ATTENTION TO CONTEXT IN HIGH FUNCTIONING CHILDREN WITH AUTISM

by

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ABSTRACT

The present study investigated the sentence processing skills of high-functioning children with autism and Asperger Syndrome. Specifically it aimed to determine whether these children were able to attend to and use linguistic constraints during real-time processing in the same way as their age peers. Nineteen children, divided into two groups, an autistic group and an age-matched group, participated in the study. Sentence processing abilities were assessed using a word-monitoring paradigm. The participants were required to press a button as soon as they heard a prespecified target word in an auditorily presented sentence. The target words occurred in four different sentence conditions: Normal, Syntactic, Random Word Order, and Semantic Anomaly. Reaction times were recorded. Working memory span was also assessed using a counting span task.

The children in the autistic group resembled their age peers in their overall response pattern across the sentence conditions, but they were faster in three of the four conditions. Across both groups reaction times increased from the Normal condition to the Syntactic condition to the Random Word Order and Semantic Anomaly conditions. Working memory spans were comparable between the groups. Results are seen to indicate that high-functioning children with autism or Asperger Syndrome are able to attend to and use local linguistic contextual constraints but may have deficits in constructing and/or integrating global context during on-line processing.
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CHAPTER ONE
LITERATURE REVIEW

Introduction

Disturbances in language and social communication are central features of autism. To receive a diagnosis of autism an individual must show "the presence of markedly abnormal or impaired development in social interaction and communication" (p. 66, APA, 1994). However, this, in itself, doesn't explain the nature of these deficits in language and communication.

The language of autistic individuals has been the focus of much research over the past few decades. Research has found that phonological development in autistic children appears to follow the same developmental course as in typically developing children, as does the developmental course of syntax (Tager-Flusberg, 1981a). Any delays in these areas are likely related to the developmental level of the child rather than a specific deficit in syntax or phonology.

Some researchers have found that autistic children appear to have specific abnormalities in semantic information-processing abilities (Tager-Flusberg, 1981a). Studies have shown that they make little use of meaning when recalling verbal material (Hermelin & O'Connor, 1967), are poorer than control groups at using semantically based strategies (Tager-Flusberg, 1981b), and show frequent violations of semantic constraints while speaking (Simmons & Baltaxe, 1975).

Despite these findings, other studies have shown that some autistic children develop large vocabularies and can perform well on standardized vocabulary tests, such
as the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997). This seems to imply that it is not word meanings per se that the children have difficulty with, but rather the ability to conceptualize and understand the meanings and relationships that exist between words (Tager-Flusberg, 1981a).

Another area that autistic individuals struggle with is using language appropriately. In fact, Frith (1989a) concluded, "there is nothing autistic in the language itself, just in the use of language" (p. 148). They appear to be impaired in their ability to extract meaning from a wider context (Frith, 1989a). In order to use language appropriately, social context, the communicative environment, and linguistic context (i.e., the semantic, syntactic and pragmatic cues) must be attended to. There is evidence that individuals with autism have trouble paying attention to social context, suggested by their often "inappropriate" or "odd" social interaction style (Baron-Cohen, 1988). However, less is known about their attention to linguistic context. An inability to integrate linguistic cues during communication could also lead to inappropriate language use. For example, homophones have more than one meaning (e.g., "bank" can mean the side of a river or a building where money is kept). In order to understand the word appropriately an individual must take the sentential context in which the word is embedded into account. Failure to do so could lead to inappropriate comprehension. Recent research by Jolliffe and Baron-Cohen (1999, 2000) found that autistic individuals were less likely than normal individuals (matched for age and IQ) to use linguistic context to interpret ambiguous sentences and also less likely to provide context-appropriate pronunciation of a homograph.
To date, no research has been done specifically examining autistic children’s ability to use linguistic contextual constraints during real-time processing. Research, such as that done by Jolliffe and Baron-Cohen (1999, 2000), looking at autistic individuals’ ability to use sentence context in off-line comprehension suggests that autistic individuals may have difficulty using linguistic contextual cues during on-line processing. This study hopes to fill this gap in the research by investigating autistic children’s ability to use contextual information during real-time sentence processing. Based on previous research, we expect that the autistic children will show difficulties in this area.

To set the stage for this investigation we look next at the literature on language processing itself and particularly on the development of language processing.

The Nature of Language Processing

Language processing is an instance of information processing. It involves representations, processes to generate, transform or manipulate the representations, and a finite amount of attentional resources used to activate the representations and processes (Kail & Bisanz, 1982). Research done with normal adults has provided us with a significant amount of data on the processing characteristics specific to language. First, there is considerable evidence that processing takes place incrementally and continuously. Listeners form intermediate representations rather than waiting until the end of the word or utterance. Other work has shown that language processing is also contextually influenced, in that processing can be shown to be facilitated or inhibited depending on the presence and nature of contextual information. Finally, studies involving working memory have shown that it plays an important role in the
comprehension of language. The following sections will explore the research done in each of these areas.

**Contextually Influenced**

Marslen-Wilson and Tyler (1980) investigated how different contextual constraints influenced word recognition during real-time processing. They used an online word-monitoring task, in which the subjects listened to a sentence for a target word previously specified, and made a response as soon as the target word was detected. The target words occurred in three different prose contexts. The Normal Prose sentences were syntactically and semantically normal and the lead-in sentences provided some discourse context for the test sentences. For example:

(1) The church was broken into last night. Some thieves stole most of the *lead off* the roof. (*lead* is the target word) (p. 8, Marslen-Wilson & Tyler, 1980).

The Syntactic Prose sentences were syntactically interpretable but had no coherent semantic interpretation. The lead-in sentence did not provide an intelligible context for the test-sentence. For example:

(2) The power was located into great water. No buns puzzle some in the *lead off* the text. (p. 8, Marslen-Wilson & Tyler, 1980).

Finally the Random Word-Order sentences were neither syntactically nor semantically interpretable. For example:

(3) Into was power water the great located. Some the no puzzle buns in *lead* text the off. (p. 8, Marslen-Wilson & Tyler, 1980).
In this way each sentence type contained a different amount of contextual support from full support to no support at all. They predicted that word monitoring would be facilitated in the Normal Prose sentences by the presence of the syntactic and semantic information.

As predicted, Marslen-Wilson and Tyler (1980) found that reaction times were faster when more contextual constraints were available (i.e., in the Normal Prose sentences). It appeared that both semantic and syntactic information was made available during processing and interacted with the incoming acoustic-phonetic information to increase processing efficiency. From these results they developed a “cohort”-based interactive recognition theory. They argued that the acoustic-phonetic information activated a cohort of candidate words that began with the sound sequence that had been heard up to that point. The way in which a final candidate was chosen could be determined by one of a variety of factors. Subsequent acoustic-phonetic input could further reduce the number of candidates, as more and more candidates became inconsistent with the input. However, contextual constraints could also interact with members of the cohort. The semantic and syntactic properties of the candidates in the cohort could be assessed against the requirements of the sentential context in which the word to be recognized was occurring. In this way the contextual factors, along with the acoustic-phonetic information, could allow a single word candidate to be selected from among its competitors. Furthermore, the discourse context in which a sentence occurred could also provide an immediate framework for processing subsequent words. They concluded that there was a flexible and continuous interaction between contextual constraints and acoustic information. The presence of semantic and syntactic constraints
immediately reduced the size of the initial cohort so that less acoustic-phonetic information needed to be processed. Using contextual constraints made processing more efficient. Moreover, they found that semantic constraints were almost twice as effective as syntactic constraints alone at reducing the size of the cohort. Word-candidates could not be as readily deleted from the cohort purely on the basis of syntactic constraints. This makes sense when you consider that the cohort size for “noun” is vastly larger than any semantic category, such as “animal”.

The results of the Marslen-Wilson and Tyler (1980) study provide evidence that context plays a significant role during real-time sentence processing. Semantic constraints are dominant and operate by enabling word candidates to be rejected because they map inappropriately onto the meaning representation that is available at that point in the utterance. However, both syntactic constraints and pragmatic constraints contribute to the processing by providing information on the form class of the word and creating a framework for processing. By allowing for interaction between knowledge sources during processing, the processing system is designed for optimal efficiency and speed.

Further research has also supported the idea that context plays an important role in language processing. A study by Marslen-Wilson, Brown and Tyler (1988) also found evidence for contextual effects during processing. Their study used target words that were either normal with respect to the preceding verb or which violated either pragmatic, semantic or categorical constraints imposed by the verb’s argument structure. They found that the syntactic and semantic constraints had immediate effects on processing. They concluded that their results were consistent with a model of language processing.
that was both continuous, incremental and used higher-level information (i.e., context) during processing.

Finally, research using "garden-path" sentences, where the listener is expecting the sentence to have one meaning when in fact it may have a completely different meaning, has demonstrated that context can mediate the garden-path effects. For example, lexically specific syntactic information, semantic plausibility, frequency of lexical co-occurrence and referential context have all been found to rapidly constrain adults' on-line commitments to interpretation (Trueswell et al., 1999).

Altmann et al. (1994) explored whether contextual information could influence a parser's initial decision. The study used two sentence types, object relatives (e.g., The politician told the woman that he'd been meeting that he was going to see the minister.), and subject relatives (e.g., The politician told the woman that had been meeting him that he was going to see the minister.). They presented these sentences to participants with either no preceding context or a preceding referential context. They predicted that the reading times to sentences containing "that had been" would be greater than those to sentences containing "that he'd been" because the latter supports the preferred sentence complement reading. They also predicted that this difference would disappear when the target sentences were preceded by their appropriate contexts. They measured reading time by tracking eye movements. They found that reading time was faster to "that he'd been" than to "that had been", revealing a garden-path effect for the latter sentence types. When the sentences were preceded by an appropriate referential context, however, the differences between the sentence types disappeared. The authors interpreted the results as showing that the context led the parser to the appropriate interpretation right away,
avoiding the garden-path. They concluded that referential context could influence the parsing mechanism toward a specific interpretation.

**Incremental and Continuous Processing**

In the cohort theory (Marslen-Wilson & Tyler, 1980) discussed above word recognition takes place rapidly in time. The theory proposes that multiple candidates are activated prior to completion of the acoustic-phonetic input and that candidates are continuously eliminated by the subsequent acoustic-phonetic input and by contextual constraints. This characteristic has been labeled “incremental processing” (Swingley, Pinto, & Fernald, 1999). Evidence for incremental processing in adult word recognition has been found using a lexical decision task (Marslen-Wilson, 1984) and a visual fixation task (Allopenna et al, 1998).

Marslen-Wilson (1984) used a lexical decision task to investigate incremental processing in word recognition. The task required participants to listen to words and non-words and to indicate whether auditory targets were words of English or not. The discrimination points of all of the targets were determined, where the discrimination point was defined as the point at which the target word diverged from all other words in the language. For example, the sequence “trenker” becomes a non-word at the /k/, since there are no words of English beginning with /tren/ with /k/ as the next sound. Marslen-Wilson (1984) hypothesized that if speech was processed incrementally the non-word decision could be made at the discrimination point in each item. He found that response latencies to non-words could be predicted if the discrimination point was known. Marslen-Wilson
(1984) concluded listeners could continuously assess the incoming speech signal against possible word candidates.

A recent study by Allopenna et al. (1998) also demonstrated incremental processing of speech using an on-line visual fixation task. The task required participants to view a computer display showing four pictures of familiar objects arranged in a square. In each trial the participant fixated on the center of the square and then followed spoken instructions to manipulate the pictures on the screen with the mouse (e.g., take the beaker and put it above the triangle). During the task the participants’ eye movements were monitored using an eyetracking system. On some trials two of the objects could be named using words with identical onsets (e.g., beaker, beetle). Allopenna et al. (1998) found that when the spoken words matched one of the two pictures subjects tended to fixate both objects with the overlapping onsets. Shortly after the target word became inconsistent with the unnamed object, fixations to this object sank to the baseline frequency. The authors claimed that the results provided strong evidence that listeners continuously mapped speech input onto potential lexical representations as the input unfolded over time.

The above results provide evidence that speech is processed incrementally with acoustic-phonetic information and contextual information constantly being used to recognize the word. Initially activated candidates can be eliminated by evaluation of both the context in which the word to be recognized is situated and the continuing acoustic-phonetic input the listener hears. The role that working memory plays in processing will be examined next.
The Role of Working Memory in Language Processing

Working memory is a resource-limited system that includes both storage and processing functions, where both storage and processing share a finite pool of resources (Montgomery, 2000). It plays an important role in all forms of complex thinking, including language processing. In language processing working memory is critical for storing the intermediate and final products of a listener's computations and for simultaneously constructing a message from the continuous stream of input (Just & Carpenter, 1992). Storage at the lexical level involves retrieving representations of earlier words and phrases in a sentence and relating them to later words and phrases. There are also storage demands at other levels such as storing the theme of the conversation, the representation of the situation to which it refers, the major ideas from the preceding sentence and a running multilevel representation of the sentence that is currently being processed (Just & Carpenter, 1992). Processing demands involve language operations and computations (e.g., comparisons, retrieval) that generate various types of representations (e.g., lexical, grammatical) from the input.

The fact that storage and processing occur simultaneously during comprehension and that they share the same pool of resources has important consequences for language processing. If storage demands are high, fewer resources will be left for processing and vice versa. If the total amount of resources available to the system is less than is required to perform a given comprehension task then comprehension will suffer. For example, representations constructed early in a sentence may be forgotten so that processing can continue. In this situation processing is likely to continue more slowly since resources
are limited. This implies that when task demands are high, processing will slow down and some partial representations may be forgotten (Just & Carpenter, 1992).

Just and Carpenter (1992) also hypothesized that the nature of a person’s language comprehension abilities is dependent on his or her working memory capacity. They proposed that individuals vary in the amount of resources they have available for the computational and storage demands of language processing. The research done with high-span and low-span individuals has shown that there are indeed qualitative differences among individuals whose working memory capacity differs (Just & Carpenter, 1992; King & Just, 1991). When task demands were high enough to strain capacity, individuals with smaller working memory capacities were less able to perform computations quickly or to store intermediate products. Just and Carpenter (1992) argued that when capacity is exceeded those processes that are less demanding of resources, such as lower level processes and automatic processes are likely to be favoured over higher-level processes. For example, in a spoken language processing task a person whose working memory capacity is exceeded may depend only on acoustic-phonetic input and may not execute higher-level processes such as integrating contextual constraints into processing. They also argued that individuals could differ in the time or resources required for any one component of processing. For example, if an individual were particularly slow at lexical access then that process might consume so much of the resources that an insufficient amount of resources would be left for other processes.

To summarize, researchers have found that working memory plays an important role in the comprehension of language, both in storing intermediate representations and in processing incoming information. It seems that working memory capacity can differ
among individuals and, as such, can affect their comprehension performance. Individuals with less working memory capacity are likely to show less effective and efficient processing when the demands of the task exceed the capacity available in their system.

The next section will explore what changes, if any, occur in language processing during development and when those changes occur. One way to look at developmental difficulties, such as the poor comprehension abilities observed in autistic children, is to view these difficulties as reflections of some failure to achieve the expected developmental change.

**Developmental Changes in Language Processing**

During development there are likely to be changes in both the processes and representations used in language processing and in working memory. These changes could occur in four areas (Kail & Bisanz, 1982). First, there could be changes in the procedures used, with more sufficient and efficient procedures replacing initial procedures. For example, processing could become increasingly incremental and continuous, and contextual constraints could be taken advantage of as children get older. Second, these procedures could be executed more rapidly. Third, the actual representations could change in that the number of representations could increase and the size of the representational unit could also increase during development. For example, children's vocabulary size increases rapidly throughout development, as does the "size" of each element in the lexicon as more meaning is attached to it. Finally, the amount of available resources in working memory may also increase with age, thereby allowing more and more complex information to be processed without breakdowns in
comprehension. The increase in working memory resources can be accomplished by either an increase in the total amount of resources or by automatization (amount remains constant but processes require fewer resources). (Kail & Bisanz, 1982)

The next sections explore the possibility that children’s ability to process language incrementally and to use contextual constraints does differ from that in adults and hence is an area of developmental change. The development of working memory is also explored to determine whether there are any differences between adults and children.

Incremental Processing

Research has shown that speech processing in adults is incremental (i.e., that the listener’s interpretation of what is said is updated continuously). Recently researchers have begun to ask whether this is also true of children’s speech processing. For a number of reasons researchers have suggested that children and adults might differ in their ability to use speech incrementally over time in interpreting speech (Swingley, Pinto & Fernald, 1999). First, continuous interpretation of speech may be possible only with the benefit of massive practice. Since children have less practice they may need to process speech more slowly, and with more effort (Swingley et al., 1999). Second, in adult models of processing, segmentation is facilitated by matching portions of speech with words in the lexicon (Marslen-Wilson & Tyler, 1980). Children, who know fewer words, are more likely to encounter words they don’t know and so may be less likely to process speech in this way since matching may occur too infrequently to make it helpful (Swingley et al., 1999). Finally, some researchers have suggested that young children’s representations of the sound forms of words are qualitatively different from adults’ representations. If this
is the case, then rapid and incremental processing may not be effective for early word recognition (Swingley et al., 1999). If the representations in children’s lexicons are different from those of adults’, then identifying words in an adult manner may result in unnecessary activation. On the other hand, it is also possible that young children process speech continuously and incrementally, just as adults do. They may perform just like adults with small lexicons.

A recent study by Swingley et al. (1999) used a visual fixation procedure to explore whether children’s on-line speech processing differed from that of adults with regard to being incremental and continuous. In this procedure infants are seated on their parent’s lap facing two computer monitors that each display a picture of a common object. The pictures are shown in silence for a few seconds and then a prerecorded utterance is played labeling one of the pictures. The pictures continue to be displayed, during which time the infants generally fixate on the labeled picture. The infants’ fixations are measured from videotapes made during the session, which allows researchers to determine the proportion of instances that the infants fixated on the labeled picture as well as the infants’ response latencies in orienting to the target picture. By choosing words that either start with the same sound or a different sound researchers can assess whether it takes the infants longer to orient to the target in trials in which the objects have overlapping onsets compared to trials in which the objects do not have overlapping onsets (Swingley et al., 1999).

Swingley et al. (1999) found that children as young as 24 months old showed a delay in responding to the onset-overlap items compared to the non-overlapping items. They argued that the children awaited the arrival of acoustic-phonetic input that
distinguished the object alternatives and responded only once a particular word could be
singled out. They interpreted this as evidence of incremental and continuous processing.
To ensure that the results from the children were in fact similar to those of adults, they
conducted the same procedure with adults. They found that the adults’ responses were
very similar to the children’s, both in the pattern of results and in the magnitude of the
differences between conditions. However, in absolute speed the adults were predictably
faster. The authors speculated that the differences in absolute response latencies likely
reflected the adults’ greater experience in word recognition (Swingley et al., 1999).
These results would also be consistent with the notion that children need to hear more of
a word to recognize it than adults do.

In summary, there is new evidence that by 24 months of age, children can, and do,
process speech incrementally and continuously (Swingley et al., 1999). However, the
fact that the children were slower than the adults suggests that, although children do
process speech incrementally, they are still less efficient at it and might require more
acoustic-phonetic information than adults before they can recognize a word.

Context Effects

Adults’ language processing system is capable of rapidly coordinating linguistic
properties of the message with information from the context. The use of contextual
information, such as semantic context, facilitates word recognition. The ability to use
context is believed to increase the efficiency of on-line word processing because it
enables the listener to use multiple sources of information together to constrain possible
word candidates (Marslen-Wilson & Tyler, 1980). However, children just learning their
first language may be unable to use semantic context to facilitate language processing because they know comparatively fewer words and may not know enough about semantic or syntactic relations. In order for semantic context to be useful, the listener must know that particular words are likely to occur in the context of other words or that semantic relations can limit the possible candidates of an upcoming word (Goodman, 1997). Very young children may also have difficulty using contextual information because of limits in processing capacity. That is, since the analysis of acoustic information and the various contextual constraints all demand resources, very young children may be unable to take advantage of contextual information during sentence processing (Goodman, 1997).

As a follow-up to their study with adults, Tyler and Marslen-Wilson (1981) conducted a similar study with children aged 5-, 7-, and 10-years-old. As in their earlier study (Marslen-Wilson & Tyler, 1980), the children performed an on-line word monitoring task under different contextual conditions. They found that the children had faster response latencies when more contextual information was available, just as the adults had. The results showed that children as young as 5-years-old were able to use essentially the same types of analysis of the input as older children and adults. They did, however, find some developmental differences. The 5-year-olds’ performance was worse when asked to monitor for the target having been given only the category of the target (not the actual target). For example, in (4) below, the target word is *hand* but the child would be told to monitor for a word that is part of the category “body parts”.

(4) John had to go back home. He had fallen out of the swing and had hurt his *hand* on the ground. (p. 402, Tyler & Marslen-Wilson, 1981).
The authors interpreted this to indicate that the younger children had not yet mastered the use of discourse cues, which help to guide the mapping of an utterance onto its discourse context (Tyler & Marslen-Wilson, 1981). Moreover, they found that the absolute reaction times of the children decreased with age, suggesting that children become more efficient processors as they get older. Despite this, the results of the study suggest that children as young as 5-years-old are able to take advantage of contextual information during sentence processing.

A recent study by Trueswell, Sekerina, Hill and Logrip (1999) investigated children’s on-line processing using an eye-tracking system. Their study involved ambiguous sentences to determine whether the children were able to use different contextual cues to resolve the ambiguity. For example, in the sentence “Put the frog on the napkin in the box” the prepositional phrase “on the napkin” could be interpreted as a destination for the frog (i.e., put the frog onto the napkin), or as a modifier for the frog (i.e., put the frog that’s on the napkin in the box). The target sentence was heard in one of two visual contexts, a 1-Referent context and a 2-Referent context. The 1-Referent context supported the destination interpretation and consisted of one frog, on a napkin, another animal (not on a napkin), an empty box and an empty napkin. Since the scene consisted of only one frog, modification with “on the napkin” would be unnecessary, and the listeners were expected to interpret the phrase as a destination, referring to the empty napkin. The 2-Referent condition supported the modifier interpretation and consisted of two frogs, one on a napkin and one not on a napkin, as well as an empty napkin and an empty box. In this case, when the listeners heard “the frog” they would not know which one and should interpret the phrase “on the napkin” as a modifier. They conducted the
experiment with children, aged 4 years 8 months to 5 years 10 months, and with adults. They found that the children were able to incrementally interpret speech and to scan the scene in a manner similar to the adults. In terms of resolving the ambiguities the adults pursued a modifier interpretation of the ambiguous phrase when the visual context supported this interpretation and a destination interpretation when visual context supported it. The children, on the other hand, preferred the destination interpretation regardless of context. Moreover, the children showed an inability or reluctance to revise initial interpretation commitments, whereas adults seemed able to recover from the temporary consideration of an incorrect interpretation. The authors concluded that the results of this study showed that children rely more heavily on local linguistic factors to influence parsing preferences and have a general inability to revise initial commitments to interpretation (Trueswell et al., 1999).

Finally a recent study by Roe et al. (2000) looked at the effect of sentence priming on picture naming in participants aged 3- to 87-years-old. Object pictures were presented in auditory contexts that were semantically congruent, incongruent, or neutral in relation to each picture, and participants were asked to name the picture as quickly as possible. The sentences below are examples of the three contexts (p.757, Roe et al., 2000).

(5) Peter eats his soup with a [spoon].

(6) Peter eats his soup with a [book].

(7) Here is the [cat].

Sentence (5) is an example of the congruent condition, in which the sentence stem provided strong semantic constraints for the target word. Sentence (6) is an example of the incongruent condition, in which the sentence stem was semantically inappropriate for
the target word. Sentence (7) is an example of the neutral condition, in which the
sentence stem was contextually unbiased.

They found that overall reaction times for the children were much slower than the
reaction times for the adults. However, the pattern of results across sentence type was
similar to that observed with adults. They argued that this suggested that sentence
context affected picture naming even in young, preschool-aged children and that the
pattern of context effects for children was qualitatively similar to those observed in
adults. There was, however, a significant decrease in magnitude of the interference
component (from the incongruent contexts) from age 3- to 5-years. Comparatively, the
facilitative component of sentence priming (from congruent contexts) was clearly
established by 4-years of age (Roe et al., 2000).

The data presented provides some evidence that young children are able to take
advantage of context to some extent during processing. However, there are obvious
developmental differences in this ability from childhood to adulthood. Young children
appear to be inefficient at using discourse cues (Tyler & Marslen-Wilson, 1981), are
more likely to use local linguistic cues than visual context to resolve ambiguous
structures (Trueswell et al., 1999) and are poor at revising initial parsing commitments
(Trueswell et al., 1999). Since young children appear to be unable to take full advantage
of contextual information it is likely that their language processing will be less efficient
than adults' who are able to take full advantage of the contextual information.
Working Memory Development

As previously defined, working memory is a processing resource of finite capacity, which is involved in storing information while simultaneously processing the same (or different) information. Research done with adult high- and low-span readers (Just & Carpenter, 1992) suggested that there are qualitative differences among individuals whose working memory capacity differs. Similar results were obtained by Siegel (1994). Her study looked at the development of working memory in relation to verbal information in individuals aged 6 – 49 years, with and without a reading disability. The working memory task was a listening span task. The participants were auditorily presented sentences with the final word missing. The task was to supply the missing word and to repeat all the missing words from the set, at the end of the set. In addition to the working memory task, two reading tests were performed. Siegel (1994) found that there was an increase in working memory capacity for the normal readers until the age of 20 at which point the scores began to decline. A similar pattern was found for the reading disabled group although the rate of decline was steeper and the overall scores were lower at all ages, with differences at most ages reaching significance. A significant correlation was found between the reading tasks and the working memory task. Like the evidence from the adult literature this suggests that a low working memory capacity can lead to poor reading performance at all ages.

A similar pattern of results was found in relation to working memory and sentence comprehension in children with and without a language impairment (Montgomery, 2000). Montgomery found that children with specific language impairment (SLI) performed more poorly than their age- and language-matched peers on
a working memory task and a sentence comprehension task. He also found a correlation between performance on the working memory task and performance on the sentence comprehension task. The results from both of these studies suggest that working memory is important for both reading and spoken language comprehension in children as young as 6 years old. The results from Siegel’s (1994) study also suggest that working memory capacity increases throughout childhood.

To probe further into the age-related changes in working memory Swanson (1999) investigated whether working memory span differences across ages are attributable to specific or general processing functions and whether the differences are related to processing efficiency or storage capacity. Four working memory tasks were used, two verbal and two visuospatial, under three different conditions, initial (no probes or cues), gain (cues to bring performance to a peak level) and maintenance (peak conditions without cues). The verbal tasks consisted of an auditory digit sequence task and a semantic association task. The former required that participants look at a figure depicting four strategies for recalling numerical information. Then they were presented with a short sentence, and asked a process question. For example, a sample sentence might be:

(8) Now suppose somebody wanted to have you take them to the supermarket at 8651 Elm Street. (p. 987, Swanson, 1999)

The process question for this sentence would be “What is the name of the street?”. Once they had answered the process question they would be told that they would have to recall the numerical information in the sentence after they selected the strategy they would use to remember the information. In the semantic association task the participant was
presented some words, asked a process question and asked to recall the words that went together. The visuospatial tasks consisted of mapping and directions and visual matrix. The mapping and directions task had participants remember a sequence of directions on a map that was void of labels and answer a process question about the map. In the visual matrix task participants were presented with a matrix containing a series of dots for 5 seconds. They were asked a process question about the matrix and then required to draw the dots in the correct boxes on a blank matrix.

With respect to processing efficiency versus capacity, Swanson (1999) found that effect sizes were comparable across conditions. He argued that this indicated that age-related performance was best predicted by processing capacity and not processing efficiency. With respect to general versus domain specific changes, he found that both verbal and visuospatial working memory tasks contributed significant variance to age-related performance. He suggested that this indicated that age-related changes were not domain specific but rather due to changes in a general resource. Swanson (1999) concluded that working memory capacity can be considered a general resource that is constrained early in development by limited capacity.

The results of these studies suggests that working memory capacity increases throughout development, until well into adulthood. Like adults, however, individual children vary in the amount of resources they have available for the computational and storage demands of language processing. Children with smaller working memory capacities will be less able to process language quickly and to store information when task demands are high. This suggests that similar to adults, when children’s working memory capacity is exceeded, less demanding lower level processes are likely to be
favoured over higher level processes. Empirical evidence on children’s use of contextual information has shown this to be the case, as children, who have lower working memory capacities than adults, are less skilled at using contextual information during processing (Tyler & Marslen-Wilson, 1981; Roe et al., 2000; Trueswell et al., 1999).

We have seen that developmental changes affect some aspects of language processing. Although children as young as 24 months process speech incrementally they are less efficient at it than adults and need to hear more of the word before responding. In terms of context effects, research has shown that children are able to take advantage of context to some extent. However, once again they are less efficient than adults and do not take full advantage of it. A possible cause of the inefficiency apparent in children’s processing may stem from a lower working memory capacity, which constrains the amount of information the children can process and store at the same time.

The developmental literature just reviewed provides a basis for hypotheses about ways in which comprehension problems could result for certain children in a clinical population, such as autism. Although it is likely that children with autism are able to process language incrementally, they may be less able to take advantage of context and to have more constrained working memory capacities, which could underlie their comprehension problems. These areas will be addressed in the final section.

**Language Processing in Autism**

In the previous sections we have explored the nature of language processing and the changes in processing that take place during development. This information provides a framework for understanding the language processing abilities of children with autism.
Starting with their speech and language abilities, some studies of high functioning autistic individuals have found that basic procedural linguistic skills (vocabulary, syntax, etc.) are generally intact in these individuals (Tager-Flusberg, 1981a; Minshew, Goldstein & Siegel, 1995). A study by Minshew and colleagues (1995) compared high-functioning autistic individuals' performance with non-autistic controls (matched for age and IQ, among other things) on different language tests. The tests included those that assessed language abilities at a lower level, intermediate level and a higher level. The lower level assessed phonetics, simple syntax, word retrieval and word recognition skills. At the intermediate level, tests evaluated word knowledge, retrieval from semantic long-term and short-term memory, and adequacy of syntactical structure. The tests of higher linguistic functions involved problem solving, inference development, and using and understanding the subtleties of language as they appear in ambiguity, metaphor and meaningful interpretation of written material. Minshew et al. (1995) found that on tests of mechanical and procedural basic language skills (lower and intermediate levels) there was little difference between the groups. On the tests of complex linguistic functions (e.g., Test of Language Competence, which looks at the use of language in communication), however, there was a significant difference between the groups, with the control group outperforming the high-functioning autistic group. Minshew et al. (1995) concluded that there was a general dissociation between basic mechanical or procedural skills and comprehension or interpretive abilities. This conclusion is a bit misleading. The autistic individuals did show intact comprehension abilities at the word level. It was only at the sentence and discourse level that they showed deficits in comprehension. This conclusion is in agreement with that reached by Tager-Flusberg...
(1981a) who concluded that autistic children were specifically impaired in comprehension at the sentence level and language use, despite showing typical phonology and syntax.

Why do these individuals have comprehension problems in the absence of basic language problems? The hypothesis motivating the current study is that the real-time language processing abilities of autistic children differ from that of their peers specifically in their ability to use contextual cues during processing. This hypothesis grows out of three lines of research. First, evidence suggests that children with autism have particular difficulties using semantic information in comprehension. Second, autistic individuals have been shown to be overselective in their use of stimulus cues. And third, they could have reduced working memory capacities compared to that of their peers, which could prevent them from being able to take advantage of contextual constraints. These possibilities will be explored further below.

**Semantic Abilities**

There have been a number of studies that have suggested that autistic children may have specific impairments in their semantic information processing abilities. Hermelin and O'Connor (1967) compared the recall ability of autistic and severely "subnormal" children on two tasks. The first required the children to listen to strings of words, which were either frequent or infrequent word sentences or frequent random words. The second task required the children to recall word sequences, which could be broken into categories. For example the word list
(9) Blue three red five six white green eight (p. 217, Hermelin & O'Connor, 1967)

can be broken into two groups, colours and numbers. Some of the lists had words of one
category interspersed with words that made up a sentence (e.g., Nine this one tea four
is ten cold.). Based on the results of the studies, Hermelin & O'Connor (1967)
concluded that the autistic children, compared to the subnormal children, made less use
of meaning when recalling the stimuli. The groups, however, were only matched on the
Peabody Picture Vocabulary Test. No language testing or cognitive testing was done and
no definition of “severely subnormal” was given.

Another study by Simmons and Baltaxe (1975) analysed language samples from
seven autistic adolescents, taken during an interview in an informal situation. The
analysis showed that, in terms of linguistic structure, semantic constraints were violated
most often, where semantic constraints referred to the rules restricting the co-occurrence
of elements of meaning (e.g., The bachelor is married.). There was no control group for
this study, however, so it is unclear whether the number of semantic violations made by
the autistic individuals, while higher than other violations, was abnormally high or within
normal limits.

Hermelin and Frith (1971) also conducted a study looking at autistic children’s
ability to use semantic information. The autistic children were compared with normal
and subnormal children of the same mental age on various recall tasks. The tasks all
involved recalling random words versus recalling related words, such as sentences or
highly redundant patterns of words. The autistic children showed little difference
between recalling random words and recalling meaningful information. Like the
Hermelin and O'Connor (1967) study, however, no language testing was done with the children to control for language ability between the groups. And, because the children were matched for mental age, the chronological ages of the children varied widely between the groups (Austistic: 7-15 years; Normal: 3-7 years; Subnormal: 10-16 years).

Tager-Flusberg (1981b) conducted two experiments to examine comprehension and strategy use by autistic children. The first experiment compared autistic children's and normal children’s use of comprehension strategies with active and passive sentences. The children listened to sentences and then selected the two relevant toys from the array and acted out the sentence using the toys. The autistic children scored significantly lower than the normal children on overall comprehension of the sentences. The autistic children were more likely to use a word-order strategy in sentence comprehension rather than a probable-event strategy. The normal children used both strategies equally. The second experiment was similar to the first one, except the test sentences were modified so that they included only the two nouns and a transitive verb. For example, the sentence

(9) The girl pushes the car. (p.17, Tager-Flusberg, 1981b)

would become

(10) Girl push car. (p.17, Tager-Flusberg, 1981b)

The children were, again, expected to act out the “sentences” using the relevant toys. The results of this experiment confirmed the findings from the first experiment. The autistic children were comparable to the normal children in their sensitivity to word order and use of a word-order strategy, but were much less likely to use a probable-event strategy. Tager-Flusberg (1981b) concluded that autistic children didn’t appear to use semantic
knowledge to the same extent as normal children did and appeared to have a language comprehension deficit.

There were some methodological problems with the two experiments by Tager-Flusberg (1981b). First, the two groups were matched on vocabulary scores and nonverbal ability. However, recent research (Minshew et al., 1995) suggests that autistic children have relatively normal basic language skills (such as vocabulary) but are likely to have deficits in more complex linguistic abilities. It is possible that although the groups had comparable vocabulary skills, the autistic children may have been specifically impaired in other language abilities (e.g., sentence level comprehension) compared to the normal children in the control group. Second, the age difference between the two groups was quite substantial (Normal M: 3-10; Autistic M: 8-1). The task, which involved manipulated toys, may not have been as appropriate for the older autistic children as for the younger normal children.

A recent study by Dunn, et al., (1999) looked at semantic classification in autistic children. Using event-related potentials as a measurement technique, the authors tested the hypothesis that high functioning autistic children were less influenced by global semantic context than their normal peers. The children were auditorily presented with lists of single words, presented in three blocks of 52 trials each, where 27 of the trials were targets and 25 were non-targets. The words were either animal labels (targets) or nonanimal labels (non-targets) (e.g., cat versus bed). The children were asked to lift a finger each time they heard an animal word. Event-related potentials were recorded from 32 scalp locations. Dunn et al. (1999) found that although the autistic children understood the semantic processing requirement, neural processing of semantic information was
different in the autistic and normal children. They concluded that the autistic children did not use the global context to set up a selective activation of animal words over words from other categories (like the controls did). The authors hypothesized that these findings may represent a general failure to use context, a deficient semantic representation, or both (Dunn et al., 1999). The children in this study were not matched for language ability, like the previous studies, however the stimuli in this experiment involved only single words rather than sentences. The conclusions reached by the authors would be more convincing if the children had been matched on language ability which would eliminate the possibility that the differences between the groups were due to differences in language ability.

Based on the evidence presented we might expect that autistic children will have difficulties taking advantage of semantic information during processing. However, given the methodological problems in the studies, it is unclear whether the problems in semantics demonstrated by the autistic children was due to a more general language deficit. If they do, in fact, have difficulty using semantic information, their word recognition may not be facilitated by the meaning relations present in a sentence context. They may treat meaningful sentences and nonsense sentences the same, as far as word recognition abilities are concerned. Failing to take semantic context into account in a word recognition task is likely to result in slower processing while failing to take semantic context into account during communication could result in failed comprehension as well as inappropriate production.
Overselectivity

One of the essential features of autism is a markedly restricted repertoire of activities and interests (APA, 1994). Analogous highly selective behaviour in perception has been the focus of much research over the years. This older body of research points to stimulus “overselectivity” as a characteristic of autism. For example, Lovaas, Koegel and Schreibman (1979) found that autistic children respond primarily to one of the component cues when responding to stimuli with multiple cues. These children responded to only part of a relevant cue, or even to a minor, often irrelevant feature of the stimuli, for both visual and auditory stimuli. Lovaas et al. (1979) argued that since many learning tasks, such as learning language, necessitate responding to multiple cues, it is essential that individuals are able to use all of the cues available in the environment. If a child responds to only one or two of these dimensions, he or she may not understand what is said (Lovaas et al., 1979).

Recently researchers have again begun to focus on the selective way that autistic children respond to stimuli. Mottron, Belleville and Menard (1999) had autistic individuals and control individuals copy common objects and non-objects and possible and impossible geometric figures. When drawing objects and non-objects normal individuals typically begin to copy figures by tracing their global traits, such as the outline. When drawing possible versus impossible figures, normal individuals typically find impossible figures more difficult to copy than possible ones. They found that autistic children produced more local features (e.g., drawing the windows of a house before the outline of the house) at the start of the task and were less affected by figure impossibility
than were the controls. The authors interpreted these results as evidence of a local bias in visual information processing (Mottron et al., 1999).

A study by Plaisted, Swettenham and Rees (1999) had children with autism and typically developing children complete two variations of the Navon task, which required responding to a target that could appear at the global level, the local level, or both levels. In a Navon task, participants are briefly presented with a large letter shape made up of smaller letters of either the same kind or a different kind and are required to identify the letters at the global (big letter) or local (small letter) level. The first variation of the task was a divided attention task, in which no information was given to the children regarding the level at which the target would appear on any one trial. The second variation was a selective attention task, in which the children were instructed to attend to either the local or the global level. Plaisted et al. (1999) found that children with autism made more errors when the target appeared at the global level in the divided attention task. In the selective attention task, they found that the autistic children, like their peers, responded quicker to the global target than the local target. The authors concluded that the autistic children showed local precedence in the divided attention task and global precedence in the selective attention task. The authors suggested that global processing was intact in autism, but operated only under conditions of overt priming (Plaisted et al., 1999). They suggested that the autistic children showed an inability to filter out information at the local level rather than a deficit in the ability to draw together component features of an object into a global whole (Plaisted et al, 1999). This implies that autistic children possess the ability to perceive stimuli as a whole but that they are unable to do so (unless primed to do so) because they cannot filter out all the parts.
Two recent studies by Jolliffe and Baron-Cohen (1999, 2000) also looked into local processing but used a linguistic processing task rather than a visual processing task. The first study (1999) explored whether local coherence was impaired in the linguistic processing of high functioning autistic or Asperger Syndrome individuals. They defined local coherence as the ability to make contextually meaningful connections between linguistic information in memory. The results of the experiments showed that individuals with autism or Asperger Syndrome were less likely to use sentence context spontaneously to provide context appropriate pronunciation of a homograph. They were less likely to choose the most coherent (bridging) inference from alternatives and, finally, they were less likely to use context to interpret auditorily presented ambiguous sentences. The authors concluded that individuals with autistic spectrum disorders were impaired in their ability to achieve local coherence and they appeared to have a preference not to strive for coherence unless instructed to do so (Jolliffe & Baron-Cohen, 1999).

A second study by Jolliffe and Baron-Cohen (2000) investigated whether or not global coherence was impaired in the linguistic processing of high functioning individuals with autism or Asperger Syndrome. The participants completed two tasks. In the first one they were asked to arrange 5 sentences into a coherent story. There were two types of sentences sets, those that contained temporal cues (e.g., first, then) and those that did not. In the second task the participants were presented with a short story and asked three questions, a global inference question (Why did X do A?), a desire question (Why did X want B?) and a comprehension question (Did X do/get C?). They found that on the first task the clinical groups were less able to integrate sentences with each other and with the theme to provide the most coherent arrangement of sentences. On the
second task, the clinical groups provided significantly more context-inappropriate explanations for a story character's actions. The authors concluded that the individuals with an autistic spectrum condition have difficulty in achieving global coherence (Jolliffe & Baron-Cohen, 2000). Importantly, they were not unable to achieve global coherence but rather were relatively inefficient in doing so. They seemed to have difficulty linking distant sentences and generating contextually appropriate inferences (Jolliffe & Baron-Cohen, 2000).

The selective behaviour of autistic children, as shown in the studies discussed previously, is so significant that Frith (1989b) developed a theory about it, called the (weak) central coherence theory. This theory suggests that there is an abnormality in global or gestalt processing in autism (Plaisted et al., 1999). These individuals have a deficit in central control processes that are responsible for drawing together component features into a coherent whole. The theory predicts that individuals with autism will show local precedence when processing stimuli (Plaisted et al., 1999). The results from the studies discussed above all support the (weak) central coherence theory. The results from Plaisted et al. (1999) suggest that information at a particular level is processed in isolation from higher levels of information. This is consistent with the idea that central coherence processes in autism are "weak" rather than absent.

The results of these studies suggest that individuals with autism often fail to interpret information within a wider context. This may partially explain some of their difficulties with the pragmatic aspects of communication. However, the results also suggest that if instructed, these individuals may be able to attend to the global level, although this has yet to be shown with linguistic processing. In conclusion, it is possible
that this difficulty with attending to context may affect their on-line processing by making their word recognition less efficient than their peers.

Working Memory

As was shown earlier in the chapter, working memory is essential for language processing. A reduced working memory capacity is likely to result in less efficient processing and possibly breakdowns in comprehension. This leads to the question of the working memory capacity of individuals with autism and whether memory limitations could be affecting their comprehension abilities. A study by Bennetto, Pennington and Rogers (1996) looked at the memory functioning in autism. They had two working memory tasks. The first was a sentence span task, in which the participants were required to listen to sentences and fill in the final word. At the end of a set of sentences, the children had to recall the supplied words in the order the sentences were presented. The second task was a counting span task. The children were instructed to count aloud yellow dots, which were interspersed with blue dots. After the children counted the yellow dots on a set of cards, the experimenter asked them to recall, in order, the number of yellow dots that appeared on each card. They found that working memory was specifically impaired in the autistic individuals compared to a clinical group with non-autistic learning disorders.

A second study by Russell, Jarrold and Henry (1996) also investigated whether children with autism were specifically impaired in working memory abilities. The children completed three working memory tasks, with complex and simple versions of each. The first task, was a counting task. It was similar to that used in the Bennetto et al.
(1996) study, where the children counted dots in a set of cards and then recalled the counted totals at the end of each set. In the simple version the dots were presented in the canonical form used on dice. In the complex version the dots were spread in a random pattern and distracters were included. The second task was an odd-man-out task. In the simple version the child had to identify the position of a black dot, which appeared in one of three possible positions, by pointing. In the complex version all three positions were filled and the child had to locate the dots whose pattern differed from that of the other two by pointing to it. The third task was a sums task, which required the children to recall the answers to a number of simple additions. In the simple version the answer to each sum was provided. In the complex version the child had to work out the answer for themselves. The three tasks were presented in similar ways. The children were given three trials at each list length and list lengths increased until a child was incorrect on two or more of the three trials at any length. They found that the children with autism performed more poorly than the normally developing group but similarly to the group with moderate learning difficulties. This was in contrast to the results of the Bennetto et al. (1996) study. Russell et al. (1996) argued that the difference in the two studies was likely due to differences in the participant populations and the tasks used. The participants in the Bennetto et al. study were adolescents and the participants in Russell et al.'s study were children. Russell et al. (1996) concluded that although children with autism do have reduced working memory capacity compared to normal children this problem may not be specific to autism but rather part of a more general cognitive deficit. If so, high-functioning individuals with autism, who have normal non-verbal intelligence scores, may not show any working memory deficit compared to their typical peers.
Summary

Based on the evidence discussed in the last three sections, some predictions can be made as to the performance of autistic children on an on-line word recognition in sentences task. It is predicted that those children with high-functioning autism or Asperger's will be less able to use semantic contextual constraints to facilitate word-recognition during on-line processing. The evidence discussed above suggests that this is likely to be due to a combination of overselectivity and specific deficits in semantic processing. The study by Russell et al. (1996) suggests that it is unlikely that a working memory deficit would affect the performance of high-functioning autistic children on a word-recognition in sentences task compared to their same age peers.

Statement of the Problem

High functioning children with autism often show deficits in language comprehension. These deficits generally occur in the absence of basic linguistic deficits. We are led to question what is causing the comprehension problems experienced by these children. Previous research suggests that autistic children may be unable to take advantage of contextual information, which could facilitate processing.

This study will attempt to determine whether the real-time processing abilities of high functioning children with autism are similar to those of their peers. Specifically, it will look at their ability to use different contextual constraints to determine if there are some, if any, contextual cues that are more difficult for the autistic children than others. It will also attempt to relate their processing abilities to their working memory span.
Research Hypotheses

1. Children with high-functioning autism will be unable to use contextual constraints (i.e., syntactic, semantic and pragmatic constraints) available in sentences to aid in their word recognition in sentences.

2. Children with autism will differ in their ability to use contextual constraints from their age peers.

3. Working memory span will correlate with real-time processing abilities.

4. Children with high-functioning autism won’t have deficits in working memory compared with their peers.
CHAPTER TWO

RESEARCH METHODOLOGY

Overview

A word-monitoring task was employed to evaluate the real-time sentence processing abilities of high-functioning children with autism or Asperger Syndrome, and children with normal language development under four different processing conditions. The four conditions varied in the amount of contextual information that was available to the children, from full contextual support to no support. The conditions were designed to determine which, if any, constraints the autistic spectrum children and language normal children were able to use. In the word-monitoring paradigm, participants monitor ongoing language input for a previously designated target word (Kilborn & Moss, 1996). This allows researchers to address issues such as the role of acoustic and phonetic information in identifying spoken words and the ways in which semantic, syntactic and pragmatic information contribute to word identification.

On-line tasks have a number of advantages over off-line procedures. Language processing occurs very rapidly in time and people only occasionally have time for reflection during communication. To understand the complex mechanisms which underlie language representations and processes, it is necessary to study language during processing as well as after (von Berger et al., 1996). On-line tasks can be used to examine unconscious mental representations and operations that are automatically involved during the course of comprehension (Tyler, 1992). The time course of
processing can be isolated, as can specific processes. Off-line tasks, on the other hand, rarely attempt to link responses to any one specific aspect of the stimulus. Moreover, off-line tasks require the listener to be aware of the utterance they heard and may require more working memory resources. So although both types of tasks are useful for research, on-line tasks allow a more detailed look at processing.

Word monitoring tasks can be used to examine the role of context in identifying a target word. Previous studies have shown that people show faster responses with greater contextual support (Marslen-Wilson & Tyler, 1980) and slower reaction times when the carrier sentence contains a syntactic or semantic violation (Marslen-Wilson et al., 1988). Furthermore, because the task is relatively easy for participants it is suitable for use with children (Tyler & Marslen-Wilson, 1981) and special populations (Montgomery et al., 1990). Although to date it has never been used with autistic children the fact that it has been used successfully with children in clinical populations suggests that it is likely to also be suitable for high functioning autistic spectrum children.

Participants

Twenty elementary school students between the ages of 8 and 14 from various school districts within the Greater Vancouver area participated in this study. There were 10 8- to 14-year-old high functioning children with autism or Asperger Syndrome (Autism group, M = 126.33 months) and 10 children with normal language matched for chronological age (Age-Matched group, M = 129.10 months). The Autistic group contained 9 boys and 1 girl and the Age-Matched group contained 4 boys and 6 girls. All of the children had normal hearing as determined by a hearing screening (1000 Hz, 2000
Hz at 20dB; 4000 Hz, 500 Hz at 25dB) and came from English speaking homes. The age-matched children were selected by their classroom teachers for having normal speech and language abilities and were average in academic achievement. All of the children scored in the normal range on the Test of Nonverbal Intelligence – Third Edition (TONI-3) (Brown, Sherbenou, & Johnsen, 1997). The children also completed two subtests, Sentence Structure and Formulated Sentences, of the Clinical Evaluation of Language Fundamentals – Third Edition (CELF-3) (Semel, Wiig, & Secord, 1995) and the Peabody Picture Vocabulary Test – Third Edition, Form B (PPVT-IIIB) (Dunn & Dunn, 1997). Both the CELF-3 (Semel et al., 1995) and the PPVT-IIIB (Dunn & Dunn, 1997) were chosen for several reasons. The Sentence Structure subtest of the CELF-3 is a receptive test that assesses the knowledge of English structural rules at the sentence level. The Formulated Sentences subtest is an expressive test that assesses the ability to formulate compound and complex sentences with given semantic and syntactic constraints. These subtests were chosen because they give a measure of receptive and expressive syntactic, and semantic abilities. It was important that all the children had comparable syntactic abilities, to ensure that any differences arising between the groups could not be attributed to one group have advanced syntactic knowledge. The PPVT-IIIB was chosen for a similar reason, to ensure that all the children were at approximately equal levels of vocabulary knowledge. Moreover, both the CELF-3 and the PPVT-IIIB are appropriate for a wide range of ages and have norms for all the children included in the current experiment, making them ideal choices. Finally, by obtaining measures of syntactic ability and vocabulary knowledge, it was possible to ensure that all the children were at
language and vocabulary levels significantly above those used in the stimuli in the word monitoring task.

Written consent from all the children’s parents was obtained as well as verbal consent from the children themselves. The children were given stickers and certificates at the end of the final session for their participation.

Selection of the Autistic Children

Children were selected for inclusion in the experimental group if they had received a diagnosis, from a psychiatrist/psychologist or a diagnostic team, high-functioning autism\(^1\) or Asperger Syndrome\(^2\) based on the DSM-IV (APA, 1994) criteria. For a diagnosis of Autism a child must show impairments in social interaction, communication and show restricted repetitive and stereotyped patterns of behaviours. At least one of these “symptoms” must have an onset prior to three years of age. Asperger Syndrome can be distinguished from Autism by a lack of delay in language development.

\(^1\) Since the early 1980’s researchers have frequently distinguished between autistic individuals with normal range performance IQ and those with subnormal performance IQ. By distinguishing individuals with autism in this way, it is possible to achieve a more homogeneous group.

\(^2\) This study combined high-functioning autistic children and children with Asperger Syndrome into a single group for a number of reasons. First, Asperger Syndrome is distinguished from Autistic Disorder by the lack of a clinically significant delay in language development (APA, 1994). But children with high-functioning autism generally display higher language skills than those with more severe autism. Second, 5 of the 9 children in the Autistic Group in this study had the dual diagnosis of high-functioning autism/Asperger Syndrome, indicating that these two diagnoses are very close to each other on the diagnostic spectrum. Finally, the language testing done prior to the experimental task showed all the participants to be functioning at the same language level. So although the autistic children may have had an early language delay when they were very young, they all appear to have “caught up” to their peers, at least on measures of basic language skills level. So although the autistic children may have had an early language delay when they were very young, they all appear to have “caught up” to their peers, at least on measures of basic language skills.
The children in the school districts were identified by either their Speech-Language Pathologists (SLPs) or by their school Support Teachers. Specific diagnostic information on these children was obtained from their school files, through the Support Teacher or SLP. Several of the autistic children were identified through private SLPs. For these children the diagnostic information was given to the experimenter by the children’s parents. Table 1 shows the diagnostic information for each of the children included in the Autistic Group.

Table 1: Diagnostic information for the Autistic Group

<table>
<thead>
<tr>
<th>Participant</th>
<th>Diagnosis</th>
</tr>
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<tbody>
<tr>
<td>ER</td>
<td>Autism</td>
</tr>
<tr>
<td>DH</td>
<td>Mild/Moderate Autism</td>
</tr>
<tr>
<td>BM</td>
<td>Asperger/High Functioning Autism*</td>
</tr>
<tr>
<td>JK</td>
<td>Severe Autism</td>
</tr>
<tr>
<td>MP</td>
<td>Asperger/High Functioning Autism*</td>
</tr>
<tr>
<td>EP</td>
<td>Asperger/High Functioning Autism*</td>
</tr>
<tr>
<td>AR</td>
<td>PDD$^1$ with Autistic Feature</td>
</tr>
<tr>
<td>AL</td>
<td>Asperger/High Functioning Autism*</td>
</tr>
<tr>
<td>PH</td>
<td>Asperger/High Functioning Autism*</td>
</tr>
</tbody>
</table>

1. PDD refers to Pervasive Developmental Disorder

*Many of the children had received diagnoses of Asperger Syndrome but also received a diagnosis of High Functioning Autism in order to receive funding.
The SLPs or Support Teachers of the children filled out a brief questionnaire, which was a pilot of the Children’s Communication Checklist (Bishop et al., 2000). This 12-question questionnaire is non-standardized and was used to give a descriptive account of the children’s language abilities. A score of 12 or over was taken to indicate some pragmatic difficulties (Bishop et al., 2000) (although a diagnosis of autism presumes this). All of the children scored above 12 on the questionnaire, except for one child who received a score of 11.5. The children all scored within 1 SD of the mean on the TONI-3 (Brown et al., 1997), indicating normal non-verbal intelligence. Additionally, all of the children in the Autistic group scored within 1 SD from the mean, on measures of syntactic ability (Sentence Structure and Formulated Sentences subtests of the CELF-3 (Semel et al., 1995)) and receptive vocabulary ((PPVT-IIIB) (Dunn & Dunn, 1997)) indicating age-appropriate language abilities. For this reason no language-matched control group was included in the study.

Selection of the Age-Matched Children

All but one of the children in the control group were selected by their classroom teachers (one child was contacted privately). They were selected for having normal language abilities as well as no history of speech or language problems, and for being average in academic achievement. The age-matched children were matched for chronological age with the autistic children. The control children also completed the two subtests of the CELF-3 (Sentence Structure and Formulated Sentences) (Semel et al., 1995) and the PPVT-IIIB (Dunn & Dunn, 1997) and scored within 1 SD of the mean,
indicating normal language abilities. All of the language normal children also scored within 1 SD on the TONI-3 (Brown et al., 1997), indicating normal non-verbal intelligence. Table 2 shows the mean ages and test scores of the two experimental groups. The ages, language scores and cognitive scores of the two groups were not found to be significantly different.

Table 2: Mean ages, language scores and cognitive scores

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Autistic Group M, (SD)</th>
<th>Age-Matched Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in months</td>
<td>126.33 (19.91)</td>
<td>129.1 (17.12)</td>
</tr>
<tr>
<td>Quotient Score, TONI-3</td>
<td>113.55 (20.97)</td>
<td>102.10 (17.41)</td>
</tr>
<tr>
<td>Raw Score, CELF-3, FS</td>
<td>34.56 (5.05)</td>
<td>37.10 (4.20)</td>
</tr>
<tr>
<td>Raw Score, CELF-3, SS</td>
<td>19.22 (0.83)</td>
<td>19.20 (0.79)</td>
</tr>
<tr>
<td>Raw Score, PPVT-IIIB</td>
<td>140.56 (20.82)</td>
<td>151.10 (15.87)</td>
</tr>
</tbody>
</table>

Notes: TONI-3: Test of Nonverbal Intelligence-3; CELF-3: Clinical Evaluation of Language Fundamentals-3, FS: Formulated Sentences subtest, SS: Sentence Structure subtest; PPVT-IIIB: Peabody Picture Vocabulary Test-3 Form B.

Stimuli

Word-Monitoring Task

The target words for the word-monitoring task were 10 common, easily depictable, monosyllabic nouns appropriate for 6-year-olds’ lexical knowledge (Walley and Metsala, 1992; Morrison, Chappell and Ellis, 1997). Target word duration ranged
from 329 milliseconds to 534 milliseconds. All of the target words began with a stop consonant for ease of identifying word onset within the sentence context. A black and white line drawing (Alario & Ferrand, 1999) of each target word was also used as a tool for maintaining the children’s interest in the task, giving them something to orient to at the start of each trial. The target words were all high frequency words of approximate equal frequency (Kolson, 1961; Zeno, Ivens, Millard & Durvvuri, 1995), where high frequency indicates that the words are common and appear frequently in spoken language. They also had the same approximate age of acquisition (Morrison, Chappell, & Ellis, 1997), which was before the age of 5 years. Thus, the words selected were assumed to be familiar to all of the children who participated in the study.

There were 40 sentence pairs consisting of an introductory sentence and a carrier sentence containing the target word. There were 10 sentence pairs in each of 4 conditions, containing vocabulary and sentence structures appropriate for 6- and 7-year-olds’ comprehension and production abilities (Miller, 1981). There were four sentence conditions, modeled after those used in two previous studies (Marslen-Wilson & Tyler, 1980; Marslen-Wilson, Brown & Tyler, 1988), in which the target word could be embedded: a Normal condition, a Syntactic condition, a Random Word-Order condition and a Semantic Anomaly condition. These different sentence conditions were intended to represent different points along a continuum in the amount of linguistic information available. Each of the 10 target words occurred four times, once in each sentence condition. To ensure that there was no pattern as to where the target word occurred in the sentence and to evaluate the contribution of working memory and the build up of contextual constraints, the target word was placed in one of two positions early in the
sentence or late in the sentence. Since reaction time has been shown to improve the later in the sentence the target word occurs (Marslen-Wilson & Tyler, 1980), sentences were designed such that each condition had an equal number of target words in each of the two positions. All words preceding the target word were acoustically dissimilar to the target word to prevent acoustically based false alarms.

The Normal sentences were constructed to provide full contextual constraints. These sentences contained intact syntactic and semantic relations and a coherent discourse context was provided by a lead-in sentence. Moreover, these sentences conformed to real-world expectations. Thus, the sentences in this condition provided the listeners with strong linguistic and discourse constraints, which could act to prime the appropriate syntactic-class (i.e., noun) of the target word and to limit the candidates to those consistent with the prior context. For example:

(1) Sue loves animals. She has a cat on her lap and she is petting it.

The Syntactic sentences were derived from the Normal sentences by systematically replacing all of the words in the Normal sentence (except the target word) with other words of approximately equal frequency (Zeno et al, 1995), which were from the same syntactic-class and had similar thematic role structure. These sentences maintained syntactic constraints but violated semantic expectations, in that the sentences did not have any “meaning”. Similarly the lead-in sentence maintained syntactic structure but was devoid of any “meaning”. Thus these sentences provided listeners with syntactic constraints which could prime only the syntactic-class of the target words but did not provide any semantic context which could help in limiting the possible candidates. For example:
(2) Worms eat everything. They want this *cat* in the bag and fish are sleeping there.

The Random Word-Order sentences were derived from the Syntactic sentences by randomly mixing up the words in the Syntactic sentence, except the target word, which was left in the same position in the sentence. These sentences did not conform to syntactic or semantic constraints and no coherent discourse context was provided in the lead-in sentence. Essentially these sentences represented an unconstrained condition since no linguistic or discourse information was available to the listener. The only way to identify the target word in this condition was through acoustic-phonetic information. For example:

(3) Eat worms everything. Want they bag *cat* the fish sleeping are this in there and.

The Semantic Anomaly condition was included as a further probe into the real-time semantic processing involved in sentence comprehension by autistic spectrum children. The sentences in this condition contained a semantic anomaly that occurred immediately preceding the target word, and were modeled after the sentences used in Marslen-Wilson et al. (1988). Thus, this condition maintained syntactic constraints, semantic constraints and provided listeners with a coherent discourse context developed in the lead-in sentence. However, the sentences contained a semantic violation right before the target word. Previous studies have shown that a semantic violation before a target word will slow word recognition reaction times (Marslen-Wilson et al, 1988). For example:

(4) The mouse is scared. It chews the *cat* in the house and then runs far away.

It was hoped that these four conditions would provide information about whether the children were able to use semantic constraints or syntactic constraints, both, or neither
in their word recognition processes. The contrast between the Normal condition and the Syntactic condition investigated the general role of semantic constraints and real-world knowledge in immediate processing. The contrast between the Syntactic condition and the Random Word-Order condition investigated the extent to which the children could use the available structural (syntactic) information in immediate processing. The final condition, Semantic Anomaly, investigated the extent to which the children's processing abilities were affected by the anomalous semantic information. That is, if the children were to show effects of the semantic anomaly (i.e., slower response times), then this would provide evidence that the semantic aspects of the lexical representation were immediately activated in their on-line processing (Tyler, 1992). By comparing the reaction times obtained in each of the conditions we hoped to obtain a picture of which contextual constraints were being used in processing by children with autistic spectrum disorders.

**Creation of Auditory Stimuli**

To generate the stimuli, the carrier sentences, introductory sentences and target words were read aloud by an adult female native speaker of English, who was naïve to the target words and to the nature of the task. To ensure that she remained naïve to the target words, the target words were recorded only after all of the sentences had been recorded. All of the stimuli were recorded in a sound treated booth and were recorded directly onto the computer using CoolEdit2000 software. Sentences were recorded in stereo at a sampling rate of 44 100 Hz. All of the sentences in each of the four conditions were read at a normal speaking rate (mean of 149 words per minute) with normal prosodic variation, whereas target words were read in a list fashion. Each recorded
sentence and target word was amplified to 100% (the CoolEdit2000 software adjusted the amount each stimuli needed to be amplified to reach 100%) so that all stimuli were equal in amplitude. Following this the stimuli were low-pass filtered (4 kHz) and passed through a bass cut filter (>100Hz) to reduce the background noise. The waveforms were then analyzed to identify the acoustic onsets of the target words in the sentences so that reaction times could be calculated from target word onset. The digitized sentences and target words were then transferred into the experiment, which was designed and run on E-Prime software Beta version 5.0 (PST, 2000).

**Working Memory Span Task**

The second experimental task was a working memory span task. The task required the children to count random displays of dots, while remembering the totals from previously counted displays, until prompted to recall all of them. The images for the task were 10 displays of random dot patterns, 2 of each numbering 4, 5, 6, 7, and 8. The displays were made using Microsoft Paint, where one dot was created and then copied and distributed around the screen to create each of the 10 displays. The task was set up so that there were 3 trials at each span length starting with a span of one. The images were displayed using E-Prime software and the software randomly chose the image displayed. All answers were recorded on-line by the experimenter. Testing was discontinued when a child achieved less than 2 of 3 correct at any span length, up to a possible span length of 9. In this way, the child determined when the task was stopped, and none of the children were presented with all of the items.
Design & Procedures

Pretesting

All of the sessions were conducted at either the child’s home or their school, depending on whether the children were contacted privately or through their schools. During the first session all of the children received a hearing screening (except one child who was unable to wear headphones) and completed the TONI-3 (Brown et al, 1997), the Sentence Structure and Formulated Sentences subtests of the CELF-3 (Semel et al., 1995), and the PPVT-IIIB (Dunn & Dunn, 1997). Of the original 10 children in the Autistic group, 1 was excluded. This child was excluded because he did not pass the hearing screening and his test scores from the language testing on the CELF-3 were below 1 SD from the average and were, thus, significantly below that of the other participants.

Word Monitoring Task

Experimental Design

The word monitoring task occurred in two parts; first a target word was presented auditorily to the participant simultaneously with a black and white line drawing matching the target word. Then an introductory sentence and a carrier sentence containing the target word were presented. The participant’s task was to remember the target word and respond as quickly as possible by pressing a button when the target word was detected in the carrier sentence (Kilborn & Moss, 1996). Each trial consisted of a simultaneous presentation of a target word and black and white line drawing of the object for 1000ms. Then the image was replaced with a blank screen and there was a 250 ms pause where
nothing was seen or heard. Then the introductory sentence and carrier sentence were heard (the screen remained blank). The experiment was run on a Toshiba Satellite laptop computer. The monitor was fourteen inches and the spacebar was covered with red tape to make it more prominent. The rest of the keyboard (except for the "1" key, used by the experimenter) was covered so that the other keys did not act as distractions for the children. The computer recorded reaction times from the onset of the introductory sentence to the button being depressed by the children. Later calculations determined the reaction time from the onset of the target word. All stimuli were played over Sony Digital Reference MDR-CD170 headphones to ensure good sound quality and to ensure that the experimenter was unable to hear what the children were hearing and influence their responses. The children were instructed to press the spacebar upon hearing the target word in the sentence. Each trial was started by the experimenter to ensure the child was focussed and paying attention to the stimuli and to allow for breaks when necessary.

**Experimental Procedure**

During the second session the children were told they were going to play a “word finding game” on the computer. They were seated in front of the computer with the experimenter to the left. All stimuli were presented to the children binaurally via headphones at a comfortable listening level. This was determined by setting the volume at a midway setting and adjusting it to the child’s preference during the practice trials. One child was unable to wear headphones so stimuli were played out over speakers while the experimenter listened to music over headphones. The children were told they would hear a word and see a picture of the word and then they would hear a short story that the word was hiding in somewhere. They were told that their job was to find the word and to
press the red button as soon as they heard the word. They were also told that some of the stories would make sense and others might be kind of funny, but they still had to try and find the word and press the button as soon as they heard it.

Prior to the experimental sentences, 4 live voice practice sentences and 4 computer practice items were presented to ensure that the children understood the procedure. None of the children had any difficulties with the task. All of the sentences were presented in random order, as generated by the E-Prime software, so that each child received the 40 sentences in a different order.

**Working Memory Task**

**Experimental Design**

The design of this task was modeled after the task used in Russell, Jarrold, and Henry's (1996) study. The images were all displayed using E-Prime software and the computer randomly chose a dot display from 10 possible choices. The image remained on the screen until the experimenter pressed the spacebar, which was done as soon as the child indicated the number of dots on the screen. Once the spacebar was pressed the dot display was replaced by either a second dot pattern or a “+”. The + prompted the child to recall and state the number of dots that had been counted in each previous display. The displays started at a span length of one, in which only one pattern of dots appeared before the “+” appeared on the screen. There were three trials at each span length and testing continued until the child achieved fewer than 2 correct out of 3 at any span length. After each trial a happy face and an encouragement (Great! or Wow!) appeared. This was
included to break up each trial so that the children wouldn’t try to remember dots counted from previous trials.

**Experimental Procedure**

The children were told that they were going to play a memory game, where they would have to count dots and remember the numbers until asked to tell them to the experimenter. The children were shown the dot patterns and asked to tell the experimenter how many they counted before the next screen was shown. Once the “+” sign appeared the children were asked to recall all of the numbers they had counted in the order they appeared. For example, a trial at a span of 2 would proceed as follows. A display of 4 dots would appear and the child would count the dots and respond “Four”. The display would then be replaced by another display of dots, this one with 5 dots. The child would again count the display and respond “Five”. This display would then be replaced by a “+”, at which point the child would respond “Four and five”. The experimenter recorded all of the responses on-line and kept track of the number of trials, which were correct, so that testing could be discontinued at an appropriate level. Prior to the experimental trials the children were given three practice trials each, one at each span of one, two and three, to ensure that they understood the task. None of the children had difficulty understanding what was required of them during the task.

**Data Management**

The independent variable for the experiment was Group and the dependent variable was Reaction Time for each of the Sentence Conditions. E-Prime software recorded the reaction times from the onset of each sentence pair, and the target word
onset time was entered manually into a data spreadsheet. Reaction time from the target word onset was computed by subtracting the onset time of the target word in the sentence from the reaction time recorded by E-Prime. This was done when these data were exported to the statistics program Statistica. A mean response time for each participant was calculated for each of the four conditions. A maximum of ten reaction times were available for each condition, for each child, to be used in the calculation.

Before performing any statistical analyses, extreme values and false starts were eliminated from the data. Extreme values, in this case, were any values below 100ms (which were counted as false starts) and any values over 2 SD from the group mean. Values under 100 ms were removed because previous research (Tyler & Marslen-Wilson, 1981) suggested that it was not possible to react that quickly to acoustic information. Values over 2 SD from the mean were eliminated because it was likely that these values represented lapses in attention rather than true responses to the stimuli. Any child with fewer than 6 values left after extreme values were removed was given the group mean value instead of the mean resulting from the remaining values. Only one child in one sentence condition required this replacement. In total 44 false starts (26 from the Autistic group; 18 from the Age-Matched group) and 43 extreme values (19 from the Autistic group; 24 from the Age-Matched group) were removed. An independent t-test (p<.05) was performed to compare the number of false starts and extreme values in each group. No significant differences were found between the groups for either extreme values or false starts (p=.40 and p=.70 respectively). These removed trials accounted for only 11% of the data, leaving 89% of the data for further analysis.
CHAPTER THREE

RESULTS

Overview

The purpose of this study was to determine whether children with autism are able to attend to and use linguistic context during real-time language processing. Specifically, the main research question was whether autistic children would respond in the same way their peers did in different sentence conditions offering different amounts of contextual information. To address this question, autistic and age-matched groups of children completed a word-monitoring task with four different sentence conditions, normal, syntactic, random and semantic anomaly. They also completed a working memory span task. In order to address the experimental questions the data logged by the computer was analysed by first computing mean reaction times in each of the four sentence conditions for each child. Additionally, mean reaction times for the early and late word positions were computed for each sentence condition yielding eight mean values for each child. Following this a mixed model analysis of variance (ANOVA) was used. The working memory span means for each group were computed and compared across groups and with each of the sentence conditions.

Results of Analysis

Reaction-time Analysis

The group means and standard deviations for reaction times in the four sentence conditions and for early and late words are presented in Table 3 below.
Table 3: Mean reaction times

<table>
<thead>
<tr>
<th>Group</th>
<th>Sentence Condition</th>
<th>M, (SD)³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Autistic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>330.5, (57.5)</td>
<td>212.3, (48.7)</td>
</tr>
<tr>
<td>Age-Matched</td>
<td>417.1, (101.5)</td>
<td>283.0, (52.1)</td>
</tr>
<tr>
<td>Both Groups</td>
<td>376.1, (92.7)</td>
<td>251.6, (58.3)</td>
</tr>
<tr>
<td>Syntactic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autistic</td>
<td>451.4, (77.3)</td>
<td>322.7, (64.5)</td>
</tr>
<tr>
<td>Age-Matched</td>
<td>483.1, (81.8)</td>
<td>353.8, (86.5)</td>
</tr>
<tr>
<td>Both Groups</td>
<td>468.1, (79.2)</td>
<td>339.1, (76.4)</td>
</tr>
<tr>
<td>Random Word Order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autistic</td>
<td>543.0, (91.8)</td>
<td>425.5, (108.7)</td>
</tr>
<tr>
<td>Age-Matched</td>
<td>524.8, (85.4)</td>
<td>402.1, (39.3)</td>
</tr>
<tr>
<td>Both Groups</td>
<td>533.4, (86.5)</td>
<td>413.2, (78.5)</td>
</tr>
<tr>
<td>Semantic Anomaly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autistic</td>
<td>486.0, (116.1)</td>
<td>355.2, (87.1)</td>
</tr>
<tr>
<td>Age-Matched</td>
<td>550.4, (162.1)</td>
<td>463.7, (150.0)</td>
</tr>
<tr>
<td>Both Groups</td>
<td>519.9, (142.2)</td>
<td>412.3, (133.1)</td>
</tr>
</tbody>
</table>

³ All reaction times are in milliseconds. The brackets ( ) indicate standard deviations.
In looking at Table 3 there appears to be a difference in the reaction times between the sentence conditions. Between the groups there appears to be a small difference but it is smaller than that between conditions. Moreover, there appear to be differences between the reaction times in early word positions and those in late word positions. To further explore these trends, reaction times were analysed in a mixed model ANOVA with a between subjects factor of Group (2 levels: Autistic, Age-Matched) and two within subjects factors, Sentence Condition (4 levels: Normal, Syntactic, Random Word Order, Semantic Anomaly) and Word Position (2 levels: Early, Late). Levene's Test for Homogeneity of Variance was performed and the assumption of homogeneity was met for all sentence conditions. The ANOVA resulted in significant main effects for Sentence Condition, $F(3,51) = 34.94, p<.01$, and Word Position, $F(1,17) = 99.95, p<.01$. The ANOVA also yielded a two way interaction of Group by Sentence Condition, $F(3,51) = 3.79, p<.05$. The next sections will analyze each significant finding in more detail.

**Main effect of sentence condition**

Reaction times were fastest in the Normal Condition (M: 318.5, SD: 57.1) and slowest in the Random and Semantic Anomaly Conditions (M: 474.0, SD:72.1; M: 469.7, SD:125.3 respectively). Reaction times for the Syntactic Condition (M: 403.8, SD: 60.4) fell between those in the Normal Condition and the Random Word Order and Semantic Anomaly Conditions. A posthoc Tukey Honest Significant Differences (HSD) Test (p<.05) indicated significant differences between all sentence conditions except for the Random Condition and the Semantic Anomaly Condition. The lack of a significant difference between the Random Word Order condition and the Semantic Anomaly
condition could be a by-product of the significant interaction between group and sentence condition. This indicates that across groups linguistic context did affect the speed with which the target words could be identified.

Main effect of word position

Across sentence conditions the mean reaction times for words in late positions were faster than those for words in early positions (M: 352.8 and M: 473.3 respectively). These results indicate that word recognition is facilitated by the presence of more contextual support.

Interaction of group and sentence condition

The group by sentence condition interaction is presented graphically in Figure 1.
Figure 1 shows that the autistic group appear to be faster than the age-matched group in all sentence conditions except for the Random Word Order Condition, in which they appear to be slightly slower.

Working Memory Analysis

The mean working memory spans and standard deviations for each group are presented in Table 4 below.

Table 4: Mean working memory spans

<table>
<thead>
<tr>
<th>Group</th>
<th>Working Memory Span</th>
<th>Work Memory Span</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M, (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Autistic</td>
<td>5.2, (1.1)</td>
<td>3.5-7.0</td>
</tr>
<tr>
<td>Age-Matched</td>
<td>4.8, (0.9)</td>
<td>3.0-6.0</td>
</tr>
</tbody>
</table>

From the mean values in Table 4 it appears that there is a small difference between the Autistic group and the Age-Matched group, with the Autistic group having a slightly larger working memory span. However, an independent t-test did not find a significant difference between the two means (p = .32). \(^4\) Individual scores can be found in Appendix II.

A final analysis looking at the relationship between working memory span and sentence processing in the different sentence conditions was also performed. This analysis was done with the groups combined since the previous analysis indicated that

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\(^4\) Even though no significant difference was found between the groups in terms of working memory span, as a further test of the possible role of working memory in sentence processing the ANOVA was repeated with working memory span as a covariate. However, the results of this ANOVA were no different from the results of the previous ANOVA.
there was no significant difference between the groups. Person product-moment correlations ranged from -.04 to -.28, however, none (p<.05) were significant. These results failed to indicate a relationship between working and performance in an on-line task of sentence processing.

**Summary of Findings**

The ANOVA and the analysis of working memory span resulted in the findings summarized below:

2. The children responded fastest to target words that occurred later in the sentences than target words that occurred early in the sentences.
3. The children in the autistic group performed similarly to the children in the age-matched group but appeared faster on 3 of the 4 sentence conditions.
4. There were no differences between the groups in working memory span and the results failed to show any relationship between working memory span and performance on an on-line sentence processing task.
CHAPTER FOUR
DISCUSSION

Overview

This study compared the performance of children with high-functioning autism or Asperger Syndrome to their age peers on an on-line word-monitoring task. The study attempted to answer four research questions. First, do children with high-functioning autism use contextual information during on-line language processing? Second, do children with high functioning autism differ from their age peers in their ability to use contextual information? Third, does working memory span correlate with real time processing abilities? Finally, do children with high functioning autism have deficits in working memory compared to their age peers? In the following discussion the results of the study will be addressed with reference to the research questions as well as to findings reported in the literature. Following this, the implications of the findings for future research and clinical practice will be discussed.

Summary of Findings

Effects of Sentence Condition

The analysis of the mean reaction times for both groups of children reveals that the children's response latencies increased from the Normal Sentences to the Syntactic Sentences to the Random Word Order and Semantic Anomaly Sentences. These results, while they don't directly answer any of the research questions, are important for examining the validity of the study. Previous research (Marslen-Wilson & Tyler, 1980; Tyler & Marslen-Wilson, 1981; Montgomery et al., 1990) has shown that both adults and children, with and without language impairments, are faster in normal sentences.
conditions and become progressively slower as contextual information is removed from the sentences. Although there has been no single study previously to include all four of the conditions used in the current study, the pattern of the Normal, Syntactic and Random sentences matches that of previous studies (Marslen-Wilson & Tyler, 1980; Tyler & Marslen-Wilson, 1981; Montgomery et al., 1990). Additionally, it was expected that the response latencies to the Semantic Anomaly condition would be larger than at least the normal condition (Marslen-Wilson et al., 1988). The results of the sentence conditions matched both the predictions made earlier as well as data from previous studies. This suggests that the task measured what it intended to measure, namely the effects of context on real-time word recognition abilities.

Effects of Word Position

The analysis of word position showed that response latencies were faster to words occurring late in the sentences than to words occurring early in the sentences across all sentence conditions. Previous research also found that response latencies tended to decrease from earlier word positions to later word positions. Marslen-Wilson and Tyler (1980) did not find a significant main effect of word position, but they had nine different word positions, compared to the two extremes used in the present study. What they found was a linear effect of word position, with reaction times decreasing in later word positions. However, the linear effect was only found in the Normal Prose and Syntactic Prose conditions. The reaction times in the Random Word-Order condition were randomly distributed across word positions. Similar results were obtained with children (Tyler & Marslen-Wilson, 1981), where reaction times became progressively faster.
throughout the course of the sentence for Normal Prose and Syntactic Prose sentences but not for the Random Word Order stimuli. The authors of these studies interpreted the results as indicating that the monitoring times were facilitated by the syntactic and interpretative contexts that developed as more of the sentences were heard (Marslen-Wilson & Tyler, 1980; Tyler & Marslen-Wilson, 1981). In a similar study with language impaired children Montgomery et al. (1990) found that reaction times decreased across word position for both the language impaired and the language normal children. The decrease in reaction time was most obvious for normal sentences and syntactic sentences. The difference was less obvious in the acoustic sentences (equivalent to random word-order sentences) although graphs showed a very small (non-significant) trend for reaction times to decrease in later positions. Montgomery et al. (1990) also attributed the decrease in reaction times to the accumulation of syntactic and semantic context facilitating word monitoring.

The results of the present study call this explanation into question. There was no word position by sentence condition effect found. Reaction times were faster in later word position for all sentence conditions, including the Random Word Order condition. This suggests that there are two different types of context which could facilitate word monitoring. The first is the one argued for by Marslen-Wilson and Tyler (1980) and Montgomery et al. (1990), namely linguistic context. There is little doubt that the more syntactic and semantic information there is the more word monitoring will be facilitated. However, there is also the context of “getting to the end”. As more of the sentence is heard, the probability that the target word will occur increases, since it has to occur before the end of the sentence. Just knowing that the target word has to be coming
“soon” would facilitate participants’ word monitoring latencies. The lack of word position by sentence condition in this study reveals that both contexts are likely facilitating word monitoring and that it is not possible based on these results to separate the two. It is unclear whether the facilitation in the Normal and Syntactic Prose conditions is due to the linguistic context or to the “getting to the end” context or a combination of the two.

Performance of the Autistic Children

It was predicted that the autistic children would be impaired, relative to their age peers, in their ability to use context during processing, especially semantic context. This was not what was found. The autistic children performed similarly to their age peers in all sentence conditions and, in fact, had faster reaction times in three of the four conditions than those of their age peers. Previous research on the semantic processing abilities (Tager-Flusberg, 1981b, 1991) and linguistic processing (Jolliffe & Baron-Cohen, 1999, 2000) abilities of autistic individuals suggested that autistic individuals should show some deficit in using context compared to their peers. The results indicate that children with high functioning autism or Asperger Syndrome can use linguistic context during on-line processing. Moreover, the basic pattern of reaction times was similar for both groups of children.

Working Memory

There were two questions related to working memory that this study was attempting to answer. The first one questioned the possibility of a relationship between
working memory capacity and performance on on-line processing tasks. The discussion on working memory in the first chapter highlighted that working memory is critical for language processing. Given this, it was expected that working memory might correlate with real-time language processing abilities. However, no correlations between performance on any of the sentence conditions and working memory span were found. This may seem, initially, unexpected. However, the same results were found by Montgomery (2000) in a study he did with children with specific language impairment. In his study he had three tasks, a working memory task, an off-line comprehension task and an on-line word-monitoring task. He found that although the children’s performance on the working memory task correlated with the off-line comprehension task (i.e., the children with SLI did worse on both the working memory and the off-line tasks than their peers), there was no relationship found between performance on the on-line task and performance on the working memory task. Similar findings have been reported in the literature on aging (i.e., Waters & Caplan, 2001), and Alzheimer’s disease (i.e., Kempler et al., 1998). The results from the current study agree with previous findings that working memory capacity does not correlate with on-line processing performance. However, MacDonald and colleagues (2001) suggest that it is not necessarily the difference between on-line and off-line tasks that is the defining feature but rather the nature of the stimuli (the degree of complexity).

The second research question asked whether children with autistic spectrum disorders have working memory deficits. The children with high-functioning autism or Asperger Syndrome were not found to have any deficits in working memory compared to their age peers. Research done by Russell et al. (1996) suggests that working memory
deficits are not specific to autism but rather part of a more general cognitive deficit. In their study, Russell and his colleagues found that although the autistic children were more impaired in working memory span than the normal children they performed the same as children with learning disabilities. In contrast to these results, a study by Bennetto et al. (1996) found that autistic individuals were impaired in working memory function compared to a group of individuals with non-autistic learning disorders. No normal control group was included in the study however, so it is hard to predict how either group would have done compared to normal individuals. All the children in the current study had non-verbal intelligence scores within the normal range, suggesting normal (or near normal) cognitive functioning. The research done by Russell et al. (1996) would predict that these children would not show a working memory deficit compared to their peers, which is what was found.

In terms of the research questions posed in the first chapter the results show that autistic children can use linguistic contextual constraints during on-line processing and can use them in much the same way that their age peers do. In terms of working memory, this study found no relationship between working memory and real-time language processing abilities and children with high functioning autism or Asperger Syndrome do not appear to have deficits in working memory compared to their age peers. Although the research questions have been answered, a few issues remain for further discussion. First is the issue of the differences between the groups. The performance of both groups was similar but the children in the autistic group were faster on three of the four conditions. The question remains as to why there were differences in performance between the groups. Second is the issue of working memory. Why was no relationship
found between working memory and the word-monitoring task, when working memory is so important in language processing? These issues will be addressed in the following sections.

**Group Differences**

There are three ways of looking at the differences observed between the children in the autistic group and those in the age-matched group. Either the autistic group was faster than the age-matched group or the age-matched group was slower than the autistic group. While these alternatives may appear to be the same, they have quite different implications. A final way of looking at the data is to describe the autistic group’s performance as normal except in the semantic anomaly condition.

The first way of looking at the data is to say that the autistic group was faster on average than the age-matched group. One explanation for this could be that the autistic children were more efficient processors and therefore had faster reaction times than their age peers. This explanation seems unlikely for three reasons. First, research on sentence comprehension (Tager-Flusberg, 1981b), and linguistic processing (Jolliffe & Baron-Cohen, 1999, 2000) suggested that autistic individuals should be slower to process than their peers. Although these studies did not use on-line tasks, it would be unexpected to find that the autistic children were faster in an on-line task than their peers but slower in an off-line task. However, there is some research which suggests that individuals perform better on on-line than off-line tasks. This is attributed to a fast decay rate of information during processing. Second, a study by Jolliffe and Baron-Cohen (2001)
suggests that individuals with high-functioning autism or Asperger Syndrome have deficits in conceptual or higher-level processing, whereas perceptual or low-level processing is normal but not superior. Jolliffe and Baron-Cohen (2001) found that although the autistic spectrum individuals were impaired in their ability to integrate objects into a coherent scene they were not impaired in looking for similarities in sets of line drawings. However, they also found that the autistic spectrum individuals were no faster than their peers at locating a named incongruent object in a scene. The authors interpreted this as evidence that although their perceptual processing seemed normal, it was not better than that of their peers (Jolliffe & Baron-Cohen, 2001). Third, on the random word order condition, which must be processed by acoustic-phonetic information only since it contains no contextual constraints, the autistic group was slower than the age-matched group. This suggests that they were not faster processors, at least of the acoustic-phonetic information.

A second possible explanation as to why the autistic group appeared to be faster than the age-matched group is that the autistic group was better at using context than the age-matched group. Again this is highly unexpected given the research by Jolliffe and Baron-Cohen (1999, 2000) which found that high-functioning individuals with autism were worse than their peers at using linguistic context during processing. The two studies involved numerous off-line comprehension tasks, such as arranging sentences into a coherent story, using context to pronounce a homograph appropriately, or using context to interpret ambiguous sentences. Although their (Jolliffe & Baron-Cohen, 1999, 2000) research used off-line tasks, it would be strange to find that the autistic children were
better than their peers at using linguistic context in an on-line processing task but worse than their peers at using linguistic context in an off-line task.

Another way to describe the data is to say that the age-matched children were slower than the autistic children. This implies that there was something in the task that was making the performance of the age-matched children suffer, which was not affecting the autistic children, at least not to the same degree. Looking at the task, we can see that 75% of the sentences, those in the Syntactic, Random Word Order and Semantic Anomaly conditions, do not reward the listener for trying to process the sentences for meaning. Only the Normal sentences, 25% of the total number of sentences, reward the listener for adopting a strategy such as this. This is not to say that they did not show a main effect for condition, they did. However, it appears that there is something else going on in the data besides the main effect of condition. The children in the age-matched group seemed to have been affected by the overall lack of meaning in the task. It is possible that they may have adopted a strategy whereby they put more emphasis on acoustic-phonetic analysis and used contextual constraints cautiously, perhaps less than they would in a natural setting. This strategy would make them slower overall, although they would still show the effects of condition, but in fact faster on the random word order condition where all that was needed was acoustic-phonetic analysis. This is exactly what was found. The children in the autistic group did not seem as affected by the task context and appeared to have processed each sentence as it came, not adopting any particular strategy. They did not attend to the overall task context and were therefore not affected by the lack of meaning in the sentences.
A study done by Ceci (1983) with normal and language/learning-disabled (L/LD) children found a similar pattern of results. Ceci was looking at the processing characteristics of L/LD children. He identified two types of processing, automatic and purposive. Automatic processing refers to processing that takes place without intention or awareness, in which the presentation of a stimulus automatically activates the corresponding pathways containing its representation (Ceci, 1983). Purposive processing requires a conscious and deliberate plan to process a stimulus’ meaning and takes place within the limited capacity of the working memory system (Ceci, 1983). The experiment set up two different processing conditions. The automatic condition was composed of primes and pictures constructed to discourage deliberate semantic processing of primes, by setting up a situation where deliberate processing of primes would result in slower picture naming in most instances. This was achieved by having the condition contain 80% unrelated primes (e.g., “Here is a fruit” – HORSE) and only 20% related primes (e.g., “Here is an animal” – HORSE). The purposive condition was designed to maximize the likelihood of deliberate semantic processing. This was achieved by having the condition contain 80% related primes and 20% unrelated primes. This set up a situation where deliberate processing of primes would result in faster picture naming for most stimuli. Ceci (1983) hypothesized that if the children were using purposive processing in the purposive condition they would show larger benefits to the related primes and larger costs to the unrelated primes than in the automatic condition.

Ceci (1983) found that in the automatic condition both the L/LD children and the normal children performed the same, with similar benefits from related primes and very few costs from unrelated primes. In the purposive condition, however, the L/LD children
showed exactly the same pattern of costs and benefits as they had shown in the automatic condition, they did not appear to distinguish between the different conditions. In comparison, the normal children showed the expected result, with higher benefits and higher costs than they had shown in the automatic condition. Additionally, the benefits shown by the normal children were larger than those shown by the L/LD children. This was the expected pattern of results if the children appreciated or discovered that it was advantageous to purposively attend to the primes' meanings. The L/LD children did not appear to intentionally process the primes' meanings in the purposive condition, either because they failed to appreciate the expectancy of high prime relatedness or did appreciate the expectancy but were simply passive. Hence, they paid little costs to the 20% of unrelated primes but did not show as much benefit on the 80% of related primes. The L/LD children were not as strategic as the normal children in the purposive condition. They did not attend to the task until the slide actually appeared and at that time actively processed the item (Ceci, 1983).

There are some obvious parallels between the results of the current study and those found by Ceci (1983). Although the tasks were very different, the autistic group, like the L/LD group in Ceci's study, did not attend to the task context, but processed each stimuli individually. In comparison the age-matched children were aware of the task context, in which processing for meaning was not rewarded 75% of the time. It is possible that they, like the normal children in the Ceci (1983) study, adopted a strategy that would minimize the costs associated with processing for meaning when there was none, but would also minimize the benefits in the instances where the stimuli contained meaning. This is evidenced in their apparently slower performance in the word
monitoring task. There are two possible reasons why the autistic children were not affected by the task context. One, autistic children may simply have not noticed the task context. This is supported by previous research on overselectivity (Plaisted et al., 1999), which suggested that children with autism were unlikely to attend to global context unless instructed to do so. Other researchers (Iarocci et al., 2001) have also suggested that individuals with autism voluntarily attend to local stimuli unless directed to attend to the global level. Two, they may have been unable to construct a global (task) context as suggested by Jolliffe and Baron-Cohen (2000), who found that autistic individuals were impaired in their ability to achieve global coherence in linguistic processing tasks. They found that individuals with autistic spectrum disorders had difficulty arranging sentences into a coherent whole. They were impaired in their ability to construct a global context within which the sentences would make sense. While it is not possible, based on the current data, to choose between these alternatives, the fact remains that autistic children appear to be impaired in their ability to automatically construct and integrate global context during language processing. They do however, seem able to use the local linguistic context during on-line processing.

There is a third way of looking at the data. In examining Figure 1, it appears that in the first three conditions, Normal, Syntactic and Random Word Order, the children in the autistic group perform normally, with the assumption that the children in the age-matched group performance was normal. They follow the same pattern, with increasing reaction times from the Normal Condition to the Random Word Order condition. After this point however, the two groups appear to diverge, with the age-matched children continuing to get slower in the Semantic Anomaly condition, while the autistic children
get faster. Initially this seems to suggest that the autistic children were not as sensitive to the semantic anomaly in the stimuli as the age-matched children were. This would indicate that, as hypothesized, the autistic children were impaired in their ability to use semantic context compared with their age peers. In taking a closer look at Figure 1, however, their performance in the Normal condition complicates this conclusion. If you compare the performance on the Normal condition to that on the Semantic Anomaly condition in both groups, it becomes apparent that the difference between the two conditions, between the groups is small. This calls into the question the conclusion that the autistic children were impaired in their ability to use semantic context compared to their peers.

**Working Memory**

The results of this study found no relationship between working memory span and on-line processing. This seems somewhat counterintuitive given that working memory is essential for storing representations and performing computations during language processing. So why were no relationships found? It could be that the task didn’t tap into working memory. However, this seems unlikely for a number of reasons. First, the working memory spans obtained in this study are similar to those obtained in the study by Russell et al. (1996). Russell and his colleagues found working memory spans of 4.41 for the control group of normal children and spans of 2.86 for the group of autistic children. However, in his study the autistic children also had cognitive deficits along with a diagnosis of autism. The present study found working memory spans of 4.75 for the normal children and 5.22 for the autistic children (who did not have any cognitive deficits). The difference in working memory spans for the autistic groups is likely due to the severity of autism of the two groups. The present group included high-functioning
children with normal non-verbal intelligence, while the Russell et al study (1996) included children with more severe autism with concurrent cognitive deficits. The numbers for the two control groups however, suggest that both the current study and the Russell et al. (1996) study were measuring the same thing. Second, the children who completed the task displayed obvious signs of trying to store numbers while counting new displays. Many of the children were observed to be rehearsing the numbers from previous displays while also trying to count new displays of numbers. These observations suggest that both storage and processing functions were being tapped in this task, thus providing a measure of working memory span.

A second possible reason why no relationship was found is that language processing is so automatic for children that working memory was not involved in the task. This too is an unlikely explanation given that no relationship was found between any of the conditions and working memory, even the random word order condition. Since there was no meaning or structure involved in the random word order condition it could not be automatically processed in the same way as those with meaning and/or structure, so the same argument cannot apply to sentences in those conditions. Yet no relationship was found between the random word order condition and working memory. This suggests that it is unlikely that automaticity was responsible for the lack of any relationships between working memory and the language processing task.

A third possible reason why no relationship was found is that the demands of the task did not exceed the children’s working memory capacity. The task was easy enough for all of the children that demands stayed well below working memory limits. This could explain why no relationship was found. This is the same argument that
Montgomery (2000) used to explain why the children in his study, who were found to have working memory deficits compared to the control group, did not show effects of their deficits in an on-line word monitoring task. He argued that the task did not place enough demands on the children's working memory for it to be noticeable.

While the latter explanation is a plausible explanation for the lack of a relationship between working memory and performance on the on-line processing task, a more likely reason lies in the data itself. There was very little variation in the working memory data and without variation it is unlikely that any correlations will be found. So the most likely explanation for the lack of correlation between working memory span and performance on the on-line task, is the lack of variation in the working memory data. However, it is important to note that the results of this study are not unique. Numerous other studies, conducted with a range of populations, have also failed to find correlations between working memory and performance on on-line processing tasks (e.g., Montgomery, 2000; Waters & Caplan, 2001; Kempler et al., 1998), despite having variation in their data. So while the current study had little variation in the working memory data, other studies that had variation have come up with the same results. Current research by MacDonald et al (2001) suggests that this may be due to the nature of the stimuli used in the tasks. They suggest that the nature of the stimuli used in the task will determine whether there will be a relationship with working memory capacity, and that the reason that performance on on-line tasks often doesn’t correlate with working memory capacity, whereas off-line measures do, is because the stimuli used in the on-line tasks require only shallow processing. When only shallow processing is required working memory is not taxed and no correlation between working memory capacity and
task performance will be found. MacDonald et al (2001) did find a correlation between an on-line task and working memory capacity in participants with Alzheimer's Disease. They took this as evidence that it is not on-line task performance, per se, that is unrelated to working memory capacity, but rather the demands of the task that will determine whether a relationship is found. They propose that many on-line tasks require only shallow processing and, as such, demands are so low that working memory is not taxed enough to show any relationship. This line of reasoning could be applied to the task in the current study (assuming that variation had been found in the data and no correlations were found). The demands of the word-recognition task in sentences are relatively low. So it may be this, more than the fact that it is simply an on-line task that would result in a lack of correlations being found. However, in this case, as stated above, it is likely due to the lack of variation in the data that no relationships were found.

Summary of findings with respect to the research questions

Evidence from the analysis of reaction times in each of the sentence conditions indicated that the autistic children, like their age-matched peers, were able to use the linguistic context provided in the sentence conditions to facilitate language processing. Both groups showed the same pattern of results as has been found in numerous other word-recognition studies (Marslen-Wilson & Tyler, 1980; Tyler & Marslen-Wilson, 1981; Marslen-Wilson et al, 1988; Montgomery et al., 1990). However, the fact that the age-matched group appeared slower on three of the four conditions suggests that the autistic children had difficulties attending to or integrating the global context of the task.
into their language processing. The results show that the autistic children can use linguistic context but have deficits in constructing global (task) context.

In terms of working memory, no relationships between working memory and language processing were found for the on-line word-monitoring task. This is likely because there was very little variation found in the working memory data. Finally, there were no working memory deficits found for the autistic children. This was expected given that they were all classified as high functioning and showed normal non-verbal intelligence.

Implications

For Future Research

The current experiment was done to fill a gap in the research on the on-line processing abilities of autistic children. Given that this is the first study to look at this area, replication of the study is needed to confirm the data found. Further research could also explore whether blocking the sentences into conditions or changing the percentage of those that could be processed for meaning would make a difference in the results.

Research is also needed to tease apart the claims that autistic children can’t attend to/construct global context or don’t attend. Research done using visual processing suggests that they don’t voluntarily attend to the global level but can if directed to do so (Plaisted et al., 1999; Iarocci et al., 2001). Similar research done with linguistic processing is needed to confirm or disconfirm this claim.

A final note concerns working memory capacity and on-line tasks. Research has shown in numerous cases (Montgomery, 2000; Waters & Caplan, 2001; Kempler et al., 1998) that working memory capacity and performance on on-line tasks are not correlated,
which make on-line tasks ideal choices for studying processing in populations with memory deficits. This is in contrast to performance on off-line tasks, which is often correlated with working memory capacity (e.g. Montgomery, 2000, Waters & Caplan, 2001). It is not clear, however, exactly why this is the case. Montgomery (2000) hypothesized that the on-line tasks do not sufficiently tax working memory, so that even individuals with working memory deficits can perform at normal levels. MacDonald et al. (2001) propose that most on-line tasks only require shallow processing so the complexity of the stimuli differ between on-line and off-line tasks, and that this accounts for the differences in performance. They found that if on-line tasks are sufficiently complex, people with lower working memory capacities will show impaired performance. Waters and Caplan (2001) have a very different hypothesis. They propose a separate working memory resource for on-line processes involved in recognizing words and determining literal, coherent meanings of sentences. More research in this area is clearly needed to further distinguish between these two alternatives.

For Clinical Practice

The current study is the first to look at the on-line processing abilities of autistic children, so application of the results to clinical practice is somewhat premature and should be done with caution. However, assuming the results are valid they imply that children with high-functioning autism or Asperger Syndrome fail to interpret information within a wider context. This could mean that their ability to appreciate communicative situations is impaired (Jolliffe & Baron-Cohen, 2000) and lead to difficulties with comprehension, since information will remain disconnected for them (i.e., a collection of
disconnected sentences). It could also partly explain their difficulties with the pragmatic aspects of communication.

The findings here support the idea that children with autistic spectrum disorders have problems attending to the global context of a task or situation. Taking this into account, intervention for high-functioning autistic children should focus on trying to make the situational, or global, context more salient for them. Research (Plaisted et al., 1999; Iarocci et al., 2001) suggests that autistic individuals can attend to global context if directed to do so. If this is indeed the case, then, intervention should aim to direct attention to the global context. However, it also possible that the problem is not just one of attention to the global context, but rather, an impairment in constructing and integrating the global context into their language processing. If this is the case then, intervention must do more than bring attention to the global context, it must teach these children to construct a global context out of the local cues available and to integrate this context into their language processing.

A final, more practical implication of the research concerns the use of computers for assessment and intervention. The children in this study seemed to really enjoy the experimental tasks performed on the computer. Most of the children were comfortable using computers and felt that it was a particular area of strength for them. This made the tasks less intimidating than the standardized tests done with the examination book. All of the children were able to complete the tasks and did so in a short amount of time. These results could serve to justify the future development of more computerized assessments and even interventions for clinical practice. Given the portability and accessibility of
computers available to clinicians today, incorporating computer-based assessments and interventions into clinical practice is becoming more plausible.
REFERENCES


APPENDIX I: STIMULI

Test Items:

Early

Cat
NC: Sue loves animals. She has a cat on her lap and she is petting it.
SC: Worms eat everything. They want this cat in the bag and fish are sleeping there.
RC: Eat worms everything. Want they bag cat the fish sleeping are this in there and.
SA: The mouse is scared. It chews the cat in the house and then runs far away.

Bed
NC: David is sleepy today. He said his bed is too hard and he can't sleep at night.
SC: Tables are ugly outside. She heard the bed was very hot and they don't play by hands.
RC: Ugly tables outside are. They hot was bed very don't play she by hands the heard and.
SA: Clare put her pajamas on. She drove the bed next to the light and went to sleep.

Door
NC: We are ready to go. Please open the door and meet everyone outside on the grass.
SC: Cans are waiting to eat. Please save this door and put animals inside in a box.
RC: To cans waiting are eat. In a put door save inside and box please this animals.
SA: Matt puts his coat on. He eats the door and goes outside to get the newspaper.

Car
NC: Tom went to the race track. He liked the car with big stripes on top.
SC: Birds run to a blue shoe. They ate a car with a big house last.
RC: Blue run a shoe to birds. A with they car last a big house ate.
SA: Bill was late for hockey practice. He read the car and got to practice on time.

Book
NC: Peter likes to read. He likes the book about dinosaurs more than the one about flowers.
SC: Apples want to play. They want a book about elephants more than some things around rocks.
RC: Want play to apples. More they rocks book want than elephants around things a some about.
SA: Jen is at the library. She wears a book about horses to the counter to take it out.
Late

Tree
NC: The bird was building a nest. He built it on a branch in a tree by the house.
SC: That plant is eating the snake. She puts it by a mouse on the tree in a room.
RC: Is plant that snake the eating. It she a by puts the on room tree a mouse in.
SA: The deer walked in the forest. It was sleepy and stopped to ride a tree before going on.

Boat
NC: Jimmy went fishing. The fish he caught were lying in the boat next to him.
SC: Tigers are dancing. A hat she played is sleeping on a boat by the sun.
RC: Dancing tigers are. She the sleeping a played sun on is boat a by hat.
SA: The water was calm. It was a perfect day to swallow the boat and go fishing.

Dog
NC: Paul has two pets. He has a fish named Frank and a dog named spot.
SC: Chairs are red shoes. We want the hat put here and the dog called moon.
RC: Red are chairs shoes. Moon want we hat the called here put dog the and.
SA: Bill wants a pet. He went to the pet store to grow a dog and bring it home.

Bear
NC: The girls were walking outside. They went into the forest and saw a bear and a squirrel.
SC: A smile was swimming inside. We ran over the fish and watched that bear and some dishes.
RC: Swimming was inside smile a. Over ran the we and fish that and bear watched dishes some.
SA: The forest was quiet. The animals were sad when someone mailed the bear far away.

Ball
NC: The girls were playing soccer. The game ended when someone kicked the ball into the bushes.
SC: A rock can wash cards. A plane waited when flowers found a ball under the apple.
RC: Can a wash rock cards. When a waited the under plane found ball apple a flowers.
SA: The kids wanted to play catch. They all had gloves and Jim ate a ball from his house.

Practice Items

Doll
NC: The girls went upstairs to play. They played with the doll in the bedroom.
Pig
SC: Goats want to be in the light. He sees a pig and some socks watching the pretty forks.

Bike
RC: A cow pizza a sleeps. Ate chair a table on bike the purple some.

Duck
SA: Tim went to the park. He wrote a duck and then played on the swings.

Boot
NC: It was raining outside. Kevin put on one boot and then the other before going out.

Truck
SC: Small lizards run around. Fish run into the boxes and truck until coming in to sleep.

Train
RC: Under monkeys big swim people. Circles in until walk bird wanting to train many sleep and.

Cake
SA: It is Allison's birthday. Her mom walked the cake and everyone sang Happy Birthday to her.
## APPENDIX II: INDIVIDUAL TEST SCORES

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</table>

1. TONI scores are presented as quotients.

2. PPVT and CELF-SS, -FS scores are presented as raw scores.

Notes: AM: age-matched; A: autistic; TONI: Test of Nonverbal Intelligence; PPVT: Peabody Picture Vocabulary Test; CELF: Clinical Evaluation of Language Fundamentals, SS: Sentence Structure, FS: Formulated Sentences; WM SPAN: working memory span.