of our language structures and educational systems (Wilkinson & Rosenquist, 2006), and AAC systems specifically.

It appears that interaction with (or being required to make inferences about) new category properties lead to a ready absorption of those properties into existing category knowledge which can then be applied in category-based judgments or in classification tasks (Ross, Gelman, & Rosengren, 2005). This is known as the category-use effect (Hayes & Younger, 2004). Children as young as 5 years demonstrate the same category-use effects as adults, despite having a less mature categorisation development. Category-use effects may play an important role in how children learn and use categories from early stages in their categorical development.

Flexibility in categorization involves the ability to switch between categorizing the same objects thematically or taxonomically, depending on the demands of the situation (Blaye & Bonthoux, 2001). Blaye and Bonthoux (2001) conducted a within-participant or intra-individual study to investigate the development of flexibility of initial categorization decisions to adjust to contextual information and to consider the same object from different points of view and suggested a significant improvement in flexibility between 6 and 7 years.

There is a wide range of variability and inconsistency in the specific organizations of children. Fallon et al. (2003) noted this inconsistency in their study, where much variety was found in the schema described by 4-5 year old children as well as very little stability across sessions. Children performed differently from each other and from themselves in subsequent sessions. Blaye and Bonthoux (2001) proposed that a consistency of response co-occurs with the beginning of the adaptive flexibility mentioned above.

Tasks requiring complex categorization knowledge can present children with considerable difficulty (Callanan, 1985). When children are required to use categories they do not understand well, they may experience confusion, frustration and failure because the task requires too much effort (Oxley & Norris, 2000). The effectiveness of a system depends on how well children understand it, how stable it is and how logical it is (Oxley & Norris, 2000). However, when the logic is of a categorisation is explained to young school children, there is a reasonable expectation that the children will be able to understand and use that semantic organization, even if it was not immediately transparent to them.

2.4.2 Alphabetical order development

Being able to order items alphabetically is an essential skill for functional literacy. Alphabetic skills are used in information gathering activities such as the use of dictionaries and telephone directories, indexes and glossaries, internet searching and a host of other activities (Rule, 2001). Mastering the principle of alphabetical order is a skill that is learned through education and although cognitively taxing at first, it is a well-established skill in most adults, requiring minimal cognitive demands (Oxley & Norris, 2000).

The ability to navigate through an AAC system alphabetically is a useful skill for an AAC user to acquire. Alphabetically ordered systems have a stability and predictability that is not possible in taxonomically designed systems. In a taxonomical AAC system each category will have its own unique subcategories, the principles of which will have to be learned for each category. Taxonomic categories are based on nouns (Hochstein et al., 2004), with the result that it is challenging to categorise verbs, adjectives, high frequency words, phrases etc. into taxonomic groups. However, the same alphabetic principle will hold throughout an AAC system.

To find words which are alphabetically ordered, various skills are required. Firstly, there must be knowledge of the individual letters of the alphabet with their associated letter forms (graphemes), letter sounds (phonemes) and letter names. Secondly, knowledge of the sequence of the 26 alphabet letters is required. A third requirement is the ability to break down words into their constituent parts (phonemic units or spelling units). Fourthly, a functioning articulatory loop is required to rehearse the spelling sequence in parallel with accessing the word (Beech, 2004) because the target word is approached letter by letter.

There is a paucity of research literature on the use of alphabetic ordering in visual search tasks. Little is known about how the developing reader uses a dictionary or whether young readers have the necessary componential cognitive skills to use dictionaries (Beech, 2004). However, alphabetic learning is directly related to schooling. Although many children are first introduced to the alphabet and instructed in phonic awareness in pre-school, formal phonic instruction only begins in Grade 1. The Foundation Phase of school comprises the first three years of school, by which time children should have acquired the basics of literacy (Revised National Curriculum Statement. Grade R-3 (Schools). Foundation Phase. C2005., 2002). By the middle of Grade 1 children should have a fair grasp of letter sounds and be able to identify the component phonemes of words and most of their matching graphemes. It is in the second grade that children first get introduced into ordering items alphabetically, but only considering the first letter in the word. In the third grade, more complex ordering is introduced (Revised National Curriculum Statement. 2002).

The speed of recognition of words is developmental. Children in lower grades have a smaller repertoire of words in their sight word bank. They have to rely more on decoding word strategies to read words than children in higher grades. The bank of sight words is constantly growing as words from the decoding bank are transferred into the sight word bank.

This shift is associated with increasing reading proficiency within the first three grades (Sturm et al., 2006). The awareness of onsets (all letters before the first vowel in a word) is another decoding strategy useful to reading (Sturm et al., 2006) in general and to alphabetizing words in particular.

2.5 Concluding remarks

The literature review has indicated that there are many factors influencing symbol location (visual search), including perceptual, display design, semantic and developmental factors. Combining the knowledge gained from AAC practice and visual search research (from both within AAC and the cognitive science discipline), a research study was designed.

It is important to note that this study is positioned as a translational study between applied AAC research and visual cognitive science research (Jagaroo & Wilkinson, 2008). AAC is a field which has its roots in clinical and educational practice, in contrast to the field of cognitive science which has a theory development focus (Light & Lindsay, 1991). It is considered that the principles identified in laboratory research may have direct relevance to AAC because both experimental studies and AAC (in visual symbol-based systems) involve a direct visual input-output channel (Jagaroo & Wilkinson, 2008).

This study draws on information provided by both of the theoretical frameworks in visual cognitive science – cognitive neuroscience and cognitive psychology. Cognitive neuroscience seeks to understand cognition and behaviour in relation to underlying neural systems (Wilkinson & Jagaroo, 2004). Cognitive psychology, on the other hand, addresses issues such as memory, attention, learning and information processing (Light & Lindsay, 1991). Both bottom-up neural factors as well as top-down cognitive influences will be considered in the design of this research study and the analysis of the research data.

It is recognized that there are significant challenges to be faced when attempting to relate and apply the findings of the basic science of visual cognition to the applied discipline of AAC (Wilkinson & Jagaroo, 2004). Visual search research designs are extremely structured and controlled, using unnatural symbols and visual fields. However, the research already conducted in AAC where principles from cognitive science have been investigated, has indicated that there is much that AAC can benefit from this science.

2.6. Summary

Three major aspects were discussed in this chapter: the factors relevant to AAC display design in terms of symbol location rate enhancement, visual search theory and the development of Grade 1 to 3 children with respect to their development in taxonomic categorization and alphabetical order skills. This chapter also highlighted the importance of working memory demands in visual cognitive tasks. Finally, visual search research was applied to AAC usage, acknowledging the significant challenges faced when attempting to relate the basic science of visual cognition to the applied discipline of AAC.

Chapter 3

Research Methodology

3.1 Introduction

In this chapter, the methodology of the research project is explained. The study required a pre-experimental phase (Phase 1) for the development of the material, a pilot study to test the suitability of the material and procedures on the targeted participants and to inform adjustments to the material (Phase 2), and an experimental phase (Phase 3). Figure 3 presents these three phases of the study in the form of a flow chart diagram.

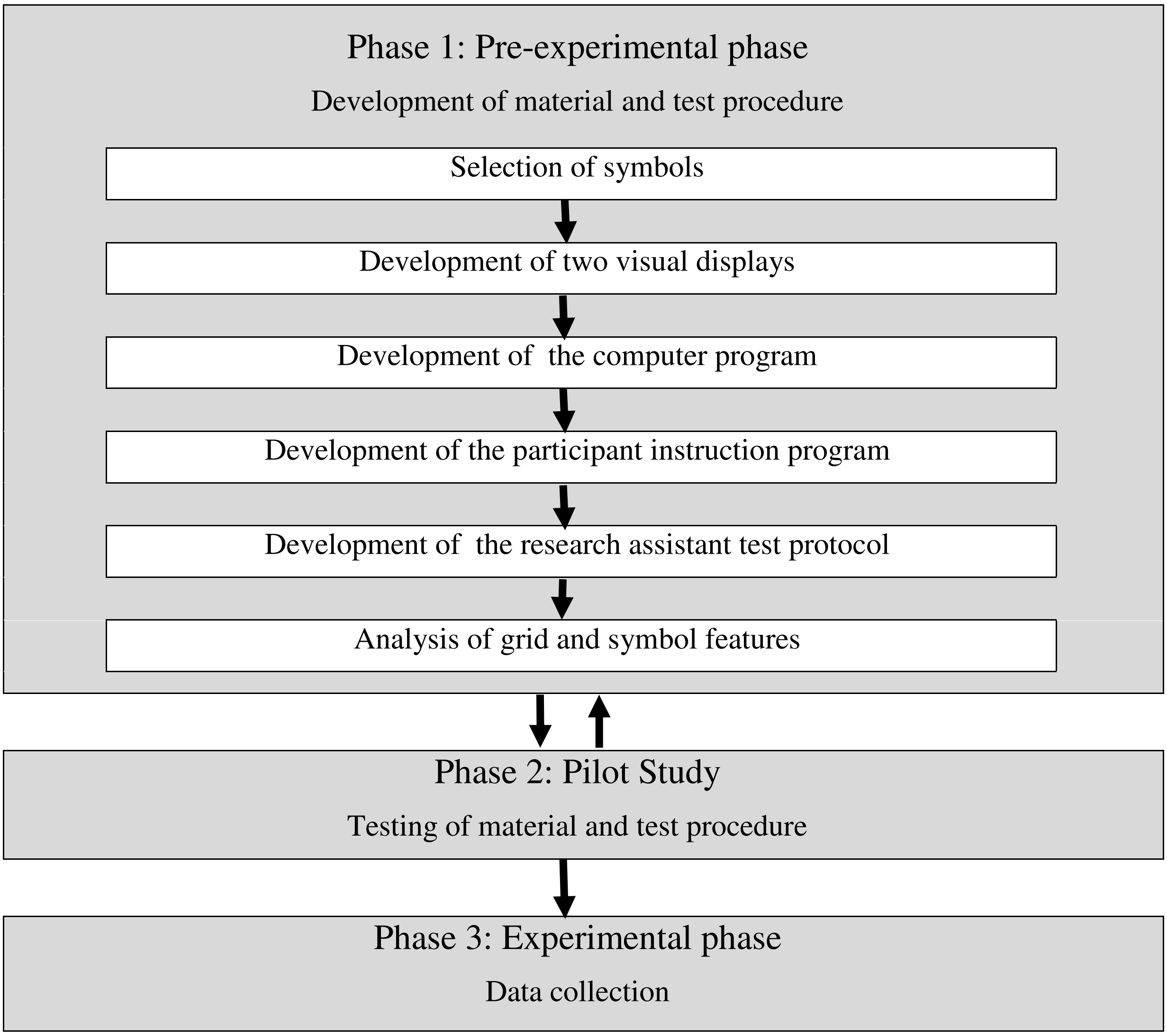


Figure 3. The phases of the study

3.2 Research question

Research question 1

Is there a significant difference between the performance of the participants with respect to rate (time) and accuracy (score), in locating symbols in a large colour-coded visual display using either an alphabetical or a categorisation arrangement?

Subquestion: Are there significant differences between the performance of the participants with respect to grade and gender, in their use of colour-coded alphabetical and categorisation arrangements to locate symbols in a large visual display?

Research question 2

Did the bottom-up factors of vigilance, position in display, size, colour and visual complexity impact on the results?

3.3 Research design

The study used a cross-over group design (DePoy & Gitlin, 1994) in which both groups were exposed to the same tasks in alternating order to control for order effect. A stratified sample was used to ensure both groups were the same with regard to grade level and gender.

3.4 Phase 1: Pre-experimental phase

The pre-experimental phase was for the development of the material for the study. The steps of the pre-experimental phase identified in Figure 3 will be expanded on briefly:

Phase 1 included: (1) selection of symbols to include in the study; (2) development of the alphabetically ordered and categorically ordered displays; (3) development of the computer program that presents the tests and the data management system to record the testing procedures; (4) development of the instruction necessary for participants to complete the tasks; (5) development of the research assistant instruction protocol; and (6) and analysis of the grid and symbol features.

3.4.1 Selection of graphic symbols

The important issues to consider in the selection of the graphic symbols were that the symbols had to be familiar to all the participants – (easy to recognize (iconic) and given the same name when labelled), available in a large set, suitable for subcategorisation into a number of groups, coloured and of high interest to the participants.

Coloured PCS symbols (Mayer-Johnson, 1992) were chosen as the symbol set to represent the animals in the study because of their availability, the extensiveness of the PCS set relative to other picture sets and because of their widespread use in the AAC field (Thistle & Wilkinson, 2009).

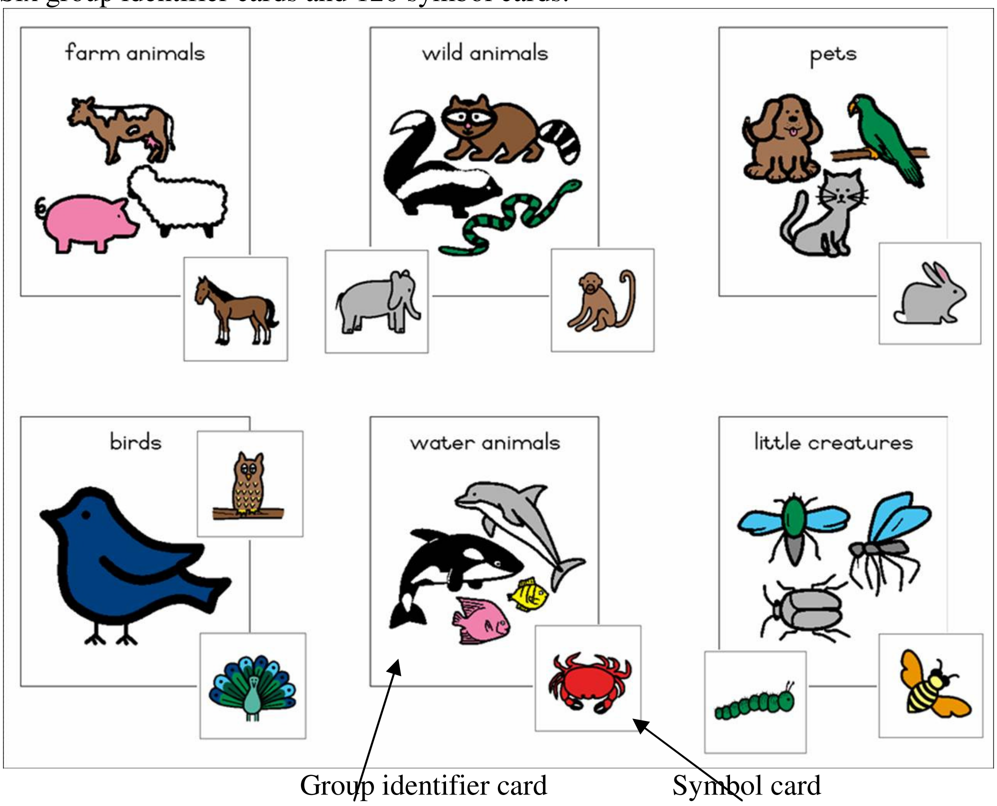
The superordinate category of Animals, with the subcategories wild animals, water animals, farm animals, birds, pets and little creatures was chosen.

The full range of 194 animal symbols available in a basic PCS set was analysed with the purpose of reducing the list to a more manageable size of 120 animal symbols which would most likely represent familiar animals to participants in Grades 1 to 3 in the South African context. Appendix A provides a record of all the animal symbols that were originally available for selection, the animal symbols which were discarded in this initial reduction process and the reasons for their removal.

The potential list of 120 symbols was refined to 81 symbols through testing 12 participants to identify the most familiar and consistently named animals symbols and the animal symbols most consistently assigned to the six pre-determined subcategories. The purpose was to find the most suitable symbols for the development of the two visual displays required for the two tests. Table 2 describes the process of selecting the symbols and describes the procedures followed in refining the potential list of 120 animal symbols to 81 animal symbols.

Table 2

Refining the Symbol List

Elements of the refining process	Brief description of the procedures
Participants	Twelve typically developing Grade 0 to Grade 3 learners, drawn from personal contacts, a local school after care facility and a local nursery school participated in this step. Verbal permission was obtained from the relevant parents, supervisor and headmistress.
Material	Six group identifier cards and 120 symbol cards. 
Method	The six group identifier symbols were laid out in front of the child as shown above and were defined by the researcher by their most identifying criteria. The small symbol cards were handed to the child one by one, who had to name the animal symbol and then place the symbol card on the group identifier card where he thought the symbol card belonged. As PCS did not have a group identifier symbol for birds, the single symbol for bird was used. The name or names given by the child (exactly as the child said it) and the category the child assigned the animal symbol to, was recorded. Appendix B provides the scoring sheet that was used.
Results	Scores for naming the animal symbols the same name correctly covered a wide range of 42–93 correct names out of 120 symbols (Appendix C). It is important to note that the scores were subject to strict scoring criteria. If the child said *little bird* rather than *bird*, the response was marked as incorrect. If the child provided two names, even if the one was correct, the response was marked as incorrect. Category placement was shown to be much more constant across the participants than labelling. Scores for assigning the animals to the same categories as the researcher assigned them ranged from 93-109 correct scores out of 120 symbols (Appendix C).

Elements of the refining process	Brief description of the procedures
	It was considered that some of the categorization of symbols into different categories than expected could be averted by changes to details within the graphics, since the original PCS group identifier symbols were not adequately suitable for defining the subcategories used in the study. It was important to the study that strong category concepts be established in the learners and that the group identifier symbols fulfil the criteria of representativeness (being prototypical) of the animal category group and familiarity to South African children. The written word labels for the animals represented on the test symbols did not appear above the animal symbols during the above screening procedure. The researcher considered that this omission may have influenced the labelling discrepancies among the learners and that labelling issues could be reduced by having the gloss present.
Decisions for implementation in pilot study	Ninety two symbols were chosen that fulfilled both the requirements of eliciting the same basic, simple name across the full range of the learners, as well as being the most frequently assigned to the same subcategories. Eighty one were then selected from this group to be included in the visual displays, fulfilling additional requirements of a balanced distribution of symbols across the six categories and letters of the alphabet. When explaining the categories to the participants during instruction, the definition of the categories would need to be thorough. A computer graphic artist adjusted some of the group identifier symbols. Appendix D indicates what the original PCS category symbols looked like, what difficulties they presented with and how they were reworked to be more suitable. Changes were also made to three of the original PCS animal graphics for the pilot study, either to add or remove detail that would facilitate the desired category placement or would prevent an incorrect category placement (Appendix E). It was decided that in the tests in the pilot study the written word label (gloss) would appear above the animal symbol. A table displaying the 81 animal symbols selected and the reasons for their inclusion or rejection on the basis of naming inconsistencies is presented in Appendix A.

3.4.2 Development of the visual displays

After the selection of the 81 animal symbols two visual displays were developed. The first was an Alphabetical Order (ALP) visual display (Figure 4) and the other a Subcategory (SUB) visual display (Figure 5).

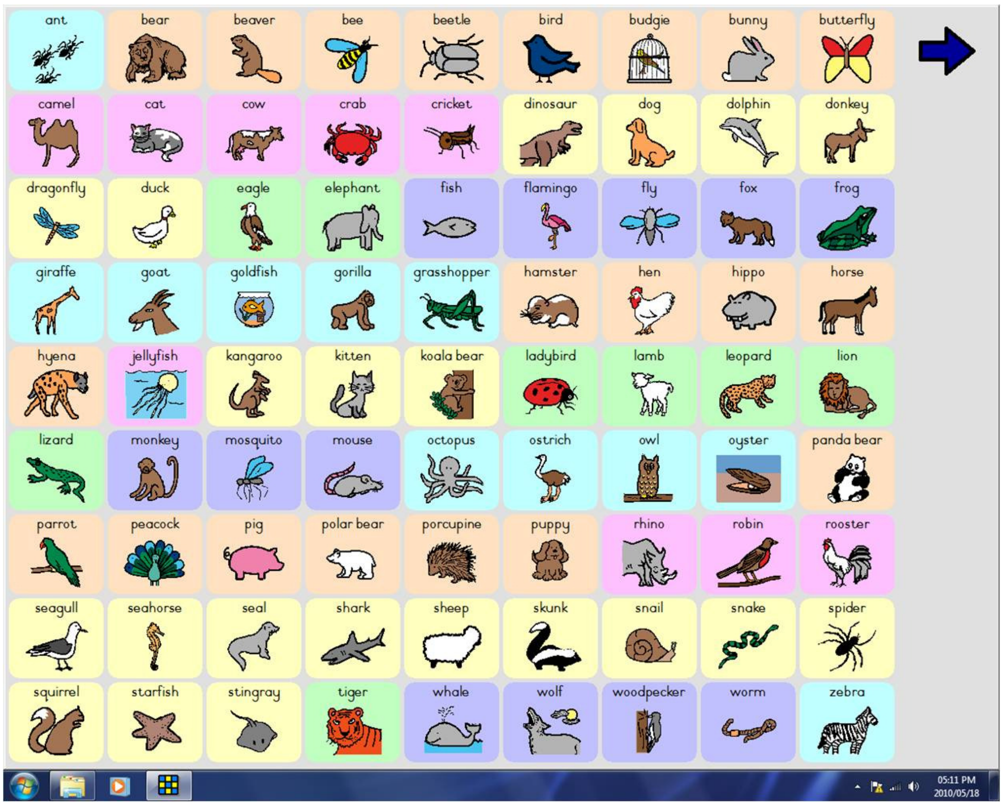


Figure 4. Screen view of ALP visual display

Figure 5. Screen view of SUB visual display

The symbols in the ALP visual display were arranged in alphabetical order, starting from the upper left corner of the top row through to the bottom right corner of the bottom row. The symbols in the SUB visual display were placed in their category groupings. Symbols were chosen and shuffled so that in each display each third of the display (left-centre-right, top-middle-bottom) had as equal a number of test symbols as possible. The final number of symbols in each third of the display varied from 10 to 14. This is important for later statistical analysis of the influence of the position of the symbols in the display. Appendix F presents the layouts of the symbols across the two visual displays.

Six colours were chosen for the SUB display that represented colours that were distinct from each other, but were not bright or dominating, so as not to distract visually from the symbols. The same six colours were used in the ALP display.

It is important to note that the colours in the visual displays appear a little stronger in the printed form of the visual displays than they appeared on the computer screens. The function of the background colours was to serve as area markers only – muted colours were sufficient for this demarcation. It was considered important to avoid the possibility that stronger colours may distract in the visual perception of the symbols themselves.

3.4.3 Development of the computer program

An independently operated program was created for the research study using The Grid™ software (The Grid, 2002). The purpose of this program was to present the pre-tests and tests, and to manage the data collection.

The tests required the presentation of 36 test items within a set of 72 linked grids that could be operated independently by the participants. Each test item was presented as a single symbol cell with a white background in the centre of a grey display and was followed by either the alphabetical order visual display or the subcategorisation display. Appendix G provides greater detail about these tests.

The Mouse Control Screening (Herold, 2004), a pre-test, served to screen the functional mouse ability of the participants as mouse control was a fundamental skill required for execution of the tests. Mouse control can be impacted by motor difficulties, visual difficulties and inexperience. Appendix H describes this pre-test in greater detail.

The ALP Pre-test was designed to test the ability to determine the starting letter of the animal name and then find that letter in an alphabetically ordered array. The SUB Pre-test was developed to test the ability to subcategorise animals into the given groups. The ALP and SUB Pre-tests were both selection criteria pre-tests. There were five test items in each of the tests, within a set of 10 linked grids. Four out of five test items had to be selected correctly for the participant to pass the pre-test selection criteria.

An orientation program for the ALP and SUB pre-tests and tests followed the identical pattern of the pre-tests and tests. Six practice symbols were built into the program to be worked through before formal testing began. The six practice symbols were chosen to cover a range of initial letters and all six subcategory groups. Appendix A provides a list of the symbols used for this purpose.

A set of grids preceding the tests were designed to capture within the data log files the participant information comprising the participant (A or B), the participant number, session (1 or 2), grade (1,2 or 3), gender (M or F), research assistant (1-4) and computer number (1-4). This procedure ensured rigorous control of data. The session, research assistant and computer numbers were not used in data analysis, but for administrative control purposes only. The research assistant would be required to enter the administrative details associated with each participant at the beginning of each session. An overview of the administration process and grids is presented in Appendix I. The computer program began with the administrative section before guiding the participants through the pre-tests, and then the tests. The two testing sessions (to test ALP and SUB) were divided by a 10-minute break.

Internal logging on the computer was set to occur automatically throughout the pre-tests and tests.

After the operating program was developed, it was tested on various children and fellow research students to ensure that there were no errors in it and that it was sufficiently simple to operate independently.

3.4.4. Development of the participant instruction program

An instruction program was required to prepare the participants for the pre-tests and tests. This included orientating the participants to; (1) the principle of searching a visual field in terms of categories; (2) the principle of searching a visual field in terms of alphabetic order; and (3) the structure of the computerised test program and the pre-tests.

The instruction was designed as a group session. It had two components – a pen and paper instruction workbook and watching a demonstration of the computer test program. It also included A3 visuals of the computer screens so that the researcher could point directly to the specific aspects of the procedure during instruction.

A structured script for the instruction program was drawn up and modified on the basis of input and recommendations by fellow research students. Appendix J provides the complete instruction script used by the researcher in instructing the learners while Appendix K provides the complete instruction workbook used by the participants during instruction.

The principle aspects of the instruction included: (1) equivalent instruction of all of the participants through structured scripts; (2) presenting the instruction and task requirements in sufficiently simple language for all the participants to understand and execute; (3) equipping the participants with sufficient knowledge to enter the research task confident that they know what to do and that they have the skill to do it; (4) stressing the need for the participants to work both quickly and accurately during the research task; (5) providing repetition to consolidate the concepts; (6) providing a booklet to structure in active participation, concretise concepts and maintain optimal attention; (7) providing feedback by having research assistants check that the participants execute instructions correctly, and correct the participants where errors are noted; (8) instructing the participants on what to do when they have difficulties during the research task; (9) providing opportunities to ask questions; and (10) group watching of a visual demonstration of what the participants could expect in the computer test program in order to make them feel comfortable with the process.

3.4.5 Development of the research assistant test protocol

A structured script was provided for the research assistants to guide them through the test administration (Appendix L). It took the form of an A4 booklet with large font text, one page for every section of the test – administration, pre-test, test, break, administration, pre-test and test.

3.4.6 Analysis of grid and symbol features

To later investigate the relationship between the results and the position of the symbols in the grid and the size, colour and visual complexity of the symbols, these characteristics had to be determined and recorded.

For the position of the symbols in the display, the rows and columns of the 9 x 9 grids in the two visual displays were divided into thirds, both horizontally and vertically, as can be seen in Figure 6. The horizontal thirds were termed top, middle and bottom and recorded as Group 1, 2 or 3. The vertical thirds were termed left, centre and right, and recorded as Group 1, 2 or 3.

Top (1)
Middle (2)
Bottom (3)

Left (1)	Centre (2)	Right (3)

Figure 6. Position in display

The size of the symbols was determined through the use of a software program called Analysing Digital Images (a free Internet download). The pixel value of each symbol was calculated and recorded as a percentage of the total area covered by the symbol. Figures 7 and 8 are screen views of the analysis for one of the symbols. The size of the symbols ranged from 22.25% to 95.37% of the area covered by the symbol. This size difference was a feature of the PCS symbols themselves, and not manipulated by the researcher.

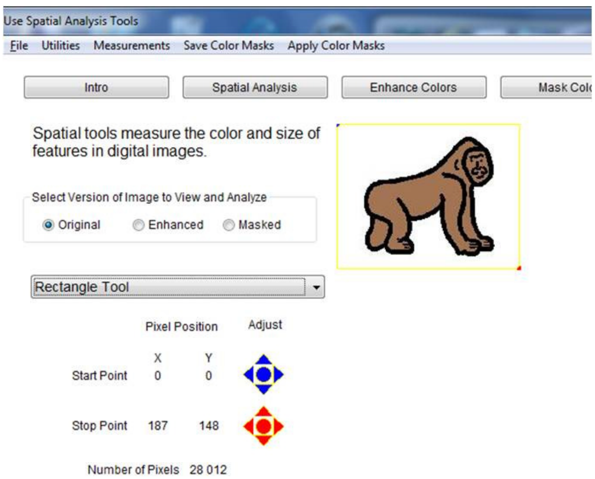


Figure 7. Pixel count of total area

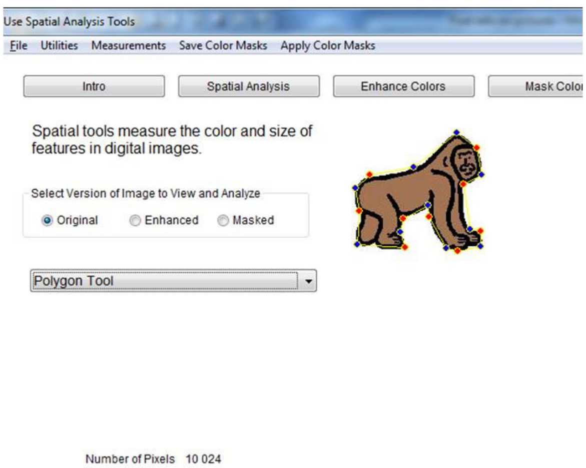
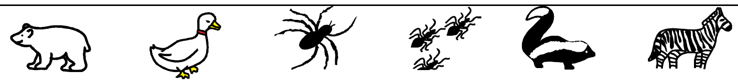
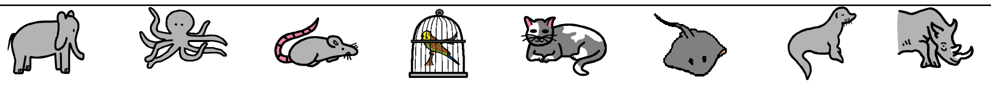
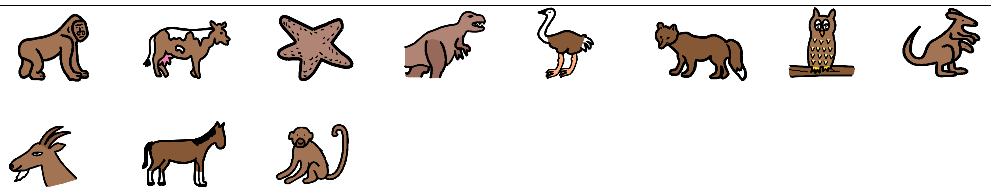
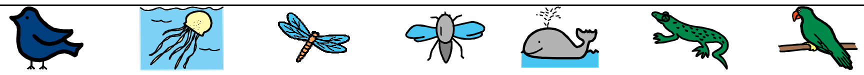
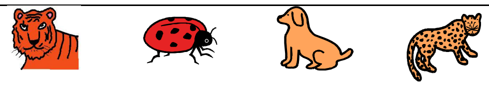


Figure 8. Pixel count of symbol area

The 36 test items were allocated to one of five colour groups, depending on their dominant colour – *Black & White*, *Grey*, *Brown*, *Blue/Green* and *Red/Orange*. Table 3 shows the distribution of the symbols.

Table 3

Distribution of Symbols into Colour Groups

Colour	Animal symbols
Black and white	
Grey	
Brown	
Blue/Green	
Red/Orange	

For a measure of visual complexity, the Joint Photographic Experts Group (JPEG) value of the symbol was recorded for each of the 36 test items. JPEG values have been used in previous research as an objective measure of visual complexity (Szekely & Bates, 2000). The JPEG values across the test items of this study ranged between 4.13KB and 9.28KB.

Appendix M provides a record of the information pertaining to *Position in the Display*, *Size*, *Colour* and *Visual Complexity*. The size, colour and visual complexity of the symbols were identical in the two displays, as the same PCS symbols were used in both displays.

3.5 Phase 2: Pilot study

3.5.1 Participants

The 12 participants for the pilot study were drawn from the Sunday school children of a local church. The children's parents were informed of the nature of the study and their signed permission was obtained to conduct the pilot study with their children as participants.

Although the sample group for the main study would be drawn from Grade 1 to Grade 3 children, piloting included Grade 0 children because it was considered important to understand the performance of the youngest participants in the sample group with the aim to determine the lowest age-group that would cope with the main study.

3.5.2 Aim, problems and recommendations

The objectives of the pilot study were to determine the following: (1) the logistics and flow of the test procedure (administration); (2) the suitability of the instruction program; (3) the suitability of the test program for the target age-group with respect to task comprehension and fatigue; (4) the usability of the data captured in the log files; and (5) the suitability of the research assistant instruction.

Firstly, problems were found with the administration of the test. Participants finishing their tests before others were disruptive to them, so the logistics of participant arrival and departure had to be tightened.

Secondly, the instruction program appeared adequate and suitable, although it was found that some of the participants worked faster than others did. To streamline the time taken for test execution, adult support would be maximized by having all research assistants available to ensure all participants kept up with the instructions at the same pace. Also, class teachers would be present to facilitate control of the group.

Thirdly, a number of changes were made to the test program after piloting. It was found that the ALP test took significantly longer than the SUB test. Also, the three repeat trials of each test (to investigate the impact of practice) proved to be too long for some of the participants, especially in the ALP test. Reflection resulted in the decision to remove the repeat trials from the test and contain the study to an investigation of first exposure visual search only. This would reduce the number of test items from 72 (18 items + 3 repeats of those 18 items) to 18. This significant reduction in the number of test items (and therefore testing time) allowed for the addition of test items to the test. It was decided to present 36 items in each test in the main study. Further reduction of total test time was made by removing the second ALP pre-test, which had been designed for descriptive purposes only.

Participant instruction would need to pay greater attention to the use of the escape option and the need to work accurately and carefully, as participants were sometimes insecure in knowing what to do when they couldn't find the target symbol.

Fourthly, problems were identified when linking participant information to the log files created during testing. This was solved through adding into the program design the requirement that the necessary participant information such as grade, gender, group and sessions be entered prior to *both* sessions of the testing so that all the administration data would be integrated directly into a new log file for each testing event.

Also, on analysing the data in the log files, it became apparent that managing multiple errors would, statistically, be a problem. Participants sometimes made multiple selections to find the correct one. The program was originally designed so that only the correct selection activated the link to the next test item. This problem would be addressed by redesigning the program so that every selection, whether incorrect or correct, would now result in the next test item appearing.

Finally, the research assistant instruction would need to be addressed, as the assistants were sometimes insecure in their role and uncertain of what to do when problems arose. A detailed script would be provided with hands-on experience before testing.

Appendix N presents a more detailed report on the problems encountered in the pilot study and the solutions to those problems.

3.5.3 Discussion of results of the pilot study

A summary of the data from the pilot study is presented in Appendix O. Some insights that were gained from the pilot study data were:

In the pilot study, the ALP Test (first exposure) took on average 225 sec (almost 4 min.) and the SUB Test (first exposure) took on average 153 sec (about 2.5 min.) to complete.

The Grade 1 participant who scored the highest mouse screening time of 115 sec, which was much longer than the next highest score of 85 sec, was also the participant who struggled the most with the ALP test. His time for the first round of the test was 391 sec. Because he was clearly struggling with the test, he did not complete it. This reinforced the need to determine competency in mouse control as a selection criterion.

Although there was a marked average reduction in the time taken to complete the four phases of the tests (first exposure and three practice rounds), there were a number of participants whose times increased during the last two phases. This indicated a conflict between the effects of practice and fatigue. To reduce the effects of fatigue, the task in the main study was made less demanding with respect to the length of the test by reducing the length of the test in the main study to one half of the length it was in the pilot study. This was done by removing the three repeat rounds and doubling the number of test items.

3.6 Phase 3: Main study

3.6.1 Introduction

The main study was conducted in a middle-class socio-economic suburb, all participants coming from the same school. There were 155 potential candidates in the Grade 1 to 3 classes distributed between three Grade 1 classes, two Grade 2 classes and two Grade 3 classes. The average class sizes ranged between 20 and 24 learners. Testing was executed in June, the middle of the academic year in South Africa.

Ethical clearance for the study was obtained from the University of Pretoria (Appendix P). Formal permission to conduct the study was obtained from the principal of the school as well as from the school's Governing Body, all the teachers from whose classes children were used for the study and the parents of the children. The consent documents included information concerning the purpose of the study, what the study at the school involved, what was required of them and what would be required of their children.

3.6.2 Participant selection criteria

Table 4 outlines the selection criteria for the participants for the study and indicates how the criteria were assessed. The table also includes some comments that explain the importance of the criteria to the study.

Table 4

Participant Selection Criteria

Selection Criteria	Method	Motivation
School Grade 1 to 3	Obtain the class lists for all the Grade 1, 2 and 3 children in the school from the school secretary.	The possible impact of the participants' academic level on test performance
Permission from parents.	Forms requesting informed consent sent home to parents two weeks before testing. Reply slips signed by parents were required.	Ethical obligation (Appendix P)

Selection Criteria	Method	Motivation
Child assent	Assent forms were required to be signed by each child. These were attached to the instruction manuals and signed before commencing with instruction.	Ethical obligation
No attention deficit	Teacher's questionnaire: Does the child show difficulty with independent completion of school tasks demanding concentration for less than 10 min.?	As the research task was timed, and required maintained concentration for about 20 min., it was important that the participants be able to maintain focus on the task for its duration. Children with uncontrolled attention difficulties and difficulties in maintaining attention were not eligible for selection. Appendix Q contains the teacher's questionnaire.
Absence of specific sensory difficulties that may impact on test performance	Teacher's questionnaire: Does the child have any other specific difficulties, such as uncorrected hearing or uncorrected vision difficulties?	
Motor and visual difficulties	Participants scoring speeds of more than 2 standard deviations longer than their peers on the mouse control screening were considered to have co-ordination skill difficulties and/or insufficient visual skills for the research task.	Motor and visual difficulties could impact on functional mouse control and speed of symbol identification on the screen. Because timing and visual discrimination was an issue in this study, it was considered important to control for it. Test symbols that had to be clicked on were significantly bigger than the symbols used in the mouse control screening. Therefore, if participants could complete the mouse control screening within 2 standard deviations of scores for the group, they were considered to have adequate motor skills and visual acuity for this test.
Passing of SUB Pre-test	Allocation of five animal symbols to one of six subcategory animal groups.	Participants had to demonstrate the ability to categorise. They had to allocate 4 out of 5 test items correctly to qualify for selection.
Passing of ALP Pre-test	Indicating the starting letter of five animal symbols.	Participants had to demonstrate the ability to identify the first sound of a word and to locate the written letter representing that sound on an ordered sequence of alphabet letters. They had to indicate four out of five test items correctly to qualify for selection.

Table 5 summarises the information relating to the number of participants who were available for selection, how many participants were disqualified on the basis of the selection criteria and for what reason they were disqualified. Appendix R records the information in more detail.

Table 5

Summary of the Number of Participants Qualifying for the Study

Criterion	Grade 1			Grade 2			Grade 3			Total		
	F	M	Tot	F	M	Tot	F	M	Tot	F	M	Tot
Total number of children available initially	**29**	**33**	**62**	**24**	**24**	**48**	**19**	**26**	**45**	**72**	**83**	**155**
Parental permission denied	*2*	*2*	*4*	*4*	*1*	*5*	*0*	*3*	*3*	*6*	*6*	*12*
Parental permission no reply	*3*	*4*	*7*	*2*	*1*	*3*	*0*	*2*	*2*	*5*	*7*	*12*
Parental permission granted	**24**	**27**	**51**	**18**	**22**	**40**	**19**	**21**	**40**	**61**	**70**	**131**
Selection criteria disqualifications	*2*	*4*	*6*	*3*	*2*	*5*	*1*	*5*	*6*	*6*	*11*	*17*
Child assent denial	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total number of participants tested	**22**	**23**	**45**	**15**	**20**	**35**	**18**	**16**	**34**	**55**	**59**	**114**
Mouse screening failure	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Subcategories Pre-test failure	*2*	*0*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*2*	*0*	*2*
Alphabetical order Pre-test failure	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Spoiled data due to procedural errors	*0*	*0*	*0*	*2*	*0*	*2*	*0*	*1*	*1*	*2*	*1*	*3*
Total number of participants whose data was used for analysis	**20**	**23**	**43**	**13**	**20**	**33**	**18**	**15**	**33**	**51**	**58**	**109**

3.6.3 Participant description criteria

In Table 6 a summary is presented of the participants according to age, gender and grade. For a more detailed record of the age range of the participants, see Appendix R. Only participants whose data was used for analysis are recorded in the table.

Table 6

Participant Description Criteria

	Male			Female		
Grade	Years	Range (years)	Number	Years	Range (years)	Number
Grade 1	6.07 - 8.08	2.01	23	6.05 – 7.05	1.00	20
Grade 2	7.07 – 9.03	1.08	20	7.05 – 9.00	1.07	13
Grade 3	8.02 – 9.05	1.03	15	8.06 – 9.05	0.11	18
All	6.07 – 9.05	2.10	58	6.05 – 9.05	3.00	51

The age range within the grades varied between 11 months and 2;1 (years;months). This age-range is acceptable within the South African context (where late school entrants, academic year repeats and absorption of children from other international school systems are common occurrences). As formal instruction was deemed an important factor in the acquisition of the alphabetical and categorisation skills required for the task, construction of the sample according to grade rather than age was preferred.

3.6.4 Distribution of sample into two groups

The sample was divided into two groups (A and B). The participants who passed all the permission and teacher-measured criteria were sorted and arranged firstly by grade, then by gender within grade and then by age within grade and gender. Once the 114 participants were arranged as explained, they were systematically divided off, one by one, into A and B groups. Appendix R explains the grouping procedure. The two groups executed the two tests in opposite order (ALP then SUB and SUB then ALP).

Five participants were lost before final compilation of the two groups, two due to pre-test failure and three due to procedural errors. There was also a gender allocation error, where a participant was marked male but was found to be female during testing. To determine if there were differences between the two groups in terms of grade and gender, a chi-square test was done which confirmed that there were no statistically significant differences between the groups on the 5% level on these variables ($p=0.96$ for Grade and $p=0.92$ for Gender). The groups remained equal after the loss of the five participants and the gender allocation error, as indicated in Tables 7 and 8.

Table 7

Analysis of Group by Grade

Group	Grade			Total
	1	2	3	
A	22	16	17	55
B	21	17	16	54
Total	43	33	33	109

Table 8

Analysis of Group by Gender

Group	Gender		Total
	Female	Male	
A	26	29	55
B	25	29	54
Total	51	58	109

3.6.5 Materials and equipment used in the study

Additional material and equipment required for this study included computers, mouses, The Grid™ software and the venue facilities for the testing.

Four laptop computers with the following specifications were used for all sections of the research study: ACER Amd Athlon 2650, 2GB memory, 160GB, DVD writer, 14.1" crystal bright screen, SD card reader, Windows VISTA Home Basic.

The laptops were bought specifically for the purposes of this study. They had no programs other than The Grid™ (The Grid, 2002) installed on them and were never used for any other function than this study.

Four identical mouse pointers were linked to the four laptops. They were conventional laptop mouse pointers, smaller than the average PC mouse, which was well suited to the smaller hands of the participants. The model of the mouse was MS Compact 500.

The Grid™ (The Grid, 2002), a PC software program created by Sensory Software International, was used for all the tests and data collection during the tests. The program was well suited to the creation of linked grids that could hold the large number of graphic content cells required for the tests in this study. In addition, The Grid™ had the facility to internally log every mouse click during an activity within The Grid™ program, as well as to document the contents of any cells that were selected, together with a time stamp of the mouse click event – all vital requirements for the execution and recording of the tests in this study.

Four computer stations were set up in one large room. Immediately outside the venue a registration point was set up from where the researcher could control the arrival of each participant, administer the registration process and manage the refreshment station.

3.6.6 Data collection procedures

The total amount of time required for each participant to complete the full test procedure was about 30 min. Table 9 outlines the steps and the time allocated to each step.

Table 9

Sequence of Events and Time Requirements

Group A	Group B	Time required	Time
Administration		1.5 min.	
Mouse Control Screening		1 min.	10.5 min.
Subcategories Pre-test	Alphabetic Order Test	1 min.	
Subcategories Test	Alphabetic Order Test	7 min.	
Break		10 min.	10 min.
Administration		1.5 min.	
Alphabetic Order Pre-test	Subcategories Pre-test	1 min.	9.5 min.
Alphabetic Order Test	Subcategories Test	7 min.	
Total		30 min.	30 min.

Note. min.=minute

The participants were collected four at a time from their classes by a research assistant (after prior arrangement with their teachers). They waited outside the testing room until it was time for their turn. As they entered the room they were given a registration slip (Appendix S) and directed to a computer station. A research assistant then immediately began following through the procedural script (Appendix L), beginning with a welcoming of the participant by name, followed by the administration requirements, the testing sequence and closing thanks. The procedural script served to guide the research assistants in the exact testing procedure and handling of the participant (including putting them at ease and informing them of what was expected of them). After completion of the test, the participants were given a gift of a pack of playing cards and escorted back to class.

Data collection procedures included the creation of a log file for each participant, processing of the log files, a procedural integrity check for the instruction program and a procedural integrity check for the testing.

The dependent variables were coded in the following manner: Time was measured in seconds and was the time taken between the mouse click on the target symbol and the first mouse click on the visual display which followed the presentation of the target symbol. Score was recorded as a 1 if the symbol located in the visual display was the same symbol as the target symbol, and as a 0 if it was not the same symbol as the target symbol (whether it was an incorrectly selected symbol or an escape option).

To keep participant information and test data linked, all participant information was entered into the computer by the research assistants at the beginning of each session. The information was prepared in advance on individual registration slips (Appendix S).

Log files in coded digital information were created for every test session, which had to be collated and processed into a MS Office Excel spreadsheet for statistical analysis. A more detailed explanation of the steps required for the processing of the log files is provided in Appendix T.

Three instruction sessions were executed by the researcher (one for each grade). Each session was assessed for procedural integrity through direct observation by two raters who were equipped with a copy of the researcher's instruction manual and participant workbook. They assessed the extent to which the instruction was implemented as originally designed (Lane et al., 2004). Their task was to check that all units of the instruction procedure had been executed in the same manner for each instruction session, note any deviations or irregularities in the research protocol, any imbalances in instruction style between the three grade instruction sessions and any other observations deemed relevant. The raters scored the researcher with 100% for executing the required steps. Appendix U contains the form the raters had to fill in as well as their scores and comments. Comments included that the participants were sometimes not able to see the computer screen and that sometimes the participants were not asked if they had any questions. The researcher considered these problems to not have had a significant impact on the study, as the participants had further opportunities to observe and ask questions during the computer orientation practice session preceding the testing.

Procedural integrity for the testing procedure administration was verified through an assessment of the sound recordings made during testing. A percentage of 23.39 of the sound files were found to be either missing or damaged. A random sample of 16.97% of the available sound files collected from the four research assistants was checked by an independent rater. The rater's task was to listen to the sound files of all verbal communication occurring between the research assistants and the participants to ensure that the testing procedure was executed as originally planned (Lane, et al., 2004). The rater was also required to note any deviations or irregularities in the testing protocol as well as any evidence of unauthorised verbal assistance. The rater scored the research assistants with an average of 93.92% in this check. Errors were mainly due to omission of enquiring of the participant which side he wanted the mouse on and absence of recording of a greeting or *thank you*. Appendix V contains the form the raters had to fill in as well as their scores and comments. Comments were primarily related to paraphrasing of instructions considered to be important ones. The mouse pointer positioning omission is considered by the researcher to not have presented the study with any difficulties, as the participants positioned the mouse pointers to their own comfort themselves (especially in the second testing session). The paraphrasing of instructions, such as "Think carefully" (during pre-tests) and "Work fast but be careful" (during tests) may have had methodological implications because different instructions in categorisation tasks can lead to different results (Blaye & Bonthoux, 2001; Osborne & Calhoun, 1998).

Further integrity checks were made during processing of the log files (where it could be determined if any sections had been omitted, repeated or incorrectly recorded) and through statistical analysis of the data in the extensive spreadsheet resulting from collation of all the participants' logged data, where missing or repeated data would manifest itself. There were three procedural errors made – two participants (No 47 and No 106) executed the SUB Test twice with the ALP Test not being executed, and one participant (No 46) did not complete the ALP Test. The data from these three participants had to be removed from the data bank.

Two data recording errors were found during the statistical procedures. Two time measures had been incorrectly recorded in the data (participants No 65 and No 109). The mean time over the 36 ALP items for those two participants was therefore underestimated by 4.96% and 1.78% respectively. The same items were recorded as correctly marked when they were in fact incorrect selections. Therefore, the mean correct score over the 36 ALP items for these two participants was overestimated by 3.00% and 2.98% respectively. These errors could not be corrected, having only been detected at the end of statistical analysis. However, considering that the mean time and score was mostly calculated over the 109 participants, the impact of the errors was probably minimal.

3.6.7 Data analysis

Table 10 outlines the statistical procedures (Tabachnick & Fidell, 2007) that will be applied to the data in order to interpret the results within the framework of the research questions. An analysis of variance (henceforth ANOVA) for Test, Group, Grade and Gender will determine which of the independent variables have significant rate and accuracy differences between them, Time and Score being the dependent variables. The outcome of the ANOVA will indicate how the main research question will be answered. If significant differences are found between the two organisational strategies, further investigation will determine if those differences extend through Grade and Gender, both with respect to within-group and between-group differences. Statistical analysis will then focus on an item analysis, investigating the influence of some bottom-up processes on the results.

Table 10

Data Analysis Procedures

Aim	Test
Determine which independent variables had significant differences in rate (Time) and accuracy (Score)	
Do an analysis of variance for Test, Group, Grade and Gender, to determine which variables had significant differences between them.	ANOVA
Research question 1: Is there - with respect to rate and accuracy of symbol location - a significant difference between the performances of the participants in locating symbols using either a colour-coded alphabetical or colour-coded categorisation organisational strategy for children in Grades 1 to 3?	
Compare ALP and SUB across the full sample	Means and SDs
Research sub-question: Are there differences in the performances of these children in their use of these strategies, with respect to grade and gender?	
Investigate within group differences with respect to grade and to gender.	ANOVA and Duncan
Investigate between group differences with respect to grade and gender.	T-Tests
Research question 2: Did the bottom-up factors of vigilance, position in display, size, colour and visual complexity impact the results?	
Compare the items with respect to rate and accuracy (across full sample)	Means and SDs of items
Investigate a relationship between rate and accuracy	Pearson
Investigate the impact of vigilance during the test procedure on location rate.	Spearman
Investigate the impact of the position of the symbols in the visual field (with respect to left, centre or right positioning, or, top, middle and bottom positioning) on location rate.	Friedman
Investigate the impact of the size of the symbol on location rate.	Pearson
Investigate the impact of colour groups on location rate.	Friedman
Investigate the impact of visual complexity of the symbols on location rate.	Pearson

Note. ANOVA=Analysis of variance

Note. SD=Standard deviation

3.7 Summary

A research plan was drawn up to compare the performance of the participants – with respect to rate and accuracy of symbol location – in locating symbols using either a colour-coded alphabetical or a colour-coded categorisation organisational strategy. The development of the research material was described.

The study was executed at a mainstream school. A sample of 114 Grade 1 to 3 participants was selected from the children passing the selection criteria. After a group instruction session, the participants were individually tested in a computerised research task.

A pilot study tested many aspects of the study, the results and recommendations of which were incorporated into the final design and procedures of the main study. Material used in the study was described, as well as data collection and analysis procedures.

Chapter 4

Results

4.1	Introduction
4.2	Overview of the effect of the independent variables on the dependent variables.
4.3	Research question 1: Is there a significant difference between the performance of the participants, with respect to rate (time) and accuracy (score), in locating symbols in a large colour-coded visual display using either an alphabetical or a categorisation arrangement?
4.4	Subquestion: Are there significant differences between the performance of the participants, with respect to grade and gender, in their use of colour-coded alphabetical and categorisation arrangements to locate symbols in a large visual display? 4.4.1 Differences within tests in grade and gender 4.4.2 Differences between tests in grade and gender 4.4.3 Errors
4.5	Research question 2: Did the bottom-up factors of vigilance, position in display, size, colour and visual complexity impact the results? 4.5.1 Vigilance 4.5.2 Position in display 4.5.3 Symbol features – size, colour, visual complexity
4.6	Summary

Figure 9. Overview of Chapter 4

4.1 Introduction

This chapter presents the data collected during the experimental research phase. Firstly, an overview of the effect of the independent variables on the dependent variables will be presented, which will enable the researcher to determine the areas of significance that require further probing. Following the introduction, the data relevant to answering the research questions and subquestion are presented. Figure 9 provides an overview of the chapter.

4.2 Overview of variables

In this study there were four independent variables: (1) *Test:* ALP (Alphabetical order test) or SUB (Subcategorisation test); (2) *Group:* A (ALP first) or B (SUB first); (3) *Grade:* 1 (Grade 1), 2 (Grade 2), 3 (Grade 3); and (4) *Gender:* M (Male), F (Female). There were two dependent variables: (1) *Time* (time measured in seconds); and (2) *Score* (number of correctly selected items).

An analysis of variance (ANOVA) was done to determine if the independent variables had a significant effect on the dependent variables. The ANOVA is frequently used when an independent variable is between-subjects in nature and has three or more levels (Tabachnick & Fidell, 2007). The ANOVA results are reflected in Table 11 where it can be seen that at the p<.05 significance level: (1) *Test* differs significantly for both dependent variables - *Time* F(1,212)=166.32, p=<01) and *Score* F(1,212)=33.67, p=<.01; (2) *Group* (order of presentation) is not significant, neither with respect to *Time* F(1,212)=.13, p=.72 nor *Score* F(1,212)=.00, p=.97; (3) *Grade* differs significantly for both dependent variables - *Time* F(2,212)=43.60, p<.01 and *Score* F(2,212)=28.29, p=<.01); and (4) *Gender* differs significantly with respect to *Time* F(1,212)=4.42, p=.04 but not with respect to *Score* F(1,212)=.38, p=.54.

Table 11

Overall Analysis of Variance on Time *and* Score

		Dependent variables					
		Time			Score		
Independent variables	*df*	*F*	*p*	ηp^2	*F*	*p*	ηp^2
Test	1	166.32	<.01*	.44	33.67	<.01*	.14
Group	1	.13	.72	.01	.00	.97	.00
Grade	2	43.60	<.01*	.29	28.29	<.01*	.21
Gender	1	4.42	.04*	.02	.38	.54	.00
Error	212						

Note. An * indicates significance at *p*<.05.

The partial eta squared was used to calculate the effect size of the ANOVA. The effect size indicates the strength of the relationship between the independent variable and the dependent variable (Tabachnick & Fidell, 2007). An effect size in the range .01 - .05 is considered small, .06 - .14 medium and >.15 large. The effect size for *Test* was therefore large for *Time* and medium for *Score*, for *Grade* it was large for *Time* as well as *Score*, and for *Gender* it was small for *Time*.

On the basis of the areas of significance determined by the ANOVA, the influence of *Test, Grade* and *Gender* is presented in this chapter. *Group* did not receive any further consideration in the data presentation or analysis because there were no significant differences between the means of the tests with respect to the order of presentation. Differences regarding *Test* are discussed in reference to Research Question 1, and the effect of *Grade* and *Gender* differences in reference to the subquestion. Research Question 2 addresses the impact of bottom-up factors on the results.

The means, standard deviations and ranges of all the independent variables for *Time* and *Score* have been tabulated in Table 12 for reference purposes.

Table 12

Means and Standard Deviations of all Variables

Variable		Number of participants	Time		Score	
			Mean	SD	Mean	SD
Test	ALP	109	337.55	142.17	31.38	4.06
	SUB	109	180.50	51.80	33.64	2.06
Group	A	110	261.13	125.82	32.50	3.24
	B	108	256.89	139.77	32.52	3.58
Grade	1	86	324.42	159.24	30.83	4.23
	2	66	245.98	103.22	32.86	2.40
	3	66	186.86	61.56	34.35	1.50
Gender	M	116	273.71	146.58	32.33	3.62
	F	102	242.33	113.13	32.72	3.15

For a summary of all data by grade and gender, inclusive of all pre-test and test data, as well as mean time and score, see Appendix W. For a record of the mean time and mean score data for each item across the 109 participants, see Appendix X.

4.3 Research question 1: Is there a significant difference between the performance of the participants, with respect to rate (time) and accuracy (score), in locating symbols in a large colour-coded visual display using either an alphabetical or a categorisation arrangement?

The ANOVA indicated that for *Test*, the means for *Time* and *Score* in ALP and SUB were significantly different (Table 11).

The mean for *Time* for ALP across all the participants was 337.55 sec., whereas the mean time for SUB was 180.50 sec. (Table 12), indicating that the participants completed SUB faster than ALP.

The mean for *Score* in ALP across all participants was 31.38 correct scores whereas for SUB it was 33.64 correct scores (Table 12), indicating that the participants were more accurate in their selections in SUB than in ALP.

4.4 Subquestion: Are there significant differences between the performance of the participants, with respect to grade and gender, in their use of alphabetical and categorisation arrangements to locate symbols in a large colour-coded visual display?

The means, standard deviations and ranges for *Time* and *Score* within *Grade* and *Gender* are shown in Table 13 as a summary reference of all the data pertaining to *Grade* and *Gender*. This table will be referred to in further presentation of the results.

Table 13

Means and Standard Deviations for Time *and* Score *Within* Grade *and* Gender

Variable		Test	Number of participants	Time			Score		
				Mean	SD	Range	Mean	SD	Range
Grade	1	ALP	43	434.07	155.10	204-1140	28.91	4.83	10-36
	2		33	324.15	89.57	224-708	31.91	2.63	26-36
	3		33	225.18	53.78	146-393	34.06	1.48	31-36
	1	SUB	43	214.77	51.37	122-320	32.74	2.32	26-36
	2		33	167.82	31.87	103-242	33.82	1.70	29-36
	3		33	148.55	42.17	105-284	34.64	1.50	31-36
Gender	M	ALP	58	361.52	157.28	159-1140	31.09	4.38	10-36
	F		51	310.29	118.47	146-667	31.71	3.68	20-36
	M	SUB	58	185.90	54.03	103-320	33.57	2.04	26-36
	F		51	174.37	48.94	105-319	33.73	2.11	27-36

Grade and *Gender* differences were analysed firstly with respect to the differences within the tests and secondly with respect to the differences between the tests.

4.4.1 Grade and Gender differences within the tests

An ANOVA was done per *Test* on both *Time* and *Score*, with *Grade*, *Gender* and the interaction between *Grade* and *Gender* as independent variables (Table 14).

Table 14

Analysis of Variance on Grade *and* Gender

Variable	Test	*Df*	Time			Score		
			F	*p*	ηp^2	F	*p*	ηp^2
Grade	ALP	2	31.72	<.01*	.37	20.71	.01*	.29
Gender		1	3.71	.06**	.02	.40	.53	.00
Grade*Gender		2	.24	.78	.00	.19	.82	.00
Error		103						
Grade	SUB	2	22.54	<.01*	.29	9.09	<.01*	.15
Gender		1	1.19	.28	.00	.08	.78	.00
Grade*Gender		2	.26	.77	.00	.22	.80	.00
Error		103						

Note. An * indicates significance at p<.05

Note. An ** indicates significance at p<.10

According to the ANOVA on *Grade* and *Gender*, there were significant differences on both tests on a 5% significance level between the grades, for both *Time* (ALP F(2,103)=31.72, p=<.01 and SUB F(2,103)=20.71, p=.01) and *Score* (ALP F(2,103)=22.54, p<.01 and SUB F(2,103)=9.09, p=<.01). All the grade differences had a large effect size. Between the genders, there were only significant differences at a 10% significance level for *Time* in ALP F(1,103)=3.71, p=.06, with a small effect size. There were no significant differences in *Gender* in ALP for *Score* F(1,103)=.40, p=.53, nor in SUB for *Time* F(1,103)=1.19, p=.28 or *Score* F(1,103)=.08, p=.78.

There were no statistically significant interactions between *Grade* and *Gender*, in either ALP or SUB, for both dependent variables – *Time* F(2,212)=.26, p=.77 and *Score* F(2,212)=.22, p=.80.

4.4.1.1 Grade differences within the tests

Because significant differences were found between the grades within test in the ANOVA for both *Time* and *Score* (Table 11), the Duncan Multiple Range Test (Duncan's new multiple range test, 2009) was applied to the tests within the grades. The results indicated that for ALP all three grades differed significantly for *Time* and *Score*. In SUB, only Grade 1 differed significantly from Grades 2 and 3 for *Time* and *Score* (Table 15).

In terms of *Time,* the mean time taken to complete ALP decreased as *Grade* increased. The mean for *Score* increased in ALP as *Grade* increased. The same pattern of results was noted in SUB, except that the differences between the Grade 2 and Grade 3 groups were not statistically significant. These results indicate that as *Grade* increased, participants made faster and more accurate selections.

Table 15

Post-Hoc Duncan Test Applied to Grade *Within the Tests*

Test	Grade	Number of participants	Time		Score	
			Mean	SD	Mean	SD
ALP	1	43	434.07[a]	155.10	28.91[a]	4.83
	2	33	324.15[b]	89.57	31.91[b]	2.63
	3	33	225.18[c]	53.78	34.06[c]	1.48
SUB	1	43	214.77[a]	51.37	32.74[a]	2.32
	2	33	167.82[b]	31.87	33.82[b]	1.70
	3	33	148.55[b]	42.17	34.64[b]	1.50

Note. The means of the variables with different superscripts ([a, b, c]) differ significantly.

4.4.1.2 Gender differences within the tests

As indicated in Table 14, mean time differences between the genders were significant in ALP (p=.06) at a 10% significance level. The female participants completed the ALP test faster (310.29 sec.) than the male participants did (361.52 sec.) (Table 13).

4.4.2 Grade and Gender differences between the tests

The means and standard deviations of the independent variables for the differences between ALP and SUB are reflected in Table 16. The paired T-Test was used to determine if ALP and SUB differed significantly with regard to *Time* and *Score* within *Grade* and *Gender* and the results are also presented in Table 16. The paired T-Test was used because the two variables that were compared were not independent.

Table 16

Comparison of ALP and SUB per Grade *and* Gender

Variable		Number of participants	Time				Score			
			Mean ALP-SUB diff	SD	*T*	*p*	Mean ALP-SUB diff	SD	*T*	*p*
Grade	1	43	219.30	144.41	9.96	<.01*	-3.84	3.76	9.96	<.01*
	2	33	156.33	86.98	10.33	<.01*	-1.91	2.67	10.33	.01*
	3	33	76.64	42.92	10.26	<.01*	-0.58	1.62	10.26	.05*
Gender	M	58	175.62	136.50	9.80	<.01*	-2.48	3.54	-5.35	<.01*
	F	51	135.92	95.12	10.20	<.01*	-2.02	2.80	-5.14	<.01*

Note. An * indicates significance at p<.05

4.4.2.1 Grade differences between the tests

In terms of *Time,* the mean time difference between ALP and SUB differed significantly for all three grades (Table 16). The mean time difference between ALP and SUB decreased as *Grade* increased. For Grade 1, the mean time difference was 219.30 sec., for Grade 2 it was 156.33 sec. and for Grade 3 it was 76.64 sec. The mean time in ALP was higher than the mean time in SUB (except for one participant in Grade 3). This indicated that for most participants (across all grades) SUB was faster to complete than ALP.

In terms of *Score,* the mean score difference between ALP and SUB differed significantly for all three grades (Table 16). The mean score difference between ALP and SUB decreased as *Grade* increased. For Grade 1, the mean score difference was -3.84 correct scores, for Grade 2 it was -1.91 correct scores and for Grade 3 it was -0.58 correct scores. The mean score for SUB was higher than the mean score for ALP (except for four Grade 1, four Grade 2 and seven Grade 3 participants who had small ALP-SUB score differences where there were higher mean scores in ALP compared to SUB). This indicated that most participants (across all grades) scored more accurately in SUB than ALP.

4.4.2.2 Gender differences between the tests

For *Time,* the mean difference between ALP and SUB was significant for both *Male* and *Female* (Table 16). The mean time difference between ALP and SUB was greater for

Male (175.62 sec.) than *Female* (135.92 sec.). The mean time for ALP was greater than the mean time for SUB, for both *Male* and *Female* (except for one female participant), indicating that for most participants (across both genders) SUB was faster to complete than ALP.

The mean differences for *Score* between ALP and SUB were significant for both *Male* and *Female* (Table 16). The mean score difference for *Male* was -2.48 correct scores, and for *Female* it was -2.02 correct scores. The mean score for SUB was higher than the mean score for ALP (except for seven male and eight female participants who had small score differences where there were higher mean scores in ALP compared to SUB), indicating that most participants (across both genders) scored more accurately in SUB than ALP.

4.4.3 Errors

4.4.3.1 Grade

The number of correct and incorrect selections was calculated across *Test* and *Grade*. Incorrect selections were further separated into *Escape* selections and *Error* selections. (Escape selections were primarily made when the participants could not find the target, and gave up on the search. Error selections were target identification errors). Frequencies of selection were calculated as percentages and are reflected in Table 17.

Table 17
Percentage of Correct, Escape *and* Error *Selections Across* Grade

	ALP				SUB			
		Incorrect				Incorrect		
Grade	Correct	Escape	Error	Total	Correct	Escape	Error	Total
1	80.30	13.05	6.65	19.70	90.96	4.26	4.78	9.04
2	88.55	5.72	5.72	11.45	93.94	2.36	3.70	6.06
3	94.53	2.69	2.78	5.47	96.21	1.26	2.53	3.79

From Table 17 it can be seen that with an increase in *Grade*, the percentage of *Escape* and *Error* selections decreased in both ALP and SUB. For all the grades, both the *Escape* and *Error* percentages were higher for ALP than for SUB. The *Escape* option was frequently used by participants in Grade 1, particularly in ALP where 13.05% of all selections were *Escape* selections (compared to 4.26% in SUB). By Grade 3, 94.53% of the participants' ALP selections and 96.21% of their SUB selections were accurate.

Table 18 records the mean time taken for all the items, as well as the mean time taken for the *Escape* and *Error* selections. It can be seen that the mean time for *Escape* selections (24.08 sec. in ALP and 17.83 sec. in SUB) was greater than for *Error* selections (10.74 sec. in ALP and 6.70 sec. in SUB). This indicates that in both tests the participants took longer making escape selections than error selections. It can also be seen in Table 18 that *Escape* selections had a much larger mean time (24.08 sec. in ALP and 17.83 sec. in SUB) than the mean time across all the test items (9.11 in ALP and 4.92 in SUB). *Error* selections, however, only had a marginally greater mean time (10.74 sec. in ALP and 6.70 sec. in SUB) than the mean time over all the items (9.11 in ALP and 4.92 in SUB). This, together with the greater percentage of *Escape* selections than *Error* selections noted in Table 17, suggests that E*scape* selections had a more important impact on overall mean times than *Error* selections, especially for the Grade 1 participants.

Table 18

Mean Time *for* Escape *and* Error *Selections*

	All items	Escape selections			Error selections		
Test	Mean time (sec.)	Mean time (sec.)	Min. time (sec.)	Max time (sec.)	Mean time (sec.)	Min. time (sec.)	Max time (sec.)
ALP	9.11	24.08	3	145	10.74	1	51
SUB	4.92	17.83	3	75	6.70	1	45

4.4.3.2 Gender

The number of correct and incorrect selections was calculated across *Test* and *Gender*. As for *Grade*, incorrect selections were further separated into *Escape* selections and *Error* selections. Frequencies of selection were calculated as percentages and are presented in Table 19.

Table 19
Percentage of Correct, Escape *and* Error *Selections Across* Gender

	ALP			SUB		
		Incorrect			Incorrect	
Gender	Correct	Escape	Error	Correct	Escape	Error
Male	86.25	8.14	5.60	93.25	2.39	4.36
Female	88.07	7.19	4.74	93.68	3.21	3.10

From Table 19 it is noted that in terms of incorrect selections, the differences in performance between *Male* and *Female* were minimal, for both ALP and SUB. For both *Male* and *Female* there were greater percentages of *Escape* and *Error* selections in ALP than in SUB.

4.4.4 Variability of performance within Grade and Gender

The SD-values across the results indicate variability in the performance of the participants, both within the tests (Table 13) and between them (Table 16), with a tendency to decreasing variability between the tests as *Grade* increased and greater variability in the performance of *Male* between the two tests compared to *Female*.

The variability within tests tended to decrease as *Grade* increased (Table 13). In ALP *Time*, the SD-values decreased from 155.10 in Grade 1, to 89.57 in Grade 2 and 53.78 in Grade 3. In ALP *Score*, the SD-values decreased from 4.83 in Grade 1, to 2.63 in Grade 2 and 1.48 in Grade 3. Variability within SUB was not as marked as in ALP.

The variability between the tests also tended to decrease as *Grade* increased (Table 16). With respect to the time difference between the tests, the SD-value was 144.41 sec. in Grade 1, 86.98 sec. in Grade 2 and 42.92 sec. in Grade 3. With respect to the score difference between the tests, the SD-value was 3.76 sec. in Grade 1, 2.67 sec. in Grade 2 and 1.62 sec. in Grade 3.

Variability of performance was also noted in *Gender* (Table 13). Greater variability in performance was seen within *Male* than *Female*. In ALP *Time*, SD-values were 157.28 sec. in *Male* compared to 118.47 sec. in *Female*. Variability within tests was not marked for SUB *Time*, nor ALP and SUB *Score*.

There was variability in performance in *Gender* between the tests (Table 16). With respect to the time difference between the tests, for *Male* the SD-value was 136.50 sec. but for *Female* it was 95.12 sec. With respect to the score difference between the tests, for *Male* the SD-value was 3.54 but for *Female* it was 2.80.

4.5 Research question 2: Did the bottom-up factors of vigilance, position in display, size, colour and visual complexity impact the results?

There was, within both of the tests of this study, a wide variability across the items with respect to both the speed with which items were located, and the accuracy with which they were located. The means, standard deviations and ranges in terms of *Time* and *Score* over the 36 items are recorded in Table 20. A more detailed record of the data pertaining to the items can be found in Appendix Y and Appendix Z.

Table 20

Means and Standard Deviations for Time *and* Score *Across all Test Items*

Variable	Number of items	Time			Score		
		Mean	SD	Range	Mean	SD	Range
ALP	36	9.11	3.95	2.52 - 21.05	.88	0.10	0.53 - 1.00
SUB		4.92	2.34	2.21 - 13.58	.94	0.06	0.72 - 1.00

From Table 20 it is clear that the participants responded variably to the individual symbols, both *within* and *between* the two tests. The mean time for ALP was 9.11 sec., whereas for SUB it was 4.92 sec. The mean time across the 36 test items ranged from 2.52 to 21.05 sec. in ALP compared to 2.21 to 13.58 sec. in SUB. The mean score across the 36 test items was 88% correct scores in ALP compared to 94% correct scores in SUB. The mean score ranged from 53% to 100% in ALP compared to a range of 72% to 100% in SUB.

The factors (other than the two strategies that were used for target location) that were investigated for relationships between the visual symbols and the speed and accuracy with which they were located in the visual display were vigilance, position in field and three symbol characteristics (size of picture, colour of picture and visual complexity).

Pearson correlation was applied to size and visual complexity. Friedman's 2-way analysis of variance was applied to the data for factors that were analysed in groups – position in visual field and colour. Spearman correlation was applied to the data for features where the scores of both variables were in the form of ranks, the variables were both measured for the same individual, and the observations on each variable were between-subjects in nature (Tabachnick & Fidell, 2007) – vigilance.

Pearson correlation coefficients were also found for *Time* and *Score* (Table 21) and indicated a significant negative relationship between them - as *Time* increased, *Score* tended to decrease. The coefficients were -.84 (p=<.01) for ALP and -.67 (p=<.01) for SUB, representing a large effect (Field, 2009). That is, the longer it took to find an item in the tests, the less likely it was that the item would be found accurately. This relationship was stronger for ALP than for SUB.

Table 21

The Relationship Between Time *and* Score *Across all Test Items*

Variable	Number of items	Time			
		ALP		SUB	
		Correlation coefficient	*P*	Correlation coefficient	*P*
Score	36	-.84	<.01*	-.67	<.01*

Note. An * indicates significance at p<.05

Analyses on the items were done for ALP and SUB, but without further analysis of *Grade* or *Gender* within *Test*. The purpose of these analyses was exploratory only, to investigate if there were any tendencies towards interactions between the results of the research task and the features mentioned above. It is important to note that the features explored were not controlled for in the design of this research study, but may still have had an impact on the results.

From this point on, only relationships of *Time* with the independent variables are presented in the analysis of the results. Due to: (1) the overview nature of this analysis; (2) the close relationship between *Time* and *Score* in this study (see the high correlations noted in Table 21 above); and (3) the close relationship between the various variables and *Time* in visual search literature, it was considered an unnecessary distraction for the purposes of this section of the study to analyse the impact of the variables on *Score* as well.

4.5.1 Vigilance

In terms of *Time,* the impact of the sequence of items on the data was analysed to investigate whether there was an increase or decrease in the time taken to complete the tests as the test progressed. Spearman correlation coefficients were used to investigate the relationship between *Time* (the mean time per item) and the *Item Number* (order of presentation of items) (Table 22).

Table 22
Spearman Correlation Between Time *and* Item Number

Variable	Item No. (Order of items)			
	ALP		SUB	
	Correlation coefficient	*P*	Correlation coefficient	*p*
Time	.12	.21	-.17	.07

Note. p<.05

All the correlations were very low and not significant. This suggests that vigilance (the ability of an observer to maintain a high level of detection performance in visual search tasks over long periods (Uttal, 1998)) did not significantly influence the time taken to complete the test items as the tests progressed, neither for ALP nor for SUB.

4.5.2 Position in Display

The impact of the position of the symbols in the visual field was analysed. The visual field was divided into three areas for both columns and rows (Figure 6). The mean times for *Position in display* were compared (Table 23).

Table 23

Friedman Analysis of Variance for Time *with Respect to* Position in Display

Variable	Column + Row Groups		ALP			SUB		
			Mean	SD	*p*	Mean	SD	*p*
Time	Column	Left	9.37^{a}	3.88		5.22^{a}	1.91	
		Centre	8.69^{b}	4.83	.01*	4.77^{a}	1.64	.11
		Right	10.20^{a}	4.96		5.07^{a}	2.05	
	Row	Top	8.83^{a}	5.10		5.83^{a}	2.24	
		Middle	9.90^{b}	4.25	.06*	5.10^{b}	2.01	<.01*
		Bottom	9.36^{cb}	4.28		4.11^{c}	1.32	

Note. An * indicates significance at p<.05.

Note. The means of the variables with different superscripts ($^{a, b, c}$) differ significantly.

There are significant differences in the mean times for *Column* in ALP, but not in SUB, and for *Row* in both ALP and SUB (Table 23).

With respect to *Column*, in ALP the centre column or area of the visual display was the area in which target symbols were located fastest (8.69 sec., compared to 9.37 sec. in the left area and 10.30 sec. in the right area).

With respect to *Row*, in ALP the symbols were located fastest in the top area of the visual display but slowest in the middle area (9.90 sec.). In SUB, the mean times for target location decreased from top to bottom (5.83 sec. in the top area, 5.10 sec. in the middle area and 4.11 sec. in the bottom area).

4.5.3 Symbol features

4.5.3.1 Size

Pearson correlation coefficients were determined for *Size* by correlating the mean times of the 36 test items with *Size* (calculated as the percentage area covered by the symbol in the grid cell for each item and ranked from smallest to largest). (Table 24)

Table 24

Pearson Correlation Between Time *and* Size

Variable	Size			
	ALP		SUB	
	Correlation coefficient	*P*	Correlation coefficient	*p*
Time	-.01	.95	-.31	.01*

Note. An * indicates significance at p<.05

The mean time for *Size* was 41.62 sec. with a range of 22.25 to 95.37 sec. (SD=13.26).

The Pearson correlation coefficients for *Time* were significant for SUB. The correlation coefficient for *Time* in SUB was negative (-.31, p=.01). This represented a medium effect (Field, 2009) and indicated that as the size of the symbol increased, the time to locate the symbol decreased (locating the symbols became faster).

4.5.3.2 Colour

The mean times for each of the colour groups were compared (Table 25).

Table 25

Friedman Analysis of Variance for Time *with Respect to* Colour

Variable	Colour groups	ALP			SUB		
		Mean	SD	*p*	Mean	SD	*p*
Time	Black + white	7.24^{c}	4.91		5.01^{b}	2.46	
	Grey	9.81^{ab}	4.72		5.62^{ab}	2.27	
	Brown	10.79^{a}	4.92	<.01*	6.05^{ab}	2.12	<.01*
	Blue / green	9.77^{b}	5.91		3.76^{c}	1.62	
	Red / orange	7.14^{c}	5.02		3.17^{c}	1.10	

Note. An * indicates significance at p<.05.

Note. The means of the variables with different superscripts ($^{a,\ b,\ c.\ d,\ e}$) differ significantly.

There were significant differences between the mean times for the colour groups in both ALP and SUB.

The mean time was highest for the brown group of items in both ALP (10.79 sec.) and SUB (6.05 sec.), indicating that the brown group of symbols was the slowest to locate. There were significant differences between the brown group and all the other groups (except the grey group), in both ALP and SUB.

The mean time was lowest for the red/orange group of items in both ALP (7.14 sec.) and SUB (3.17 sec.), indicating that the red/orange group was the fastest to locate. The differences between the red/orange group and all the other groups were significant (except for the blue/green group in SUB).

4.5.3.3 Visual complexity

Pearson correlation coefficients were determined for *Visual Complexity* by correlating the mean times for each item with the JPEG value of each item (Table 26).

Table 26

Pearson Correlation between Time *and* Visual Complexity

Variable	Visual Complexity			
	ALP		SUB	
	Correlation coefficient	*P*	Correlation coefficient	*p*
Time	-.11	.24	-.26	.01*

Note. An * indicates significance at p<.05

The mean time for *Visual Complexity* was 6.33 sec. with a range of 4.13 to 9.28 sec. (SD=1.26).

Pearson correlation coefficients were only significant for *Time* in SUB, but weak (-.26, p=01), representing a small effect of size on *Time* in SUB. The correlation coefficient was negative, indicating that as the visual complexity of the items increased, so the time to locate the items tended to decrease (locating the symbols became faster). This must, however, be treated with caution as the correlation coefficients were low.

4.6 Summary

Research Question 1: Test differences

The participants were faster and also more accurate in SUB than in ALP.

Subquestion: Differences regarding Grade and Gender

Differences within the tests: An increase in *Grade* resulted in both higher rate and higher accuracy in both the tests. Females were faster in ALP than males, but not more accurate.

Differences between the tests: Concerning *Time* and *Score* the mean difference between ALP and SUB was significant for all the grades and also for both the male and female participants. The mean differences between ALP and SUB decreased as *Grade* increased, for both *Time* and *Score*. Most of the participants, with respect to *Grade* and *Gender*, were faster as well as more accurate in SUB than they were in ALP.

Error selections for Grade and Gender: For all the grades, both the escape and error selection percentages were higher for ALP than for SUB. The escape option was frequently used in Grade 1, particularly in ALP. The differences in performance between males and females in terms of incorrect selections were minimal.

Variability: There was a variability of performance in both *Time* and *Score* within and between the tests in *Grade*, which decreased as grade increased. The variability was greater in ALP than SUB. There was also a variability of performance in *Gender*, which was more evident in *Male* than *Female*.

Research question 2: Impact of bottom-up factors

There was a wide variability in the rate and accuracy with which individual items were located in the study, in both ALP and SUB. There was also a strong relationship between the time taken to select an item and the accuracy of selection.

There was no indication of fatigue or practice having influenced this study. Items were located with variable speed with respect to their position in the visual field.

Size and visual complexity impacted on speed of target location in SUB only, and colour in both ALP and SUB.

Chapter 5

Discussion and clinical implications

5.1 Introduction

5.2 Why was it faster and more accurate to search using SUB compared to ALP?
- Structure of the visual displays
  - *Colour-coding, gloss*
- Task requirements of the tests
  - *Search strategy, mental representations, working memory*

5.3 Impact of development on visual search in ALP and SUB
- Alphabetical order development
- Categorisation development
- Working memory development

5.4 Impact of gender on visual search in ALP and SUB

5.5 The influence of bottom-up factors in ALP and SUB
  - *Vigilance*
  - *Position in display*
  - *Symbol features: size, colour, visual complexity*

5.6 Clinical implications of the study
- Variability in performance across individuals
- The error cost
- Implications for display design
  - *Display organisation, symbol features, colour-coding, gloss*

5.7 Summary

Figure 10. Overview of Chapter 5

5.1 Introduction

An overview of the chapter is presented in Figure 10.

The results indicated that the participants were faster and more accurate locating symbols using the categorisation strategy than the alphabetically order strategy (Table 12).

Significant differences were found within the grades, with rate of task completion decreasing and accuracy of task increasing as grade increased (Table 15). The differences between the tests decreased as grade increased (Table 16). There were also significant gender differences in the rate of task completion, but not in accuracy (Table 13), with the female participants completing the task faster than the male participants did (Tables 14). The males had greater between test differences than the females (Table 16). Bottom-up factors found to have influenced the results were the position of the symbols in the display (Table 23) and some visual features of the symbols themselves, specifically size (Table 24), colour (Table 25) and visual complexity (Table 26).

The main issues to be discussed in reviewing the results are: (1) an analysis of why the SUB visual display may have been more efficient for visual search than the ALP visual display for the age-group of the participants in this study; (2) the impact of the development of the participants on the results; (3) the impact of gender on the results; (4) the influence of the perceptual features of the symbols used in the study on the results; and (5) the clinical implications arising from the study.

5.2 Factors influencing rate and accuracy in ALP and SUB

The possible reasons for the decreased visual search efficiencies when using the ALP search strategy compared to the SUB search strategy are the factors inherent in the structure of the visual displays (primarily bottom-up influences), and the task requirements of the strategies used to search for targets within those displays (primarily top-down influences). However, it must be noted that the structure of the visual displays and the task requirements were interrelated. Bottom-up and top-down processes are not mutually exclusive, but impact one another (Chen & Zelinsky, 2006).

5.2.1 Structure of the visual displays

Figures 11 and 12 indicate the grid structure and colour-coding characteristics of the two visual displays (without the symbols that were placed in them in the tests, but with the letters and animal categories assigned to each group indicated).

Figure 11. ALP visual display with phonic groups

Figure 12. SUB visual display with category groups

5.2.1.1 *Colour-coding*

In this study, visual organisation of the display through colour-coding was used extensively to guide visual attention to specific areas on the visual displays. The ALP visual display consisted of 19 letter groups, with the symbols arranged alphabetically in a left-to-right, top-to-bottom orientation, forming horizontal groups defined by the first letter of the gloss. The size of the groups varied across the letter groups, but the 19 colour groups were small compared to the six visually distinct category groups formed in the SUB display. There were up to four repeats of each colour group in the ALP display, but only one of each colour in the SUB display. The colour cued groups in the two displays fulfilled both direct and symbolic cue criteria.

Direct cues take the form of visual features at or near the probable location of the target, such as boxes or other markers and serve primarily as bottom-up influences (Wright & Ward, 1998). Direct cueing of attention in this study was seen in the use of distinct coloured areas in the display. These areas represented finite areas of probability where the target could be found, reducing the functional set-size (Wolfe et al., 2011). Direct cueing to a unique, relatively large colour group was more evident in the SUB visual display compared to the ALP visual display where cueing was to multiple, relatively small coloured areas.

Symbolic cues direct attention to probable locations of the target, serving as top-down influences in the task (Wright & Ward, 1998). Symbolic cueing of attention in this study was in the form of category and phonic information which, if determined through cognitive processes, could direct attention to the specific areas to begin searching in. In the ALP visual display, search could be guided to areas on the screen such as the top, middle or bottom of the visual field, depending on the first letter of the target symbol and its place in the alphabet. In ALP, for a few cases such as for targets beginning with the letters *a* and *z*, a more precise initial search location was prompted – search could be guided to commence at the top or the bottom of the screen, as well as on the left or the right of the visual field. Visual search rates for the *ant* item and the *zebra* item were the lowest across ALP and also were among the very few items that were faster to locate on the ALP display than on the SUB display (Appendix Z). However, in the ALP visual display, most of the letter groups lay somewhere between the *a* group and the *z* group, and many cognitive processes were required to manage a search for a specific target. Intuitively, it can be understood that the further away the initial letter of the target item was from the two ends of the alphabet, the less known the relative positioning of the letter in the alphabet would be and the less deductive the positioning of the target item in the visual field would be. The rows had to be scanned until the group representing the first letter was found; that group then had to be scanned symbol by symbol. It could be expected that target location rates would decrease the closer to the centre of the alphabet the initial letter of the target symbol was. Analyses support this concept. The middle third of the visual field had the slowest mean times for target location (Table 23).

Alphabet knowledge was relatively inefficient in serving as a direct cue to guide search to specific locations in the ALP visual display (except for symbols starting with letters at the beginning or end of the alphabet) as it was not supported by a unique colour-coded area. The colour-coded areas in ALP were not distinct groups that could be visually isolated with one attentional fixing, but were spread out horizontally.

The combination of symbolic and direct cueing may have had a strong influence on the results of target location in the SUB visual field. Category knowledge (symbolic cueing) directed search (even prior to search beginning) to a specific area in the SUB visual display which was further facilitated by strongly demarcated unique colour groups (direct cueing) reinforcing the symbolically cued area. Set-size was efficiently reduced (Wolfe et al., 2011).

However, where incorrect category identification had occurred (invalid cueing), there may have been prolonged or unsuccessful searching, with resultant reduction in rate and accuracy (Wright and Ward, 1998). Escape responses (the opportunity given the participants to move on to the next test item without locating the current item by selecting the *forward* arrow) were considered to be mostly due to the inability to locate the target symbol, and had a mean time of 17.83 sec. in SUB, compared to a mean time of 4.92 sec. across all the test items (Table 18).

5.2.1.2 The gloss

Each symbol had a gloss above it. However, there was no way to guarantee that the information in the gloss would be noticed or used during the tests. It may be that the participants focused their attention on the picture only.

Use of the ALP search strategy was dependent on the correct name being assigned to the symbol. In ALP, a wrongly assigned mental name would result in the participant searching in an area of the alphabetically ordered field that would not lead to efficient location of the target symbol. No name assigned to the mental representation of the symbol (despite its presence above the symbol) would lead to a random search through the visual display. For example, if the dragonfly was incorrectly given the mental name of *fly* or *mosquito* in ALP, it would be searched for amongst the *f* or *m* symbols instead of the *d* symbols.

This *one and only* name demand for the ALP search strategy was not as important in the SUB visual display, because search was guided by category awareness rather than the phonic information abstracted from the symbol's name. It was possible for the search to be guided to the correct category without any knowledge of the symbol name, or even with a wrongly assigned name. Categorisation of symbols can bypass name retrieval (Snodgrass & Vanderwart, 1980), or be processed without language (Schlosser, 1997b). If the category of the symbol could be deduced from picture recognition alone, an efficient search (a search utilising the information cue) could begin and the target could be selected using visual memory only. For example, if a dragonfly was incorrectly named in SUB, it could still be mentally assigned to the *Little Creatures* category and searched for efficiently.

5.2.2 Task requirements

5.2.2.1 Search strategy

In ALP, symbols were positioned alphabetically in a left-to-right and top-to-bottom orientation in the visual display. Once the first letter of the symbol name was correctly identified and the relative positioning of that letter in the alphabet was determined and used to inform where in the visual display the search should commence, a cued search could begin. Eye movements had to scan horizontally from left-to-right along the rows for the letter group in which the target symbol could be found and then had to scan further from symbol to symbol within a group. Sometimes, eye movements had to jump from the far right of the display to the far left of the next row in the display if the group of symbols beginning with the same letter had to scroll on to the next row. A visual search in an alphabetically ordered display could often not be processed in a manner approaching a parallel method, but rather had to be processed serially.

In SUB, the symbols were placed in six visually distinct areas of the visual field. Cueing to a group in SUB resulted in a more compact area being searched, one that would probably be processed in fewer attentional fixings, maybe even in parallel for the smaller groups.

Serial processing is mostly slower than parallel processing (Wolfe, 1998). The serial processing required in ALP probably contributed to the slower location rates noted in ALP compared to the faster parallel processing that was facilitated in SUB. Over the full sample, the mean time for ALP was 337.55 sec. compared to the mean time for SUB which was 180.50 sec. (Table 12).

For those participants who did not make use of the cued information, search was probably close to a random search, although not totally so. Where there is structure in a visual field, people learn to exploit that structure in their visual searches (Chun & Yuhong, 1998) and where targets are presented in identically arranged (repeated, predictable) displays they are located faster and more accurately than in novel or random displays (Geyer et al., 2010). It may seem a reasonable assumption that any organisation in the visual display would result in faster location rates than in a random display, even when that organisation is not perceived. Therefore, participants who did not make use of the cued information and who searched randomly could be expected to have had slower location rates than those who did apply the cued information, but probably not as low rates as would be the case if the display was randomly organised.

An incorrect application of the cued information may have led to a different search performance compared to non-application of the available cueing information. The cost of invalid cueing is a reduction in speed and accuracy (Wright & Ward, 1998).

It could be that location rates are found to be *slower* when attempting to apply organisational strategies with cognitive demands that are beyond the current skills of the user, compared to location rates in randomly organised displays. During the ALP test, it was noted that some of the participants who were not scanning for letter groups were searching systematically through the rows and columns, item by item, rather than randomly scanning through the full visual field as would be expected in a random display.

5.2.2.2 Mental representations

The processing of both linguistic symbols and visual-graphic symbols systems need to be considered in language processing when a visual mode is used (Wilkinson & Jagaroo, 2004), as was the case in this visual search task. The visual representations of the target, together with their semantic associations, had to be kept in active memory while linguistic processes directed the search.

It could be that, for the age group in this study, linking taxonomic information to the mental representation of the symbol was easier than linking alphabetical information. Associating taxonomic information to a symbol is a process that is aligned to a natural categorisation process occurring in all symbol recognition and in language comprehension itself (Schlosser, 1997a). Phonemic and alphabet rules, however, are learnt through formal education. The difficulties with associating alphabetic information with the symbols may have been one of the factors impacting on the slower and less accurate performance of the participants in ALP compared to SUB (Table 15).

Although both phoneme identification and letter matching to those phonemes becomes increasingly efficient through educational instruction, it was still a developing skill for the age group in this study. The increasing rate and accuracy of performance in ALP as grade increased (Table 15) as well as the decreasing difference between the use of ALP and SUB as grade increased (Table 16), is indicative of the growing efficiencies of alphabetic skill in these grades.

5.2.2.3 Working memory

It appears that the working memory demands of applying alphabetical ordering principles compared to applying taxonomic information had an important influence on the results. The slower and less accurate performance in ALP compared to SUB (Table 15) are indicative of the working memory demands in ALP being greater in ALP than in SUB. Figure 13 is an extension of Figure 2, a schematic representation of the various processes that active attention has to switch between in a visual search task (Olivers et al., 2011) and includes a description of the working memory processes required specifically for this study, highlighting the differences in processing between ALP and SUB. The processes in grey blocks are common to all visual search tasks. The purple blocks refer specifically to working memory processes related to the alphabetical order search strategy. The green blocks refer to processes related to the categorisation search strategy. The differences between ALP and SUB processing will be referred to throughout the following text.

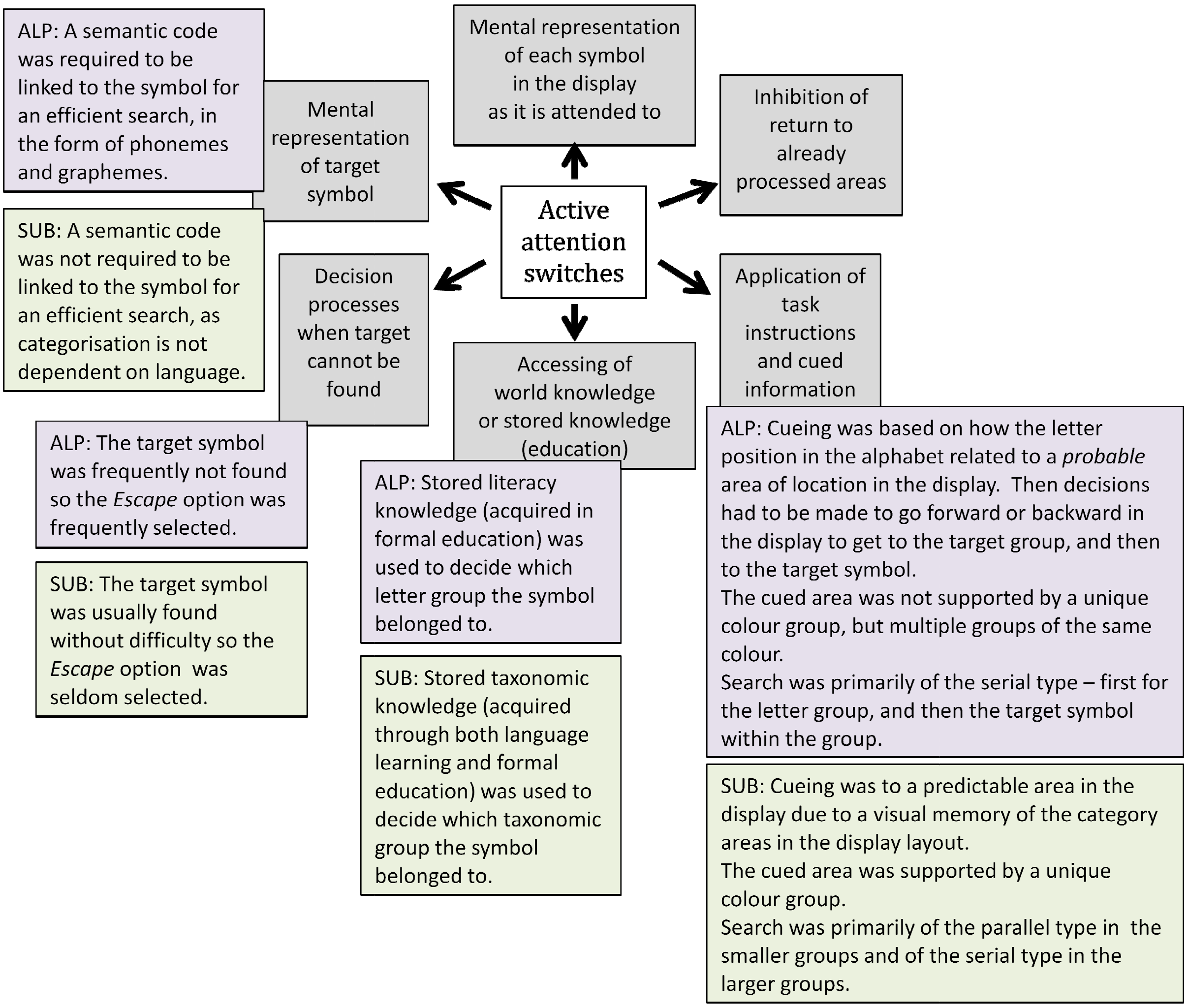


Figure 13. Active attention switches in ALP and SUB

A process specific to this study's task requirements compared with the visual search task of many other visual search studies is the active application of stored literacy and taxonomic knowledge. While the taxonomic knowledge of the participants of this study was relatively mature, their literacy knowledge was in the early stages of development. Allocation of a taxonomic category to a symbol may have been a relatively efficient process, being a similar process to that occurring in language (Schlosser, 1997b). However, abstracting a phoneme out of a word representing a symbol, matching a letter of the alphabet to the phoneme, working out the letter's relative positioning in the sequence of the 26 letters of the alphabet (which may or may not have been learnt yet), then locating the position of the group of symbols represented by that letter in a field of symbols through a loop of correction and over-correction, may have been costly on working memory demands.

Managing the search strategy required more mental processing in ALP than in SUB because eye movements had to scan mostly serially in ALP (from left-to-right in horizontal areas) but could scan mostly in parallel in SUB. However, what most differentiated the working memory demands of ALP and SUB appears to be the application of the cued information that was required in ALP but not in SUB. In ALP, much decision making processing was required to direct the search process, whereas in SUB the search process benefited from memory of distinct, unique category area location.

Information is required at each stage of working memory processing, but may only be available for a limited time frame (Roivainen, 2011). It may be that where working memory processes were too demanding to maintain all the processes, the mental representations of the symbols could not be sustained over the full processing time. Loss of the target symbol from working memory may be the explanation for the many selections of the escape option which occurred during testing. Indicative of the possibility that the mental representations dissipated over time is that the mean time across all items in the ALP test was 9.11 sec., but for the escape selections was 24.08 sec. The mean time across all items in the SUB test was 4.92 sec., but for the escape selections it was 17.83 sec. (Table 18). Escape selections were probably frequently made when the participant forgot the target symbol. Escape selections occurred more frequently in ALP than in SUB for all grades (Table 17), probably because of the greater working memory demands in ALP.

It may also be that the mental representations of the distractor symbols and inhibition of return factors differ when task requirements vary, as in the ALP and SUB search strategies, but are beyond the scope of this study, as there is little literature to support the enquiry.

5.3 Developmental factors

Within both the search strategies that were investigated in this study, increasing grade had a significant impact on the rate and accuracy of the participants' performance. This indicated the developmental nature of the use of both these strategies. Not only did visual search efficiencies increase as grade increased, but there were also decreasing differences between the participants' performance in the two strategies as the grade of the participants increased.

The developmental factors that were considered most likely to impact on this study in the use of these strategies in this study (based on the literature survey and the results are: (1)

alphabetical order skills; (2) categorisation skills; and (3) working memory (including attention and concentration). These skills are interrelated and cannot be isolated, nor can their relative influence be inferred. However, investigating them separately will aid in highlighting their influence on the results of this study.

5.3.1 Alphabetical order development

The results of this study clearly indicated the growing efficiencies of the participants in their use of alphabetical ordering skill as grade increased. The mean time to complete the test decreased from 434.07 sec. in Grade 1, to 324.15 sec. in Grade 2 and 225.18 sec. in Grade 3 in ALP (Table 13). The mean score increased from 28.91 correct scores in Grade 1, to 31.91 in Grade 2 and 34.06 in Grade 3 (Table 13). It appears that with each increasing grade the task became cognitively less demanding. It may be that increasing competencies in this skill would continue to increase in grades beyond the grades investigated in this study.

The difference between the efficiency in SUB compared to ALP decreased markedly as grade increased, indicating that the efficient use of the two strategies may become more similar as learners move to higher grades. In Grade 1, the mean time difference between ALP and SUB was 219.30 sec., decreasing to 156.33 sec. in Grade 2 and 76.64 sec. in Grade 3) (Table 13). In a similar trend, the mean score difference decreased from -3.84 correct scores in Grade 1 to -1.91 in Grade 2 and -0.58 in Grade 3 (Table 16).

Functional alphabetical ordering requires practice to master increasingly complex alphabetizing tasks. It cannot be achieved by an explanation of the process only. Because of the pre-requisite learned skills and working memory demands in executing an alphabetizing task, functional alphabetical ordering is cognitively a highly demanding skill. This is especially so for learners at the beginning stages of acquiring literacy. However, it is a trained skill that most learners acquire within the first few years of schooling and become increasingly adept at using. Alphabetizing skills are usually mastered to a high level of automaticity in adults (Oxley & Norris, 2000).

Although the youngest of the participants had sufficient alphabetic knowledge to pass the selection criteria, identifying the first phoneme of a word may not have been a well-developed skill for them yet. For the oldest of the participants, identifying the first phoneme of a word was probably a well-established skill.

Due to literacy development, it could be expected that the participants in the lower grades decoded the gloss slower and less accurately than the participants in higher grades did

(Sturm, et al., 2006) and therefore probably made less use of the information in the gloss during their searches

5.3.2 Categorisation development

Categorisation skill increased as grade increased. The mean time to complete the test decreased from 214.77 sec. in Grade 1, to 167.82 sec. in Grade 2 and 148.55 sec. in Grade 3 in SUB (Table 15). The mean score increased from 32.74 correct scores in Grade 1, to 33.82 in Grade 2 and 34.64 in Grade 3 (Table 15). The Grade 3 participants were faster and more accurate at visual search in SUB than the Grade 2 participants were, and the Grade 2 participants were faster and more accurate at visual search in SUB than the Grade 1 participants were.

Whereas applied alphabetical order is predominantly a learned skill, categorisation is more of a language skill with a learned, educational component. It was important to this study that the participants were developmentally ready, had sufficient category knowledge and had the cognitive learnability and flexibility to adapt to the given category framework.

Firstly, categorisation in language is mostly presented in the research literature as dependent on age and cognitive development (Section 2.4.1). A developmental milestone is described by many researchers as occurring around 6-7 years of age with respect to categorization (Krackow & Gordon, 1998; Wilkinson & Rosenquist, 2006), as children absorb the taxonomic categorisation patterns of adults. However, taxonomic categorisation continues to develop through young childhood and into many years of school (Scott & Greenfield, 1985). The youngest participants in this study were between the ages of 6 and 7 years. They represented the age-group that would be developing a taxonomic system for organizing items in their lexicons (Fallon et al., 2003; Wilkinson & Rosenquist, 2006). The Grade 1 learners (6-7 years) were able to understand and use the category framework in this study, but they may have been less secure in the categorisation tasks required of them than the Grade 3 learners were, as can be seen in the increasing efficiency in the categorisation task as grade increased.

Secondly, besides being a function of cognitive development, categorisation is also dependent on world knowledge and education. It has been shown that the development of concept organization in typically-developing children is related to language experience, the level of adult language input and modelling, the child's overall language mastery, formal school instruction (Fallon et al., 2003) and taught associations (Quist and Lloyd, 1997).

Category knowledge of the symbols used in this study was maximised through the piloting phase (where the most consistently named and categorised symbols were selected), as well as through the instruction (where category definitions were well explained) and pre-testing (which served as a selection criterion of competence in the use of the category groups of this study).

Thirdly, in this study, the subcategorisation of symbols within a category was presented as an externally created, absolute, unchangeable framework within which the user was required to make choices. How close the enforced categorization mapped to the participant's internal cognitive or lexical organizational strategies (Wilkinson et al,, 2006) was a concern in the study, as was the expectation that the participants would be able to understand and use that semantic organization (once explained to them and practice opportunities allowed), even if it was not immediately transparent to them. However, there is much literature to support the view that children of the age-group in this study have sufficient learnability and flexibility in their categorization skills to meet the demands of the categorization framework given them (Blaye & Bonthoux, 2001).

The skill of flexibility in categorisation was utilized in the current study, since the participants had to adjust their categorical concepts to fit the category definitions set for them. Instruction before the test made use of the category-use effect, where new category properties are readily absorbed into existing category knowledge (Hayes & Younger, 2004; Ross et al., 2005). Defining the principles on which the participants could base their classifications may have enlarged or refined their own internal concepts of the categories used in this study. Learning may have taken place not only for the demands of this study, but also as a contribution to the participants' general world knowledge. This positive effect of instruction could be expected over the full age range of participants in the current study (6-9 years).

As taxonomic categorisation skills continue to develop throughout the school years (Scott & Greenfield, 1985), the trend seen in the results in this study of increasing efficiency in the SUB test as grade increased could be expected to continue in grades beyond the sample group of this study (Grades 1-3). However, the incremental differences between participants in Grade 2 and Grade 3 was already not statistically significant in the SUB test, indicating that by Grade 2 or 3 categorisation skills were probably reaching maturity (Table 15). It may even be that developing categorisation efficiencies after Grade 2 is more due to increases in attention, concentration and working memory than to development in the cognitive skill of categorisation.

This study supports the literature which suggests that children of the age of 6-7 years are developmentally able to use and apply taxonomic categorisation, are able to adjust to a given taxonomic organisation and are probably still maturing in the categorisation skills.

5.3.3 Working memory development

Working memory in visual search skills require both the ability to focus attention on task-relevant features in a visual field while simultaneously limiting attention to irrelevant elements (Carlin et al., 2002). Younger children show little ability to display selective attention, whereas older children are much better than younger ones at concentrating on relevant information and filtering out extraneous input that may interfere with task performance (Shaffer, 2002). The ability to focus and maintain attention is therefore a developmental process and may be an important reason for the developmental trend seen in the results. The decreasing tendency to opt for escape selections as grade increased may be an indicator of an increasing ability to focus and maintain attention. In ALP, escape selections decreased from 13.05% in Grade 1, to 5.72% in Grade 2 and 2.69% in Grade 3. In SUB, escape selections decreased from 4.26% in Grade 1, to 2.36% in Grade 2 and 1.26% in Grade 3 (Table 19).

5.4 Gender factors

Significant gender differences were only noted in the rate with which the participants completed ALP. The female participants completed ALP in a mean time of 361.52 sec. while the male participants completed ALP in a mean time of 310.29 sec. (Table 13). There were no significant gender differences in the rate with which the participants completed SUB or in their accuracy levels in either of the two tests (Table 14).

Research has shown that females generally have faster processing rates than males (Roivainen, 2011). However, although gender differences have been noted in many of the specific cognitive and motor subtests, such as higher rapid naming rates and phonological coding tasks in females and greater reaction times in males, no significant differences have been found in general intelligence (Roivainen, 2011).

The results of this study could be interpreted as consistent with the data presented in Roivainen’s literature review referred to above. It is only in the cognitively more demanding requirements of the ALP test that gender differences in rate were noted. Males were no less accurate in their selections than females, nor slower in SUB. The reasons for slower processing rates in males are inconclusive and often involve the nature-nurture debate (Roivainen, 2011).

Gender differences were also seen in greater variability in the results of the male participants compared to the female participants. The males showed greater variability in the time means in ALP compared to SUB, as well as greater mean differences between their rate performances in ALP compared to SUB. This variability of performance was not noted in the accuracy scores (Table 13).

5.5 The impact of bottom-up influences

Visual search theory has identified many perceptual features that impact on visual search efficiencies. However, the symbols used in this study were not the single-featured basic symbols of most visual search research. They were complex symbols, having numerous perceptual and semantic components associated with them.

There is already some support in the literature for the proposal that the influence of perceptual features in experimental research symbols carries over into the meaningful symbols of AAC use (Wilkinson et al., 2006). In this study there were strong top-down cognitive processes guiding the visual search. Although it is cognitive factors that predominantly guide attention, not the influence of low-level features (Betz et al., 2010) and although when top-down and bottom-up guidance are placed in competition, top-down guidance dominates (Chen & Zelinsky, 2006), the results of this study suggested the possibility that bottom-up factors still had an influence during the execution of the tasks in the strong top-down requirements of this study. There was a wide range of search rates and accuracy scores for the symbols used (Appendix Z). The mean location times for the 36 test items ranged from 2.52 sec. to 21.05 sec. in ALP, and 2.12 sec. to 13.58 sec. in SUB (Table 21). Some items were clearly easier to find than others were, indicating that there may have been bottom-up factors influencing visual search efficiencies in this task with its strong top-down component.

It was proposed, firstly, that if statistical relationships between the results and some features could be found, despite the study not being designed to measure those relationships, then there was a strong probability that the impact of those features did carry through from experimental visual research to this more functional and real-life study with its heavily loaded top-down task requirements. Secondly, if visual perceptual influences were to be evident in this study, they would probably be less evident while using the strategy that was cognitively more demanding. This is because the sensory information gathered on initial perception would be so loaded with the heavy top-down processing demands that there would be fewer opportunities for bottom-up processes to lead to pop-out effects or to capture attention (Chen & Zelinsky, 2006). Most of the attention would be deployed to the task itself. When search tasks are demanding, top-down context cueing guidance predominates, but when tasks are more efficient, bottom-up guidance can capture attention more readily (Geyer et al., 2010).

It has already been shown that the top-down search strategies used and the participants' developing alphabetical order and categorisation skills influenced the results of this study.

Bottom-up factors of vigilance, position in the visual field, colour, size and visual complexity were also explored for influence on the results. However, it is highly likely that these are only a few of the bottom-up factors influencing the results in this study as the variations in Time and Score data across the items cannot be explained by these factors only.

5.5.1 Vigilance

The impact of vigilance (the ability of the participant to maintain a high level of detection performance in visual search tasks over long periods (Uttal, 1998)) was investigated in this study, comparing the performance of the participants over time. It was considered important to investigate the impact of vigilance, because the ability to perform in a repetitive visual search task has been shown to generally decline as time goes by (Uttal, 1998), and the tasks in this study demanded a high level of attention.

The cross-over design of the study sought to ensure that there was no influence of fatigue related to the order of presentation of the two tests. An analysis of variance indicated that order of presentation was not significant in this study (Table 11) and that fatigue had not influenced the results.

However, vigilance is related to a neural fatigue limiting visual search performance, not the general fatigue which is related to decreasing efficiency in one test following another. To investigate the impact of vigilance, Spearman correlation coefficients were found for the relationship between the time taken to complete the research task and the sequence of presentation of test items. All the correlations were found to be low, suggesting that vigilance did not influence the results of this study (Table 21). The participants were no slower at the end of the task than they were at the beginning of the task. Occasional very long response times were considered to be due to the lapse of attention and/or the loss of the sensory information memory store or the dissipation of the information from working memory. These events, although they may have been related to fatigue, were not more frequent during the execution of later test items than earlier ones.

However, the vigilance factor in this study must be understood alongside the learning (or practice) factor in visual search, the influence of which may have been in the opposite direction to the influence of vigilance. The influence of decreased vigilance may have been compensated for by increased learning during task execution. The participants were presented with the same visual field over multiple experiences of interacting with it and it is possible that some visual memory of the display occurred during task execution. There are learning effects in early stages of visual processing; visual search performance improves with practice (Wolfe, 2003) and reaction times to targets in identically arranged displays are faster, relative to novel or random displays (Geyer et al., 2010).

5.5.2 Position in display

The literature has indicated that visual search may be impacted by hemifield dominance, with a generalised rightward bias. The right visual field may be advantaged in reaction time tasks where stimulus discrimination is required (Reuter-Lorenz & Moscovitch, 1990).

Although there were significant differences across the means of the column and row groups in both ALP and SUB (Table 23), the results of this study did not consistently support the rightward hemifield bias noted in the literature. The right visual field was the slowest in ALP. The mean time for *Left* was 9.37 sec., *Centre* 8.69 sec. and *Right* was 10.20 sec. There were no significant differences between *Right*, *Centre* and *Left* in SUB. It is probable that other influences in this study were stronger than the influences of this rightward bias. Some of the results were also more easily understood by analysing the eye-tracking demands of the two search strategies than the above mentioned perceptual field biases.

Left-to-right eye tracking required for reading was probably a well established skill for the school-going participants in this study, so it can be expected that for at least the majority of the participants ALP was approached with a left-to-right search strategy. If search tended to start on the left for most of the items, it could offer some explanation why the right side of the field tended to slower location times. A similar line of reasoning could explain why search location rates were significantly faster in the top row of the ALP visual field, with eye-tracking movements tending to start from the top and work to the bottom.

The column variations for rate of symbol location noted in ALP were not significant in the SUB (Table 23), probably because the SUB visual field was not structured in rows requiring left-to-right eye tracking, but rather for searching in distinct areas that could be rapidly located from memory. Row variations in SUB indicated a decrease in location rates from top-to-bottom. The mean time for *Top* was 5.83 sec., *Middle* 5.10 sec. and *Bottom* 4.11 sec. The reason is unknown but a possible explanation may be that the laptop computer screen, with its slight backward tilt to maximise visual clarity and colour, was more able to capture attention in the bottom row of the field (which was closer to the participant) than the top row of the field (which was further away from the participant).

5.5.3 Symbol features

5.5.3.1 Size

The size of the symbols was found to have significant negative correlations with visual search location times, but only in SUB (correlation coefficient -.31 p=.01) (Table 24). That is, as the size of the symbols increased in SUB, the search times decreased or, the location rates became faster. It could be that because the alphabetical strategy was more cognitively demanding, perceptual influences of size were inhibited by the greater processing demands of the task relative to the demands of categorisation.

Experimental visual search literature reports that if the size difference is sufficient, a target of one size will be found efficiently among distractors of another size, but looking for the medium sized item among larger and smaller items is inefficient unless the size differences are very large (Wolfe, 1998).

5.5.3.2 Colour

Colour has already been shown to have an influence in visual tasks (Wilkinson & Jagaroo, 2004) and is extensively used in AAC practice.

The results suggest that colour in the symbols had an impact on the rate of target location in both the ALP and the SUB tests of this study. There were significant differences between the location times of the colour groups. The mean time was highest for the brown group (followed by the grey group) in both ALP (10.79 sec.) and SUB (6.05 sec.). The mean time was the lowest for the red/orange group in both ALP (7.14 sec.) and SUB (3.17) (Table

25) which is consistent with the finding that warmer colours are more salient than cool colours (Bruce & Tsotsos, 2009).

Colour within symbols increases perceptual salience (Wilkinson & Jagaroo, 2004). For symbols to pop-out due to colour in the symbols, the colour of the distractors has to be different. Only four of the 36 symbols were classified as red/orange in colour. The contrast between their colour and the other colours may be another reason for the faster location times.

Although some of the positive effects of a highly coloured visual field may be offset by the confounding effects of distractors, it appears that maximising the physical differences among symbols in a visual field reduces inter-stimulus confusions, increasing the rate of location of targets (Wilkinson et al., 2006).

5.5.3.3 Visual complexity

The results indicated that visual complexity had a weak negative relationship with visual search time. As visual complexity increased, location times tended to decrease (Table 26). However, this relationship was significant only in the SUB strategy (correlation coefficient -.26, p=.01). It may be that the symbols that were visually more complex (had more detail) were able to capture attention more effectively in the categorisation strategy than the alphabetical order one. Conversely, it could be that, because the alphabetical order strategy was more cognitively demanding, perceptual influences of visual complexity were inhibited by the greater processing demands of the task relative to the demands of categorisation.

A relationship between visual complexity and picture naming times has been found in the literature, where the relationship is one where greater visual complexity results in increased naming response times (Szekely & Bates, 2000). It may be that increased visual complexity is related to slower naming rates (due to slower picture recognition) but to faster visual search times.

In the literature the impact of visual complexity appears uncertain. Visual complexity may facilitate visual memory and visual search through the provision of more details to capture attention. However, visual working memory may be negatively impacted by visual complexity (or the feature load of the item) due to the cost of maintaining the mental representation of the symbol (Fougnie et al., 2010). The more complex the symbols, the smaller the number of items that can be maintained in working memory are.

Wilkinson & Jagaroo (2006) suggested that message preparation in AAC usage may be enhanced if the symbols were visually simpler to locate. The results of this study seem to indicate the converse may be true in the large displays of meaningful symbols used in this study.

5.6 Clinical implications

A discussion on the variability amongst the participants noted in the results and the tendency to error selection amongst the participants, as well as some implications for display design arising out of the results follows.

5.6.1 Variability between performance of individuals

This study was designed as a group study, and the data have been presented for the groups as a whole. However, within-test variability in the results indicated a wide range of participant performance, although variability between the participants decreased as grade increased (Table 13). Within-test variability was particularly evident when using the alphabetical order display. Between-test variability indicated that the difference between the performances of the participants in the categorisation visual display compared to the alphabetical order visual display decreased with increasing grade (Table 16).

The variability of responses between the participants indicated that it cannot be assumed that all children within a given grade will respond similarly to the group tendencies with respect to their visual search performance with one strategy over another and that it is ill-advised to draw conclusions about individual behaviour on the basis of the group characteristics (Wilkinson & Rosenquist, 2006). An assessment of individual skills may be necessary before clinical decisions are made concerning the provision of organised visual displays.

It may be that the variability between the participants in each grade will also continue to decrease as grades increase, as well as the variability between their performance using an alphabetical order search strategy or a categorisation strategy.

5.6.2 Errors

Errors in target selections were made during the visual searches. The results indicated that with increasing grade the percentage of escape and error selections decreased in both

ALP and SUB. For all the grades both the escape and error percentages were higher for ALP than for SUB (Table 17). The escape option was frequently used in Grade 1, particularly in ALP where 13.05% of all selections were escape selections (compared to 4.26% in SUB). By Grade 3, participants were achieving 94.53% accuracy in their selections in ALP and 96.21% in SUB.

The lower accuracy in ALP compared to SUB must be seen in the context of the increased tendency to make escape selections in ALP, and not simply as an increased tendency to make error judgments. That the alphabetical search strategy resulted in more errors was rather due to the inability to locate symbols in an alphabetically ordered visual field than to make target identification error selections.

Escape selections could have been made for many reasons, including when the participants could not find the target item and gave up searching for it, forgot the target item that was being searched for (loss of sensory information or dissipation of coded mental representations from working memory during processing), did not attempt to find the target item, or made a selection error due to an accidental mouse click.

Error selections could have been made when the participants made a target identification error due to incomplete, inaccurately coded or fading mental representations, or made a selection error due to an accidental mouse click. Incomplete, inaccurately coded or fading mental representations may be due to too little time to perceive and encode a full mental representation, loss of attention or being held for too long in working memory.

The actual errors made may be informative as to the coding of the mental representation (Brady et al., 2011) after perception of the symbol. Appendix AA is a record of the symbols that had the most errors associated with them. It is beyond the scope of this study to analyse why specific errors were made. However, it would be informative to understand if the errors were due to errors in the visual codes or the semantic codes.

5.6.3 Implications for display design

For AAC interventionists, it is important to consider both visual and semantic factors when designing effective visual displays for storing vocabulary (Wilkinson & Rosenquist, 2006). Once the vocabulary has been determined and the graphic system chosen, the interventionist has to determine how the message symbols will be displayed for most efficient retrieval when required (Strauss et al., 2007). Decisions such as the number of symbols and type of organisation have to be made. If the choice is a large number of related symbols in a grid system, the following criteria could be considered: (1) a taxonomic or alphabetical organisation; (2) the features of the symbols; (3) colour-coded visual organisation of displays; and (4) the addition of a gloss.

5.6.3.1 Alphabetical versus categorised display arrangements

For pre-school learners who have not yet learned the alphabet, alphabetically organised displays would be similar to randomly organised displays and are clearly unsuitable. However, for learners of increasing grade, growing literacy skills would result in increasing visual search competencies using alphabetical order as their search strategy.

It may appear on a theoretical basis that for children with emerging taxonomic categorisation skills individually designed AAC systems are the most suitable option (Lucariello, in Fallon et al. 2003). This is because any given set of symbols pre-grouped into categories in an AAC system will probably have symbols that are not compatible with the internal lexicon and semantic organization of people using that system. The problem with individually arranged displays is that it may be difficult to assess and accurately represent those individualized organizations on behalf of the children (not knowing exactly where each exemplar lies within their internal systems). The children would need to participate in the arrangement of the symbols in the display, but adult mediation would be required from the earliest stages of organization, through to on-going instruction of the vocabulary arrangements (Fallon et al., 2003). There is also little certainty that displays organised according to children's current needs would be accessible to those same children when they tried to access the vocabulary items in functional use. It may be that they are unable to efficiently access their own arrangements, because placement of items into categories does not mean efficient retrieval out of those categories. Inconsistency has been noted in children's categorisation attempts between sessions (Fallon et al., 2003). Individuality of associations across various children and their rapid cognitive development resulting in changes to their internal semantic organisation networks would mean frequent changes to the AAC system. It is extremely inefficient to build idiosyncratic systems customized for each individual's use and developing needs. Clinicians cannot be expected to accommodate such customization (Wilkinson & Rosenquist, 2006). Also to be considered is the partner who has to teach the user or interact with the user. If the semantic organization of the system is not transparent to the partner, it may be difficult for the partner to navigate through it or to teach it (Wilkinson & Rosenquist, 2006).

Due to the above practical issues and limitations, in a clinical situation a taxonomically arranged AAC system vocabulary is usually organized for the user on the basis of the linguistic concepts of the professional/caregiver who sets up the AAC system, often with fairly standardized vocabulary arrangements. For beginner users of dynamic visual displays the most practical solution is often for clinicians to provide a ready-made option. Researchers have shown how learnable and flexible a given categorization system is (even for young children) (Blaye & Bonthoux, 2001), thereby giving the clinician confidence that a pre-programmed taxonomical system could, once taught, be readily learned and used. As a user's communication competence develops, a more meaningful personalized reordering of location of symbols in categories and subcategories can occur. Through use (and where the clinician is aware that structural organization is not transparent), explicit highlighting and teaching of relations may be sufficient to aid the user in successful use of the system. Besides, learning conventional organizational structures is important because they form the basis of most educational curricula (Wilkinson & Rosenquist, 2006).

This study has indicated that for children in Grade 1, Grade 2 and Grade 3 a taxonomically organised visual display would be more efficient (faster to locate the symbols and less cognitive demands) than an alphabetically organised display. Also, the literature and this study support the premise that children in this age-range are capable of using a taxonomic categorisation framework designed and provided for them by adults.

However, alphabetically ordered displays may serve children's developmental interests better than taxonomically ordered displays, especially after the first few grades as alphabetical skills develop and become cognitively less demanding to apply. The ability to navigate through an AAC system alphabetically is an important skill for an AAC user to achieve. In a taxonomical AAC system each category will have its own unique subcategories, the principles of which will have to be learned for each category, whereas the same alphabetic principle will hold throughout an AAC system.

There is little research about how effectively the Grade 1 to 3 children would respond to instruction to develop alphabetical order skills. Because phonemic and spelling skills are rapidly increasing at this stage, it is possible that instruction in application of alphabetical skills to locate words and symbols in a display would see marked decreases in visual search rate. Mizuko, Reichle, Ratcliff and Esser (1994) argued that complex AAC systems can become automated with the acquisition of skill.

If optimising an efficient comprehensive AAC system is the long-term goal, more important than temporary efficiency, visual search instruction in an alphabetically ordered grid system may be more advantageous in the long term than visual search instruction in category use, provided that longer instruction time is acceptable (Hochstein et al., 2004). However, due to the high visual and cognitive cost of searching alphabetically for learners in the early grades, a phased approach may be more suitable. A phased approach could have the symbols ordered alphabetically within their category groups, having the groups themselves alphabetical and where category grouping is not intuitive, smaller pages of alphabetically ordered displays can be used.

However, it is important to note that in AAC populations, specific challenges in alphabetical or categorisation skills, or even in picture use skills, may influence performances in alphabetical and categorised visual displays.

5.6.3.2 Symbol features

It is clear from the literature review of previous research as well as from this study that the features of the symbols used in AAC displays influence the rate of symbol location. The use of foreground colour (Thistle & Wilkinson, 2009) and maximising the physical differences among symbols in a visual field increases the speed of location of targets (Wilkinson et al., 2006). Motion has also been shown to be effective in enhancing symbol location rate (Jagaroo & Wilkinson, 2008). This study suggests the influence of other symbol features such as size and visual complexity. AAC users and clinicians are advised to maximise these facilitators. AAC computer software often allows for manipulation of these features.

5.6.3.3 Colour-coding

Of interest in this study was the use of colour-coding to visually organise the display. The colour-coding served to demarcate areas in the grid, the purpose being to limit the set-size or the search area.

The colour coding used by FitzGerald and Goosens' served to identify parts of speech that were related (Beukelman & Mirenda, 1998). The symbols with similar background colours were not specifically grouped in a spatial manner, but may have been found in various positions within one display. However, it does not seem to be the colour background itself that facilitates the visual search (Thistle & Wilkinson, 2009), but the grouping of the visual field that the colour backgrounds allow.

It is proposed that cueing is most effective if there is convergence of symbolic (top-down) cues and direct (bottom-up) cues. This convergence was applied in this study where the symbolic cue in the form of a specific group of symbols to a distinct area in the display was the same as the direct cue in the form of a coloured area in the display.

The FitzGerald colour-coding method was consistently applied across all displays. In an AAC system organised by categories, consistency of colour-coding would not be possible. Every category in the system would require a unique application of categorisation. However, alphabetically ordered displays could capitalise on the consistency seen in the FitzGerald systems, having all words starting with the same letters have the same colour backgrounds. A predictability of colour association with the initial letter of a word would result over time.

It has been found that targets presented within identically arranged (repeated, predictable) displays are located faster and more accurately than targets in novel or random displays (Geyer et al., 2010). Although this predictability is referring to spatial predictability (where the same items appears on each display), the principle could probably hold true for cueing as well. For example, if all the words beginning with *m* are always in the centre of the visual display, with a blue background, visual search for words beginning with *m* could be expected to be facilitated.

5.6.3.4 Gloss

A gloss accompanying the symbol has become standard in AAC use and has theoretical support. Besides securing a consistency between labels, Callanan (1985) points out that the presence of a word or label helps children sort by category, allowing them to overcome their preference for thematic relations and focus on similarity among members of the same taxonomic category. This concept is similar to that presented by Schlosser – whenever something is named, it is also categorized (Schlosser, 1997a). The support of a gloss in an alphabetically ordered display is important, as it identifies the exact word by which the symbol will be organised in the display, as well as guides the search to a probable location in the display.

The role of the gloss in guiding visual search in ALP and SUB was discussed in Section 5.2.1.2, where it was argued that the information in the gloss was more important to efficient search in ALP than it was in SUB. This may indicate an advantage of using categorised visual displays over alphabetised visual displays in multi-lingual contexts. In these contexts, the same visual display can be provided for users in different languages if the symbols are organised taxonomically, but not if they are organised alphabetically.

5.7 Summary

Searching in a taxonomically arranged display was faster and more accurate for Grade 1 to 3 participants than it was in an alphabetically ordered display. The greater efficiency of searching in the taxonomic display was probably due to a more effective cueing system (both top-down and bottom-up), less demands on working memory and less reliance on learned skills still in development.

The difference between the efficiency of the search in the taxonomically and alphabetically ordered displays decreased as grade increased, suggesting the possibility that the differences between them may become negligible in later grades.

Top-down influences were shown to be more efficient in SUB than in ALP. Bottom-up perceptual influences were shown to have an influence in the tasks of this study, despite the heavy top-down requirements of the search tasks. Bottom-up influences were often greater in SUB than in ALP. It may be that the greater cognitive demands of ALP compared to SUB inhibited the influence of bottom-up factors more in ALP than in SUB.

The integration of top-down guidance and bottom-up colour coded areas in the displays was discussed as an efficient cueing strategy for visual search in the large displays used in this study.

This study indicated the advisability of provision of taxonomically arranged AAC displays for young users. However, it was argued that, based on the decreasing between-test differences between the participants, it may be advantageous to future requirements to phase the children into an alphabetically ordered system. This can be done through use of alphabetical order within taxonomic groups, and alphabetical order arrangements where taxonomic arrangements are impractical. Instruction and experience was also presented as a means of reducing the working memory demands of the initially more complex alphabetically ordered displays.

AAC clinicians could also consider the influence of symbol perceptual features in display design, particularly the colour, size and visual complexity of the symbols.

Chapter 6

Conclusion and critical reflection on the study

6.1 Introduction

In this chapter, the aim of the study, its purpose, design, methodology, and results and findings are summarized. The study is also evaluated in terms of its strengths and limitations and some recommendations for future research are suggested.

6.2 Summary of study

This study was conducted to investigate the effectiveness of, and differences between, visually locating symbols in alphabetically ordered layouts on the one hand and categorized layouts on the other. The participants were children at the beginning stages of acquiring literacy (Grades 1 to 3).

The 114 participants executed two computerized tests in which they were required to visually locate 36 animal symbols. The visual displays were either ordered alphabetically and colour-coded by initial letter, or arranged and colour-coded in subcategory groups. The order of presentation of the two tests was alternated. The participants also executed three computerized pre-tests before commencing the main tests. The pre-tests served to determine mouse control proficiency, basic alphabetical knowledge and ability to use the categories chosen for the tests. Data were automatically collected in a log file.

It was found that the participants located symbols faster and more accurately in a categorized layout compared to an alphabetically ordered layout, but with decreasing variation between the use of the two strategies as grade increased. However, variation in performance was found between the participants, both within the two tests as well as in the range of differences between the two tests.

It was also found that bottom-up perceptual factors influenced the participants in their rate of symbol location. Position in the display, size, colour and visual complexity were identified as bottom-up attention-drawing factors for the participants in this study while they were executing visual searches.

Young AAC users at the beginning stages of literacy acquisition may find the cognitive processing required for using alphabetically ordered displays costly for efficient use but colour-coded categorised visual displays within their categorization skills. However, the efficient use of alphabetically ordered displays increases as grade increases. Beyond Grade 3 the differences between the efficient use of these two organization methods for visual displays may no longer be significant.

Alphabetical order is a useful organizing strategy to aim for in AAC users because it can be applied across all visual displays. However, where literacy problems present in AAC users, it may be more suitable to provide message symbols organised in categorized displays.

6.3 Critical evaluation of the study

A critical evaluation of the study will be given in terms of the strengths of the study, the limitations to the study and the weaknesses of the study.

6.3.1 Strengths of the study

Strengths of the study are: (1) the cross-over counterbalance design; (2) the user-friendly computer interface; (3) appropriate materials and instruction; (4) the participants' independent control of the task; and (5) the position of the study as a bridge between visual cognitive science and AAC.

Firstly, the cross-over group design of this study added strength in terms of the validity of the results. The design sought to counterbalance the threats to the internal validity of the study caused by the interactions between aspects of the design (DePoy & Gitlin, 1994) which, in this case, was the order of presentation of the two tests. The results indicated that the ALP test took longer and was probably cognitively more demanding than the SUB test. Order of presentation was therefore indeed an important variable to consider. Statistical analysis indicated that there were no statistically significant differences between the groups in terms of order of presentation. In addition, the sample number (114) divided into two equivalent groups was large enough for the meaningful application of statistical procedures.

Secondly, the user-friendly, easily-operated computer interface was a successful method of presenting the test. All the participants were able to successfully work through the procedural aspects of the tests (even although they might not have successfully applied the available strategies for efficient search). Also, the use of computer logging allowed for objective measurement of the dependent variable.

Thirdly, the materials used and the instruction of the participants appeared well-suited to the study. The symbols used for the study were carefully selected during the development phase through pre-testing their familiarity, naming consistency, and categorization suitability for the age range of the participants. The instruction program for the participants and practice opportunities which were provided before the test to familiarize them with the two strategies of searching for symbols in a visual display appeared to be adequate and suitable. Only two participants failed to pass the pre-tests. This pre-testing of the skills required for the task also verified that the participants had the requisite skills for the task.

Fourthly, the participants could control the progress of the task. Only the time between activating the single target symbol and finding it in the visual display was measured. The time taken to activate the target symbol was not measured. This method resulted in the participants only progressing through the task if their attention was engaged, because they had to activate the next step in the procedure themselves. For methodologies where the appearance of the next target is unsolicited, unnecessary long times may have resulted before the participants reengaged their attention to the task.

Fifthly, the current study is positioned within the field of AAC, a field which has its roots in clinical and educational practice, as well as in the field of cognitive science, with its focus on theory development focus (Light & Lindsay, 1991). The study endeavoured to investigate principles of visual cognition in AAC use, thereby bringing together the disciplines of visual cognitive science and AAC. It attempted to align the task that the participants were required to do more closely to typical AAC use than typical visual search experimental tasks do. Appendix AB presents a detailed analysis indicating the similarities and differences between experimental research, typical AAC use and this study. This study is aligned with AAC graphic display usage primarily with respect to the visual characteristics of the symbols, the arrangement of the symbols within a grid, the colour cueing in the symbols and grid, the referential nature of the symbols, the use of a gloss and the direct selection of a target which remains available until located. It is, however, also aligned to experimental visual search primarily with respect to the non-contextual, non-functional use of single symbols that are exposed to the observer for a subsequent recognition match. There is very little similarity between experimental visual search research and typical AAC use, but this study has commonalities with both. This study may be useful in informing the AAC discipline concerning principles of AAC board design, as well as in informing cognitive science concerning the interaction between top-down task demands and bottom-up influences, thereby bridging a gap between two disciplines that have seldom communicated with each other (Alant et al., 2006).

6.3.2 Limitations to this study

Limitations to this study were seen primarily in: (1) the use of a typical population during the experimental phase; (2) the non-contextual, non-functional single noun symbol use in the ALP and SUB tests; (3) the absence of practice and memory support in the test (which was a first exposure search only); (4) visual perception of the target before search; and (5) the measurement measure.

Firstly, although the use of typical participants in this study is a limitation in the applicability of the findings to the AAC population, it was considered the most appropriate methodology for this translational study where a sound understanding of the topic was required before it could be tested and analysed within an atypical population (Alant et al., 2006). In AAC it is often generally accepted to use typically developing children as a means to evaluate processes in children who do not present with confounding factors of sensorineural, cognitive, social, motor or emotional impairments (Wilkinson et al, 2006). The topic investigated in this study required this approach (Section 2.3.3 provides a more detailed discussion on this topic). Despite the acceptable practice in AAC research of using typical populations, it is acknowledged that not only are the results of this study based on the performance of typically developing children, but the literature review which supports this study is based on the performance of typical adults with intact visual systems. The study is therefore based in a population that is dissimilar to the population to which it is being applied. However, preliminary research has shown that the principles of experimental visual search may transcend across non-typical populations (Wilkinson et al., 2008).

Secondly, the use of non-contextual, non-functional use of single symbols for nouns in this study is mostly a non-typical use of AAC symbols (although people communicating with graphic symbols do sometimes use single symbols to generate messages). AAC use is by nature a purposeful, functional communication of a message which often requires a number of words of different grammatical classes strung together. Visual search performance may be different if applied to sentence generation rather than to searching for and selecting one symbol only.

Thirdly, an integral part of functional AAC use – but not required in this study – is the application of memory. Memory is required to know whether a symbol is present or absent in a display, on which display to begin the search and where the symbol is located in the display. In typical AAC use, the user of the communication boards (displays) has usually had multiple exposures to the symbols. Memory storage of symbol location would almost certainly impact on the efficiency of performance in the visual search tasks of this study because practice may significantly reduce the demands of symbol search on working memory. In addition, this study investigated the rate and accuracy performance in first exposure to the symbols only. Search after repeat exposures may give different results. It may be that symbol categorisation variances between where users make their initial search and where they actually find them are rapidly adapted to, making subsequent searches more efficient. It may also be that the skill of searching by alphabetical order can improve rapidly with instruction and practice. It could even be that memory of symbol location is so influential that the search strategies are only minimally applied in subsequent exposures.

Fourthly, in typical AAC use, although there is visual search for each and every symbol selection, there is no prior perception of the target before a search begins. In visual search experiments, a target is presented and must then be searched for, with the perception of the target active as a mental representation. In AAC use, the target exists only as a concept in the mind of the user as a dormant mental code. In experimental visual search, as in this study, a target presented by the researcher initiates the search process. The visual perception of the target then resides in working memory, awaiting a recognition match during the search. In AAC use, the user initiates the target search on the basis of a message that needs to be communicated. A match in the visual display has to occur against a coded symbol pulled out of long-term memory storage. In typical AAC use there is no actual recognition match, so it is not a true visual search task.

And lastly, the selection time was measured in seconds, because The Grid™ software used in the study did not provide for smaller units of time. There was therefore no differentiation between selections made within 1.01 seconds or 1.99 seconds, which would have given a more detailed analysis. However, in most experimental visual search research, the response times for target locations are very quick, necessitating a measure within milliseconds, whereas in this study, with its heavy top-down demands, target selection times were generally much longer. Also, as mean times were considered in all analyses, rather than individual times, across 109 participants and 36 items, the mean times resulting from measuring in seconds could be expected to be close to the mean times resulting from measuring in milliseconds.

A weakness of this study was the integration of the pre-testing and testing and the procedural errors that resulted in some compromised data. The pre-testing and testing was conducted in the same session. The purpose of this procedure was to ease ethical considerations of not having children aware of failure to meet the selection criteria. However, this resulted in a great deal of unnecessary testing for the research team (19 additional participants), as well as unnecessary complications in the subsequent management of data. It was fortunate that the two sample groups remained balanced after the loss of participants who failed the selection criteria. Another weakness in this study was the 23.39% missing and compromised sound files required for verifying procedural integrity. The rating of the procedural integrity by an independent assessor also indicated some paraphrasing in the script while the research assistants were giving instructions to the participants. Although representing a weakness in a study, it is considered by the researcher not to have significantly influenced the results, due to the detailed and repetitive nature of the instruction.

6.4 Recommendations for further research

The results of this study revealed a variety of interesting trends, thereby raising many more questions that may be answered in subsequent research.

Application of a similar study conducted amongst children in higher grades. It could be informative to investigate if the differences between searching by alphabetical order and searching with a categorisation strategy in Grade 1 to 3 children, as noted in this study, would continue to decrease with respect to time and accuracy as grade increases. It could be that alphabetical order search may even become more efficient than categorization search as literacy competencies increase, or that individual preferences may emerge rather than strong group tendencies.

Application of a similar study conducted with people with disabilities. Although it has been shown that the principles of visual cognitive science are fairly consistent across many clinical conditions (Wilkinson et al., 2006; Hochstein et al., 2004), application of the principles of visual cognitive science to AAC user populations is still to be researched. It would be valuable to investigate to what degree the principles of visual cognitive science can be applied to these populations (Wilkinson & Jagaroo, 2004). In the case of people with cognitive disabilities it may even be that the differences in their performance on cognitive processing tasks lie more in differences in the sensory information they receive than in cognitive mediation differences (Carlin et al, 2002). Due to the extensive language challenges often faced by young AAC users, and the meaningful nature of the symbols used in the tests, AAC user performances in alphabetic or category organised displays may appear very different compared to those described in this study with typically developing children.

A study of the impact of colour-coding on location rate and accuracy in visual search. Colour-coding was integrated with the organizational strategies of presenting the symbols in the displays in this study and therefore may have been influential on the results, although its specific influence could not be analysed separately from the influence of the layout design itself. Colour-coding is used a great deal in AAC intervention, but variably and with a paucity of research to support choices (Wilkinson, Carlin, & Jagaroo, 2006). Thistle and Wilkinson's (2009) study investigated colour-coded cell backgrounds, but there is still much to learn about their impact on visual search. Is there a difference between the impact of colour-coded cell backgrounds or colour-coded cell borders? Are brighter or more muted colour backgrounds more influential? Under what conditions are colour-codes distracting rather than helpful? How many colour groups would facilitate search, how large do they need to be and how must they be distributed to maximize visual search efficiency?

The influence of the gloss on location rate and accuracy. Future research could determine the influence of the gloss which is associated with the symbols in visual search tasks, and whether the presence of a gloss improves rate of location and accuracy.

The impact of practice on reducing location rates and increasing location accuracy. This study only investigated the impact of first exposure of a symbol on location rate and accuracy. It would also be interesting to investigate the impact of repeat exposures to reduce visual search times and increase location accuracy or to investigate how many repeat interactions on a symbol are required to approach a location rate and accuracy that no longer improves. It is important to establish whether the effect of bottom-up factors changes over time, practice, familiarity and learning (Thistle & Wilkinson, 2009). Uttal (1998) pointed out that serial processing can convert to parallel processing with increased experience, indicating the adaptability of the observer.

Can the skill of visual search be improved? In addition to visual search practice on a familiar display, research could seek to determine if there is also an impact on the skill of visual search in novel displays. Visual search performance can improve with experience (Baeck & Op de Beeck, 2010), but does practice only carry-over within a task, or across tasks as well?

The impact of individual search variables on location rate and accuracy. This study did not control for any of the search variables discussed in research question 2, yet some variables were found to have been influential on the results. Future studies might well venture to try and control for the impact of individual search variables on the process. The variable that has been investigated the most in an AAC context is colour. Size and visual complexity are variables that are well suited to further AAC symbol research, since they are characteristics of most AAC symbols and are controllable. This study indicated that they may be influential in typical AAC displays.

Do bottom-up influences increase or decrease as top-down requirements increase? This study indicated that bottom-up processes may be more influential when top-down requirements are less. Future studies could more formally determine the relationship between bottom-up influences and top-down requirements. Studies could investigate whether bottom-up influences are greater or lesser in randomly organized displays (where top-down task requirements are minimized) compared to organized displays, or in displays that have variable working memory demands.

Studies investigating the nature of mental representations. Research has not yet been able to identify the nature of mental representations of symbols, or the extent to which they are coded visually or semantically in the mind (Uttal, 1998). In AAC use, the form of the mental representations (which may vary across diagnostic populations and language development) could impact on search efficiencies. Some other methods of presenting a target symbol could be explored to add to the understanding of mental representations, such as: (1) an auditory presentation of the target symbol name, rather than a visual one (for example the word *dog* rather than the graphic). The word would have to be mentally translated from an auditory code into a visual code for a recognition match to occur; (2) an indirect prompting of the target symbol (for example a photograph of a dog, a phrase clue *The animal that barks* or a sound recording of a bark). The target would have no initial direct mental code, auditory or visual, to serve as the code for a recognition match; (3) a different visual representation to the target symbol in the display (for example the *dog* symbol used in the initial presentation is different to the one used on the display). The mental representation elicited on the initial presentation of the symbol would have to be matched against any possible representation of that symbol in the display; and (4) presentation of the target as a single symbol which has to be searched for in complex symbols (for example searching for a dog in a garden scene with a kennel and a dog beside it).

6.5 Summary

This study was designed and executed to investigate and compare the efficiency of visual search using alphabetical order and categorization search strategies in Grade 1 to 3. 114 participants executed two computerized tests. Results indicated that this age group was faster and more accurate using a categorization search strategy, but that the differences between the two tests decreased as grade increased. Perceptual features of the symbols were also found to have influenced the results. Reasons for these differences and implications of the findings for AAC use were discussed. This study, which was aligned to both experimental visual search in the field of cognitive science, as well as to the field of AAC research, fulfilled its initial objectives and revealed a number of questions for future research.

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Appendix A: Animal symbols available, used and rejected

No.	Animal symbol	Subcategory	Function of included symbols and reason for rejected symbols
1	eagle	birds	Category identifiers on group animal symbols - used in subcategory training and in the SUB Pre-test
2	flamingo	birds	
3	woodpecker	birds	
4	donkey	farm animals	
5	hen	farm animals	
6	sheep	farm animals	
7	butterfly	little creatures	
8	grasshopper	little creatures	
9	worm	little creatures	
10	bunny	pets	
11	goldfish	pets	
12	kitten	pets	
13	crab	water animals	
14	dolphin	water animals	
15	seahorse	water animals	
16	bear	wild animals	
17	snake	wild animals	
18	squirrel	wild animals	
19	bird	birds	36 test items for the 2 tests
20	ostrich	birds	
21	owl	birds	
22	parrot	birds	
23	cow	farm animals	
24	duck	farm animals	
25	goat	farm animals	
26	horse	farm animals	
27	ant	little creatures	
28	dragonfly	little creatures	
29	fly	little creatures	
30	ladybird	little creatures	
31	lizard	little creatures	
32	mouse	little creatures	
33	spider	little creatures	

No.	Animal symbol	Subcategory	Function of included symbols and reason for rejected symbols
34	budgie	pets	36 test items for the 2 tests (cont)
35	cat	pets	
36	dog	pets	
37	jellyfish	water animals	
38	octopus	water animals	
39	seal	water animals	
40	starfish	water animals	
41	stingray	water animals	
42	whale	water animals	
43	dinosaur	wild animals	
44	elephant	wild animals	
45	fox	wild animals	
46	gorilla	wild animals	
47	kangaroo	wild animals	
48	leopard	wild animals	
49	monkey	wild animals	
50	polar bear	wild animals	
51	rhino	wild animals	
52	skunk	wild animals	
53	tiger	wild animals	
54	zebra	wild animals	
55	bee	little creatures	5 animal symbols for the SUB Pre-test
56	giraffe	wild animals	
57	pig	farm animals	
58	puppy	pets	
59	shark	water animals	
60	camel	wild animals	5 animal symbols for the ALP Pre-test
61	frog	little creatures	
62	hippo	wild animals	
63	lion	wild animals	
64	snail	little creatures	

No.	Animal symbol	Subcategory	Function of included symbols and reason for rejected symbols
65	beetle	little creatures	3 animal symbols used for demonstration in instruction program
66	oyster	water animals	
67	wolf	wild animals	
68	peacock	birds	6 animal symbols for the participants to practice with in the instruction program
69	lamb	farm animals	
70	mosquito	little creatures	
71	hamster	pets	
72	fish	water animals	
73	koala bear	wild animals	
74	robin	birds	No specific use made of these symbols in the main study, but used as fillers for the visual displays for the two tests
75	seagull	birds	
76	rooster	farm animals	
77	cricket	little creatures	
78	beaver	wild animals	
79	hyena	wild animals	
80	panda bear	wild animals	
81	porcupine	wild animals	
82	pelican	birds	Not used - excess symbols from 120 available (After rejection of some of the 120 symbols, there were 92 symbols left. Only 81 were required for the visual displays)
83	stork	birds	
84	turkey	farm animals	
85	caterpillar	little creatures	
86	killer whale	water animals	
87	lobster	water animals	
88	walrus	water animals	
89	buffalo	wild animals	
90	bull	wild animals	
91	deer	wild animals	
92	hedgehog	wild animals	

Refected *after* testing (developmental stage)			
93	canary	birds	Rejected, either because of low subcategorisation scores, or low picture naming scores
94	crow	birds	
95	hummingbird	birds	
96	penguin	birds	
97	swan	birds	
98	vulture	birds	

No.	Animal symbol	Subcategory	Function of included symbols and reason for rejected symbols
99	chck(en)	farm animals	Rejected, either because of low subcategorisation scores, or low picture naming scores (cont.)
100	bat	little creatures	
101	chameleon	little creatures	
102	cockroach	little creatures	
103	moth	little creatures	
104	mouse2	little creatures	
105	scorpion	little creatures	
106	wasp	little creatures	
107	otter	water animals	
108	prawn	water animals	
109	chimpanzee	wild animals	
110	crocodile	wild animals	
111	rabbit	wild animals	
112	raccoon	wild animals	
113	reindeer	wild animals	
114	tortoise	wild animals	
115	birds	birds	Group symbols were not placed on the visual display.
116	farm animals	farm animals	
117	little creatures	little creatures	
118	pets	pets	
119	water animals	water animals	
120	wild animals	wild animals	

Rejected *before* testing (developmental stage)			
1	alligator/crocodile	wild animals	Rejected - another name for same animal
2	locust/grasshopper	little creatures	
3	animals	other	Rejected - collective name
4	cattle	farm animals	
5	baby animals	baby animals	Rejected - diminutive
6	calf	baby animals	
7	colt	baby animals	
8	duckling	baby animals	
9	joey	baby animals	
10	kid	baby animals	
11	piglet	baby animals	
12	tadpole	baby animals	

No.	Animal symbol	Subcategory	Function of included symbols and reason for rejected symbols
13	dragon	other	Rejected - mythical creature
14	monster	other	
15	animal	other	Rejected - not transparent
16	baby animal	baby animals	
17	insect	little creatures	
18	insects	little creatures	
19	shellfish	water animals	
20	bear (grizzly bear)	wild animals	Rejected - similarity to another animal
21	cheetah (leopard)	wild animals	
22	ox (cow)	farm animals	
23	turtle (tortoise)	water animals	
24	toad (frog)	little creatures	
25	black cat	pets	Rejected - specificity
26	Brontosaurus	other	
27	cockatoo	birds	
28	cuckoo	birds	
29	daddy longlegs	little creatures	
30	Dalmatian	pets	
31	Diplodocus	other	
32	Pteranodon	other	
33	rattlesnake	wild animals	
34	Stegasaurus	other	
35	Triceraptops	other	
36	armadillo	wild animals	Rejected - unfamiliar to South African children of target age group
37	badger	wild animals	
38	blue jay	birds	
39	boar	wild animals	
40	chipmunk	wild animals	
41	clam	water animals	
42	coyote	wild animals	
43	dingo	wild animals	
44	emu	birds	
45	firefly	little creatures	
46	gerbil	little creatures	
47	goose	farm animals	Rejected - unfamiliar to South African children of target age group (cont)
48	groundhog	wild animals	
49	guinea pig	pets	
50	hare	wild animals	
51	hawk	birds	
52	heron	birds	
53	iguana	wild animals	
54	jackal	wild animals	
55	kookaburra	birds	
56	llama	wild animals	
57	lyre bird	birds	
58	magpie	birds	
59	mole	little creatures	
60	moose	wild animals	
61	mule	farm animals	
62	newt	little creatures	
63	oppossum	wild animals	
64	parakeet	birds	
65	pheasant	birds	
66	platypus	water animals	
67	pond skater	little creatures	
68	puffin	birds	
69	quail	birds	
70	shrimp	water animals	
71	squid	water animals	
72	tropical fish	water animals	
73	wallaby	wild animals	
74	wombat	wild animals	

Appendix B: Development of a symbol list - scoring sheet

Name	
Number	
Gender	
Grade	
School / Centre	
Home language	
School language	

	Animal	Name given	Subcategory	Subcategory chosen
1	ant		little creatures	
2	bat		little creatures	
3	bear		wild animals	
4	beaver		wild animals	
5	bee		little creatures	
6	beetle		little creatures	
7	bird		birds	
8	budgie		pets	
9	buffalo		wild animals	
10	bull		wild animals	
11	bunny		pets	
12	butterfly		little creatures	
13	camel		wild animals	
14	canary		birds	
15	cat		pets	
16	caterpillar		little creatures	
17	chameleon		little creatures	
18	chicken		farm animals	
19	chimpanzee		wild animals	
20	cockroach		little creatures	
21	cow		farm animals	
22	crab		water animals	
23	cricket		little creatures	
24	crocodile		wild animals	
25	crow		birds	
26	deer		wild animals	
27	dinosaur		wild animals	
28	dog		pets	
29	dolphin		water animals	
30	donkey		farm animals	
31	dragonfly		little creatures	
32	duck		farm animals	

33	eagle		birds	
34	elephant		wild animals	
35	fish		water animals	
36	flamingo		birds	
37	fly		little creatures	
38	fox		wild animals	
39	frog		little creatures	
40	giraffe		wild animals	
41	goat		farm animals	
42	goldfish		pets	
43	gorilla		wild animals	
44	grasshopper		little creatures	
45	hamster		pets	
46	hedgehog		wild animals	
47	hen		farm animals	
48	hippo		wild animals	
49	horse		farm animals	
50	hummingbird		birds	
51	hyena		wild animals	
52	jellyfish		water animals	
53	kangaroo		wild animals	
54	killer whale		water animals	
55	kitten		pets	
56	koala bear		wild animals	
57	ladybird		little creatures	
58	lamb		farm animals	
59	leopard		wild animals	
60	lion		wild animals	
61	lizard		little creatures	
62	lobster		water animals	
63	monkey		wild animals	
64	mosquito		little creatures	
65	moth		little creatures	
66	mouse		little creatures	
67	octopus		water animals	
68	ostrich		birds	
69	otter		water animals	
70	owl		birds	
71	oyster		water animals	
72	panda bear		wild animals	
73	parrot		birds	
74	peacock		birds	
75	pelican		birds	
76	penguin		birds	
77	pig		farm animals	

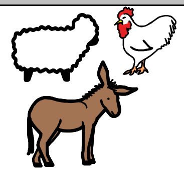
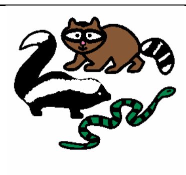
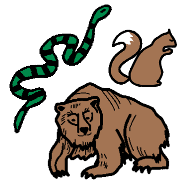
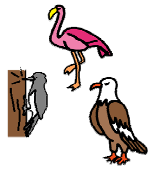
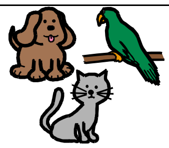
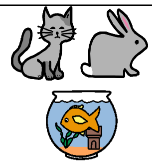
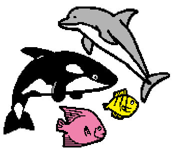
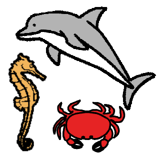
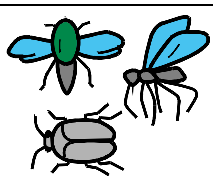
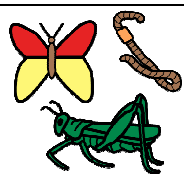
78	polar bear		wild animals	
79	porcupine		wild animals	
80	prawn		water animals	
81	puppy		pets	
82	rabbit		wild animals	
83	raccoon		wild animals	
84	rat		little creatures	
85	reindeer		wild animals	
86	rhino		wild animals	
87	robin		birds	
88	rooster		farm animals	
89	scorpion		little creatures	
90	seagull		birds	
91	seahorse		water animals	
92	seal		water animals	
93	shark		water animals	
94	sheep		farm animals	
95	skunk		wild animals	
96	snail		little creatures	
97	snake		wild animals	
98	spider		little creatures	
99	squirrel		wild animals	
100	starfish		water animals	
101	stingray		water animals	
102	stork		birds	
103	swan		birds	
104	tiger		wild animals	
105	tortoise		wild animals	
106	turkey		farm animals	
107	vulture		birds	
108	walrus		water animals	
109	wasp		little creatures	
110	whale		water animals	
111	wolf		wild animals	
112	woodpecker		birds	
113	worm		little creatures	
114	zebra		wild animals	
n/a	Birds		birds	
n/a	Farm Animals		farm animals	
n/a	Little Creatures		little creatures	
n/a	Pets		pets	
n/a	Water Animals		water animals	
n/a	Wild Animals		wild animals	

Appendix C: Name and category placement scores

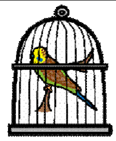
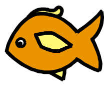
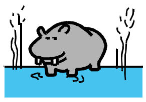
Grade	Grade 0		Grade 1				Grade 2				Grade 3	
Participant Number	0.1	0.2	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2
Gender	F	F	F	M	M	M	F	M	M	M	F	M
Expected name given to animal symbol	77	75	42	45	85	83	84	77	74	86	93	80
Placement of animal symbol into expected category	105	106	93	109	106	104	107	109	101	99	101	104

Total possible score = 120

Appendix D: Reworked PCS category group identifier symbols

No	Animal	Original PCS Symbol	Comment	Reworked PCS Symbol for the Main Study
1	Farm Animals		The cow and pig were required for the main study test items. The cow and the pig were replaced with a donkey and a hen.	
2	Wild Animals		The raccoon was not a familiar animal to the majority of the South African children of the target age range. The skunk was required for the main study. The raccoon and the skunk were replaced with a bear and a squirrel.	
3	Birds	None	No group symbol for Birds could be found amongst the PCS animal selection. Although some of the children could not name flamingo and woodpecker, these animals were fully understood by all the children as belonging to the Birds category.	
4	Pets		The puppy and the parrot were required for the main study. A bunny and a goldfish were added to the group. The goldfish was placed in an aquarium to maximise its association with the Pet category.	
5	Water Animals		The tropical fish and killer whale were not included in the list of 81 animals (only animals used in the visual displays of the main study could be represented in the category identifiers), and were replaced with a seahorse and a crab.	
6	Little Creatures		The original PCS symbol was more representative of Insects than the larger concept of Little Creatures which was required for the main study. The three PCS insects were replaced with a butterfly, worm and grasshopper.	

Appendix E: Changes to PCS animal symbols

	Animal	Original PCS symbol	Problem	Solution	Reworked Symbol
1	Budgie		The budgie was placed by some of the children in the Birds category.	The budgie was placed in a cage, so that it was clearly different from the other birds and facilitated it being understood as belonging to the Pets category.	
2	Goldfish		The goldfish was placed by some of the children in the Water Animals category.	The goldfish was placed in a fish bowl, so that it was clearly different from the other birds and facilitated it being understood as belonging to the Pets category.	
3	Hippo		The water that the hippo was standing in may have led to confusion when placing the hippo into the Water Animals rather than the Wild Animals category.	The water was removed, to prevent it being associated with the Water Animals group.	

Appendix F: Layout of visual displays

Layout of 81 symbols across the Alphabetical Order (ALP) visual display

	A	B	C	D	E	F	G	H	I	
1	**ANT**	bear	beaver	bee	beetle	**BIRD**	**BUDGIE**	bunny	butterfly	
2	camel	**CAT**	**COW**	crab	cricket	**DINOSAUR**	**DOG**	dolphin	donkey	**12**
3	**DRAGONFLY**	**DUCK**	eagle	**ELEPHANT**	fish	flamingo	**FLY**	**FOX**	frog	
4	giraffe	**GOAT**	goldfish	**GORILLA**	grasshopper	hamster	hen	hippo	**HORSE**	
5	hyena	**JELLYFISH**	**KANGAROO**	kitten	koala bear	**LADYBIRD**	lamb	**LEOPARD**	lion	**13**
6	**LIZARD**	**MONKEY**	mosquito	**MOUSE**	**OCTOPUS**	**OSTRICH**	**OWL**	oyster	panda bear	
7	**PARROT**	peacock	pig	**POLAR BEAR**	porcupine	puppy	**RHINO**	robin	rooster	
8	seagull	seahorse	**SEAL**	shark	sheep	**SKUNK**	snail	snake	**SPIDER**	**11**
9	squirrel	**STARFISH**	**STINGRAY**	**TIGER**	**WHALE**	wolf	woodpecker	worm	**ZEBRA**	
		14			**12**			**10**		

ANIMAL	36 animals selected for ALP test
number	Number of test items occuring in each third of ALP

Layout of 81 symbols across the Subcategories (SUB) visual display

	A	B	C	D	E	F	G	H	I	
1	donkey	**GOAT**	**LEOPARD**	**SKUNK**	**DINOSAUR**	beaver	wolf	**OSTRICH**	**BIRD**	
2	**HORSE**	pig	lion	**RHINO**	**MONKEY**	giraffe	hippo	flamingo	robin	**12**
3	sheep	lamb	**FOX**	squirrel	hyena	**KANGAROO**	panda bear	seagull	**OWL**	
4	**COW**	hen	bear	porcupine	**POLAR BEAR**	koala bear	**ELEPHANT**	**PARROT**	eagle	
5	**DUCK**	rooster	snake	**GORILLA**	**ZEBRA**	camel	**TIGER**	woodpecker	peacock	**12**
6	hamster	bunny	**OCTOPUS**	**STINGRAY**	crab	frog	worm	**MOUSE**	**LADYBIRD**	
7	kitten	puppy	**STARFISH**	shark	**SEAL**	cricket	bee	**FLY**	**ANT**	
8	**CAT**	**DOG**	dolphin	**WHALE**	**JELLYFISH**	mosquito	grasshopper	**LIZARD**	beetle	**12**
9	**BUDGIE**	goldfish	fish	seahorse	oyster	butterfly	**SPIDER**	**DRAGONFLY**	snail	
		11			**12**			**13**		

ANIMAL	36 animals selected for SUB test
number	Number of test items occuring in each third of SUB

Appendix G: The ALP and SUB tests and pre-tests

The two tests

The two tests each required 36 test items within a set of 72 linked grids. There were 36 test item grids (A-type grids) and 36 visual display grids either with the symbols organised alphabetically or categorically (B-type grids).

The A-type grids held the test item and were a single symbol cell with a white background within a grey display.

Test item

When the participant clicked on the test item in the A-type grid, a B-type grid would immediately appear showing an array of 81 animal symbols arranged either alphabetically or subcategorically in 9 x 9 cells (see below).

Alphabetical Order (ALP) visual display **Subcategorisation (SUB) visual display**

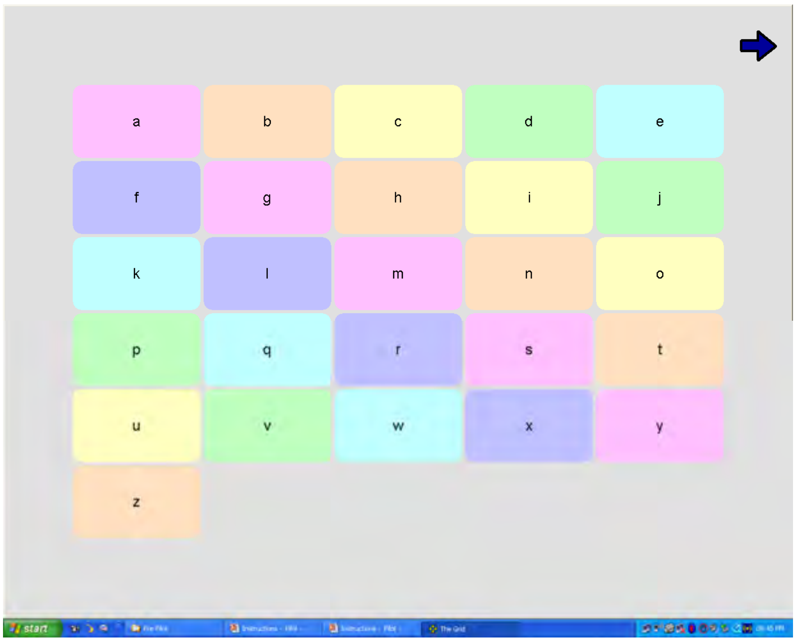
The participant's task was to locate and select the test item in the visual array. Once the symbol was selected, another single symbol (A-type grid) would appear. This process was repeated for each of the 36 test symbols.

The pre-tests

For the purposes of this study two pre-tests were designed – the ALP Pre-test and the SUB Pre-test. ALP Pre-test was designed to test the ability to determine the first letter of the animal name and to then find that letter in an alphabetically ordered array. SUB Pre-test was developed for testing the ability to subcategorise animals into the given groups.

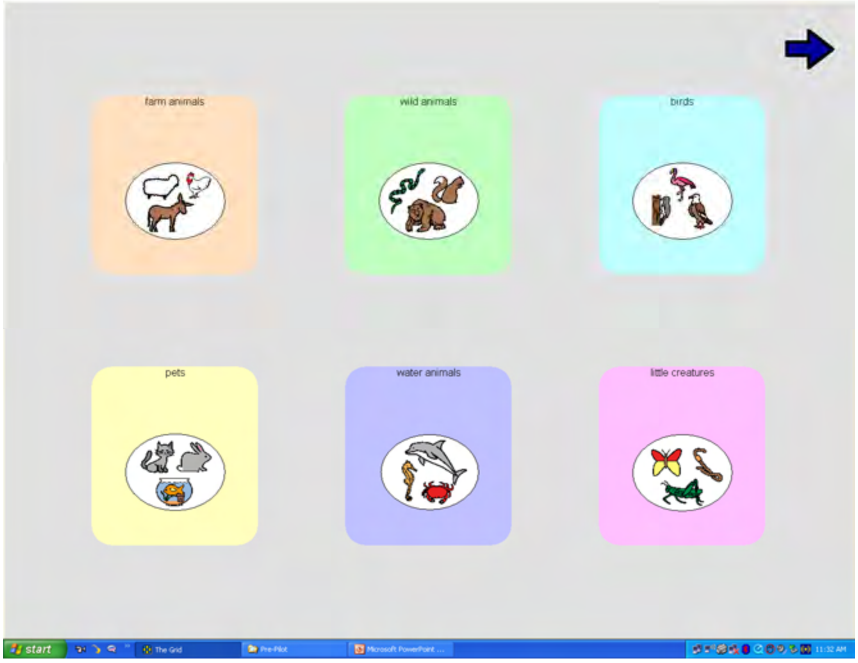
ALP and SUB Pre-tests were both used to assist in setting the criteria for the selection of participants. There were 5 test items in each of the test, within a set of 10 linked grids. Two types of grids were used, namely A-type pre-test grids and B-type pre-test grids. These pre-test A-type grids were identical to the A-type grids in the tests. When the participant clicked on the animal symbol, a B-type grid would immediately appear. 4 out of the 5 test items had to be selected correctly for the participant to pass the pre-test selection criteria.

The B-type grid in ALP Pre-test was a sequence of the 26 letters of the alphabet in a 5 X 6 array. The participants' task was to allocate the animal symbol which had been observed on the previous screen (A-type grid) to the alphabet letter which represented the first letter of the animal name. Once the letter was located and selected, another single symbol (A-type grid) would appear. This process was repeated for 5 items.



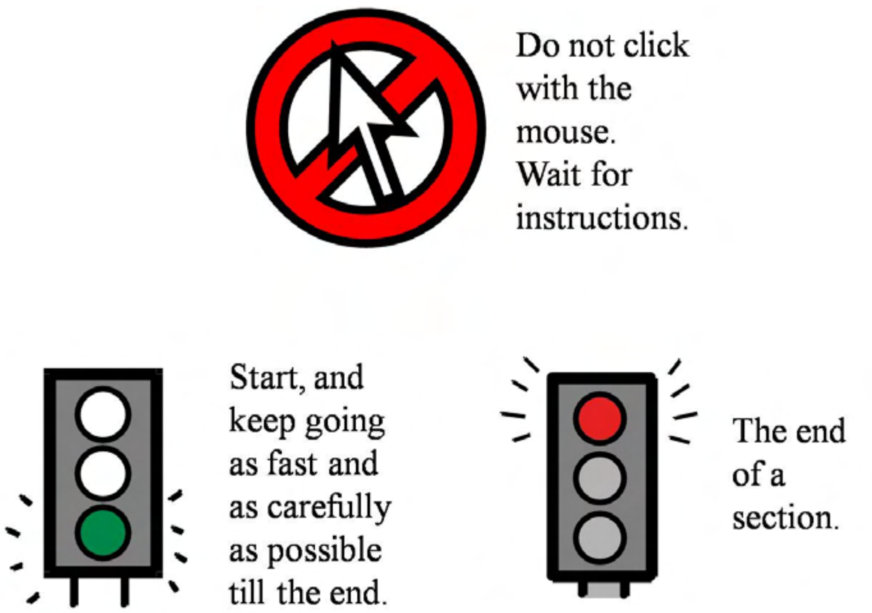
ALP Pre-test – B-type grid

The B-type grid in the SUB Pre-test was a 3 x 2 array of 6 groups of animal symbols which represented the six subcategories of animals identified in Step 1. The participant's task was to allocate the animal symbol on the previous screen (A-type grid) to its subcategory. Once the group symbol was selected, another single symbol (A-type grid) would appear. This process was repeated for 5 items.



SUB Pre-test – B-type grid

The following three symbols (*wait*, *go* and *stop*) were used to guide the participants through the test procedure.



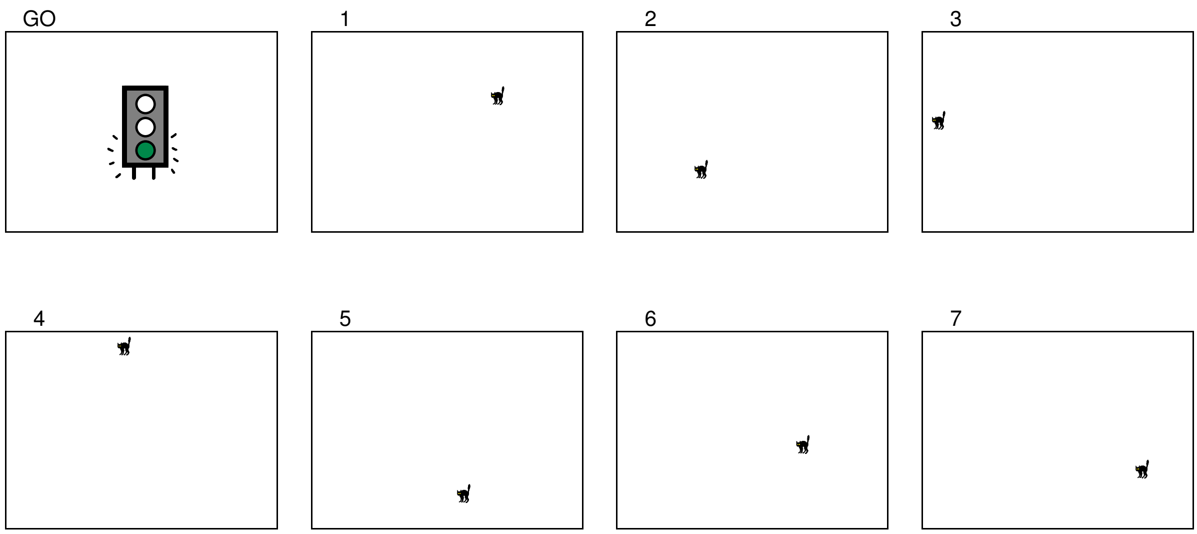
The symbols used to guide the participant through the test procedure

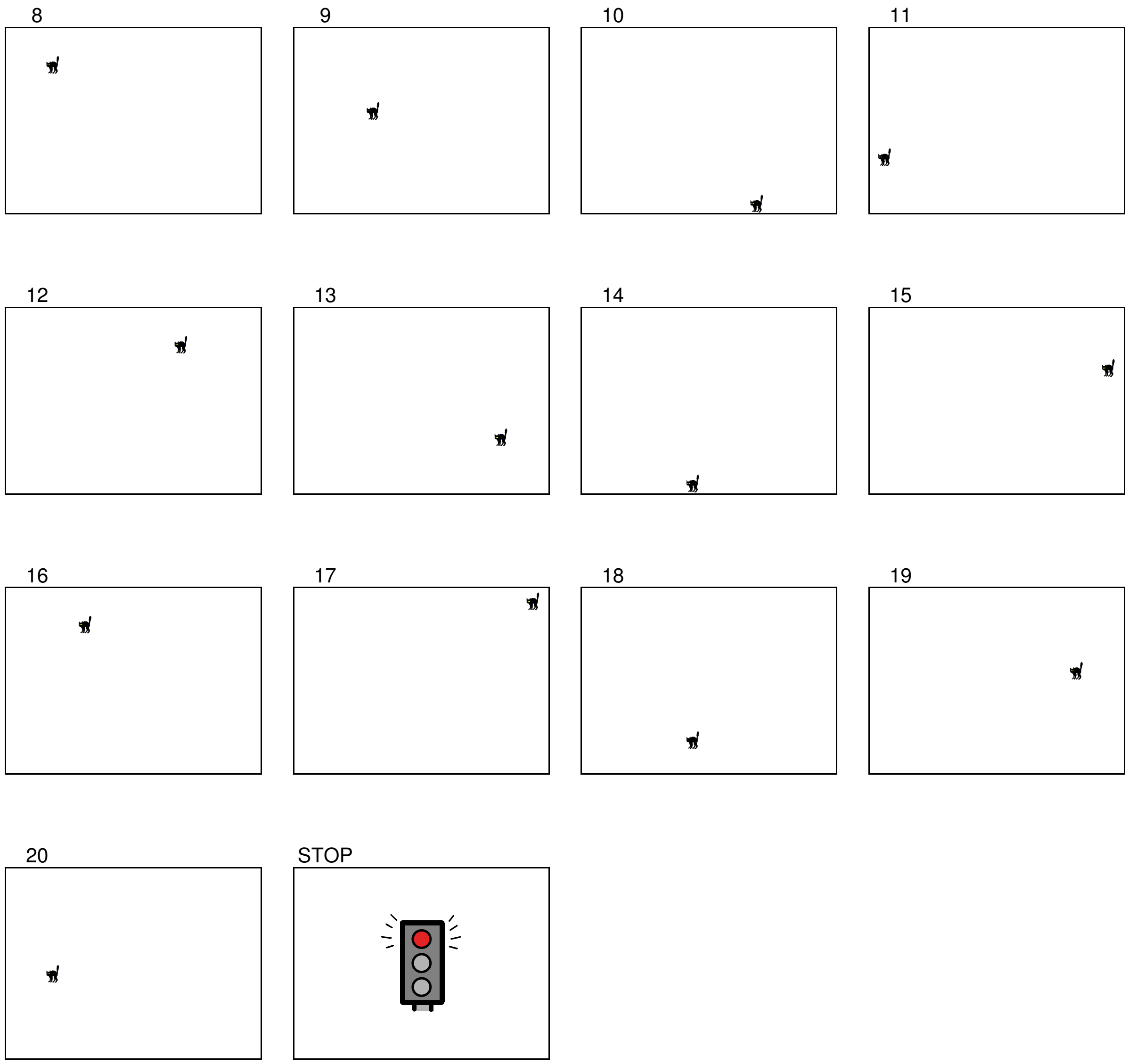
Appendix H: Mouse control screening

The mouse control screening took the form of timing the participants as they clicked on a small symbol (a cat) with the mouse for 20 mouse clicks. As the cat was located with the mouse, it appeared in another position on the screen, and the participants had to keep on locating the cat until the end of the task, indicated by a stop sign. It operated in a continuous manner. Once the participants started, they could continue to the end without any input from the administrator.

The exact sequence of steps of the mouse control screening and all the positions on the screen that the cat appeared in is presented below. The positions of the cat were chosen to cover the full area of the screen and to have large variations in position relative to the previous position. The size of the cat in the mouse control screening was chosen to be smaller than any of the cell sizes that the participants had to click on in the main study.

The mouse control screening was designed using *The Grid™* software (The Grid, 2002). Each new screen was a single-cell, interlinked grid. The mouse control screening was originally designed for the researcher's masters thesis (Herold, 2004).




8
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13
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17
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19
20
STOP

Appendix I: Overview of administration process

The computer program guided the research assistant through the following procedures. The registration slip indicated which pathway through the test the participant had to be guided.

Group A		Group B	
Session 1	Session 2	Session 1	Session2
Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer
Mouse Screening	Mouse Screening	Mouse Screening	Mouse Screening
SUB Pre-test 6 practice items 5 test items	ALP Pre-test 6 practice items 5 test items	ALP Pre-test 6 practice items 5 test items	SUB Pre-test 6 practice items 5 test items
SUB Test 6 practice items 36 test items	ALP Test 6 practice items 36 test items	ALP Test 6 practice items 36 test items	SUB Test 6 practice items 36 test items
Break	Break	Break	Break
Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer	Administration Subject Number Session Grade Gender Researcher Computer
ALP Pre-test 6 practice items 5 test items	SUB Pre-test 6 practice items 5 test items	SUB Pre-test 6 practice items 5 test items	ALP Pre-test 6 practice items 5 test items
ALP Test 6 practice items 36 test items	SUB Test 6 practice items 36 test items	SUB Test 6 practice items 36 test items	ALP Test 6 practice items 36 test items

Appendix J: Workbook instructions

Materials needed

1. Subject booklet – A4 sheets of paper stapled in the top left-hand corner
2. Pencil
3. White board for each child to press on
4. Large version of the booklet as a visual aid
5. Laptop to demonstrate the test program

The children were taught in a group, all classes of the same grade together, in one of that grade's classrooms. The children used their own white boards and pencils. Each child was given a booklet that was worked through during the instruction phase. The instructor had a large version of the booklet to use as a visual aid. The instructor stood in front of the classroom and all the actions required of the children were modeled on the booklet. The children sat on the floor so that they could see the visual aids and computer screen clearly. Children who did not assent to participation were requested to remain quietly where they were and watch. After each instruction to execute a task, time was given for the children to respond. Visual checks by the research assistants and teachers present were made to ensure that they were performing the task correctly. Children were facilitated where necessary.

Section		Time	Script
Introduction	Introduce self and study	2 min.	*Good morning, boys and girls. Firstly, I want to introduce myself. My name is Marina Herold. I am an occupational therapist and I am developing a computer program. But I need your help to understand how easy it is for children your age to find a picture hidden somewhere among many pictures on a computer screen. Thank you very much for being part of this study and helping me to find out what I need to know.* *Let me explain a little how this is going to work. Today I am going to teach you how to use the computer program. On one of the next three days, you will be able to work the computer program yourself. All you will need to do in the computer program is to try and find hidden pictures as quickly as possible. It will be easy and fun for you to work through the program. And when you have finished, you will be given a little gift to thank you for helping me.*
	Request assent		*I need to know if you give your permission to be part of this study. If you are ok with it I want you to put a circle around the word 'Yes' on the paper in front of you. If you really don't want to do this, you don't have to, and you can put a circle around the word 'No'. Is there anybody who doesn't want to do this computer game?* (Pause. If there is anybody who says 'No', ask them to sit quietly where they are and watch.)
	Fill in forms		*Let's begin. You have a booklet and a pencil. Please circle the 'Yes'.* (Pause)

Appendix J.2

Concept of subcategories	Explain concept by using six examples	6 min.	*Now turn to page 2 of your booklet.* (Pause.) *There are many, many animals in this world. If I had to put them all on one page like this one, it could take me a long, long time to find the one I was looking for. But what if I organized the animals a little better, rather than just having them all mixed up? That might make it easier to find the one I want, wouldn't it?* *Now turn to page 3 of your booklet.* (Pause.) *The first way we are going to organise our animals is to place them in categories or groups, depending on what kind of animal they are. In front of you are six categories or groups of animals.* *Firstly, we have the farm animals.* (Point to the first group – the ones with the orange background.) *These are the farm animals. Farm animals are animals that live and work on a farm. For example, sheep and donkeys and hens all live on farms.* *Then, we have the wild animals.* (Point to the next group – the ones with the green background.) *These are the wild animals. Wild animals live out in the wild. You will find these animals in the jungles, the deserts and the zoos. Wild animals are animals like bears and snakes and squirrels.* *Next we have the birds.* (Point to the group with the light blue background.) *This is the birds group. Birds are animals with feathers that can fly. For example, woodpeckers and eagles and flamingoes are all birds.* *Then there are the pets.* (Point to the group with the yellow background.) *This is the pets group. Pets are animals that we care for and have living with us in our homes. For example, we often see people having kittens and bunnies and goldfish as pets.* *Another group is the water animals.* (Point to the group with the dark blue background.) *This is the water animals group. Water animals are animals that live in rivers and dams and seas. There are many animals that live near water and who like water, but in this group we have those animals who live in water most of the time or they will die. Water animals are animals such as dolphins, seahorses and crabs.* *The last group is the little creatures.* (Point to the group with the pink background.) *These are the little creatures. Little creatures are the small animals, the creepy crawlies, the "goggas". Butterflies, worms and grasshoppers are examples of little creatures.*
	Three demonstra-tion examples		*Let's see if we can decide which animals go where.* *At the top of your page is a row of pictures. The first one is a wolf. I am sure you will all agree that a wolf is a wild animal – it lives in the wild. Draw a line from the wolf to your wild animal group.* *The second one is an oyster. Oysters live in the sea, so let's draw a line from the oyster to the water animals group.* *What about the beetle? Beetles are little creatures, so let's draw a line from the beetle to the little creatures group.*
	Six practice examples		*Now it is your turn to try.* *The next picture is of a peacock. Where would you put the peacock? I will give you a moment to think about which group the peacock belongs to and for you to draw a line from the peacock to that group.* (Pause.) *Do you all agree that because the peacock has feathers, the best place for the peacock is in the birds group?* *Now it is the lamb. Into which group do you think we should put the lamb? Draw a line from the lamb to the group you think it belongs in.* (Pause.) *Would you agree that the best place for the lamb is with the farm animals?* *Now look at the koala bear. Into which group would you put the koala bear? Think about it and then draw a line from the koala bear to the group it belongs in.* (Pause.) *I put the koala with the wild animals because it lives in the wild. Did you?* *The next picture is the mosquito. Think about which group the mosquito belongs to and then draw a line from the mosquito to that group.* (Pause.) *I think the mosquito fits best with the little creatures. Do you agree?* *The next picture is the fish. Draw a line from the fish to the group you think it belongs in.* (Pause.) *Do you all agree that the best place for the fish is with the water creatures? Fish can only live in water.* *The last picture is the hamster. To which group do you think the hamster belongs? Draw a line from the hamster to the group you think is best.* (Pause.) *I put the hamster with the pets group, because many people have pet hamsters.* *That was quite easy, don't you think? Does anyone have any questions?* (Pause.)

Appendix J.3

Using subcategories to locate symbols in visual field	Explain concept	6 min.	*Turn now to page 4 of your booklet.* (Pause.) *All the animals have been grouped into the six categories we spoke about just now. In the top left hand corner of the page are all the farm animals, grouped together with an orange background. Next to the farm animals is a group of wild animals, grouped together with a green background. On the top right hand side are all the birds, grouped together with a light blue background. In the bottom left hand corner of the page, you will see all the pets, grouped together with a yellow background. Next to the pets are the water animals, grouped together with a dark blue background. In the right hand bottom corner are all the little creatures, grouped together with a pink background.*
	Three demonstra-tion examples		*Let's try and find our animals again.* *Look at the first picture at the top of the page. It is the wolf. We decided that the wolf is a wild animal, so if we want to find the wolf quickly, we must go to the wild animal group, the green group, to look for the wolf. Can you find it? Draw a line from the wolf at the top of the page to the wolf in the big picture.* (Pause.) *The next picture is of the oyster. The oyster is a water animal so if we want to find the oyster quickly, we must go to the water animal group, the dark blue group to look for the oyster. Can you find the oyster? Draw a line from the oyster at the top of the page to the oyster in the group of water animals.* (Pause.) *What about the beetle? The beetle is a little creature, so if you want to find the beetle quickly, you can go to the little creature group, the pink group, and look for it there. Can you find it? Draw a line from the beetle at the top of the page to the beetle in the little creatures group.* (Pause.)
	Six practice examples		*Now I am going to let you try some on your own.* *The next picture is of a peacock. Can you find the peacock on your picture board? I will give you a moment to think about which group the peacock belongs to and to find the peacock as quickly as you can. When you have found the peacock, draw a line from the peacock at the top of the page to the peacock in the big picture.* (Pause.) *Did you find the peacock with the birds?* *Now it is the lamb picture. Think about which group you will find the lamb in, and then find the lamb as quickly as you can. When you have found the lamb, draw a line from the lamb at the top of the picture to the lamb in the big picture.* (Pause.) *Did you find the lamb with the farm animals?* *Next is the koala bear. Think about which group you would find the koala bear in, and then find the koala bear as fast as you can. When you have found the koala bear, draw a line from the koala bear at the top of the page to the koala bear in the big picture.* (Pause.) *Did you find the koala bear with the wild animals?* *Now let's look at the mosquito. Decide quickly in which group you would find the mosquito, then go and look there for the mosquito. When you have found the mosquito draw a line from the mosquito at the top of the page to the mosquito in the big picture.* (Pause.) *Did you find the mosquito with the little creatures?* *The next picture is the fish. In which group will you find the fish? Quickly go to that group and look for the fish. When you have found the fish, draw a line from the fish at the top of the page to the fish in the big picture.* (Pause.) *Did you find the fish with the water creatures?* *The last picture is the hamster. In which group will you find the hamster?* (Pause.) *Go to that group and find the hamster as quickly as you can. When you have found the hamster, draw a line from the hamster at the top of the page to the hamster in the big picture.* (Pause.) *Did you find the hamster in the pets group?* *I am sure you found that quite easy to do, didn't you? Does anyone have any questions?* (Pause.)

Appendix J.4

Concept of initial phonic of word	Explain concept	5 min.	Note: Each time a letter is mentioned, it will be given in both its forms e.g.. 'a' (name) and 'a' (sound). At appropriate times, the children will be given time to respond. *Please turn to page 5 of your booklet.* (Pause.) *The second way we are going to organise our animals is to order them alphabetically. In front of you is an alphabet. The alphabet has a special order, starting with 'a' and ending with 'z'.* (Point to the 'a' and the 'z'.) *Each letter of the alphabet has it own special place in the order. It is always in the same order.* *Let's see if we can decide which letter our animals belong to.*
	Three demonstra-tion examples		*Look at your first picture. It is a wolf. Wolf starts with a 'w'. A 'w' comes near the end of the alphabet, so start looking for the 'w' at the end of the letters. When you have found the 'w', draw a line from the wolf to the block with the 'w' in it.* *Now let's try the oyster. Oyster starts with the letter 'o'. Look for the 'o'. An 'o' is not at the beginning but also not at the end of the alphabet, so start looking for the 'o' more or less in the middle of the letters. When you have found the 'o', draw a line from the oyster to the block with the letter 'o' in it.* *What about the beetle? Beetle starts with the letter 'b'. A 'b' is the second letter of the alphabet, so look for the 'b' at the beginning of the letters. When you have found the 'b', draw a line from the beetle to the block with the 'b' in it.*
	Six practice examples		*Now it is your turn to try.* *The next picture is a peacock. Peacock starts with the letter 'p'. A 'p' is a letter quite far in the alphabet, so I would look somewhere after the middle but not near the end yet. Can you find it?* (Pause.) *When you have found the 'p', draw a line from the peacock to the block with a 'p' in it.* *Now let's think about the lamb* picture. *Lamb starts with the letter 'l'. An 'l' is quite far in the alphabet, but before the middle. Can you find the 'l'?* (Pause.) *When you have found the 'l', draw a line from the lamb to the block with a 'l' in it.* *The koala bear picture is next. Koala bear starts with the letter 'k'. A 'k' is quite deep in the alphabet, but also before the middle. Can you find the 'k'?* (Pause.) *When you have found the 'k', draw a line from the koala bear to the block with a 'k' in it.* *Now let's think about the mosquito. Mosquito starts with the letter 'm'. An 'm' is in the middle of the alphabet, so begin to look somewhere in the middle of the letters. Can you find the 'm'?* (Pause.) *When you have found the 'm', draw a line from the mosquito to the block with a 'm' in it.* *The next picture is the fish. Fish starts with the letter 'f'. An 'f' is fairly near the beginning of the alphabet, so look for the 'f' near the beginning of the letters. Can you find the 'f'?* (Pause.) *When you have found the 'f', draw a line from the fish to the block with an 'f' on it.* *The last picture is the hamster. Hamster starts with the letter 'h'. An 'h' is in the first half of the alphabet. Can you find the 'h'?* (Pause.) *When you have found the 'h', draw a line from the hamster to block with a 'h' in it.* *That was quite easy, don't you think? Does anyone have any questions?* (Pause.)

Appendix J.5

Using alphabetic order to locate symbols in visual field	Explain concept	6 min.	*Please turn to page 6 of your booklet.* (Pause.) *Look at the top left-hand corner of the board and point to the group of animals starting with the letter 'a'. Animals starting with the letter 'a' have a light blue background. There is only one in this group. Now point to the next group, the group of animals starting with the letter 'b'. Animals starting with the letter 'b' have an orange background. There are quite a lot of animals in this group. There are also quite a lot of animals starting with the letter 'c', which have a pink background. Point to them. Keep moving along the lines and find the letter groups. So, after the 'c' group, we have the yellow 'd' group, and then the light green 'e' group, and then the dark blue 'f' group. Keep moving along the lines, and see how the colour changes when the starting letter of the animal words change. Next we have the light blue 'g' group and then the orange 'h' group. Some letters don't have any animals in their group, like the 'i' group. Next comes the pink 'j' group with only one animal in it, followed by the yellow 'k' group which is a little bigger again. Keep pointing along the lines and find the green 'l' group and the dark blue 'm' group. Notice that there are no 'n' animals, but there is a light blue 'o' group and an orange 'p' group. There is no 'q' animal group. The next group is the dark pink 'r' group, followed by a big yellow's' group and a small green 't' group. There is no 'u' group and no 'v' group. The next group is a big dark blue 'w' group. There is no 'x' group and no 'y' group. The page finishes with a small light blue 'z' group.*
	Three demonstra-tion examples		*Let's see if we can now find the animals we are looking for in the big picture.* *Look at the first picture. It is a wolf. Wolf starts with the letter 'w'. A 'w' comes near the end of the alphabet, so start looking for the wolf by the 'w' animals in the last row of the animals. When you have found the wolf, draw a line from the wolf at the top of the page to the wolf in the big picture.* *Now take your oyster sticker. Oyster starts with the letter 'o'. Look for the oyster in the group of animals starting with the letter 'o'. They will be more or less in the middle of all the animals. When you have found the oyster, draw a line from the oyster at the top of the page to the oyster in the big picture.* *What about the beetle? Beetle starts with the letter 'b'. A 'b' is the second letter of the alphabet, so start looking for the beetle in the first row of the animals. When you have found the beetle, draw a line from the beetle at the top of the page to the beetle in the big picture.*
	Six practice examples		*Now it is your turn to try.* *The next picture is a peacock. Peacock starts with the letter 'p'. A 'p' is a letter quite far in the alphabet, so I would look for the peacock somewhere after the middle but not near the end yet. Can you find it?* (Pause.) *When you have found the peacock, draw a line from the peacock at the top of the page to the peacock in the big picture.* *Now let's think about the lamb picture. Lamb starts with the letter 'l'. A 'l' is quite far in the alphabet, but before the middle, so I would look for the lamb somewhere near the middle of the picture. Can you find it?* (Pause.) *When you have found the lamb, draw a line from the lamb at the top of the page to the lamb in the big picture.* *The koala bear picture is next. A koala bear starts with the letter 'k'. A 'k' is quite deep in the alphabet, but also before the middle, so look for the koala bear somewhere near the middle. Can you find the koala bear?* (Pause.) *When you have found it, draw a line from the koala bear at the top of the page to the koala bear in the big picture.* *Now let's think about the mosquito. Mosquito starts with the letter 'm'. A 'm' is in the middle of the alphabet, so begin to look for the mosquito somewhere in the middle of the letters. Can you find the mosquito?* (Pause.) *When you have found the mosquito, draw a line from the mosquito at the top of the page to the mosquito in the big picture.* *The next picture is the fish. Fish starts with the letter 'f'. An 'f' is fairly near the beginning of the alphabet, so look for the fish near the beginning of the letters. Can you find the fish?* (Pause.) *Draw a line from the fish at the top of the page to the fish in the big picture.* *The last picture is the hamster. Hamster starts with the letter 'h'. An 'h' is in the first half of the alphabet, so look for the hamster in the first half of the picture. Can you find the hamster?* (Pause.) *Draw a line from the hamster at the top of the page to the hamster in the big picture.* *I am sure you found that quite easy to do, didn't you? Does anyone have any questions?* (Pause.)

Appendix J.6

Subcategories pretest on the computer	Explain concept	1 min.	*When you work on the computer program, you are going to do almost exactly the same as you have just done now in your workbook. The only difference is that instead of drawing lines you will click with your mouse. Look at the screen. If you see a 'no click' sign like this you must wait to hear what you must do. When you know what to do, you can click on it. You will then see a green traffic light. Once you click on the green light, the program is starting. When you see the picture of a red traffic light, you know you have finished that section and you can wait to be told what to do next.* *In the first section, you must show which group the animal belongs to. You will see an animal in the centre of your screen.*
	Three demonstration examples		*The first one is a wolf. You must make sure you have seen the animal picture and can remember what it is. When you are ready, you will click on the wolf. The wolf will disappear and a screen of the six animal groups will appear.* *Now you will have to decide which of the six groups the wolf belongs to. Can you remember what it was? Yes, it is the wild animals. So, you must click on the wild animals group. Another animal will appear. It is the oyster. The oyster is a water animal so you must click on the water animals group. Next is the beetle, which belongs in the little creatures group.* *It is as simple as that! And don't worry – if you ever forget what the animal picture was, just click on the forward arrow in the top corner and the next animal will appear for you.*
Subcategories subtest on the computer	Explain concept	1 min.	*In the next section you must try and find the animals in the big picture, where all the animals are in their groups. A picture of an animal will appear. Remember it and then click on it. The screen will fill with the big picture of all the animals. Your job will be to find the animal as quickly as you can. Don't waste time. But don't be careless either. Think where is a good place to look for the animal you just saw and then search for that exact picture. When you have found it, click on it. There will be quite a lot of animal pictures to find. Just keep going as fast as you can and don't stop or slow down until you see the red traffic light. If you forget what picture you are looking for, don't worry, there will be a way out. Click on the forward arrow in the top right-hand corner. Can you see it? Of course, try not to use it, but if you have forgotten your picture, it is more important to keep going than to stop and waste time.*
	Three demonstration examples		*The first picture is of a wolf. I must look for the wolf in the wild animals. There he is. I click on the wolf and a new animal appears. It is an oyster. The oyster must be here in the water animals section. There he is. I click on the oyster, and a beetle appears. The beetle has to be with the little creatures. There he is. When the picture of a red traffic light appears, you know you are finished with that section.* *It is as simple as that! And don't worry – if you ever forget what the animal picture was, just click on the forward arrow in the top corner and the next animal will appear for you.*
Alphabetic order pretest on the computer	Explain concept	1 min	*In the third section, you have to click on the letter block that you think is the one the animal word starts with. When a picture of an animal appears, you must make sure you have seen the animal and remember what it was. When you are ready, you will click on the animal. The animal will disappear and a screen of all the alphabet letters will appear. You will then have to decide which letter the animal starts with. When you have decided, you will need to click on the letter you have chosen. Another animal will appear.*
	Three demonstration examples		*Let me demonstrate to you on the computer how it will all work. I start by clicking on the green traffic light. An animal picture of a wolf appears. A wolf starts with the letter 'w'. A 'w' comes near the end of the alphabet, so I can begin to look there. Here is the 'w'. I must click on it. The oyster starts with an 'o' and an 'o' is somewhere in the middle of the alphabet. Here is the 'o'. I click on the 'o'. Another animal appears. This time it is a beetle. Beetle starts with the letter 'b'. A 'b' comes very near the beginning of the alphabet, so that is where I will find it. Here it is. I click on it. I have come to the red robot, so I know this section is finished.* *It is as simple as that! And don't worry – if you ever forget what the animal picture was or what letter you are looking for, just click on the forward arrow in the top corner and the next animal will appear for you.*

Alphabetic order subtest on the computer	Explain concept	1 min	*In the last section, you must try and find the animal picture in the big picture, where all the animals are in alphabetical order. Your job will be to find the animal as quickly as you can. Don't waste time. But don't be careless either. Think where is a good place to look for the animal you just saw and then search for that exact picture. When you have found it, click on it. There will be quite a lot of animal pictures to find. Just keep going as fast as you can and don't stop or slow down until you see the red traffic light. If you happen to forget what picture you are looking for, don't worry, there will be a way out. Click on the <u>forward arrow</u> in the top right-hand corner. Can you see it? Of course, try not to use it, but if you have forgotten your picture, it is more important to keep going than to stop and waste time. When you see the picture of a red traffic light, you will know you have come to the end of that section.*
	Three demonstra-tion examples		*Let me demonstrate to you on the computer how it will all work. Let's try and find our practice animals in the big picture. The first picture is of a <u>wolf</u>. Wolf starts with a 'w' and a 'w' comes near the end of the alphabet, so I must look for the wolf here near the end of the screen. There he is. I click on the wolf and another picture appears. It is an <u>oyster</u>. The oyster starts with the letter 'o', and the letter 'o' is near the middle of the alphabet, so I must look somewhere near the middle. There it is. I click on the oyster and another picture appears. This time it is the <u>beetle</u>. The beetle starts with the letter 'b', and a 'b' is near the beginning of the alphabet, so I will look right at the top, over here. There's the beetle. I click on the beetle. I carry on this way until a red traffic light appears. Then I know I have finished that section. And don't worry – if you ever forget what the animal picture was, just click on the <u>forward arrow</u> in the top corner and the next animal will appear for you. Do you have any questions? (*Pause*).*
Closing	Thank you	1 min	*Well, that's it. I am sure you will all manage just fine with the computer program.* *Thank you so much for helping me with my work.*
	Gift		*As a 'thank you' to you, there is a chocolate for each of you.*

Appendix J.7

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YUNIBESITHI YA PRETORIA

Centre for Augmentative and Alternative Communication	Sentrum vir Aanvullende en Alternatiewe Kommunikasie

& INTERFACE

University of Pretoria

2006 Laureate Award, Education Innovation for the Eofa Project
2004 T-Systems Age of Innovation & Sustainability Awards: Excellence in Innovation and Sustainability: Social
2003 National Science & Technology Awards: Corporate Organization over the last ten years.
2002 Shirley McNaughton Award for Exemplary Communication received from the International Society for Augmentative and Alternative Communication
1998 Rolex Award for Enterprise: Associate Laureate
1995 Education Africa Presidential Award for Special Needs

Website: http://www.up.ac.za/academic/caac
Fax/Faks: (012) 420 – 4389
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E-mail: erna.alant@up.ac.za
Faculty of Education / Fakulteit Opvoedkunde
Centre for Augmentative and Alternative Communication
Sentrum vir Aanvullende en Alternatiewe Kommunikasie
University of Pretoria, Lynnwood Road
PRETORIA, 0002
SOUTH AFRICA

I want to take part in the research project on visual displays at The King's Preparatory School.

(Please circle one of the words)

Yes No

Name ____________________ Grade ____________

Date of Birth ________________ Date ____________

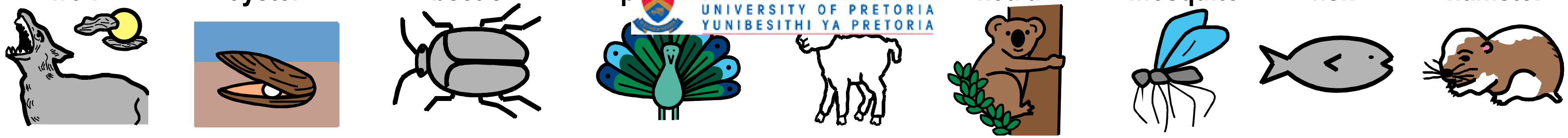
______________________ ______________________
Marina Herold Date
Occupational Therapist and Communication Specialist
B.Sc (OT) (Wits), MAAC (UP)
011-463-5203

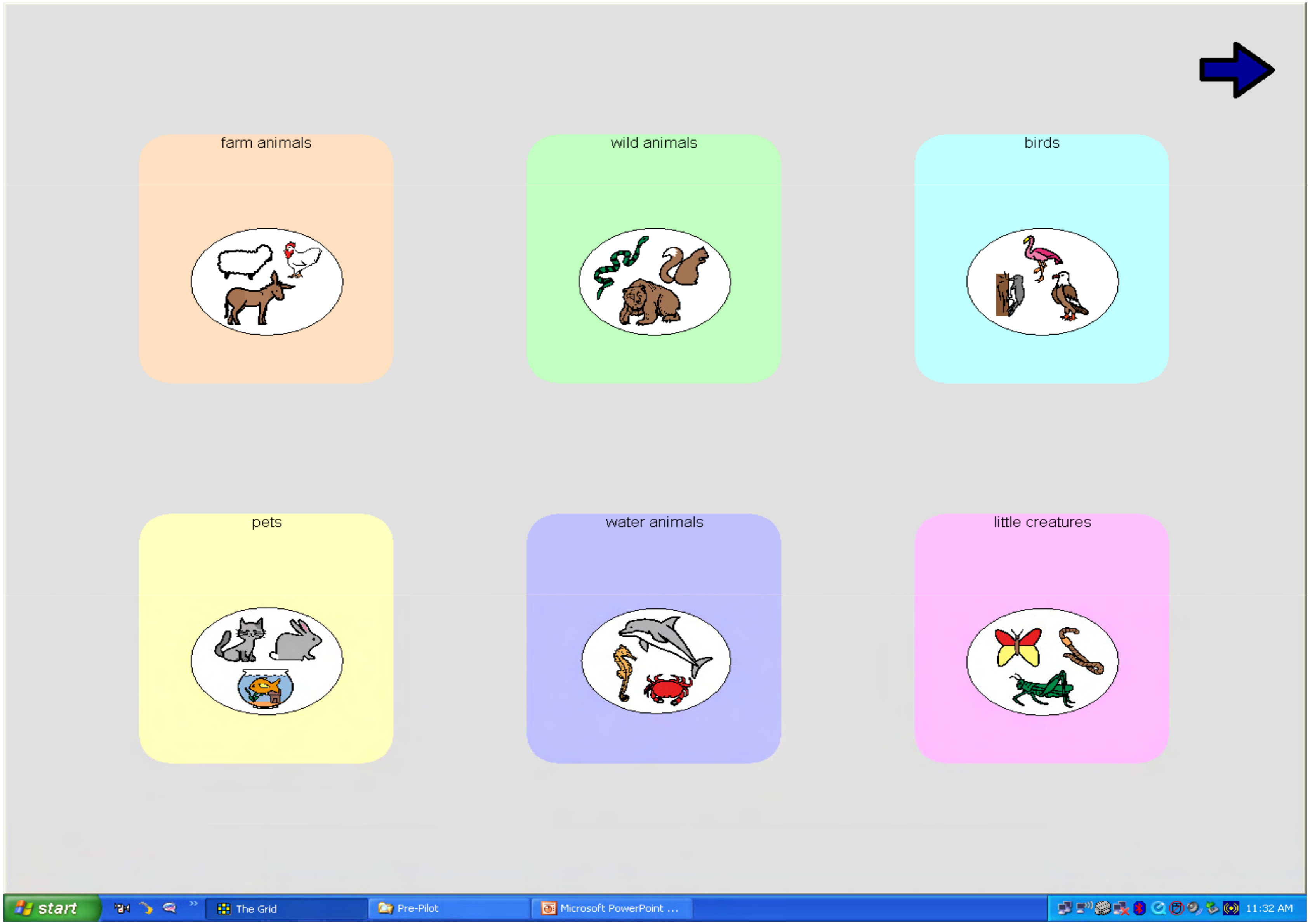
______________________ ______________________
Prof Kitty Uys Date
University of Pretoria
Centre of Augmentative and Alternative Communication
012-420-2001

Appendix K.1

Appendix K.2


hyena
pig
duck
peacock
wolf
mouse
zebra
lizard
elephant
seahorse
bunny
dinosaur
dog
deer
fly
owl
hen
hamster
monkey
beetle
fish
giraffe
jellyfish
ostrich
horse
snake
kitten
shark
bird
tiger
snail
kangaroo
cricket
whale
donkey
ant
polar bear
stingray
ladybird
skunk
hippo
woodpecker
sheep
squirrel
lion
puppy
crab
robin
oyster
lamb
koala bear
parrot
cat
grasshopper
dolphin
leopard
starfish
beaver
flamingo
butterfly
rooster
dragonfly
porcupine
seagull
panda bear
camel
mosquito
budgie
bear
bee
goldfish
spider
octopus
worm
seal
eagle
cow
fox
goat


wolf
oyster
beetle
p
koala
mosquito
fish
hamster


farm animals
wild animals
birds
pets
water animals
little creatures
start
The Grid
Pre-Pilot
Microsoft PowerPoint ...
11:32 AM

Appendix K.3

UNIVERSITEIT VAN PRETORIA
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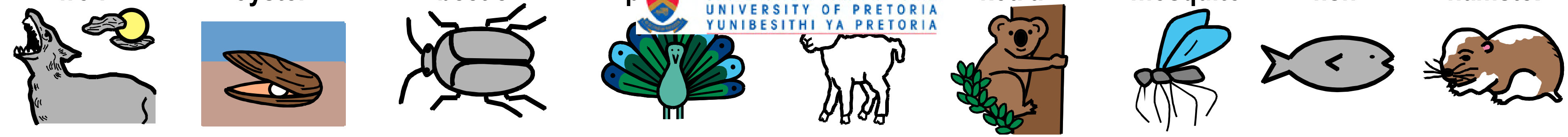

Appendix K.4

Appendix K.5

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Appendix K.6

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YUNIBESITHI YA PRETORIA

A structured script was provided for the research assistants to guide them through the various steps of the test. There were two versions of this instruction guide, which were identical in every way except for the order in which the two groups of participants were presented with the tests during the testing procedure.

Group A

(Switch on the voice recorder.)

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Administration 1 *(Click on the word.)*

Hello. What is your name?

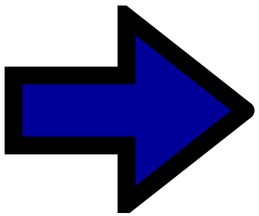
(Make a 'small talk' comment if you want to, to make the subject feel comfortable.)

Which side would you like the mouse on? *(Move it to the appropriate side if necessary.)*

Please give me your card. Let me fill in all your information. *(Fill in all the information.)*

The only rules you need to remember are ....

If you see one of these 'NO CLICK' signs *(point to the picture)*, just wait to hear what you must do next.



If you don't know what to do or forget what you have to find, don't worry. Just click on the arrow like this one *(point to the arrow)* in the top corner of the page, and it will move on the next one.

Appendix L.2

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Mouse Screening *(Click on the word.)*

(Point to the pictures below as you explain what to do.)

In this section, you have to chase a little cat around the screen as fast as you can. When you are ready, click on the green robot. A little cat will appear. Click on the cat. It will move. Keep clicking on the cat until the red robot appears.

Appendix L.3

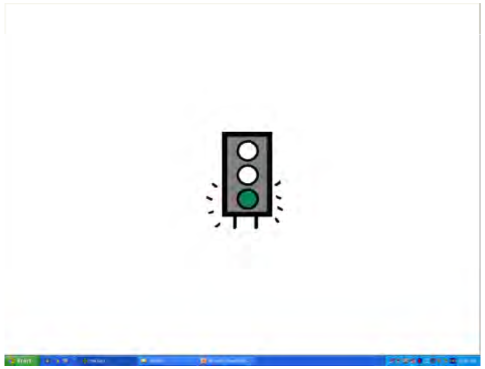
There are 20 cats to catch. <u>You must work as fast as you can.</u>
Are you ready? Then start.

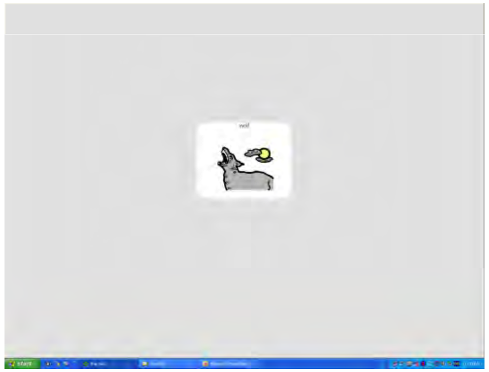
Subcategories Pre-test *(Click on the word.)*

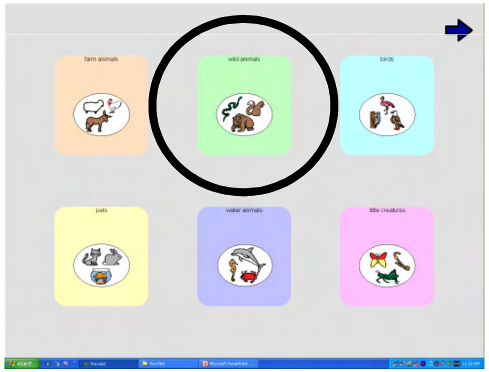
(Point to the pictures below as you explain what to do.)

In this section you must decide which group the animal must go in. When you are ready, click on the green robot. An animal with its name above the picture will appear. Remember it, and click on it. Decide which of the 6 groups the animal fits best into. Is it the Farm Animals, the Wild Animals, the Birds, the Pets, the Water Animals or the Little Creatures? When you have decided, click on the group you chose. Keep going until you see the red robot.

Appendix L.4







There will be 6 animal pictures to find, where I can help you to practice what to do. Are you ready? Then start. *(Talk through the 6 examples as they appear.)*

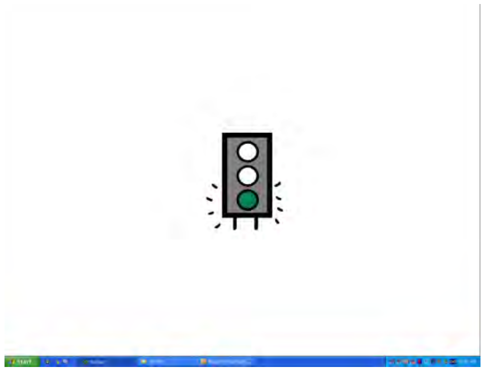
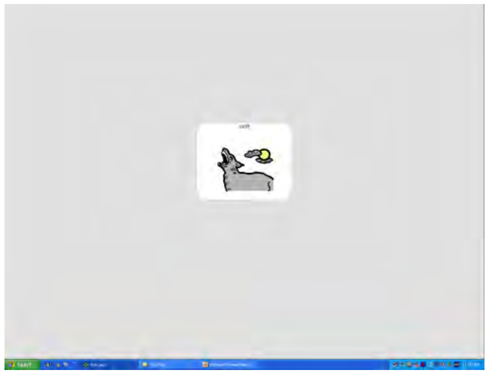
Now I want you to try the next 5 animals all by yourself. I can not help you this time. <u>Think very carefully before you click.</u> Are you ready? Then start.

Subcategories Test *(Click on the word.)*

Appendix L.5

(Point to the pictures below as you explain what to do.)

In this section you must try and find the animal picture in the big picture as quickly as possible. When you are ready, click on the green robot. An animal with its name above the picture will appear. Remember it, and click on it. You will see a big picture of animals. Look for the animal picture, <u>remembering the animal groups </u>as you look. The Farm Animals are this orange group, the Wild Animals are this green group, the Birds this light blue group, the Pets this yellow group, the Water Animals this dark blue group and the Little Creatures this pink group. When you have found the animal, click on it. Keep going until you see the red robot.

There will be 6 animal pictures to find, where I can help you to practice what to do. Are you ready? Then start. *(Talk through the 6 examples as they appear.)*

Now I want you to try the next 36 all by yourself. I can not help you this time. <u>Work as fast as you can, but still be very careful</u>. Are you ready? Then start.

Break *(Click on the word.)*

Well done!

You have finished the first half of the program.

I want you to have a rest before you start the next section.

We have got some juice and sweets for you to enjoy while you rest.

Take your paper with you, and keep it safe, because you will need it for the next section again.

(Switch off the voice recorder)

(Take the child to the refreshment area.)

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Administration 2 *(Click on the word.)*

Switch on the voice recorder!

Appendix L.7

Hello.

What is your name? *(If this is a child not met before.)*

Which side would you like the mouse on? *(Move it to the appropriate side if necessary.)*

Please give me your card. Let me fill in all your information. *(Fill in all the information.)*

You have already done the first section, so you know how this works. We are now going to do something very similar to what you did before, but the pictures are going to be arranged differently.

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Alphabetic Order Pre-test *(Click on the word.)*

(Point to the pictures below as you explain what to do.)

In this section you must decide which letter the animal starts with. When you are ready, click on the green robot. An animal with its name above the picture will appear. Remember it, and click on it. Decide which of the 26 letters of the alphabet the animal's name starts with and look for that letter in this alphabet. When you have found it, click on it. Keep going until you see the red robot.

Appendix L.8

There will be 6 animal pictures to find, where I can help you to practice what to do. Are you ready? Then start. (*Talk through the 6 examples as they appear. NB. Remember to say both letter name and sound as you mention the letters!)*

Now I want you to try the next 5 animals all by yourself. I can not help you this time. <u>Think very carefully before you click.</u> Are you ready? Then start.

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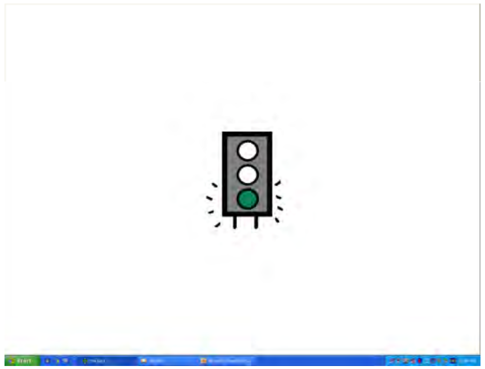
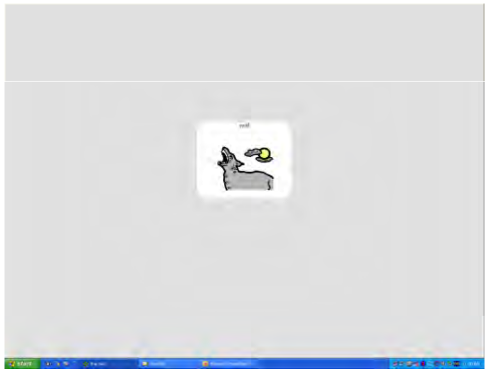
Alphabetic Order Test *(Click on the word.)*

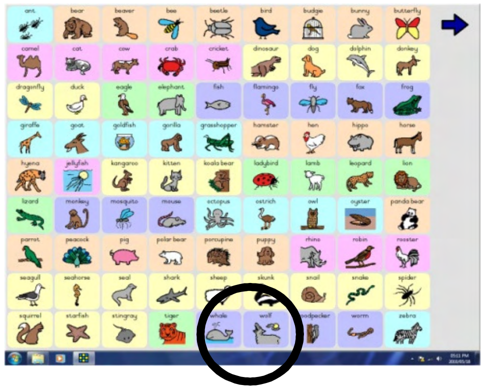
(Point to the pictures below as you explain what to do.)

In this section you must try and find the animal picture in the big picture as quickly as possible. When you are ready, click on the green robot. An animal with its name above the picture will appear. Remember it, and click on it. You will see a big picture of animals. Look for the animal picture. Remember what letter the animal starts with, and then look for the picture in that area of the alphabet . When you have found the animal, click on it. Keep going until you see the red robot.

Appendix L.9







There will be 6 animal pictures to find, where I can help you to practice what to do. Are you ready? Then start. *(Talk through the 6 examples as they appear. NB. Remember to say both letter name and sound as you mention the letters.)*

Now I want you to try the next 36 all by yourself. I can not help you this time. Work as fast as you can, but still be very careful. Are you ready? Then start.

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Close *(Click on the word.)*

Appendix L.10

Well done! You are completely finished now.

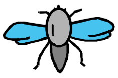
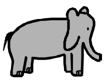
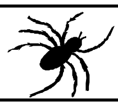
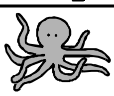
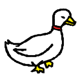
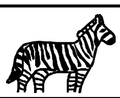
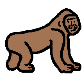
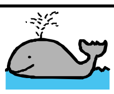
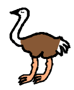
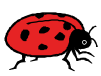
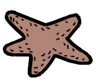
Thank you so very much for helping us.

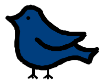
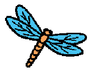
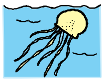
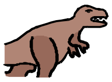
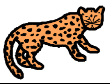
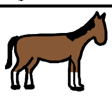
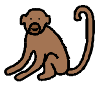
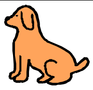
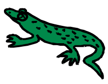
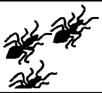
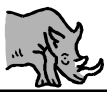
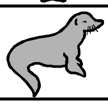
I hope you enjoyed it.

You can go back to class now, but before you go I want to give you a thank you gift.

(Take them to the gift basket and let them chose a pack of cards).

Appendix M: Various ratings of symbols used in the tests

Item No	Animal	Picture	Category	ALP		SUB		Colour	Colour groups (5 groups)	Size (% of area)	Visual Complexity (JPEG)
				Column grouping	Row grouping	Column grouping	Row grouping				
1	cow		Farm Animals	1	1	1	1	brown	3	34.01	6.41
2	mouse		Little Creatures	2	2	3	1	grey	2	34.49	5.91
3	fly		Little Creatures	3	1	3	1	blue / green	4	41.01	5.89
4	budgie		Pets	3	1	1	1	grey	2	43.15	6.40
5	elephant		Wild Animals	2	1	3	1	grey	2	59.64	5.89
6	spider		Little Creatures	3	3	3	1	black +/or white	1	45.38	6.25
7	skunk		Wild Animals	2	3	2	1	black +/or white	1	41.65	5.22
8	octopus		Water Creatures	2	2	1	1	grey	2	53.40	8.69
9	duck		Farm Animals	1	1	1	1	black +/or white	1	24.09	5.01
10	tiger		Wild Animals	2	3	3	1	red	5	66.58	9.28
11	zebra		Wild Animals	3	3	2	1	black +/or white	1	47.04	9.19
12	gorilla		Wild Animals	2	2	2	1	brown	3	35.78	5.61
13	whale		Water Creatures	2	3	2	2	blue / green	4	49.86	6.27
14	ostrich		Birds	2	2	3	2	brown	3	23.80	5.25
15	ladybird		Little Creatures	2	2	3	2	red	5	34.29	6.22
16	starfish		Water Creatures	1	3	1	2	brown	3	38.24	6.32

17	parrot		Birds	1	3	3	2	blue / green	4	37.58	5.47
18	polar bear		Wild Animals	2	3	2	2	black +/or white	1	33.56	4.83
19	bird		Birds	2	1	3	2	blue / green	4	51.42	5.02
20	dragonfly		Little Creatures	1	1	3	2	blue / green	4	22.25	5.73
21	jellyfish		Water Creatures	1	2	2	2	blue / green	4	95.37	8.94
22	dinosaur		Wild Animals	2	1	2	2	brown	3	49.02	6.05
23	fox		Wild Animals	3	1	1	2	brown	3	31.76	5.45
24	cat		Pets	1	1	1	2	grey	2	38.14	6.50
25	kangaroo		Wild Animals	1	2	2	3	brown	3	32.78	6.05
26	owl		Birds	3	2	3	3	brown	3	36.68	6.54
27	goat		Farm Animals	1	2	1	3	brown	3	40.40	6.12
28	leopard		Wild Animals	3	2	1	3	red	5	42.40	9.28
29	horse		Farm Animals	3	2	1	3	brown	3	46.26	5.86
30	stingray		Water Creatures	1	3	2	3	grey	2	34.28	4.13
31	monkey		Wild Animals	1	2	2	3	brown	3	38.55	6.77
32	dog		Pets	3	1	1	3	red	5	40.47	6.39
33	lizard		Little Creatures	1	2	3	3	blue / green	4	31.58	6.61
34	ant		Little Creatures	1	1	3	3	black +/or white	1	31.41	6.33
35	rhinoceros		Wild Animals	3	3	2	3	grey	2	55.96	7.03
36	seal		Water Creatures	1	3	2	3	grey	2	35.89	5.14

Appendix N: Pilot study - problems and solutions

Problem	Solution
1. Administration	
Each participant was given a registration slip detailing his Group Number, Participant Number, Grade and Gender. It was planned for the participants to enter their data into the test program themselves at the beginning of the test, under the supervision of the research assistant. This took time and sometimes resulted in errors that had to be corrected.	Make it the task of the research assistants to enter the information themselves. Each of the participants must have a registration tab with all the relevant information on
It was planned to keep a record of which research assistant worked with each participant, and which of the four computers used for the test program was being used by each of the participants, in order to determine whether there were any significant differences in the participant scores relating to the research assistant or the computer being used. This information was gathered on a form by the research assistant as the participants began the test. However, sometimes the information was omitted.	Integrate the information about which research assistant is officiating and which computer is being used into the log file itself, along with the information relating to the Group, Participant Number, Session, Grade and Gender of the participant. This would prevent dissociation of participant information from data. Improve the instruction of the research assistants through a formal instruction session.
The pilot study used 12 children and took place at one end of a large church hall. After the group instruction session, four children were assigned to the four computers, and their positions were refilled as soon as computers became available. The children who were not being tested at that time proved a significant distraction to the children working on the computers. Although eats and drinks had been provided for the children for the period when they were not involved in the testing, there was not sufficient planning as to how the children who were not being tested would be kept busy.	While children are waiting their turns, and during the refreshment break, they must be supervised outside the testing room.
Another problem that the above method would present in the main study was the staggering of the children's arrival at the testing station. Staggered leaving from and return to the classrooms would be disruptive to teachers and also logistically difficult to manage.	It was considered a more efficient and less disruptive approach to have the children leave their classrooms to come to the test situation in groups of four and to be returned to their classrooms in these same groups once all four had finished with their tests.

Problem	Solution
2. Participant instruction program	
The instruction program appeared understandable, adequate and engaging by the full range of children. Some children took longer than the others to execute the commands to circle symbols and join items with their pencils.	To ensure an efficient execution of the instruction program, without proceeding too fast for the slower children, or too slow for the majority of the children, adult support would be maximized. All four research assistants would be required to be present at each group instruction session to facilitate full understanding of the test instructions by all the children. The teachers would also be requested to facilitate in the supervision of the children to maximize control of the group.
After each section of the paper-based instruction, the children were shown on a computer screen what the test program would look like. The observer's comment was that this may be disruptive, and that the computer program could be shown at the end of the instruction.	The computer version of the program will be shown at the end of the paper-based instruction.

Problem	Solution
3. Test program	
It seemed that the Alphabetic Order Test was perhaps more difficult for the younger children than the Subcategories Test. It took longer and appeared to tire these children. The total testing time became unacceptably long. Ways to reduce it would have to be found to reduce frustration by ensuring that the testing procedure would not take too long.	The test design was for 4 full trials of the test – an initial trial and 3 repeats. Reflection after the pilot study led to the decision to contain the main study to an investigation of first exposure response only, and to remove all repeat trials. The number of test items for each test would therefore reduce from 72 to 18 items. Such a major reduction of the number of test items allowed for the addition of test items to the first exposure trial. It was decided to present 36 items in each test of the main study.
The research assistants were unclear about what to do when children could not find the target symbol and spent very long periods looking for the symbol.	The problem of too long location times would be addressed in the instruction programs, for both the participants and the research assistants. The participants would be urged to click on the 'Forwards' arrow (or 'Escape' option) if they couldn't find a target or forgot what target they were looking for. Research assistants would be instructed on when to suggest using the 'Forwards' arrow. An additional factor that would significantly reduce long search was that there would no longer be repeat chances at locating a symbol – the first selection would automatically result in the test program continuing.
The biggest problem resulting from the long times taken on the alphabet test by the younger children was that an on-the-spot decision had to be made to only do one test per child at this pilot trial. The data collected was therefore incomplete.	Addressing the long location times (see above) would reduce the problem of long testing times.
Memory lapses caused problems such as • Forgetting what is being searched for and remaining passive • Forgetting what is being searched for and making multiple clicks across the screen in an attempt to find it • Perseverating on a symbol, convinced that it is the target symbol, rather than moving forward	These errors will be controlled for through • Instruction • Designing the test program so that all mouse clicks will result in the program continuing automatically. Multiple errors on the same symbol will no longer be possible. The participants will also be urged to refrain from guessing, but to rather use the forward arrow should they forget what they are searching for.

The criterion for passing the pre-tests was a score of 5 out of 5 (100%). However, the participant who failed the SUB Pre-test went on to perform successfully in the SUB Test, dropping from 208 sec to 45 sec in location times from the beginning of the test to the 3rd practice round. The participant who failed the ALP Pre-test 1 went on to cope with the demands of the ALP Test.	The performance of these two participants indicated that the criterion of passing the pre-tests with no errors may be too strict. The criterion was changed to 4 out of 5 (80%).
It appeared that ALP Pre-test 2 was significantly more difficult than ALP Pre-test 1 and took much longer to complete. Two Grade 1 children failed this test, and there was a large variation in time taken across the group to complete the test – from 32 sec to 141 sec.	To restrict time demands on the total time for test administration, ALP Pre-test 2 was removed from the test procedure. ALP Pre-test 1 was designed for selection criteria purposes whereas ALP Pre-test 2 was designed for descriptive purposes only.
Some of the participants had unstable left click movements. They would sometimes press the right mouse button by mistake. In The Grid 1™ (The Grid, 2002), a right click brings up the editing menu. The window would have to be closed by clicking on 'Cancel'. Not only did this waste time, it also confused the children and research assistants.	In The Grid 1™ program (The Grid, 2002), a default setting causes the editing menu to be activated by a right click. However, this feature can be deactivated in the 'User Settings' and will be accessed for the main study. On an accidental right click, there will be no response from the program.
Speed errors were noted, such as • Selecting a symbol adjacent to the target symbol • Clicking on the white space around the target symbol in the grid presenting the target symbol	Instruction will emphasize the need to work carefully and accurately.

Problem	Solution
4. Data capture and log file creation	
An unforeseen problem was the dissociation of the first part of the logged information from the second part. The first part of the logged information of the test held the group number, participant number, grade and gender of the participant. At the end of the first test, the participant had a break and exited the program, closing the log file. Another participant then executed his first test, opening a new log file. When the first participant began his second test, there was no information in the log file linking that participant to his data.	All the participant's identifying information would have to be entered at the beginning of the test procedure, and re-entered at the beginning of the second test. Detailed paper records would also be kept, which would provide a useful backup and cross-check mechanism. The paper record would include the time the test started, serving as a direct link between the participant and his log file.
On analysing the data in the log file, it became apparent that managing errors would statistically be a problem.	The opportunity to make multiple clicks on the same symbol will be removed from the program. This will simplify the log file created during testing.

Problem	Solution
5. Research assistant instruction	
The research assistants were not as experienced with the test program as they could have been and were not fully competent at handling queries as they presented. Consequently, they addressed a number of queries to the main researcher.	The research assistants should be instructed more thoroughly, with hands-on experience of working through the program and possible problem areas. They would be provided with a structured script to work through during test administration.

Appendix O

Appendix O: Pilot study data

Participant information					ALP Pre-tests				ALP Test								SUB Pre-test		SUB Test							
Participant Number	Group	Grade	Gender	Mouse Control Screening	ALP Pre-test 1 time (secs)	ALP Pre-test 1 errors	ALP Pre-test 2 time (secs)	ALP Pre-test 2 errors	ALP Test - 1st exposure time (secs)	ALP Test - 1st exposure errors	ALP Test - 1st repeat time (secs)	ALP Test - 1st repeat errors	ALP Test - 2nd repeat time (secs)	ALP Test - 2nd repeat errors	ALP Test - 3rd repeat time (secs)	ALP Test - 3rd repeat errors	SUB Pre-test time (secs)	SUB Pre-test errors	SUB Test - 1st exposure time (secs)	SUB Test - 1st exposure errors	SUB Test - 1st repeat time (secs)	SUB Test - 1st exposure errors	SUB Test - 2nd repeat time (secs)	SUB Test - 2nd repeat errors	SUB Test - 3rd repeat time (secs)	SUB Test - 3rd repeat errors
23	A	0	F	79													39	5	192	2	93	1	128	4	119	2
2	A	0	M	85													26	5	181	3	64	1	90	12	76	6
7	A	1	F	54													22	5	123	3	70	0	56	1	62	0
8	B	1	F	60	17	5	141	1	196	1	134	0	110	0	86	0										
13	A	1	F	38													19	5	108	0	48	1	60	13	42	0
17	A	1	F	54													31	5	146	11	76	7	108	7	98	11
4	A	1	M	40													56	2	208	10	50	0	41	1	45	0
19	B	1	M	115	25	5	90	1	391	2																
21	B	1	M	36	10	4	135	5	187	1	93	0	101	0												
22	B	2	F	54	10	5	32	5	196	0	106	1	92	25	56	0										
15	A	3	F	54													23	5	111	1	48	1	69	2	66	3
14	B	3	M	37	22	5	72	5	157	0	77	0	76	1	48	0										
				59	17		94		225		103		95		63		31		153		64		79		73	

Note: Red numbers - Pre-test score failures

Note: Pre-test 2 was removed after pilot study

Appendix P: Ethical clearance

Members:
Research Proposal and Ethics Committee
Dr P Chiroro; Dr M-H Coetzee; Prof. C Delport;
Dr JEH Grobler; Prof. KL Harris; Ms H Klopper;
Prof. E Krüger; Prof. B Louw (Chair); Prof. A Mlambo;
Prof. G Prinsloo; Mr C Puttergill; Prof. H Stander;
Prof. E Taljard; Dr J van Dyk; Prof C Walton; Mr FG Wolmarans

University of Pretoria
Research Proposal and Ethics Committee
Faculty of Humanities

15 January 2008

Dear Professor Alant

Project:	**The comparison of the effect of two visual display strategies – sub-categorisation and alphabetical order – on the speed of location of symbols in a large visual display for children aged 7 to 9 years**
Researcher:	**MP Herold**
Supervisor:	**Prof. E Alant**
Department:	**Centre for Augmentative and Alternative Communication**
Reference number:	**20240245**

Thank you for your response to the Committee's letter of 13 July 2007.

I have pleasure in informing you that the Research Proposal and Ethics Committee formally approved the above study at an *ad hoc* meeting held on 14 January 2008. The approval is subject to the candidate abiding by the principles and parameters set out in her application and research proposal in the actual execution of the research.

The Committee requests you to convey this approval to Ms. Herold.

We wish you success with the project.

Sincerely

Brenda Louw

Prof. Brenda Louw
Chair: Research Proposal and Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA

Note: Minor changes were made to the title after Ethical Clearance was granted.

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Appendix Q: Teacher's form - participant selection criteria

Teacher						
Grade						
Parent Permission	Gender	Number	Child's Name		Does the child show difficulty with independent completion of school tasks demanding concentration of less than 10 mins?	Does the child have any other specific sensory difficulties, such as uncorrected hearing or uncorrected vision?
		1				
		2				
		3				
		4				
		5				
		6				
		7				
		8				
		9				
		10				
		11				
		12				
		13				
		14				
		15				
		16				
		17				
		18				
		19				
		20				
		21				
		22				
		23				
		24				

Appendix R: Participant numbers and groups

Number available per grade	Number available per grade per gender	Parent permission granted	Not disqualified from sample	Grade	Gender	Age	Group	Participant number	Comment
		1	0	1	F				
		1	0	1	F				
		1	0	1	M				
		1	0	1	M				
		1	0	1	M				
		1	0	1	M				
		1	0	2	F				
		1	0	2	F				
		1	0	2	F				Teacher-rated selection criteria failure
		1	0	2	M				
		1	0	2	M				
		1	0	3	F				
		1	0	3	M				
		1	0	3	M				
		1	0	3	M				
		1	0	3	M				
		1	0	3	M				
1	1	1	1	1	F	7-05	A	1	
2	2	1	0	1	F	7-03	B	2	SUB Pre-test failure
3	3	1	1	1	F	7-03	A	3	
4	4	1	1	1	F	7-02	B	4	
5	5	1	1	1	F	7-02	A	5	
6	6	1	1	1	F	7-01	B	6	
7	7	1	0	1	F	7-01	A	7	SUB Pre-test failure
8	8	1	1	1	F	7-01	B	8	
9	9	1	1	1	F	7-01	A	9	
10	10	1	1	1	F	7-01	B	10	
11	11	1	1	1	F	7-00	A	11	
12	12	1	1	1	F	7-00	B	12	
13	13	1	1	1	F	6-11	A	13	
14	14	1	1	1	F	6-10	B	14	
15	15	1	1	1	F	6-10	A	15	
16	16	1	1	1	F	6-10	B	16	

Number available per grade	Number available per grade per gender	Parent permission granted	Not disqualified from sample	Grade	Gender	Age	Group	Participant number	Comment
17	17	1	1	1	F	6-10	A	17	
18	18	1	1	1	F	6-10	B	18	
19	19	1	1	1	F	6-08	A	19	
20	20	1	1	1	F	6-08	B	20	
21	21	1	1	1	F	6-07	A	21	
22	22	1	1	1	F	6-05	B	22	
23	1	1	1	1	M	8-08	A	23	
24	2	1	1	1	M	7-09	B	24	
25	3	1	1	1	M	7-09	A	25	
26	4	1	1	1	M	7-08	B	26	
27	5	1	1	1	M	7-05	A	27	
28	6	1	1	1	M	7-05	B	28	
29	7	1	1	1	M	7-05	A	29	
30	8	1	1	1	M	7-04	B	30	
31	9	1	1	1	M	7-04	A	31	
32	10	1	1	1	M	7-04	B	32	
33	11	1	1	1	M	7-02	A	33	
34	12	1	1	1	M	7-02	B	34	
35	13	1	1	1	M	7-01	A	35	
36	14	1	1	1	M	7-01	B	36	
37	15	1	1	1	M	7-00	A	37	
38	16	1	1	1	M	7-00	B	38	
39	17	1	1	1	M	6-11	A	39	
40	18	1	1	1	M	6-10	B	40	
41	19	1	1	1	M	6-10	A	41	
42	20	1	1	1	M	6-10	B	42	
43	21	1	1	1	M	6-10	A	43	
44	22	1	1	1	M	6-08	B	44	
45	23	1	1	1	M	6-07	A	45	
1	1	1	0	2	F	9-00	B	46	ALP not completed
2	2	1	0	2	F	8-05	A	47	SUB tested twice, ALP not tested
3	3	1	1	2	F	8-05	B	48	
4	4	1	1	2	F	8-04	A	49	
5	5	1	1	2	F	8-03	B	50	
6	6	1	1	2	F	8-03	A	51	

Number available per grade	Number available per grade per gender	Parent permission granted	Not disqualified from sample	Grade	Gender	Age	Group	Participant number	Comment
7	7	1	1	2	F	8-02	B	52	
8	8	1	1	2	F	8-02	A	53	
9	9	1	1	2	F	8-01	B	54	
10	10	1	1	2	F	8-01	A	55	
11	11	1	1	2	F	7-11	B	56	
12	12	1	1	2	F	7-10	A	57	
13	13	1	1	2	F	7-07	B	58	
14	14	1	1	2	F	7-05	A	59	
15	1	1	1	2	M	9-03	B	60	
16	2	1	1	2	M	8-11	A	61	Participant 63 was initially incorrectly recorded as male. Participants were divided into groups on that basis. The gender numbers were corrected for in all analyses, but it did impact minimally on the A-B and Male-Female grouping numbers. Table 5 holds the corrected numbers.
17	3	1	1	2	M	8-08	B	62	
18	4	1	1	2	M	8-08	A	63	
19	5	1	1	2	M	8-06	B	64	
20	6	1	1	2	M	8-05	A	65	
21	7	1	1	2	M	8-04	B	66	
22	8	1	1	2	M	8-04	A	67	
23	9	1	1	2	M	8-04	B	68	
24	10	1	1	2	M	8-03	A	69	
25	11	1	1	2	M	8-02	B	70	
26	12	1	1	2	M	8-02	A	71	
27	13	1	1	2	M	8-02	B	72	
28	14	1	1	2	M	8-01	A	73	
29	15	1	1	2	M	8-00	B	74	
30	16	1	1	2	M	8-00	A	75	
31	17	1	1	2	M	7-11	B	76	
32	18	1	1	2	M	7-10	A	77	
33	19	1	1	2	M	7-08	B	78	
34	20	1	1	2	M	7-07	A	79	
35	21	1	1	2	M	7-07	B	80	
1	1	1	1	3	F	9-05	A	81	
2	2	1	1	3	F	9-05	B	82	
3	3	1	1	3	F	9-04	A	83	
4	4	1	1	3	F	9-04	B	84	
5	5	1	1	3	F	9-04	A	85	
6	6	1	1	3	F	9-04	B	86	

Number available per grade	Number available per grade per gender	Parent permission granted	Not disqualified from sample	Grade	Gender	Age	Group	Participant number	Comment
7	7	1	1	3	F	9-03	A	87	
8	8	1	1	3	F	9-03	B	88	
9	9	1	1	3	F	9-02	A	89	
10	10	1	1	3	F	9-02	B	90	
11	11	1	1	3	F	9-02	A	91	
12	12	1	1	3	F	9-01	B	92	
13	13	1	1	3	F	9-00	A	93	
14	14	1	1	3	F	8-11	B	94	
15	15	1	1	3	F	8-08	A	95	
16	16	1	1	3	F	8-07	B	96	
17	17	1	1	3	F	8-07	A	97	
18	18	1	1	3	F	8-06	B	98	
19	1	1	1	3	M	9-05	A	99	
20	2	1	1	3	M	9-05	B	100	
21	3	1	1	3	M	9-04	A	101	
22	4	1	1	3	M	9-04	B	102	
23	5	1	1	3	M	9-03	A	103	
24	6	1	1	3	M	9-03	B	104	
25	7	1	1	3	M	9-02	A	105	
26	8	1	0	3	M	9-01	B	106	SUB tested twice, ALP not tested
27	9	1	1	3	M	9-00	A	107	
28	10	1	1	3	M	9-00	B	108	
29	11	1	1	3	M	9-00	A	109	
30	12	1	1	3	M	8-11	B	110	
31	13	1	1	3	M	8-09	A	111	
32	14	1	1	3	M	8-09	B	112	
33	15	1	1	3	M	8-09	A	113	
34	16	1	1	3	M	8-02	B	114	
		131	109						

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Appendix S: Example of registration slip

For administrative purposes a registration slip was used for each participant. It provided a means to cross-check the participant information records with the logged information.

Name	John Smith	
Participant number	26	
Group	B	
Grade	1	
Gender	Male	
Research assistant number	Session 1 2	Session 2 2
Computer number	Session 1 4	Session 2 4
Time started	Session 1 9:32	Session 2 10:04
General comments and observations	Searched from top-to-bottom in ALP instead of left-to-right	

Red information   Example of information filled in by researcher before testing

Blue information   Example of information filled in by research assistants during testing

Appendix T: Processing of log files

First step of processing

Log files created from each testing event were gathered from the four computers, with a copy made for external storage of the original, unaltered data. See below for an example of an unaltered log file.

T:10:53:59 O:"" P:"CONTROL.CHANGEUSER.VSR Grid Set"

T:10:54:03 O:"" P:"CONTROL.NAVIGATE"

T:10:54:05 O:"" P:"CONTROL.NAVIGATE"

T:10:54:13 B:"1,2" G:"Grp A-B"

T:10:54:13 O:"" P:"CONTROL.NAVIGATE"

T:10:54:16 B:"1,1" G:"Grp A"

T:10:54:16 O:"" P:"CONTROL.NAVIGATE"

T:10:54:26 B:"2,3" G:"Num A"

T:10:54:26 O:"7" P:"TEXT"

T:10:54:33 B:"5,6" G:"Key A"

T:10:54:33 O:"" P:"CONTROL.NAVIGATE"

T:10:54:39 B:"2,1" G:"Grd A"

T:10:54:39 O:"Grd 1 " P:"TEXT"

T:10:54:46 B:"5,5" G:"Grd A"

T:10:54:46 O:"" P:"CONTROL.CHANGEUSER.VSR Grid Set"

T:10:54:47 O:"" P:"CONTROL.NAVIGATE"

T:10:54:51 B:"1,2" G:"Grp A-B"

T:10:54:52 O:"" P:"CONTROL.NAVIGATE"

T:10:54:56 B:"1,2" G:"Grp A"

T:10:54:56 O:"" P:"CONTROL.CHANGEUSER.VSR Mouse Screening"

T:10:54:57 O:"" P:"CONTROL.NAVIGATE"

T:10:55:05 B:"1,1" G:"1 Mou Scr Ins"

T:10:55:06 O:"" P:"CONTROL.NAVIGATE"

T:10:55:15 B:"2,2" G:"1 Mou Scr Go"

T:10:55:15 O:"" P:"CONTROL.NAVIGATE"

Second step of processing

The log files were processed to remove all information not required for this study. All information pertaining to access routes to the various tasks, instruction grids and rows with the words CONTROL NAVIGATE (these merely indicated that there had been a change in the grids) were removed. Below is an example of how the original log file was prepared to look after this step of processing.

T:10:55:31 B:"7,4" G:"1 Mou Scr 06"

T:10:55:33 B:"10,7" G:"1 Mou Scr 07"

T:10:55:37 B:"2,2" G:"1 Mou Scr 08"

T:10:55:39 B:"5,5" G:"1 Mou Scr 09"

T:10:55:42 B:"8,9" G:"1 Mou Scr 10"

T:10:55:43 B:"8,9" G:"1 Mou Scr 11"

T:10:55:45 B:"1,7" G:"1 Mou Scr 11"

T:10:55:48 B:"7,2" G:"1 Mou Scr 12"

T:10:55:50 B:"8,7" G:"1 Mou Scr 13"

T:10:55:53 B:"4,9" G:"1 Mou Scr 14"

T:10:55:55 B:"10,4" G:"1 Mou Scr 15"

T:10:55:59 B:"4,3" G:"1 Mou Scr 16"

T:10:56:01 B:"10,1" G:"1 Mou Scr 17"

T:10:56:04 B:"5,8" G:"1 Mou Scr 18"

T:10:56:07 B:"9,5" G:"1 Mou Scr 19"

T:10:56:09 B:"3,5" G:"1 Mou Scr 20"

T:10:56:58 B:"5,4" G:"1 Sub Pre 01 A"

T:10:57:05 B:"5,2" G:"1 Sub Pre 01 B"

T:10:57:09 B:"5,4" G:"1 Sub Pre 02 A"

T:10:57:12 B:"8,5" G:"1 Sub Pre 02 B"

T:10:57:16 B:"5,4" G:"1 Sub Pre 03 A"

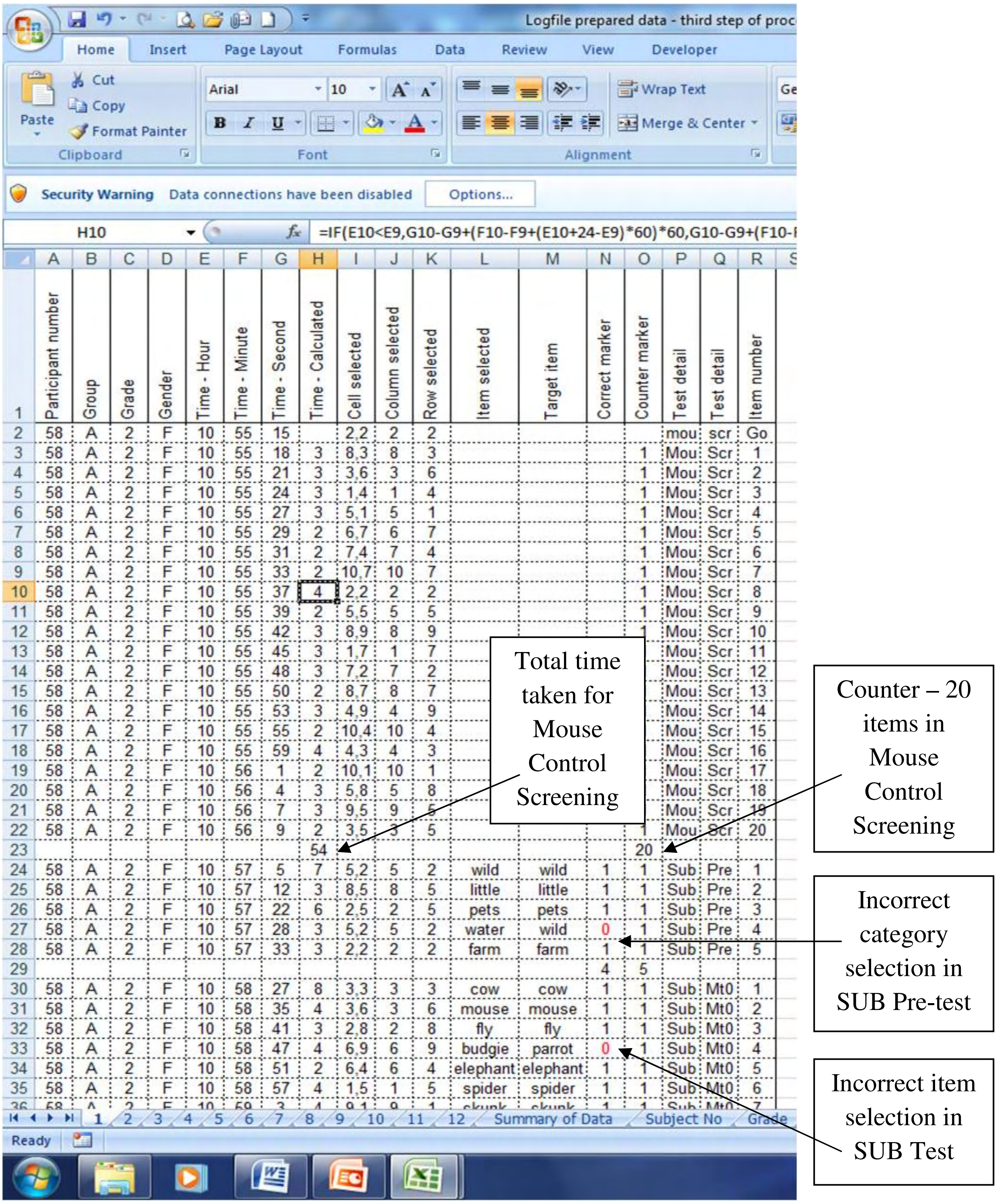
T:10:57:22 B:"2,5" G:"1 Sub Pre 03 B"

Third step of processing

The data was now ready to transfer into and Excel spreadsheet for further processing. Through Excel's import function, the data could be imported in a manner that could separate the various elements of the information into columns. With Excel's macro function, macros were created to further remove excess information, calculate the time taken for selections and add columns to hold other calculated information (such as correct/incorrect selections and symbols chosen). Below is an example of a resultant spreadsheet.

A control for accidental erasure of a line of information was embedded in the '1' in front of the test name e.g. 1 Mou Scr or 1 Sub Pre. The '1's would be summed during processing to ensure that the correct number of lines was represented. Any errors noted would be investigated in the original data.

The pre-tests were marked manually. If the participant failed to achieve 4 correct selections out of 5 in the pre-test, his data was not included in the final data bank.



Fourth step of processing

The next step of data preparation was to collect all the data files for each participant into a master spreadsheet and prepare it in a format suitable for the statistician.

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Appendix U: Procedural integrity check for particpant instruction

Scoring criteria

0 - Section omitted 1 - Section executed

Comments

Any deviation from protocol as presented in instruction manual
Any imbalance in style and time taken between sections
Any other observations that may be relevant

				Rater 1			Rater 2		
				Grd 1	Grd 2	Grd 3	Grd 1	Grd 2	Grd 3
Section	No.	Subsection	Time (30	Score					
Introduction	1	Introduce self and study	2	1	1	1	1	1	1
	2	Assent requested		1	1	1	1	1	1
	3	Forms filled in		1	1	1	1	1	1
Concept of subcategories	4	Concept explained	6	1	1	1	1	1	1
	5	3 demo examples		1	1	1	1	1	1
	6	6 practice examples		1	1	1	1	1	1
Using subcategories to locate symbols in display	7	Concept explained	6	1	1	1	1	1	1
	8	3 demo examples		1	1	1	1	1	1
	9	6 practice examples		1	1	1	1	1	1
Concept of initial phonic of words	10	Concept explained	5	1	1	1	1	1	1
	11	3 demo examples		1	1	1	1	1	1
	12	6 practice examples		1	1	1	1	1	1
Using alphabetic order to locate symbols in display	13	Concept explained	6	1	1	1	1	1	1
	14	3 demo examples		1	1	1	1	1	1
	15	6 practice examples		1	1	1	1	1	1
Subcategories computer pre-test	16	Concept explained	4	1	1	1	1	1	1
	17	3 demo examples		1	1	1	1	1	1
Subcategories computer main test	18	Concept explained		1	1	1	1	1	1
	19	3 demo examples		1	1	1	1	1	1
Alphabetic Order computer pre-test	20	Concept explained		1	1	1	1	1	1
	21	3 demo examples		1	1	1	1	1	1
Alphabetic Order computer main test	22	Concept explained		1	1	1	1	1	1
	23	3 demo examples		1	1	1	1	1	1
Closing	24	Thank you	1	1	1	1	1	1	1
	25	Gift given		1	1	1	1	1	1
			Total score	25	25	25	25	25	25
			Total percentage	100	100	100	100	100	100

Rater comments	Rater 1	Grd 2: Class slightly disruptive but well handled.
		Grd 2: Not all the children could see the PC screen.
	Rater 2	General: Three omissions of question "Do you have any questions?" after concept was explained and practice opportunity was given, and one omission of drawing attention to escape arrow.

Appendix V: Procedural integrity for testing - by participant

							Ses 1			Ses 2		
No of sessions rated	Participant number	Group	Session	Test	Grade	Gender	Sections executed - Max 12	% correctly scored	Unauthorised assitance	Sections executed - Max 9	% correctly scored	Unauthorised assistance
1	6	B	1	ALP	1	F	12	100.00	0			
1	17	A	1	SUB	1	F	11	91.67	0			
1	19	A	1	SUB	1	F	12	100.00	0			
1	21	A	1	SUB	1	F	12	100.00	0			
1	28	B	1	ALP	1	M	12	100.00	0			
1	34	B	1	ALP	1	M	12	100.00	0			
1	56	B	1	ALP	2	F	11	91.67	0			
1	57	A	1	SUB	2	F	11	91.67	0			
1	59	A	1	SUB	2	F	12	100.00	1			
1	66	B	1	ALP	2	M	11	91.67	0			
1	67	A	1	SUB	2	M	12	100.00	0			
1	68	B	1	ALP	2	M	12	100.00	0			
1	72	B	1	ALP	2	M	11	91.67	0			
1	76	B	1	ALP	2	M	12	100.00	0			
1	85	A	1	SUB	3	F	11	91.67	0			
1	86	B	1	ALP	3	F	12	100.00	0			
1	95	A	1	SUB	3	F	12	100.00	0			
1	98	B	1	ALP	3	F	11	91.67	0			
1	101	A	1	SUB	3	M	12	100.00	0			
1	1	A	2	ALP	1	F				8	88.89	0
1	10	B	2	SUB	1	F				8	88.89	0
1	11	A	2	ALP	1	F				8	88.89	0
1	20	B	2	SUB	1	F				8	88.89	0
1	21	A	2	ALP	1	F				8	88.89	0
1	22	B	2	SUB	1	F				8	88.89	0
1	24	B	2	SUB	1	M				8	88.89	0
1	26	B	2	SUB	1	M				9	100.00	0
1	39	A	2	ALP	1	M				9	100.00	0
1	60	B	2	SUB	2	M				9	100.00	0
1	68	B	2	SUB	2	M				8	88.89	0
1	75	A	2	ALP	2	M				8	88.89	0
1	79	A	2	ALP	2	M				8	88.89	0
1	82	B	2	SUB	3	F				8	88.89	0
1	91	A	2	ALP	3	F				8	88.89	0
1	94	B	2	SUB	3	F				8	88.89	0
1	95	A	2	ALP	3	F				8	88.89	0
1	97	A	2	ALP	3	F				8	88.89	0
37							Ave	96.93		Ave	90.74	
							Total average		93.84			

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Procedural integrity for testing - by section

Scoring criteria

Procedure: 0 - Section omitted 1 - Section correctly executed

Indication of unauthorised assistance: Score 1 for every occurence

Comments

Any deviation from protocol as presented in procedure manual, integrity of sound file or any other observation that may be relevant.

Section	No.	Subsection	Score: % correct execution, Session 1	Score: % correct execution, Session 2	Score: Unauthorised assistance	Researcher comments on procedural integrity errors.
Introduction	1	Greeting given	89.47			Recording only began after greeting.
	2	Mouse position determined	73.68			It may be that the participants reached for the mouse before the research assistant formally asked which side they wanted it on.
	3	Rules explained	100.00			
Mouse Screening	4	Description of task	100.00			
	5	"Work as fast as you can"	100.00			
First Pretest	6	Description of task	100.00			
	7	6 demo symbols covered	100.00			
	8	5 test symbols executed	100.00			
First Test	9	Description of task	100.00			It occurred once during a SUB Test that an assitant said "A fly is a small creature" in response to a child's question about the fly.
	10	6 demo symbols covered	100.00			
	11	36 test symbols executed	100.00		1	
Break	12	Sent for refresments	100.00			
	13	10 mins between sessions		100.00		
Introduction	14	Mouse position determined		16.67		It may be that in the second session, the participants were familiar with the task and reached for the mouse on their own, without it having to be discussed formally.
Second Pretest	15	Description of task		100.00		
	16	6 demo symbols covered		100.00		
	17	5 test symbols executed		100.00		
Second Test	18	Description of task		100.00		
	19	6 demo symbols covered		100.00		
	20	36 test symbols executed		100.00		
Closing	21	Thank you + gift given		100.00		
		Total	96.93	90.74		
		Average	93.84			

Rater Comments	Instructions for the test tended to be paraphrased. Instructions such as 'Work fast but be careful' and 'Think carefully' were often paraphrased to 'As fast as you can' or 'Look carefully' or even 'Now do it all by yourself'.'
Researcher Comments	Instructions were highly scripted but not designed to be read verbatim. The omission by the research assistants to present the prompts concerning working fast but carefully, or to think carefully, was unfortunate, and represents a weakness in the procedural integrity of this study.

Appendix W: Summary of all data collected

Grade	Gender	Number of participants	Mean mouse screening score	Failed ALP Pre-test	Mean ALP Time	Mean ALP Score	Total forward selections in ALP	Total error selections in ALP	Failed SUB Pre-test	Mean SUB Time	Mean SUB Score	Total forward selections in SUB	Total error selections in SUB	Mean ALP-SUB Time Difference	Mean ALP-SUB Score Difference	Mean ALP Item Time	Mean ALP Item Score	Mean SUB Item Time	Mean SUB Item Score
1	F	20	47.40	0	412.00	29.05	98	41	2	208.45	32.65	38	29	203.55	-3.60	11.44	0.81	5.79	0.91
1	M	23	49.30	0	451.52	28.78	104	62	0	221.61	32.83	28	45	229.91	-4.04	12.54	0.80	6.16	0.91
1	All	43	48.42	0	433.14	28.91	202	103	0	215.49	32.74	66	74	217.65	-3.84	12.03	0.80	5.99	0.91
2	F	12	38.42	0	284.33	33.08	8	27	0	166.25	34.42	8	11	118.08	-1.33	7.90	0.92	4.62	0.96
2	M	21	37.95	0	347.76	31.19	60	41	0	168.71	33.48	20	33	179.05	-2.29	9.66	0.87	4.69	0.93
2	All	33	38.12	0	324.70	31.88	68	68	0	167.82	33.82	28	44	156.88	-1.94	9.02	0.89	4.66	0.94
3	F	18	34.22	0	214.61	34.06	18	17	0	141.50	34.67	10	14	73.11	-0.61	5.96	0.95	3.93	0.96
3	M	15	34.60	0	238.13	34.00	14	16	0	157.00	34.60	5	16	81.13	-0.60	6.61	0.94	4.36	0.96
3	All	33	34.39	0	225.30	34.03	32	33	0	148.55	34.64	15	30	76.76	-0.61	6.26	0.95	4.13	0.96
		Total	Average	Total	Average	Average	Total	Total	Total	Average	Average	Total	Total	Average	Average	Average	Average	Average	Average
		109	41.06	0	337.39	31.36	302	204	2	180.79	33.64	109	148	156.60	-2.28	9.37	0.87	5.02	0.93

Appendix X: Participant data

Grade	Participant Number	ALP								SUB								ALP-SUB Diff	
		Time				Score				Time				Score				Time	Score
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max		
1	1	10.08	9.93	1	40	0.81	0.40	0	1	5.78	6.37	1	33	0.92	0.28	0	1	4.31	-0.11
1	3	9.56	6.32	2	28	0.86	0.35	0	1	6.61	3.48	2	17	0.97	0.17	0	1	2.94	-0.11
1	4	11.31	10.74	2	38	0.86	0.35	0	1	5.69	5.82	2	31	0.94	0.23	0	1	5.61	-0.08
1	5	13.58	13.17	2	50	0.83	0.38	0	1	7.39	12.10	2	75	0.97	0.17	0	1	6.19	-0.14
1	6	10.78	11.31	2	63	0.75	0.44	0	1	6.25	5.64	2	27	0.89	0.32	0	1	4.53	-0.14
1	8	9.78	11.52	1	54	0.86	0.35	0	1	4.78	4.36	1	21	0.89	0.32	0	1	5.00	-0.03
1	9	18.53	26.53	2	145	0.75	0.44	0	1	5.08	5.67	2	28	1.00	0.00	1	1	13.44	-0.25
1	10	7.17	7.27	1	30	0.94	0.23	0	1	4.58	3.02	2	15	0.94	0.23	0	1	2.58	0.00
1	11	11.42	10.77	2	44	1.00	0.00	1	1	5.00	3.95	2	17	0.97	0.17	0	1	6.42	0.03
1	12	15.61	14.16	2	69	0.81	0.40	0	1	7.86	6.64	2	26	0.86	0.35	0	1	7.75	-0.06
1	13	8.64	7.56	1	32	0.89	0.32	0	1	5.53	5.47	2	29	0.89	0.32	0	1	3.11	0.00
1	14	8.86	6.12	1	24	0.56	0.50	0	1	6.36	4.44	2	19	0.83	0.38	0	1	2.50	-0.28
1	15	11.11	8.48	1	39	0.58	0.50	0	1	4.61	3.38	1	18	0.75	0.44	0	1	6.50	-0.17
1	16	5.67	4.16	2	19	0.97	0.17	0	1	4.67	4.68	1	19	0.94	0.23	0	1	1.00	0.03
1	17	13.00	18.09	1	100	0.86	0.35	0	1	4.42	4.33	2	24	1.00	0.00	1	1	8.58	-0.14
1	18	6.61	4.78	2	16	0.83	0.38	0	1	4.28	3.15	1	13	0.86	0.35	0	1	2.33	-0.03
1	19	14.67	11.40	2	43	0.78	0.42	0	1	4.39	2.51	2	14	0.94	0.23	0	1	10.28	-0.17
1	20	13.56	13.08	3	70	0.69	0.47	0	1	8.86	5.43	2	22	0.89	0.32	0	1	4.69	-0.19
1	21	14.81	12.63	2	51	0.78	0.42	0	1	7.64	8.19	2	32	0.89	0.32	0	1	7.17	-0.11
1	22	14.17	12.90	1	69	0.72	0.45	0	1	6.03	4.88	2	23	0.78	0.42	0	1	8.14	-0.06
1	23	7.22	6.91	1	27	0.83	0.38	0	1	5.36	5.30	1	26	0.83	0.38	0	1	1.86	0.00
1	24	7.67	6.13	2	30	0.92	0.28	0	1	5.00	4.24	2	23	0.97	0.17	0	1	2.67	-0.06
1	25	11.44	9.46	1	39	0.61	0.49	0	1	7.14	10.50	1	60	0.81	0.40	0	1	4.31	-0.19
1	26	16.42	19.61	2	87	0.92	0.28	0	1	8.44	12.08	1	65	0.92	0.28	0	1	7.97	0.00
1	27	11.61	18.41	2	81	0.86	0.35	0	1	5.25	4.09	1	20	0.89	0.32	0	1	6.36	-0.03
1	28	10.31	10.91	1	63	0.97	0.17	0	1	5.42	4.51	2	23	0.92	0.28	0	1	4.89	0.06

Appendix X.1

Appendix X.2

Grade	Participant Number	ALP								SUB								ALP-SUB Diff	
		Time				Score				Time				Score				Time	Score
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max		
1	29	13.33	13.45	1	55	0.78	0.42	0	1	4.61	3.82	1	21	0.97	0.17	0	1	8.72	-0.19
1	30	5.97	5.35	1	29	0.83	0.38	0	1	3.39	1.93	1	12	0.89	0.32	0	1	2.58	-0.06
1	31	11.14	9.51	2	34	0.69	0.47	0	1	8.89	10.60	1	53	0.86	0.35	0	1	2.25	-0.17
1	32	11.00	7.85	1	29	0.75	0.44	0	1	5.33	5.05	1	26	1.00	0.00	1	1	5.67	-0.25
1	33	17.50	13.49	3	59	0.92	0.28	0	1	8.47	9.24	2	48	0.94	0.23	0	1	9.03	-0.03
1	34	11.28	9.31	2	39	0.81	0.40	0	1	8.44	4.46	2	19	0.92	0.28	0	1	2.83	-0.11
1	35	14.83	19.03	2	82	0.81	0.40	0	1	7.61	8.81	2	39	0.92	0.28	0	1	7.22	-0.11
1	36	31.67	28.62	3	108	0.69	0.47	0	1	6.53	5.39	2	26	0.94	0.23	0	1	25.14	-0.25
1	37	13.28	10.74	1	35	0.61	0.49	0	1	4.64	6.22	1	37	0.89	0.32	0	1	8.64	-0.28
1	38	9.03	8.83	2	42	0.81	0.40	0	1	4.06	2.11	2	12	0.89	0.32	0	1	4.97	-0.08
1	39	9.22	8.29	2	42	0.81	0.40	0	1	6.00	7.32	2	43	0.97	0.17	0	1	3.22	-0.17
1	40	13.92	10.99	1	43	0.28	0.45	0	1	7.42	5.17	1	28	0.72	0.45	0	1	6.50	-0.44
1	41	11.64	11.31	2	50	0.83	0.38	0	1	6.36	7.98	2	36	0.94	0.23	0	1	5.28	-0.11
1	42	13.75	25.39	1	137	0.97	0.17	0	1	5.31	4.39	1	20	0.92	0.28	0	1	8.44	0.06
1	43	9.94	8.16	2	35	0.92	0.28	0	1	6.19	6.57	2	34	0.94	0.23	0	1	3.75	-0.03
1	44	14.75	14.72	2	50	0.94	0.23	0	1	5.08	6.69	2	41	0.97	0.17	0	1	9.67	-0.03
1	45	12.67	14.57	2	74	0.83	0.38	0	1	5.78	4.74	1	29	0.94	0.23	0	1	6.89	-0.11
2	48	7.83	7.31	2	36	0.92	0.28	0	1	4.08	2.45	2	13	1.00	0.00	1	1	3.75	-0.08
2	49	8.78	9.01	2	36	0.97	0.17	0	1	5.81	6.48	1	31	1.00	0.00	1	1	2.97	-0.03
2	50	7.81	7.60	1	29	0.86	0.35	0	1	4.94	5.94	1	35	0.97	0.17	0	1	2.86	-0.11
2	51	8.92	8.44	1	37	1.00	0.00	1	1	5.11	9.19	1	57	0.89	0.32	0	1	3.81	0.11
2	52	7.61	6.20	1	28	0.92	0.28	0	1	4.50	7.06	1	45	0.97	0.17	0	1	3.11	-0.06
2	53	6.56	5.19	1	23	0.97	0.17	0	1	3.14	1.69	1	11	0.94	0.23	0	1	3.42	0.03
2	54	7.42	7.38	2	35	0.86	0.35	0	1	6.72	4.49	1	22	0.92	0.28	0	1	0.69	-0.06
2	55	6.39	4.62	2	29	0.92	0.28	0	1	4.64	3.00	2	15	0.94	0.23	0	1	1.75	-0.03
2	56	6.22	3.81	2	15	0.92	0.28	0	1	3.92	2.48	1	13	0.94	0.23	0	1	2.31	-0.03
2	57	7.06	7.26	2	44	0.94	0.23	0	1	3.19	1.83	1	9	0.94	0.23	0	1	3.86	0.00
2	58	11.14	9.41	1	33	0.83	0.38	0	1	5.00	4.08	1	16	1.00	0.00	1	1	6.14	-0.17

Appendix X.3

Grade	Participant Number	ALP								SUB								ALP-SUB Diff	
		Time				Score				Time				Score				Time	Score
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max		
2	59	9.06	8.13	2	35	0.92	0.28	0	1	4.36	3.45	2	22	0.94	0.23	0	1	4.69	-0.03
2	60	8.89	9.17	1	46	0.75	0.44	0	1	2.86	2.00	1	11	0.89	0.32	0	1	6.03	-0.14
2	61	10.89	10.20	1	44	0.72	0.45	0	1	4.19	4.08	1	20	0.97	0.17	0	1	6.69	-0.25
2	62	7.58	6.42	2	33	0.97	0.17	0	1	4.19	2.56	1	12	0.97	0.17	0	1	3.39	0.00
2	63	8.61	7.33	2	35	0.72	0.45	0	1	5.06	4.00	1	19	0.83	0.38	0	1	3.56	-0.11
2	64	8.44	4.82	2	22	0.94	0.23	0	1	4.67	5.09	1	29	0.97	0.17	0	1	3.78	-0.03
2	65	9.58	12.00	1	49	0.94	0.23	0	1	5.11	10.50	1	57	0.97	0.17	0	1	4.47	-0.03
2	66	8.58	7.55	1	29	0.89	0.32	0	1	4.33	4.43	1	21	0.94	0.23	0	1	4.25	-0.06
2	67	19.67	18.38	2	90	0.75	0.44	0	1	5.33	4.96	2	26	0.92	0.28	0	1	14.33	-0.17
2	68	8.00	8.18	1	43	0.94	0.23	0	1	4.36	6.32	1	33	0.94	0.23	0	1	3.64	0.00
2	69	9.50	7.67	2	33	0.92	0.28	0	1	5.64	8.56	2	50	0.94	0.23	0	1	3.86	-0.03
2	70	11.53	11.42	2	49	0.86	0.35	0	1	5.08	4.34	1	19	0.97	0.17	0	1	6.44	-0.11
2	71	8.97	9.65	1	47	0.89	0.32	0	1	5.28	8.89	1	52	0.92	0.28	0	1	3.69	-0.03
2	72	7.69	7.39	2	33	0.94	0.23	0	1	4.44	3.89	2	24	0.97	0.17	0	1	3.25	-0.03
2	73	8.89	6.95	2	34	0.86	0.35	0	1	5.44	4.27	1	17	0.94	0.23	0	1	3.44	-0.08
2	74	7.86	5.44	2	24	0.89	0.32	0	1	3.42	2.52	1	13	0.94	0.23	0	1	4.44	-0.06
2	75	8.25	7.75	2	39	0.81	0.40	0	1	5.86	4.99	1	26	0.81	0.40	0	1	2.39	0.00
2	76	6.39	4.95	1	26	0.92	0.28	0	1	4.22	2.71	1	14	0.83	0.38	0	1	2.17	0.08
2	77	9.36	8.90	1	36	0.94	0.23	0	1	3.69	1.62	1	8	0.92	0.28	0	1	5.67	0.03
2	78	13.58	15.04	2	78	0.89	0.32	0	1	4.81	4.70	2	27	0.92	0.28	0	1	8.78	-0.03
2	79	9.67	8.16	1	34	0.83	0.38	0	1	6.22	8.12	2	45	1.00	0.00	1	1	3.44	-0.17
2	80	10.42	11.92	2	58	0.83	0.38	0	1	4.19	3.04	2	19	0.94	0.23	0	1	6.22	-0.11
3	81	6.22	4.68	2	19	1.00	0.00	1	1	3.17	2.32	1	14	1.00	0.00	1	1	3.06	0.00
3	82	5.39	5.07	1	28	0.92	0.28	0	1	3.14	1.48	2	9	0.97	0.17	0	1	2.25	-0.06
3	83	6.36	5.03	1	23	0.97	0.17	0	1	5.00	4.43	1	25	0.92	0.28	0	1	1.36	0.06
3	84	5.64	5.86	1	25	0.92	0.28	0	1	6.53	8.57	2	53	0.86	0.35	0	1	-0.89	0.06
3	85	4.61	2.80	1	15	0.97	0.17	0	1	3.81	3.20	1	15	1.00	0.00	1	1	0.81	-0.03
3	86	6.00	4.25	2	23	0.92	0.28	0	1	2.92	1.66	1	8	0.92	0.28	0	1	3.08	0.00

Appendix X.4

Grade	Participant Number	ALP								SUB								ALP-SUB Diff	
		Time				Score				Time				Score				Time	Score
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max		
3	87	4.83	2.57	2	12	0.94	0.23	0	1	3.31	2.08	1	10	0.97	0.17	0	1	1.53	-0.03
3	88	6.03	3.76	1	15	0.94	0.23	0	1	3.31	2.05	2	11	0.97	0.17	0	1	2.72	-0.03
3	89	5.89	4.98	1	26	0.86	0.35	0	1	3.22	1.73	1	9	1.00	0.00	1	1	2.67	-0.14
3	90	7.58	5.62	1	29	0.97	0.17	0	1	5.03	3.91	2	20	0.94	0.23	0	1	2.56	0.03
3	91	6.17	4.69	2	18	0.97	0.17	0	1	3.75	2.20	1	12	1.00	0.00	1	1	2.42	-0.03
3	92	5.06	3.16	1	14	0.97	0.17	0	1	3.97	2.76	2	15	0.97	0.17	0	1	1.08	0.00
3	93	5.83	4.82	1	23	0.94	0.23	0	1	3.44	3.52	1	22	0.94	0.23	0	1	2.39	0.00
3	94	4.06	1.82	1	10	1.00	0.00	1	1	3.83	2.91	2	16	1.00	0.00	1	1	0.22	0.00
3	95	5.53	4.64	1	21	0.92	0.28	0	1	3.94	3.21	1	14	0.94	0.23	0	1	1.58	-0.03
3	96	7.42	6.78	1	27	0.92	0.28	0	1	3.94	3.37	1	14	0.97	0.17	0	1	3.47	-0.06
3	97	6.06	4.82	1	24	0.97	0.17	0	1	3.56	2.72	1	16	1.00	0.00	1	1	2.50	-0.03
3	98	8.64	10.28	2	47	0.92	0.28	0	1	4.89	3.33	2	18	0.94	0.23	0	1	3.75	-0.03
3	99	5.11	3.36	1	14	0.97	0.17	0	1	4.50	6.84	1	40	0.94	0.23	0	1	0.61	0.03
3	100	4.42	3.06	1	14	0.94	0.23	0	1	3.08	1.20	1	6	1.00	0.00	1	1	1.33	-0.06
3	101	6.06	3.58	1	16	0.94	0.23	0	1	3.53	2.27	1	12	0.92	0.28	0	1	2.53	0.03
3	102	10.92	14.36	1	51	0.97	0.17	0	1	7.89	9.24	1	34	0.92	0.28	0	1	3.03	0.06
3	103	5.56	5.17	2	27	0.97	0.17	0	1	3.67	2.79	1	13	1.00	0.00	1	1	1.89	-0.03
3	104	5.36	5.07	1	29	1.00	0.00	1	1	3.19	2.46	1	14	1.00	0.00	1	1	2.17	0.00
3	105	8.14	8.42	2	47	0.92	0.28	0	1	3.42	3.32	1	17	1.00	0.00	1	1	4.72	-0.08
3	107	6.42	5.02	1	19	0.86	0.35	0	1	5.00	5.29	1	27	0.86	0.35	0	1	1.42	0.00
3	108	5.11	3.30	1	12	1.00	0.00	1	1	3.50	3.05	1	18	0.94	0.23	0	1	1.61	0.06
3	109	6.14	3.98	1	19	0.97	0.17	0	1	3.53	1.83	1	10	1.00	0.00	1	1	2.61	-0.03
3	110	5.33	2.69	1	11	0.92	0.28	0	1	3.42	2.06	1	12	0.97	0.17	0	1	1.92	-0.06
3	111	8.25	7.59	2	36	0.86	0.35	0	1	3.50	2.30	1	14	0.89	0.32	0	1	4.75	-0.03
3	112	7.58	6.85	2	29	0.97	0.17	0	1	5.69	5.14	2	27	0.97	0.17	0	1	1.89	0.00
3	113	5.39	3.78	1	17	1.00	0.00	1	1	4.81	5.32	2	29	1.00	0.00	1	1	0.58	0.00
3	114	9.33	11.21	2	63	0.89	0.32	0	1	6.69	12.21	2	74	1.00	0.00	1	1	2.64	-0.11

Mean scores higlighted in grey indicate data in which there was one of the 36 items which was incorrecly recorded (see section 3.6.6).

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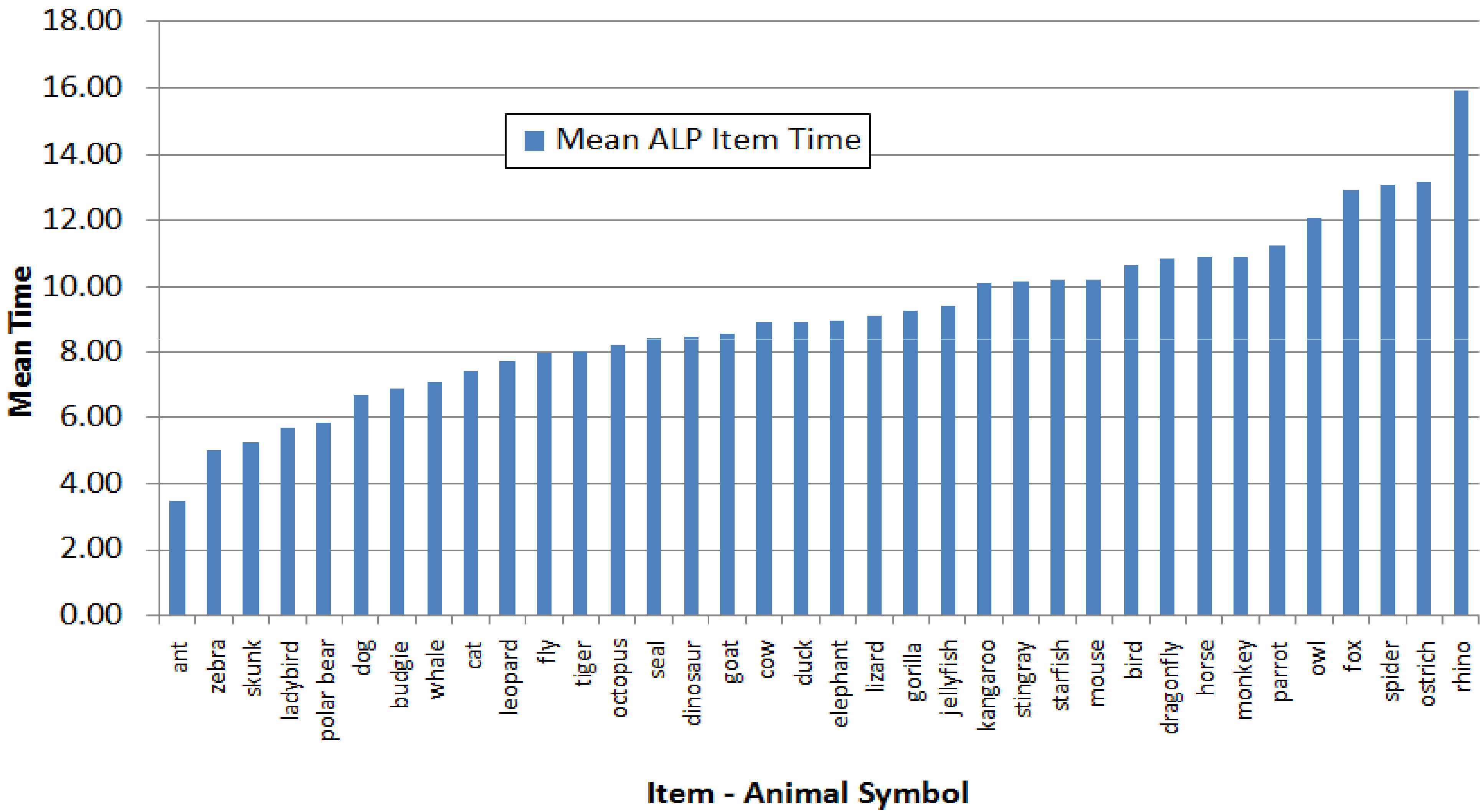
Appendix Y: Item data

Item No	Symbol	Time		Score					
		ALP	SUB	ALP			SUB		
				% Correct	% Escape	% Error	% Correct	% Escape	% Error
1	cow	9.27	5.06	91.75	4.59	3.67	92.66	3.67	3.67
2	mouse	10.77	12.68	88.07	8.25	3.67	86.24	7.34	6.42
3	fly	8.28	3.28	91.74	1.83	6.42	94.49	0.92	4.59
4	budgie	7.02	8.09	92.66	3.67	3.67	80.73	11.01	8.26
5	elephant	9.28	4.95	86.24	7.34	6.42	97.25	1.83	0.92
6	spider	13.69	4.99	83.49	10.09	6.42	97.25	0.00	2.75
7	skunk	5.49	7.36	89.91	3.67	6.42	88.99	8.26	2.75
8	octopus	8.35	3.68	90.83	6.42	2.75	94.50	0.92	4.59
9	duck	9.45	7.20	86.24	8.26	5.50	92.66	2.75	4.59
10	tiger	8.01	3.01	91.74	4.59	3.67	96.33	0.00	3.67
11	zebra	5.23	4.18	95.41	2.75	1.83	93.58	2.75	3.67
12	gorilla	9.55	7.18	87.15	8.26	4.59	90.83	3.67	5.50
13	whale	7.15	3.22	95.41	1.83	2.75	94.49	3.67	1.83
14	ostrich	13.88	8.69	82.57	10.09	7.34	87.16	7.34	5.50
15	ladybird	5.69	2.70	95.41	0.92	3.67	99.08	0.00	0.92
16	starfish	10.45	4.12	82.57	7.34	10.09	97.25	1.83	0.92
17	parrot	11.49	4.00	81.65	12.84	5.50	91.74	3.67	4.59
18	polar bear	6.04	2.49	92.66	2.75	4.59	98.17	0.00	1.83
19	bird	11.34	4.16	83.49	10.09	6.42	92.66	3.67	3.67
20	dragonfly	11.55	4.66	80.73	13.76	5.50	88.99	3.67	7.34
21	jellyfish	9.30	2.46	85.32	11.01	3.67	98.16	0.00	1.83
22	dinosaur	8.81	4.46	94.50	1.83	3.67	97.25	0.92	1.83
23	fox	12.84	6.04	83.49	10.09	6.42	92.66	1.84	5.50
24	cat	7.64	3.47	89.91	3.67	6.42	88.99	1.83	9.17
25	kangaroo	10.32	7.79	76.15	14.68	9.17	94.50	2.75	2.75
26	owl	12.73	4.47	78.90	17.43	3.67	95.41	1.83	2.75
27	goat	8.62	7.80	89.91	5.50	4.59	88.07	6.42	5.50
28	leopard	7.94	3.68	89.91	8.26	1.83	91.74	2.75	5.50
29	horse	10.98	4.94	86.24	9.17	4.59	95.41	3.67	0.92
30	stingray	10.46	4.10	81.65	9.17	9.17	95.41	0.00	4.59
31	monkey	11.23	5.97	77.07	14.68	8.26	97.25	0.92	1.83
32	dog	6.93	3.31	95.41	2.75	1.83	94.50	0.92	4.59
33	lizard	9.27	4.50	83.49	9.17	7.34	95.41	1.83	2.75
34	ant	3.56	3.85	96.33	0.92	2.75	95.41	1.84	2.75
35	rhino	16.39	4.57	69.73	22.02	8.26	92.66	3.67	3.67
36	seal	8.57	3.40	88.07	7.34	4.59	96.33	1.83	1.83

Appendix Z: Mean time for test items

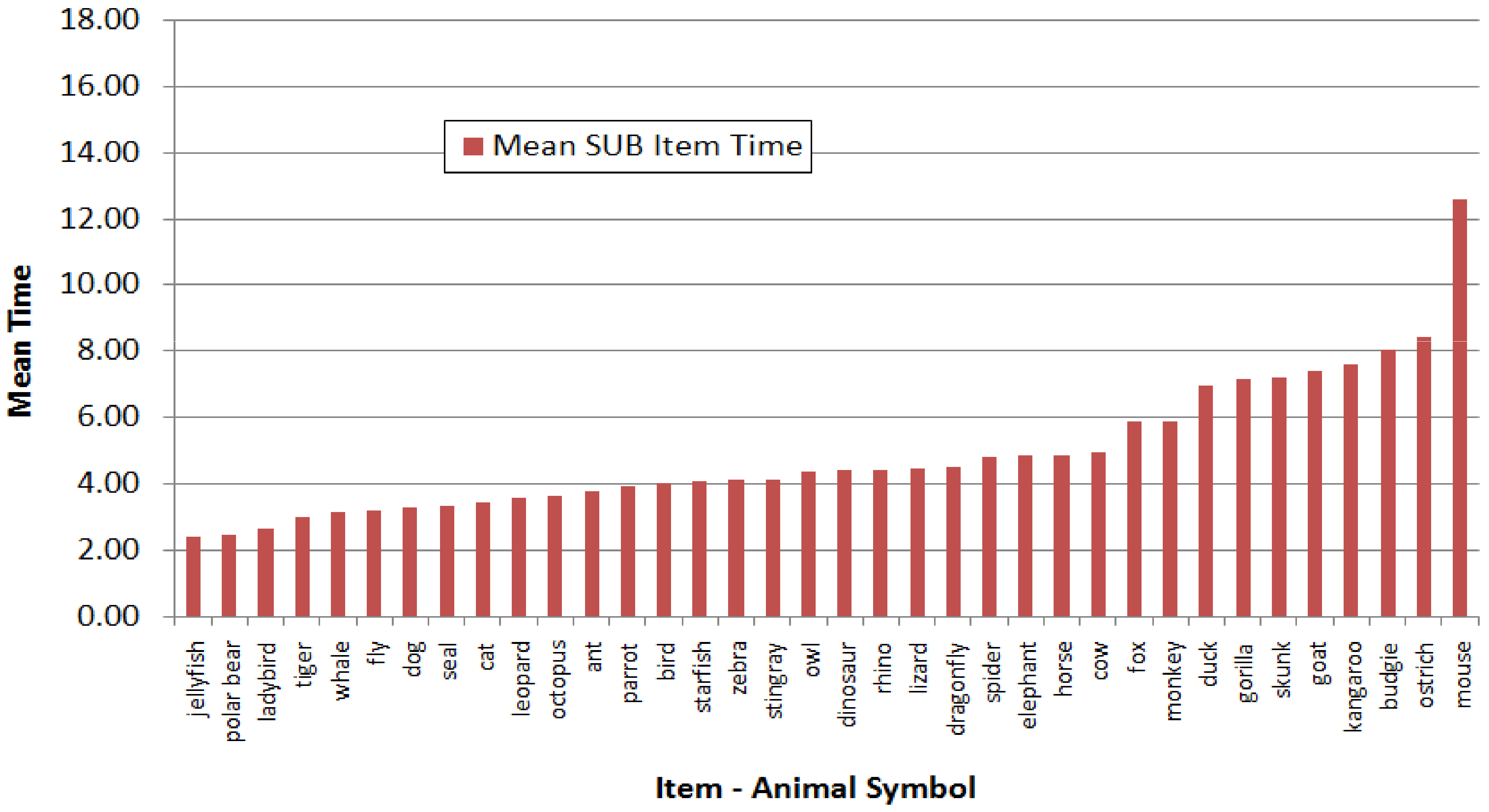
Mean time for ALP test items



Appendix Z.1

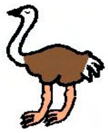
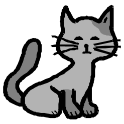
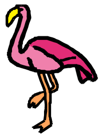
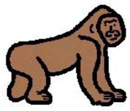
Appendix Z.2

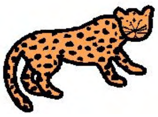
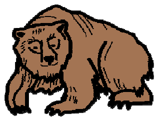
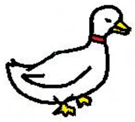
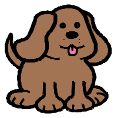
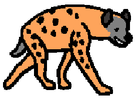
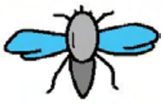
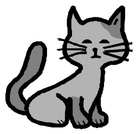
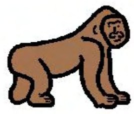
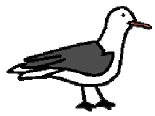
Mean time for SUB test items



Appendix AA - Error symbols

The most common errors that can not be explained by being a neighbouring cell of a target cell are presented below. Errors selections that were symbols in neighbouring cells to the target cell were considered to probably be due to mouse control factors.

ALP	Target	cat 	kangaroo 	dragonfly 	ostrich 	monkey 
	Selected	kitten 	koala bear 	fly 	flamingo 	gorilla 

SUB	Target	dog 	leopard 	dragonfly 	cat 	bear 	duck 
	Selected	puppy 	hyena 	fly 	kitten 	gorilla 	seagull 

Appendix AB: Comparison between experimental research, this study and AAC usage

Key	Equivalence between this study and AAC usage.
	Similarities between this study and AAC usage.
	Equivalence between experimental research and this study.
	Similarities between experimental research and this study.
	Minimal similarity between experimental research, this study and AAC usage.

	Experimental research	This study	AAC usage
Visual characteristics of symbols	Arbitrary visual images	Line drawings representational form (PCS symbols)	Various representational forms, such as photos, line drawings and words
	Simple images - often single featured or a simple conjunction of features	Complex images made up of very many basic features, such as lines, shapes, colours and details	Complex images made up of very many basic features, such as lines, shapes, colours and details
	Various colours, such as black on white, white on black or multi-coloured	Multi-coloured	Predominantly multi-coloured
Arrangement of symbols in visual display	Usually minimal relationship between placement of one symbol and another	Structured arrangement of symbols in rows and columns	Structured arrangement of symbols in rows and columns
	No lines or markers to demarcate areas in the visual field or to separate items	Grid format - horizontal and vertical lines (or spaces that form lines) to separate symbols	Grid format - horizontal and vertical lines (or spaces that form lines) to separate symbols
	Usually randomly placed across display	Organised by category or alphabetical order	Variably organized, often by category or alphabetical order
Colour coding	Seldom specific highlighting of individual symbols	Symbol background colour-coding to highlight category or alphabetical groupings	Variably highlighted by strategies such as symbol background colour groupings, font, cell shape and border colours
	Seldom grouping of symbols in specific areas in display	Grouping of colour-coded symbols in specific areas on display	Sometimes grouping of colour-coded symbols in specific areas in grid, sometimes colour-coded symbols are scattered in grid

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	Experimental research	This study	AAC usage
Semantic characteristics of symbol	Predominantly non-referential or non-symbolic	Referential / symbolic	Referential / symbolic
	No gloss present	Gloss present	Gloss present
	Abstract	Nouns	All parts of speech
	Non-contextual	Non-contextual	Contextual
Use of symbol	Experimental activity	Experimental activity	Functional activity
	Single symbol	Single symbol	Multiple symbols joined together
	Isolated - unrelated to the previous or subsequent symbol	Isolated - unrelated to the previous or subsequent symbol	Symbol part of a sentence – used in message generation, where user is formulating a unique message and each symbol has a specific function in the message
	On command of researcher - the participant is told what symbol to find next	On command of researcher – the participant is told what symbol to find next	Self-determined
	All symbols used are repeated in exactly the same form and order for each participant	All symbols used are repeated in exactly the same form and order for each participant	Unique interaction with symbol - symbol use is dependent on the message needs of the user
	Visual perception of a target before search begins	Visual perception of a target before search begins	No initial visual perception of a target - symbol elicited by independent thought on the part of the user
	Target location occurs when there is a recognition match between the symbol in working memory and the symbol in the display.	Target location occurs when there is a recognition match between the symbol in working memory and the symbol in the display.	Target location occurs when there is a match between a code (visual or semantic?) in memory and the target
	Decision making processes are seldom required to begin a search for a target - only decision relating to identification of presence or absence of target required	A decision making process must occur between the initial visual perception of the symbol and where to focus the search in the array	A thought process concerning which symbol to search for must occur and a decision must be made where to focus the search for the target in the array
Participants	People without disabilities	People without disabilities	People with disabilities
	All ages - mostly adults	Children, ages 6-9	All ages – mostly children if PCS symbols are used

	Experimental research	This study	AAC usage
Methodology of testing	First time exposure	First time exposure	Much exposure to system, through training, user development over time, growth of system, and functional practice
	Reaction time and accuracy are the most common variables measured	Reaction time and accuracy are the most common variables measured	The message to be communicated is the most important issue in measuring the use of the AAC system
	A 'match-to-sample' task (sometimes delayed)	A delayed 'match-to-sample' task	No match to a previously presented symbol
	Memory of the symbol is required if the target is removed from view	Memory of the symbol is required as the target is removed from view and has to be found in another field	Memory of symbol's availability and in which grid it will be found is required. Memory of specific cell location is useful
	Reaction time is the sum of the observation time + identification time + decision time (which motor response to make) + motor response execution time	Time is measured from the mouse click on the target to the mouse click on the selected symbol (i.e. identification time + motor response execution time)	Selection time not measured
	Data collected measured in msecs.	Data collected measured in secs.	Selection time not measured
	Symbol usually exposed for very brief periods	Symbol exposed for as long as participant wants. However, participants are urged to complete the test as quickly as they can	Symbol exposed for as long as user wants. AAC users have their symbols available at all times and can control how long they attend to the symbol
	The participant is required to make a choice of two different motor responses (e.g. to hit a switch to indicate yes or no for presence or absence of target)	The participant is required to indicate target location with a mouse click on the target	The participant is required to indicate target location with a mouse click on the target, direct selection on touch screens and manual boards, or a switch press if scanning
	Target may be present (about 50% of trials)	Target always present	Target usually present. If not, and required, can be added to system
	A range of two symbols to many symbols to match the target symbol against	81 symbols to match the target against	A wide range in the number of symbols to locate the desired symbol in