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.

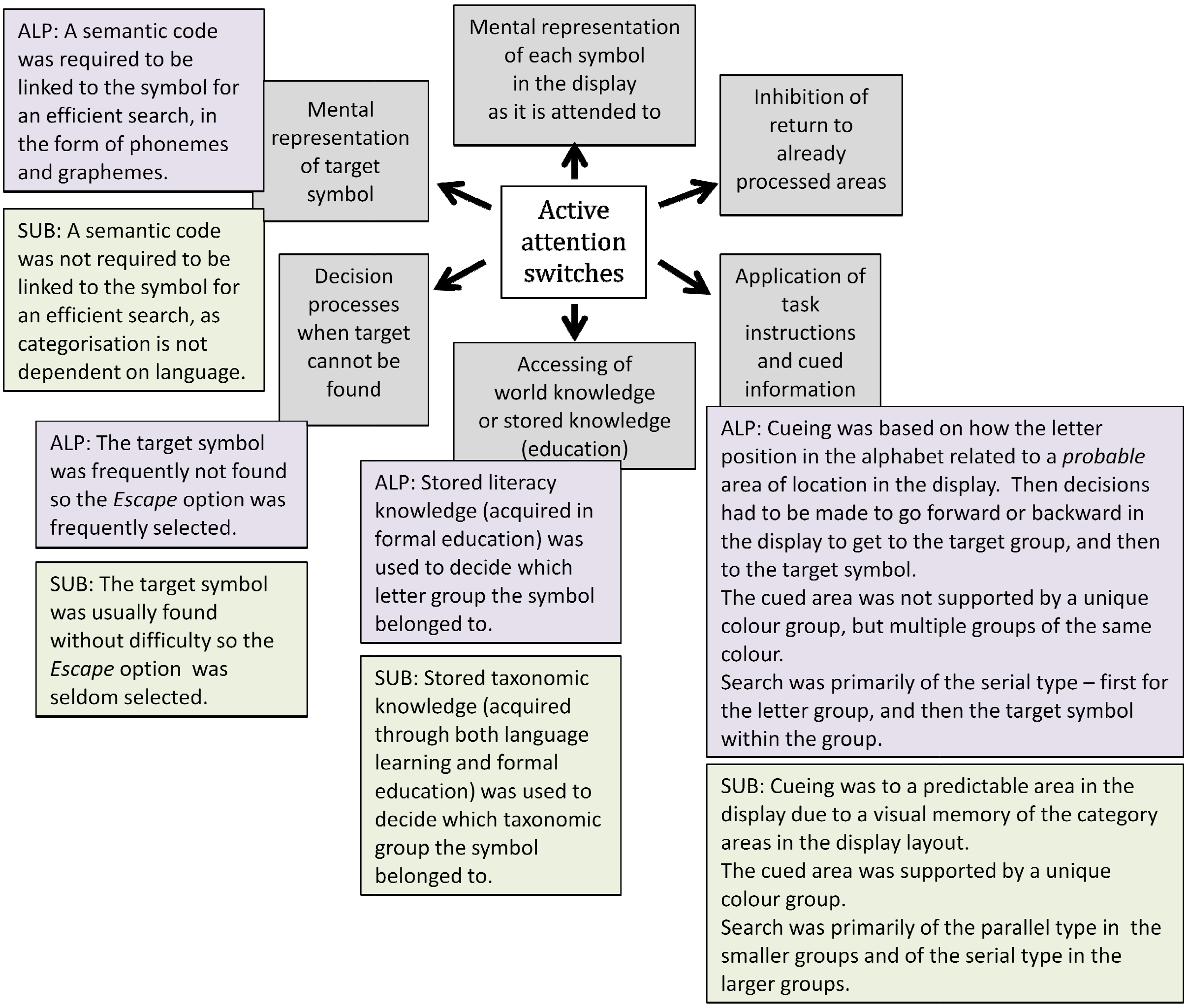

Figure 13. Active attention switches in ALP and SUB

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.