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.

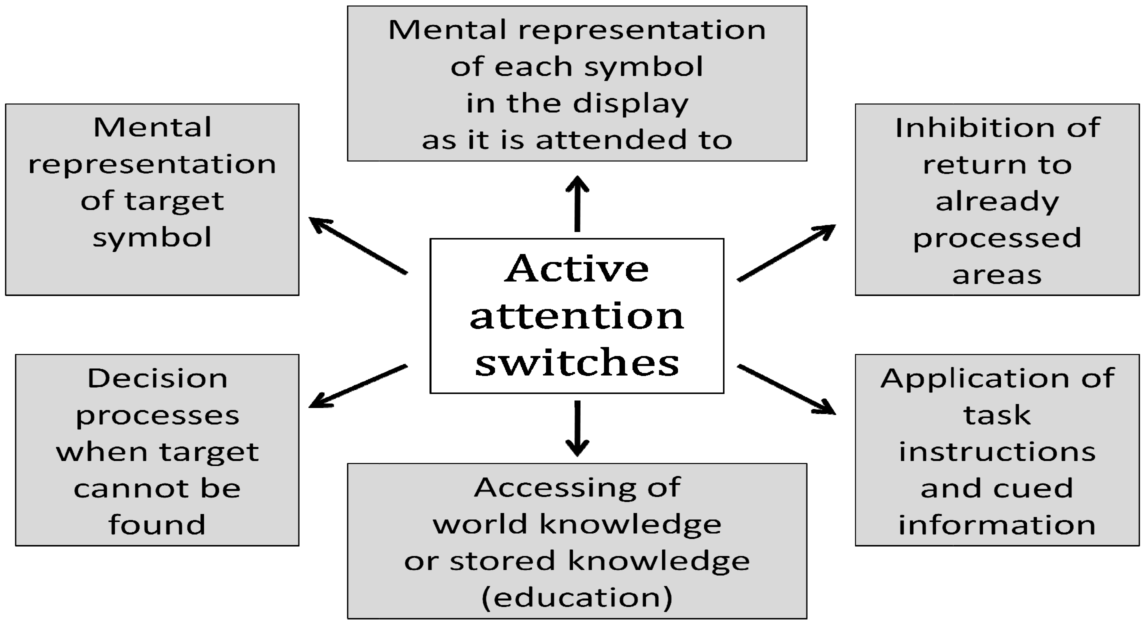

Figure 2. Active attention switches

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.