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School of Psychology

Eye Movements during Complex Information Processing in Autism Spectrum Disorder

by

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ABSTRACT

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EYE MOVEMENTS DURING COMPLEX INFORMATION PROCESSING IN AUTISM SPECTRUM DISORDER

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Autism Spectrum Disorder (*ASD*) is a neurodevelopmental condition defined by social communicative impairments and restricted, repetitive, and stereotyped patterns of behaviour, interests and activities. Some of the major influential cognitive theories of ASD include *Theory-of-Mind Deficit Hypothesis*, *Weak Central Coherence Theory* and *Executive Dysfunction Theory*. Previous research has advocated that performance on cognitive tasks designed to test these theories is complexity dependent, and that individuals with ASD show disproportionate difficulty compared to typically developing individuals on more complex tasks. The *Complex Information Processing Model* proposed that ASD could be characterised by selective impairment in complex information processing with intact simple information processing, and that this proposal can be generalised across different cognitive processing domains. In addition, this pattern of cognitive processing is thought to be the result of cortical underconnectivity in ASD.

In the studies reported in the current thesis, task instructions and stimuli from existing experimental paradigms were manipulated to test the dissociation between complex and simple information processing in ASD, as proposed by the Disordered Complex Information Processing Model. In addition, an attempt was made to investigate how complexity could be defined according to previous research in Theory-of-Mind Deficit Hypothesis, Weak Central Coherence Theory, and Executive Dysfunction Theory. Eye movement recordings of participants were taken as they inspected the stimuli and engaged with the different tasks. These recordings were used as a measure of moment-by-moment on-line cognitive processing during task completion.

In the first study participants with ASD were slower to start fixating relevant targets in tasks in which the task instruction could potentially be interpreted in multiple ways, regardless of whether or not they contain a perspective-taking element. Thus, in contrast to the predictions of the Theory-of-Mind Deficit Hypothesis, ambiguity rather than perspective-taking per se lead to more processing difficulty in ASD. In the second

study, and in contrast with Weak Central Coherence Theory, participants showed a similar ability to use context to understand ironic utterances during a reading comprehension task, indicating that figurativeness of language was not increasing complexity. Eye movements also showed a similar time-course of irony processing between ASD and Typically Developing (TD) participants. In the third study in which another reading comprehension paradigm were used but the true implicit aim of the study was to detect anomalies, eye movement data revealed that participants with ASD detected context independent anomalies earlier than TD participants, but were slower at detecting context dependent anomalies. This processing pattern is in line with both the Weak Central Coherence and the Disordered Complex Information Processing Model. Interestingly, in both reading studies, prolonged re-reading times were observed for individuals with ASD compared to TD individuals, suggesting processing of discourse information is more effortful in ASD, perhaps reflecting a reduced processing capacity. In the fourth study, participants in the TD and the ASD group showed similar eye movement patterns and recall performance in a memory for scenes task, and there was no effect of increasing either the implicitness of task instruction, or increasing working memory load. Although this suggests no impairment in memory for ASD, the results could be attributable to the nature of the stimuli.

Overall, the eye movement methodology employed for the studies in this thesis has proved to be a valuable tool to reveal the similarities and differences in how TD individuals and individuals with ASD process information on-line across a range of cognitive domains, which is unavailable from traditional methods that have relied on recording reaction times or accuracy. The findings of the current study converge with concurrent research findings supporting a domain general explanation of ASD that is not specific to the social domain. While the manipulation of the task instructions and stimuli in the current study had highlighted the difficulty in defining complexity, the Disordered Complex Information Processing Models seems to be able to account for the slowing of information processing apparent across scene perception and reading studies in the current thesis.

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Declaration of Authorship

I, Sheena K. Au-Yeung declare that this thesis entitled Eye Movements during Complex Information Processing in Autism Spectrum Disorder and the work presented in it are my own and have been generated by me as the result of my own original research. I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
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Chapter One

Cognitive Theories of Autism Spectrum Disorders

1.1 Autism Spectrum Disorders

Autism Spectrum Disorders (*ASD*) describe lifelong neurodevelopmental conditions characterised by 1) persistent deficits in in social communication and interaction, and 2) restricted, repetitive, and stereotyped patterns of behavior, interests, and activities according to the American Psychiatric Association (APA [DSM-V], 2013). Previously, ASDs were classed under Pervasive Developmental Disorders (APA [DSM-IV-TR], 2000). These included individuals with *Autistic Disorder* who have a lack of or delayed development of spoken language, and *Asperger's Syndrome* who have has no significant delay in language. In the UK, prevalence of ASD is approximately 10 per 1000 (1%) individuals (Brugha et al., 2011), with higher rates in males (18.2 per 1000) than females (2 per 1000).

Genetic research has indicated that ASD is a complex disorder that is affected by the interaction of genetic, epigenetic, and environmental factors (Eapen, 2011). From a neurological perspective, these factors contribute to pathological brain development mechanisms, leading to structural and functional abnormalities of the brain, which in turn lead to abnormalities in cognitive processing, ultimately translating into the behavioural syndrome known as ASD (Minshew, Williams & McFadden, 2008). My aim in this thesis is to investigate information processing differences between Typically Developing (TD) individuals and individuals with ASD. This chapter outlines four influential cognitive theories which have been proposed to explain the underlying cognitive mechanisms of ASD. I will attempt to identify the strengths and weaknesses in ASD using assumptions from four influential cognitive theories of ASD, in conjunction with available evidence from research testing these theories. The four theories in question are the *Complex Information Processing Deficit Model* (Minshew & Goldstein, 1998), the *Theory-of-Mind Deficit Hypothesis* (Baron-Cohen, Leslie & Frith, 1985), the *Weak Central Coherence* (Frith, 1989), and the *Executive Dysfunction* (Damasio & Maurer, 1978). In addition, I will introduce the use of eye movement methodology as an indication of online information processing for cognitive tasks and its ability to reveal subtle processing differences between ASD and TD individuals not available from other behavioural measures.

1.2 Disordered Complex Information Processing

Minshew et al. (2008) defined complex information processing tasks as those that require “integration of multiple features rather than reliance of one or two features, speed of processing, processing of large amounts of information, and processing of novel materials” (p. 384). According to the Disordered Complex Information Processing Theory (Minshew & Goldstein, 1998), the impairments in ASD lie not in lower level information acquisition, but in information processing. This cognitive model predicts that complex information processing would be selectively impaired in ASD across cognitive processing domains, where simple information processing would be either intact or enhanced. Furthermore, the abilities which are most severely affected are the ones that place the highest demand on information processing and the integration of information within and across cognitive domains.

At the neurobiological level, the model predicts a lack of development in functional connections between primary sensory cortex and association cortex for low-functioning individuals with ASD (Minshew & Williams, 2007). In high-functioning individuals with ASD, the model predicts preserved or overgrown local neural connections and underdeveloped connections within and between cortical systems. More specifically, disordered complex information processing was thought to be a result of underconnectivity between frontal-posterior cortical regions (Just, Keller, & Kana, 2013; Just, Keller, Malave, Kana, & Varma, 2012). Underconnectivity reduces the rate of inter-region information transfer, affecting performance on complex tasks that demand integration of various forms of cortical computations. This leads to coordination of activities between neural systems becoming affected. The functional consequence of reduced frontal influence is greater parietal autonomy perhaps indicated by increased activity and reliance on posterior brain area and increased connectivity amongst the posterior region. This means that individuals with ASD may become more effective in situations in which frontal contributions may impede performance; whereas performance will be lowered in tasks where processing requirements that normally involve the frontal areas cannot be performed or compensated for by posterior activities.

Complex information processing deficits have been observed in both adults and in children with ASD in various cognitive domains. Minshew, Goldstein and Siegel (1997) administered a neuropsychological battery consisting of tests in attention, motor skills, memory, language, and reasoning ability to 33 high-functioning autistic individuals and 33 individually matched TD controls. It was found that the ASD individuals were intact or superior in tasks involving basic abilities including attention, simple memory, simple language and the rule learning aspects of abstract reasoning. However, selective impairments in tasks which placed the highest demand on information processing were found within each cognitive domain. These included complex motor, complex memory, complex interpretative aspects of language, and reasoning domains. The general findings were subsequently replicated in another study (Williams, Goldstein & Minshew, 2006a) in 56 high-functioning children with autism using cognitive and neuropsychological assessment measures adapted for children, indicating that complex information processing problems persist throughout early development into adulthood.

Memory

Results from the two large scale studies (Minshew et al., 1997; Williams et al., 2006a) support the view that disordered complex information processing is not restricted to specific areas of functioning but occurs across cognitive domains. The following subsection presents examples of the findings within the memory domain to illustrate in more detail the dissociation between the simple and complex information processing deficits in ASD.

Simple verbal memory tasks are those that call for basic rote learning. High functioning individuals with autism (IQ > 80) showed intact performance compared to TD controls in verbal working memory tasks which involved recall of simple number and letter sequences (Minshew & Goldstein, 2001; Williams, Goldstein, & Minshew, 2005; Williams, Goldstein, & Minshew, 2006b), in verbal learning tasks which required immediate and delayed recall of semantically unrelated words (Minshew & Goldstein, 2001; Williams, et al., 2005; Williams et al., 2006b), and in a basic cross-modal associative learning task in which participants had to pair visual symbols with sounds that had been presented together (Williams et al., 2006b). The general finding across these studies is that individuals with ASD are able to acquire new auditory information and verbally recall this in a range of simple memory tasks.

Complex verbal memory tasks are those that require the use of organization strategies and semantic structure to support the integration of new verbal information. High functioning individuals with ASD were impaired at a verbal learning tasks which involved the recall of semantically related words (Minshew & Goldstein 2001) and complex verbal information such as sentences (Minshew & Goldstein 2001; Williams et al., 2006b). They also performed worse in the immediate and delayed recall of story materials (Minshew & Goldstein, 2001; Williams et al., 2006b). Minshew and Goldstein (2001) argue that whilst individuals with autism were able to encode words semantically, they were less efficient in their ability to use organization strategies, semantic structure or meaning to aid memory, therefore, their memory function was affected by the greater processing demands posed by the complex language structure of task stimuli.

In visuo-spatial memory tasks in which participants had to recall information that is presented visually, high functioning individuals with autism also showed a pattern of performance that is complexity dependent. Their spatial memory was intact as shown in a visual learning task which tests the memory for location (Williams et al., 2006b). In a maze learning task with three levels of complexity as defined by increasing the number of elements, participants with autism showed intact performance at the lowest level but required disproportionately more trials than TD participants to learn the mazes as complexity increased (Minshew & Goldstein, 2001). Impaired performance was also found in recall of visual pattern sequences (spatial span task, Williams et al., 2005; Finger Window task, Williams et al., 2006b).

High-functioning individuals with ASD have further exhibited problems with memory for complex visual information. They showed this in the recall of geometric shapes and complex figures (Minshew & Goldstein, 2001; Williams et al., 2006b), recognition of picture elements (Williams et al., 2006b), immediate and delayed recognition of faces, immediate and delayed recall of characters, their locations and their activity in complex social scenes (Williams et al., 2005). Taken together, research into memory function of ASD has demonstrated that memory deficits lie not in the simple acquisition of information, but selectively in complex memory tasks that place a heavy demand on information processing, regardless of whether the information was presented through auditory or visuo-spatial modalities, or both.

In summary, the current section has reviewed the distinction in performance for simple and complex tasks in the memory domain in ASD. Although other domains have not been exhaustively discussed here, there was also evidence for the same pattern of strengths and weaknesses in other cognitive domains (e.g., in language, motor, and reasoning) in which performance is enhanced or at least intact for simple processing tasks, but impaired for complex processing tasks. The next subsection of this chapter gives an overview of the findings for tasks designed to tap functioning of ASD relating to Theory-of-Mind Deficit Hypothesis.

1.3 Theory-of-Mind Deficit Hypothesis

First-, Second-order Tasks and "Pure" tasks

Theory-of-mind refers to the ability to infer other people's mental states, such as beliefs, desires, intentions, imagination and emotions that cause people to act a certain way (Baron-Cohen, 2001). In their seminal study, Baron-Cohen et al. (1985) postulated that the inability to attribute mental states of others underlies the social deficits in individuals with ASD. Twenty autistic children (Age: M = 11:11) and two control groups (27 younger TD children, Age: M = 4.5, and 14 children with Down's Syndrome of similar age, Age: M = 4.5) were tested on a first-order false belief task. The task involved telling the children a story: one character, called Sally, puts a marble in her basket, but while she was away, another character Anne took the marble out of the basket and placing it in her own box. At the end of the story, children were asked where the marble was originally located at the start and end of the story (reality question) and asked where would Sally look for her marble when she returns (belief question). The children pass the belief question if they indicate that Sally would look for her marble in the basket where she originally left it. Typically, children develop this false belief attribution ability to recognize that others might believe in something which is not true around 4 to 6 years of age (Wimmer & Perner, 1983). However, it was found that significantly fewer children with autism (20%) were able to infer Sally's false belief, compared to both TD children (85%) and children with Down's Syndrome (86%).

It was concluded that the performance of children with autism could be attributed to a specific deficit in theory-of-mind but not to general mental retardation, since even children with Down's Syndrome of lower verbal mental age were able to perform the task as well as TD children. However, one of the main criticisms of the Theory-of-Mind Deficits Hypothesis was its lack of universality (Rajendran & Mitchell, 2007), since not all autistic children failed the first-order false belief task. This led to the employment of increasingly higher level tasks in an attempt to confirm that Theory-of-mind deficit is common phenomena across the spectrum. For example, Baron-Cohen (1989; also see Holroyd & Baron-Cohen, 1993) tested autistic individuals in a second-order belief attribution task which required them to infer from a story "what does one character, Mary, think another character, John, thinks". All autistic participants who originally passed Baron-Cohen et al.'s (1985) first-order task failed this second-order task, performing significantly worse than participants with Down's syndrome and younger TD participants.

However, there is evidence that some high-functioning individuals with autism or Asperger Syndrome (Bowler, 1992; Dahlgren & Trillingsgaard, 1996; Ozonoff, Rogers, & Pennington, 1991) can pass even second-order tasks, in contrast to younger or lower functioning autistic individuals.

Tager-Flusberg (2001; 2007) argued that the verbal competence of some individuals with ASD enables them to use language-related compensatory strategies gained through the development of logical reasoning to pass first and second-order tasks, therefore suggesting that they don't possess true theory-of-mind ability. Bauminger (1999) showed that higher functioning children with autism who passed second-order theory-of-mind task had significantly higher verbal IQ than those who failed, furthermore, this correlation between task performance and verbal IQ was unique for participants with autism. Consequently, "purer" theory-of-mind tests with less reliance on verbal input were designed. For example, the "Read the mind in the eyes task" (Baron-Cohen, Joliffe, Mortimore, & Robertson, 1997). Participants were shown pictures of 25 pairs of eyes for three seconds each and were asked in each case to pick one out of two mental state terms that best described them (also see the "Revised Eyes Test" by Baron-Cohen, Wheelwright, Hill, Raste, & Plumb [2001], in which there were 36 pairs of eyes with a choice of four mental state terms). Participants were also given two simpler control tasks in which they had to judge basic emotions of whole faces (happy, sad, angry, afraid, disgust, and surprise) and judge gender from pictures of the eyes alone to ensure any differences in the experimental task was unattributable to more general deficits in recognizing basic emotions or gender. Participants with high-functioning autism or Asperger's Syndrome were poorer at inferring mental states from the eyes, although they performed comparably to normal age-matched controls and adults with Tourette syndrome on both control tasks. This indicated that difficulty with interpreting subtle social cues is present even in more able individuals with ASD with average or above IQ, however performance seems to be complexity dependent.

These findings seem to be somewhat convergent with Disordered Complex Information Processing Theory (Minshew & Goldstein, 1998). For example, second-order tasks require more information to be integrated or transmitted than first-order tasks and place greater demand on information processing. Even in the supposedly "purer" tasks, the control tasks and the experimental tasks seem to differ not only in the theory-of-mind element, they also differ in the type and subtleness of the information required to be inferred, judging gender and basic emotions seems to be more familiar and explicitly displayed, whereas judging complex mental states requires more top-down inferencing and attending to subtle facial cues. Presumably, underconnectivity between frontal and posterior regions in the brain of higher functioning individuals with ASD causes some disruption in processing due to reduced communication bandwidth (lower rate of information transfer) but are still functional and transmitting information to a degree, therefore these individuals are still able to integrate information and make top-down inferences, but the speed of processing would be restricted for increasingly more complex tasks. Another possibility is that individuals with ASD carry out first and second-order tasks by activation of different brain regions related to language processing instead of the normal theory-of-mind network, hence the link between verbal ability and task performance on these tasks in ASD (Bauminger, 1999). However, the inability to compensate using other regions in more non-verbal tasks (e.g. Baron-Cohen et al., 1997; Baron-Cohen, Wheelwright, Hill, et al. 2001) means performance is compromised.

Visual and Cognitive Perspective-Taking

A prediction from the Theory-of-Mind Deficit Hypothesis is that autistic individuals will have specific difficulty with cognitive perspective-taking tasks which require the understanding and inference of mental states, but not with visual perspective-taking, which do not. Leslie and Frith (1988) tested this hypothesis by administering four perspective-taking tasks in order of increasing difficulty. The first "line of sight" task tested whether or not the children could predict whether a doll could see an object depending on their position in relation to an obstacle that blocked the view of the object. The second test was a "memory for position" task, which tested whether or not the children could remember the position where an experimenter had placed an object. The third "limited knowledge" task tested whether children could attribute another person's knowledge of an object's location based on whether the person had seen it. The fourth task was a variation of the first-order false belief task by Baron-Cohen et al. (1985). Autistic children were unimpaired on the first and second "visual" tasks but impaired on the third and fourth "cognitive" tasks, compared to children matched for verbal mental age and with specific language impairments.

More recently, David et al., (2010) showed the distinct performance on the two types of perspective-taking task in individuals with higher verbal ability. Nineteen adults with Asperger's Syndrome, and 15 TD adults matched on IQ, judged a virtual character's preference for two objects based on its facial expression, gesture, and head/body orientation (indication of mentalising), and judged which object is elevated from the person's point of view (visuospatial perspective-taking). Participants with Asperger's Syndrome were slower and less accurate at the mentalising task but performed as well as TD participants at the visuospatial perspective-taking task. Together, these studies offer support that specific difficulty with mental state attribution unrelated to the ability to take on visual perspectives is common across individuals with ASD of different verbal abilities.

An additional finding in Leslie and Frith's study (1988) is that there is a strong asymmetric contingency between the performances in the latter two tasks, such that those who passed the false belief test were most likely to have passed the limited knowledge task, whereas those who passed the limited knowledge task still often found it difficult to pass the false belief test (also see similar studies by Perner, Frith, Leslie, & Leekam, 1989; and Reed & Peterson, 1990). It is argued that selective deficits in cognitive perspective-taking become progressively apparent in more individuals with ASD as the level of task complexity or abstraction increases (Baron-Cohen, 1988).

This argument points to an interesting confound in tasks that are deemed physical or social in nature. Baron-Cohen, Leslie, and Frith (1986) published another study shortly after their seminal study in 1985, testing an almost identical group of children from their previous study on a picture sequencing task that taps into children's understanding of causal relationships in social and physical events. The task includes five conditions: two mechanical conditions, two behavioural conditions, and an intentional condition. It was found that autistic children performed better than both TD children and children's with Down's Syndrome in the mechanical conditions; performance was equivalent to TD children and was better than children with Down's Syndrome in the behavioural conditions; but performance was more poorer than both control groups in the intentional condition. Interestingly, Baron-Cohen et al. (1986) noted that, when the conditions were looked at in terms of complexity, that is, the number of events depicted in the picture sequences (one or two events in mechanical, two to three in the behavioural condition, and three to four in the intentional condition), increasing complexity predicted performance exclusively for the autistic children.

Similarly, in a study by Reed (1994), individuals with autism completed three cognitive perspective-taking tasks which tested the ability to infer hunger, knowledge, and false belief (the Sally-Anne task) in the order of increasing complexity. Individuals with autism were impaired only at the most complex level for false belief, but at neither of the two less complex tasks. Reed interpreted this as evidence that the autistic individuals were performing poorly at the false belief task, not because of specific deficits in attributing mental states, but as a result of the transience and predictability of the social stimuli.

To sum up, the main issue with Theory-of-Mind Deficits Hypothesis is that it only attempts to account for social communicative impairments in ASD, but neglects other abnormalities in ASD including both deficits and assets in other cognitive domains. This has led to some reconceptualization of the Theory-of-Mind Deficits Hypothesis and a recent proposal of the two-dimensional Empathizing- Systemizing theory (Baron-Cohen, 2009). According to this, ASD is the result of the dissociation between poor empathizing and superior systemizing ability. It had been suggested that the two separate dimensions could be further reduced to one single dimension with empathizing and systemizing lying at the opposite end of a continuum. According to this view, empathising in ASD is impaired due to the unlawfulness and unsystematic nature of theory-of-mind tasks. This idea seems to be somewhat convergent with Disordered Complex Information Processing Theory, which predicts complexity dependent performance on higher-level cognitive tasks. However, it differs from Theory-of-Mind Deficits Hypothesis and its extension theories that impairments are not only predicted to be restricted to tasks with a mentalising element, although it is possibly that the need to mentalise could increase complexity. Since complexity is not always well-defined and it is not clear what factors raise task complexity, the first empirical study (Chapter Two) will be dedicated to investigating this issue by comparing how individuals with ASD and TD individuals viewed scenes under two task instructions, one with a theory-of-mind element (which will be operationally defined as a complex task) and one without a theory-of-mind element (which will be operationally defined as a simple task).

1.4 Weak Central Coherence

The Weak Central Coherence Theory offers a more domain general explanation for the observed abnormalities in ASD, including both processing deficits and unusual superior abilities observed in other cognitive domains aside from social and communicative symptoms (Frith & Happé, 1994). *Central Coherence* refers to the tendency for TD individuals to group parts into wholes to aid coherent perception of the world. Frith (1989) postulated that individuals with ASD have a weak central coherence, which means that they attend more to the parts rather than wholes. The most basic version of this theory makes two predictions: 1) local processing for details will be enhanced and 2) global perceptual integration will be impaired in ASD. These predictions have been tested in a number of paradigms.

Visual Detection Tasks

Research has shown that individuals with ASD perform better at simple visuospatial tasks that do not require global perception including visual search, embedded figures, and block design tasks.

Shah and Frith (1993) tested sixteen autistic individuals (age: 16 - 25, IQ: 57 – 108), on the standard Wechsler block design test which requires participants to visually break down a two-dimensional pattern into logical units presented to them on a card and reconstruct the design from separate parts using coloured blocks. Autistic individuals in both the low IQ (IQ < 85) and the high IQ group performed better than their peers in the learning disability and TD control groups. Subsequently when segmentation was manipulated, it was found autistic participants only showed a speed advantage compared to controls when the designs were presented as unsegmented wholes but not when the patterns were pre-segmented into blocks. This suggested that individuals with ASD have an enhanced ability to segment a gestalt. However, no clear distinction was made as to whether disruption in global gestalt processing or enhanced local processing, was responsible for the finding.

Visual search tasks require participants to make a decision as to whether a target is present or absent amongst a set of distractors. Here, the performance of TD and ASD individuals for two types of search task are reviewed: feature search and conjunctive search. In Feature Search, the target shares one feature with the distractors. In Conjunctive Search, the target may share multiple features with the distractors. In general, TD individuals find conjunctive search tasks harder than feature search tasks, and this is arguably due to the requirement to integrate multiple low level visual features in order to locate the target in conjunctive search (e.g., Feature Integration Theory; Treisman & Gelade, 1980). If individuals with ASD are impaired in their ability to integrate features then they should show poorer performance at this task compared to TD individuals, but show comparable performance for a feature search. One of the earliest studies (Plaisted, O’Riordan, & Baron-Cohen, 1998) investigating visual search in both TD and ASD children found that whilst TD children responded slower in the conjunctive search task than the feature task, autistic children performed equivalently in both search tasks, responding more rapidly than the TD children in the conjunctive search task. Additionally, the fact that autistic individuals made fewer errors in the conjunctive task indicates that the faster conjunctive search reaction time was not due to a speed-accuracy trade-off in that group. This enhancement of conjunctive search undermines the claim of perceptual integration deficits made by Weak Central Coherence Theory (Frith 1989).

Several drawbacks of the Plaisted et al. (1998) study have been recognised and remedied. Firstly, although the TD and autistic children were matched for verbal mental age, the autistic children had significantly higher spatial mental age as measured by block design task performance. Therefore, superior performance at the conjunctive search task could have been a result of the autistic children’s superior nonverbal IQ. However, when O’Riordan, Plaisted, Driver, and Baron-Cohen (2001) repeated the study using TD and autistic children matched on nonverbal IQ (Raven's Coloured Progressive Matrices; Raven, Court, & Raven, 1990), the superior conjunctive search performance in autistic children was still observed, thus supporting the claim that something other than general intelligence differences accounts for superior conjunctive search performance in ASD.

The second drawback of Plaisted et al.'s study (1998) was that the feature task was much easier than the conjunctive task. This meant that both the TD and autistic group were likely to be performing at ceiling for the feature task, leading to any between-group differences being masked. To test this possibility, O’Riordan, Plaisted, Driver et al. (2001) had participants complete two feature search tasks: (a) search for a vertical line target amongst tilted line distractors, and (b) search for a tilted line target amongst vertical line distractors. Typically developing children showed a search asymmetry effect. They found that searching for a vertical target amongst tilted distractors was harder than searching for a tilted target amongst vertical distractors. Autistic participants performed equivalently to the TD children on the easy task (tilted target). However, they performed better than TD participants on the harder task (vertical target), showing that search superiority in autistic children is not exclusive for conjunctive search tasks. This finding suggests that the process operating differently in autism that leads to enhanced unique item detection is common to both tasks and cannot be explained by a conjunctive search specific mechanism such as feature integration.

Another study published in the same year by O'Riordan and Plaisted (2001) further clarified the mechanism underlying visual search performance in both TD and autistic children, and importantly, superior visual search in autism. They manipulated target-distractor similarity and the number of features to be integrated in order to locate a target in a series of conjunctive search tasks. The less discriminable the target and the distractors were, the longer it took both TD and ASD participants to respond, although autistic children were not slowed as much as their TD peers by increasing target-distractor similarity, and were only significantly faster than the TD children at the harder tasks. This finding confirms that autistic children have intact feature integration ability, in contrast to the prediction from the most basic version of Weak Central Coherence Theory (Frith, 1989). It also suggests that superior visual search is due to autistic children's enhanced ability to discriminate between stimuli. Superior visual discrimination has further been found in a group of adult participants with high-functioning autism (O'Riordan, 2004).

In general, superior performance from visual detection tasks supported a processing advantage for local information in ASD which was shown in a range of individuals with ASD of varying general intelligence. However, the data from the aforementioned studies do not support that ASD is a lower level perceptual disorder as a result of disrupted feature integration to form global gestalt perception. Later revision of the theory (Happé, 1999) defined central coherence as “the everyday tendency to process incoming information in its context – that is, pulling information together for higher-level meaning – often at the expense of memory for details” (p. 217). As such, it is proposed that ability to use context is impaired in ASD.

Higher Level Influences

Plaisted, Swettenham and Rees (1999) showed how higher level cognitive influences such as task instruction can account for task performance in ASD that was originally attributed to impaired global perception. Plaisted et al. used two variations of the Navon task in which participants are required to respond to a target letter that could appear at the local level (small letters), at the global level (large letter made up by the small letters), or at both levels. In the divided attention condition, participants had to indicate by pressing a button whether a target letter “A” is presented or not. However, no information was given to participants regarding the level at which a target letter “A” would appear on any one trial. It was found that TD children responded faster and more accurately when the target was at the global level than when the target was at the local level, whereas children with autism responded faster and more accurately when the target was at the local level than when it was at the global level. This is consistent with a local processing bias in children with autism as opposed to a global processing bias in TD children in this task. In the selected attention condition, participants were instructed on some trials to judge specifically whether the small letters were either “H”’s or “S”’s by pressing one of two buttons, and were asked to do the same for the large letter in other trials. Both participant groups showed a global bias, responding faster to global targets than to the local targets in this task. This finding suggests the individuals with ASD do not have a problem with perceiving global information, but a preferential bias for information presented at the local level, unless they are overtly primed by specific task instructions.

Evidence for a detail focused processing style, in favour of local information processing in ASD, has also been provided by Booth and Happé (2010) using a verbal task. In this study, participants were asked to finish off verbally presented sentence stems which were designed to invite a local completion (e.g., In the sea there are fish and …chips/sharks). A local completion would be something that makes sense when only the last two words of the sentence were read in isolation but would not make sense when the more global context of the sentence was taken into account. Booth and Happé found that participants with ASD (including those with Autism and those with Asperger's Syndrome) made more local completions to the sentence stems than TD individuals matched on age and IQ. In addition, testing with individuals with Attention-Deficit/Hyperactivity Disorder (ADHD), who struggle with impulse control, showed that these participants with ADHD made no more local completions than TD participants, and also made less local completions than participants with ASD. This suggests that the local bias result in the ASD participants cannot be accounted for by poor impulse control. Together, the studies by Booth and Happé (2010) and Plaisted et al. (1999) show that local processing bias at the expense of contextual information processing is common across both visual and verbal tasks.

López and Leekam (2003) conducted four experiments to examine contextual influence in high functioning children with autistic disorder and TD children using both visual and verbal stimuli. In the first experiment, they tested whether pictorial context information facilitates object identification. It was found that autistic children were more inaccurate overall at naming objects; however, this was unlikely to be due to semantically related impairments as both participant groups were more accurate and faster at identifying objects when these were primed by a scene of appropriate context compared to neutral or inappropriate scenes.

The second experiment was a replication of the first experiment but presented verbally. Both groups were again faster at recognizing words following appropriate context compared to neutral and inappropriate context. Furthermore, both groups showed an interference effect of inappropriate context which slowed word naming compared to neutral primes (X's). The results for the first two studies could be due to the low task demand of simply naming objects and words, where no voluntary inferences have to be made.

Experiment Three required participants to recall objects in a picture or list of words, from either the same or different semantic categories. It was found here that autistic participants recalled fewer objects/words for both conditions, but both groups recalled more words in the semantically related condition compared to the unrelated condition. This finding shows that the autistic group were able to connect related item using semantic meaning and access schemas in both visual and verbal domains.

The task in Experiment Four was to read homographs in the context of sentences which depicted either a rare or frequent pronunciation of the homograph. Autistic children gave fewer context-appropriate pronunciations to homographs and made fewer self-corrections in sentences where the rare pronunciation was correct, compared to TD children. It is suggested that weak central coherence in ASD is characterised by specific impairment in using sentence context to disambiguate meaning and this could possibly be attributable to problems with integrating multiple items of information within the sentences. Interestingly, this conclusion seems to be converging with the Disordered Complex Information Processing model which predicts difficulty in tasks where there are multiple features to be integrated and where novel information has to be processed (Minshew et al., 2008). Furthermore, this homograph task appears to fit the criteria of more complex information processing because rare pronunciations could be considered more novel than frequent homographs, and because sentence stimuli would demand multiple words to be integrated.

Likewise, in another study by Joliffe and Baron-Cohen (1999), also using more complex sentence stimuli, it was found that individuals with ASD were less accurate and slower in selecting the correct bridging sentence (amongst two distractor sentences) to fit in the middle of two sentences (a sentence describing a situation and a sentence describing an outcome) to make them coherent and related. A further experiment by Joliffe and Baron-Cohen showed that individuals with ASD were less accurate and slower at selecting the appropriate interpretation of an ambiguous sentence when the preceding context sentence called for the rarer interpretation, compared to when it called for the more common interpretation. This is not the case for TD participants who showed equally good performance for both rare and common conditions. This finding implies that individuals with ASD were less efficient at integrating the ambiguous sentence with its prior context. In addition, this finding is also in line with Experiment Four in López and Leekam's study (2003) which showed that difficulty seems to be linked to conditions where more novel information (in rare conditions) is required to be processed.

Difficulty with context is also shown in two other experiments by Joliffe and Baron-Cohen (2001). These were designed to tap visual conceptual coherence in individuals with high-functioning autism and Asperger's Syndrome. In the first experiment, individuals with ASD performed more poorly at the top-down processing task requiring them to detect incongruent objects from a group of line drawings of objects and people that made up a scene. However, they were unimpaired at a bottom-up processing task requiring them to look for similarities, and in detecting an incongruent object from a group of objects from the same category. In the second experiment, participants with ASD were required to describe a scene and point out an odd object that was incongruent with the context of the scene. From the Weak Central Coherence Theory, two predictions were made: either participants with ASD would perform better at locating the odd object due to the tendency to focus on local details, or they would perform more poorly due to their insensitivity to context. The results showed that participants with ASD were slower and less accurate at identifying the odd object and less accurate in describing the scene compared to TD participants.   The findings from these two experiments suggest a lack of bias for local processing in ASD in these tasks, but that visual-conceptual coherence is impaired in ASD. To be clear, individuals with ASD seem to have problems identifying odd objects within a scene context.

In summary, Weak Central Coherence theory moved away from the modular and social only Theory-of-Mind Deficit Hypothesis, and put forward a more domain general information-processing mechanism to explain deviant bottom-up and top-down processing mechanisms across sensory modalities in ASD. The general consensus is that there are enhancements in lower-level visual processing (local processing) and that basic level of visual integration (global gestalt perception) is intact. Findings from higher level cognitive judgement tasks seem to point towards deficits in processing ambiguous information using context in both complex sentence stimuli and for scene stimuli tasks tapping visual conceptual coherence.

1.5 Executive Dysfunction

Executive function is an umbrella term used to describe higher-order cognitive abilities including planning, working memory, impulse control, response inhibition, shifting sets, as well as the initiation and monitoring of action (Stuss & Knight, 2002, as cited in Hill, 2004). Such functions have been found to be impaired in individuals with acquired frontal lobe damage. Based on the similarities in behavioural and motor disturbance between individuals with autism and individuals with prefrontal lobe damage, Damasio and Maurer (1978) argued that atypical functioning of the prefrontal cortex may underlie the social deficits and perseverative behaviour presented in ASD. Studies investigating planning, inhibition, and cognitive flexibility have provided some evidence for selective impairments in executive functions in ASD.

Planning, Inhibition, Flexibility

In the Stockings of Cambridge task, which is used to tap into planning ability (Hughes, Russell & Robbins, 1994), participants were required to rearrange a series of balls, in the minimum number of moves, into pockets from their starting positions to a goal position predetermined by the computer programme. Children and adolescents with autism were impaired at this task only on puzzles requiring longer sequences of moves, relative to TD children and non-autistic children with a learning disability. Interestingly, this finding is different from the pattern of impairments found in patients with frontal lobe lesions (Goel & Grafman, 1995), who performed worse than normal controls at all difficulty levels on the Tower of Hanoi task, another variation of the Stockings of Cambridge test.

Similarly, selective impairment in inhibition and cognitive flexibility has been shown in ASD using a Go/No-Go task (Ozonoff, Strayer, McMahon, & Filloux, 1994) that consisted of three conditions. In the neutral inhibition condition, participants were presented with two different target shapes (a circle or a triangle) on a computer monitor and were required to respond to the same target in all trials. In the prepotent inhibition condition, participants had to respond to the opposite target to the preceding task. In the flexibility condition, the target was switched repeatedly and participants had to change their response accordingly. Autistic children performed normally in the neutral inhibition condition, but they were moderately impaired in the prepotent inhibition condition and severely impaired in the cognitive flexibility condition compared to age-, gender- and IQ matched TD children, suggesting spared ability in automatic response inhibition, but impaired ability in shifting response set in ASD.

Selective impairments in mental flexibility were further shown in individuals with ASD. Mental flexibility was defined as the ability to shift to a different thought or action according to changes in a situation (Hill, 2004). Mental flexibility can be measured using a computerized multistage set-shifting (intradimensional/extradimensional) task in which participants are required to discriminate between stimuli patterns according to changing rules. Again, autistic individuals were only impaired in the later stages of the task in which a more complex transfer of learning is required (Hughes et al., 1994).

Executive function tasks discussed so far have shown that it seems to be the task with longer sequences (e.g. planning task; Hughes, Russell & Robbins, 1994), and tasks which have more complicated rule changes that produced between-group differences, and these tasks required more of a combination of executive processes. For example, the final condition of the inhibition task also required cognitive flexibility (Ozonoff, Strayer, McMahon, & Filloux, 1994). These features of executive tasks could be argued to produce more excessive demands on working memory capacity and they resembles the tasks which the Disordered Complex Information Processing Model proposed to be likely to show deficits in ASD, as a result of a reduction in processing capacity and slowed processing.

Another related suggestion that is related to task complexity is the explicitness of task instructions (White, 2013), and it is suggested that executive dysfunctions are shown in structural open-ended executive tasks that lack explicit instruction and involve arbitrary rules, but not in tasks which are explicit, that is, logical and constrained tasks where it is not easy for the task demand to be misunderstood. For example, while some studies (e.g. Ambery, Russell, Perry, Morris, & Murphy, 2006) reported group differences for the classic Wisconsin card sorting task for assessing cognitive flexibility in which participants had to detect rule changes and respond appropriately, these differences were eliminated when participants were explicitly told the rule on every trial (Hill & Bird, 2006), or when a rule switch was required. Additionally, while participants with ASD performed well at inhibition tasks with an unambiguous task requirement such as naming colours in a Stroop task, they had difficulties with the Hayling Sentence Completion task, which is an open-ended inhibition task that requires participants to generate an unrelated word to complete the end of sentences (Hill & Bird, 2006). It is interesting to note that these open-ended tasks also have similar requirements to complex processing tasks which individuals with ASD are hypothesized to be impaired at, according the Disordered Complex Information Processing Model Such tasks involve multiple processes (e.g. a combination of planning a strategy and inhibiting a response), as well as producing novel responses.

White, Burgess and Hill (2009) tested high-functioning children with ASD and TD children that were age- and IQ-matched, on executive tasks that were pre-defined as either constrained or open-ended. The constrained tasks included the Cards task, the

Water task, and the zoo map test. In the Cards task, participants had to respond yes or no to indicate whether a card is the same colour as the preceding card. In the Water task, participants were required to solve a multistep problem for which the aim was to retrieve a cork from a tall tube; only one solution is possible for this task. The Zoo Map task consisted of two parts, in the first part; participants had to plan a solution to problem within the limits of some rules, which involved visiting certain animals while keeping to the paths and using certain paths only once. In the second part of the test, participants were to repeat the same task but they were provided with instructions of the order to visit the animals, removing most of the planning requirements. The constrained tasks therefore provided systematic and explicit task demands for participants.

The open-ended tasks consisted of the Key Search task, the Six Parts Test and a modified version of the Hayling Sentence Completion task. In the Key Search task, participants were asked to draw a line to indicate how they would search a field (a square box on a piece of paper) to find a lost key. In the Six Parts Test, participants had to plan a strategy to complete an overall task by carrying out 6 activities including two picture naming tasks, two counting tasks and two sorting tasks. They were given five minutes to complete something from each task but were not allowed to do tasks of the same type one after the other. The Modified Hayling Sentence Completion task has two conditions. In the “correct” condition, participants had to give the most appropriate word to end a sentence. In the “incorrect” condition, participants had to give a word that was unrelated to a missing word in the sentence, or a previous answer. The two conditions were alternated by the experimenter’s hand signal. So, for the open-ended tasks, the common theme was that there were multiple ways to do things and that no particular strategy was prompted.

As predicted significant between-group differences were found for all open-ended tasks in this study (White et al., 2009). Children with ASD were less able to produce an efficient strategy in the Key Search task than TD children; they spent longer maximum time on any one subtask than controls spent on any one subtest in the Six Parts task. ASD participants were less able at producing an efficient strategy in the key search task than TD; they also gave more inappropriate responses in the “correct” condition, and were less likely to adopt a strategy to facilitate production of unrelated responses in the “incorrect” condition. The only unexpected finding was in part two of the Zoo Map task, in which participants with ASD made more rule breaks, but showed no difference in the number of moves made in the correct sequence and the time spent planning before they executed the first move. This difference might be due to the arbitrary nature of the rules imposed on this task, and those participants with ASD were not aware of the social expectation to comply with the rules. The authors argue that open-ended tasks present situations where participants have to be guided by an implicit understanding of what the experimenter wants and which require an appreciation of social contingencies. Since participants with ASD seem to have more problems with tasks of this nature, White (2013) formulated the Triple III (Inferring Implicit Information) Hypothesis which proposed that poor performance in executive function tasks in ASD were due to reduced ability to form an implicit understanding of the experimenter's expectations for the task, which leads to egocentric and idiosyncratic behaviour. This can perhaps also explain some of the relationships found between Theory-of-Mind and Executive Function tasks.

Working Memory

Working memory tasks require participants to hold information online for a short time to support continuous behaviour, and to manipulate information internally to plan complex responses. The findings reported for working memory have been mixed in ASD. Ozonoff and Strayer (2001), for example, found evidence that intact working memory in three working memory tasks when comparing autistic participants to TD controls and participants with Tourette's Syndrome. In the Running Memory Task, participants were presented with one of two possible geometric shapes one at a time, and were asked to determine whether the shape in the current trial is the same shape as one presented in the preceding trial (one-back) in one condition, or the one before that (two-back) in another condition. No group differences were found for reaction time and accuracy. In the spatial memory-span task, one, three, or five geometric shapes were presented simultaneously in five possible spatial locations of a display for three seconds. After a delay, one of the shapes was presented in the centre of the screen and participants were required to recall its previous location. Again, reaction time and accuracy showed no between group differences. In the Box Search Task, participants had to search for three targets through boxes at six possible spatial locations without returning to a box that had already been searched. The boxes were rearranged each time a box was selected to avoid the strategic use of spatial location without using working memory. There were no between-group differences for the number of errors made in which previously searched boxes were re-selected.

In contrast, Bennetto, Pennington, Rogers (1996) investigated whether participants with ASD would show memory functions similar to those of other groups with executive functions deficits. They found that autistic participants showed impaired performance compared to controls on working memory, source memory, and supra-span free recall, but were intact for short and long term recognition, cued recall, or new learning ability. To measure working memory, sentence span and a counting span task were used. In the sentence span task, the experimenter verbally presented participants with simple sentence and participants were required to supply the last word. Sentences were presented in sets of two to six and participants were required to recall the last word of each of the sentences in order. In the counting span tasks, participants had to count the number of yellow dots interspersed with blue dots on a set of cards with set size ranging of two to six cards. After a set of cards were presented, they had to recall the number of yellow dots that appeared on each card in order. Participants with ASD scored significantly lower (smaller number of total number of trials correct) on both tasks compared to TD group. However, scores for each set size for both tasks were not reported; therefore it is unclear if reduced performance were evident in all set sizes.

The difference in working memory performance between the two aforementioned studies could be due to the fact that two of the tasks in Ozonoff and Strayer's (2001) study merely required participant to match a given stimuli to a previous one (running memory task), and match a given stimuli to its previous location (spatial memory span task). Bennetto et al.'s (1996) study required a participant to maintain information across trials while computation of another response was being carried out, with an increasing number of items to be remembered within a set, which arguably, produces a higher working memory load. This task and findings again seems to fit with what would be predicted by the Disordered Complex Information Processing Model which proposed that one definition of a complex task is to involve integration of multiple features or processes.

Steele, Minshew, Luna, and Sweeney (2007) hypothesized that in individuals with ASD working memory capacity is more limited compared to TD individuals and therefore increased task demands should have more detrimental effects on their working memory performance. To test this they used a computerised spatial working memory task. Four, six, or eight boxes were presented in each set, and participants had to find a token hidden beneath one of the boxes. Once a token is found, the token is relocated in another box within the same set of boxes until all the boxes had been used. Thus, this requires participants to hold information across trials by remembering which box has already had a token in it while carrying out a search and remembering which boxes had already been searched within a trial. It was found that between search error (searching a box that already contained a token in previous trials) showed a sharper increase for autistic individuals from four to six boxes, but there was no further increase in error beyond this memory load. TD participants showed a more gradual linear increase for four to six and six to eight box searches. Furthermore, autistic participants were less likely to use a sequential organised search strategy than TD participants, which is correlated with increased rate of errors. Thus, it can be argued that this evidence also supports a limited processing capacity in ASD.

Summary

The empirical studies discussed provide some evidence that individuals with ASD demonstrate executive function impairments. However, the presentation of executive functions deficits in ASD is different to that observed in patients with frontal lobe lesions. Individuals with ASD only show impairments at more difficult stages of tasks involving planning, inhibition, cognitive flexibility, and working memory, findings that are not explained by the Executive Dysfunction Theory itself. Hill (2004) argued that the level of task complexity could be a possible explanation of performance in individuals with ASD on executive function tests**.** Some of the factors that seemed to increase task complexity included the number of elements in the task sequence, the number of processes that have to be carried out simultaneously, and the implicit nature of the task.

1.6 Integrating the Theories

So far, research related to each of the influential cognitive theories of ASD has been presented and discussed. Evaluation of the studies in relation to these theories suggest that each theory accounts for some but not all aspects of ASD, and that, across the studies, complexity has regularly been brought up as a factor that influences task performance. Recently, brain imaging studies using Magnetic Resonance Imaging (MRI) have also provided evidence that theory-of-mind deficits, weak central coherence, and executive dysfunction also share the same neurobiological basis, that is, frontal-posterior cortical underconnectivity, (Just et al., 2013), which Minshew et al., (2008) have also acknowledged to underlie complex information processing deficits. I now turn to discuss the brain mechanisms underlying different cognitive tasks linked to theory-of-mind, central coherence and executive function. .

Theory of Mind Deficits and Underconnectivity

In Baron-Cohen's paper (2009) in which the Theory-of-Mind deficit Hypothesis was reconceptualised as the Empathizing-Systemizing Theory (2009), it has been suggested that empathizing ability could be considered as part of a continuum defined by unlawfulness of information. Other authors, such as Minshew et al. (2008) have given similar proposals such that rather than recognizing social communicative abilities as a unique construct, they could be viewed in comparison to other cognitive abilities in terms of information processing demands. For example, when visual and cognitive perspective-taking are looked at in terms of information processing demands, visual perspective-taking tasks may rely on perceptual skills akin to mental rotation (Soulières, Zeffiro, Girard, & Mottron, 2011), which are governed by bottom-up processing supported by posterior brain regions. On the other hand, cognitive perspective-taking places a higher demand on top-down processing, requiring inferential judgements to be made based on prior knowledge, expectation, and context. These processes may be supported by connections with the frontal regions. Therefore, theory-of-mind deficits should share some common features in brain mechanisms as other cognitive deficits in ASD, namely, frontal-posterior cortical underconnectivity.

Support for this idea comes from Kana, Keller, Cherassky, Minshew, and Just's brain imaging study (2009). Participants were shown animations of two geometric shapes in three conditions, a theory-of-mind condition (interaction involving thoughts and feelings), a goal-directed condition (interaction with a simple purpose), and a random condition. Participants were to make forced choice responses of the word that best described the action depicted by each animation. While the theory-of-mind condition generated longer reaction time and higher error rates, there was no difference in these behavioural measures between participants with autism and controls, a finding that could be due to use of an explicit rather than an implicit task. Both groups activated the same regions related to theory-of-mind functions during the attribution of mental states and there was no difference in activation in the posterior theory-of-mind region – the superior temporal sulcus gyrus which was thought to provide cues for mentalising. However, activation was reliably lower for medial frontal areas, and amongst areas which were thought to be responsible for mental state reasoning, in the ASD group. The ASD group also showed lower functional connectivity between the frontal and posterior theory-of-mind areas during the theory-of-mind condition. This means the degree to which activation levels in the two regions rise and fall together were less synchronised for individuals with ASD than TD controls. This is in line with the idea that Theory-of-Mind deficits are underpinned by frontal-posterior cortical underconnectivity, which is also thought to underlie other non-social complex information processing deficits.

Weak Central Coherence and Underconnectivity

In a recent review of the advances made in cognitive explanations of ASD during her research career, Frith (2012) mentioned that a possible underlying neural mechanism for weak top-down control of flow of information could be a lack of synchronization of neural activity between feedback connections from the frontal regions of the brain and the feedforward connections from the posterior regions and this might be preventing effective integration of information from parts to wholes. This proposal seems to be supportive of the idea that there is a common neural basis for weak central coherence and the other cognitive deficits (e.g. theory-of-mind deficits) in ASD and the updated Theory-of-Mind deficit Hypothesis, and that basis is cortical underconnectivity.

Enhanced abilities observed in tasks such as visual search, block design, and embedded figures in ASD could be explained by difference in brain mechanisms between TD and ASD individuals. In terms of information processing, these tasks could be considered as "simple" tasks as they place a low demand on information processing in the sense that they only require visual pattern matching and thus they are purely perceptual in nature. An increment of local cortical connectivity could underlie enhancements in low level visual processes (Minshew & Williams, 2007; Minshew et al., 2008), which could be encouraged by reduced interference from higher-order processes, as a result of lower frontal-posterior synchronization in ASD.

Underconnectivity, as well being observed as reduced frontal and increased posterior activation for higher level tasks, has also been shown in a simple visual task, for which no impairments were observed in ASD. Damarla, Keller, Kana, Cherkassky, and Williams (2010) found similar performance between TD and ASD participants in terms of response times and error rates for an embedded figure task, however, participants with ASD showed greater activation in the visuospatial regions (bilateral superior parietal and right occipital areas) but less activation in frontal area (left dorsal lateral prefrontal cortex (DLPFC), left superior medial frontal gyrus), as well as lower frontal-posterior connectivity. This indicated a greater reliance on visuospatial processing and reduced reliance on executive processes in ASD. In contrast, controls show more activity in frontal regions, possibly an indication of effort in an attempt to make sense of the complex figure. Because recruitment of the frontal could be counterproductive for this task, reduction in posterior and frontal connectivity and less activity in the frontal regions would mean that simple processes to identify embedded figures that relies on visuospatial regions, is not inhibited by feedback from the frontal regions. This indicates that greater activity in the visuospatial area is responsible for at least intact, if not enhanced, performance on perceptual tasks (Keehn et al., 2009).

Executive Dysfunction and Underconnectivity

Previous research showed that executive dysfunctions for some later stages of executive function tasks, and for tasks that place a high demand on working memory load due to the requirement to coordinate multiple cognitive processes, are impaired in ASD. It is suggested that this can be explained by underconnectivity between association regions in the brain that are most activated for the task in question. Evidence from brain imagining studies showed that performance in an executive function task in ASD is linked to functional underconnectivity in the frontal-parietal network.

Participants in Just, Cherkassky, Keller, Kana, and Minshew's (2007) Study completed a variation of the Tower of London Task in which they were required to indicate by forced choice response the minimum number of moves needed to rearrange some balls to a desired location where the problems ranged from one move to three moves. There were no significant differences in error rates but individuals with autism were significantly slower than TD controls at responding for the harder conditions (which has a combination of two and three move problems). Brain imagining showed that both participant groups have activation in similar areas, such as the DLPFC, and that this activation increased in the more difficult condition. Furthermore, functional connectivity between frontal and parietal regions, the network thought to be responsible for planning and problem solving, were lower in the autism group than the controls. Frontal-parietal connectivity is also negatively correlated with autism characteristics as measured by a diagnostic instrument score in ASD participants. It was thought that the reduced communication bandwidth between those regions is disruptive to complex higher order psychological functions that depend heavily on coordination of brain regions, hence affecting the speed of processing in this task.

In sum, brain imaging studies provided evidence for functional underconnectivity between frontal and posterior regions, decreased activity in the frontal regions (and sometimes increased activity in posterior regions) during complex cognitive tasks including theory-of-mind, executive function tasks, and more simple perceptual tasks. These results support that complex information processing deficits, theory-of-mind deficits, weak central coherence, and executive dysfunction have a common neurobiological basis that is cortical underconnectivity.

1.7 Eye Movements in ASD During Cognitive Processing

In the past few decades, eye movement studies have been carried out to enrich our insight into how individuals with ASD process information differently from the neurotypical population. The two basic features of eye movements are saccades and fixations. *Saccades* are fast ballistic shifts in the location of the eye. *Fixations* are the periods when the eyes are relatively static, during which the intake of new information occurs (Rayner, 2009). Patterns of saccades and fixations vary across different tasks such as reading, scene perception, and visual search, and they are driven by different cognitive mechanisms underlying the tasks and are a function of how the cognitive system and the oculomotor system interact specifically for each task. Therefore, viewers fixate informative parts of stimuli for a given task in an often systematic and purposeful manner. Consequently, tracking of eye movements allows the measurement of moment-by-moment on-line cognitive processing for different tasks (Liversedge & Findlay, 2000), and analysis of eye movements can reveal what is driving, capturing, and maintaining attention during task completion. Comparison of eye movements between TD individuals and individuals with ASD could therefore potentially uncover the similarities and differences in online processing between these two groups for a range of tasks, across a range of cognitive domains.

Eye Movements During Mental State Attribution

Senju, Southgate, White, and Frith (2009) recorded the eye movements of participants whilst they watched a video sequence depicting a similar scenario encountered in the Sally-Anne task. Compared to TD participants, participants with Asperger's Syndrome showed less looking bias towards the location where the actor believed an object to be after it had been moved to another location by someone else unbeknownst to the actor. Also, whereas TD participants make a first saccade to the location where the actor believed the object to be positioned at significantly above chance levels (TD: 13/17 participants), the performance of participants with Asperger's Syndrome did not significantly differ from chance (ASD: 8/19 participants). These results for this nonverbal false belief task were found even though these same adults with Asperger's Syndrome were able to pass the standard verbal first-order and second-order belief attribution tasks. The lack of spontaneous gaze in accordance with the actor's false belief was interpreted as evidence that making inferences about mental states in others is not automatic in these individuals. These results are consistent with the brain imaging study by Kana et al. (2009), in which a lack of between-group difference in error rates was found in the mental state attribution condition, but reduced frontal activity as well as reduced frontal-posterior connectivity was also observed in ASD. Reduced connectivity impacting on the speed of processing could potentially explain the lack of spontaneous gaze found by Senju et al. (2009), due to a lack of reduced or delayed top-down input in ASD from frontal regions that are normally responsible for guiding spontaneous gaze in TD individuals.

Eye Movements During Visual Perceptual Tasks

As previously reported, a detection task that individuals with ASD excel at is the embedded figure test (Keehn et al., 2009). They are faster than controls to indicate whether a simple shape is present or absent in a complex figure. Eye movement analysis shows no difference in fixation frequency between participants with ASD or TD controls, but shorter fixation durations are found in the ASD group compared to the controls, indicating that participants with ASD were faster at processing the visual information. Keehn et al. also found that only the control group made longer first fixations when the target was not outlined in a different colour compared to when it was. This implies that individuals with ASD perceived the target as equally salient in both conditions, and these findings are in line with the claim of enhanced lower-level perceptual processing in ASD (Mottron, Dawson, Soulières, Hubert, & Burack, 2006), which is likely to be underpinned by overconnectivity in posterior visuospatial regions (Minshew et al., 2008).

In a study by Kemner, van Ewijk, van Engeland, and Hooge (2008), in which participants were required to indicate whether a target is present or absent amongst distractors, high-functioning individuals with ASD were significantly faster to respond than their age-matched and IQ-matched controls in all display set sizes (4, 16, and 25), with the strongest effect emerging for the largest set. Eye movement data revealed that individuals with autism did not fixate longer than TD controls, which indicates no difference in the search strategy used. However, individuals with ASD also made fewer fixations than controls for all display sizes with the effect being largest for the largest set. Furthermore, many of the participants with ASD showed no saccadic eye movements in the trials where a target was present, indicating that they were able to locate the target at first glance, without having to fixate it directly. The authors interpreted these results as evidence that superior visual search performance in ASD is due to enhanced stimulus discrimination.

A study by Joseph, Keehn, Connolly, Wolfe, and Horowitz (2009) arrived at a similar conclusion. The authors investigated the possibility that superior visual search in

ASD was due to better memory for rejected distractors. Joseph et al. tested children and adolescents with ASD and age-, sex-, and IQ matched TD individuals on both a standard static visual search task, and a dynamic visual search task. In the latter, the location of the target and distractors change randomly every 500 ms. Despite ruling out the possibility of memory use in the dynamic condition, individuals with ASD still responded faster than TD controls in this condition as well as in the static condition. Eye movements revealed no differences in the number of fixations and their distribution, but shorter fixations in the ASD group, once again supporting an enhanced ability in individuals with ASD to discriminate between stimuli at the focally attended location.

Results from these three eye movement studies during simple visual perceptual tasks are compatible with various cognitive theories of ASD; as well as being local processing tasks, they also fulfill criteria for being systematic tasks (Baron-Cohen, 2009), as well as having simple processing demands At the neural level, the findings from these visual tasks could be explained by increased activity and overconnectivity within the visual areas as result of reduced higher level influences, which would normally serve to slow detection in TD individuals as a result of a tendency to process information globally or in context.

Eye Movements During Executive Function Tasks

A number of eye movement studies have provided further evidence that executive function disturbances in attention shifting and inhibition is complexity dependent. Simple visually guided saccade tasks have been used to test whether the basic saccadic orienting system in ASD is impaired or intact. In these tasks, participants were required to saccade from a central fixation point to targets appearing at various visual angles to the left or right in the periphery. Minshew, Luna, and Sweeney (1999) found that autistic children performed normally in this task. In another simple saccade task, where participants had to make saccades back and forth between two dots, children with ASD also showed no difference to TD children across various eye movement measures of the distance travelled, and the duration and speed of the saccade (Kemner, Van der Geest, Verbaten, & van Engeland, 2004). These studies have demonstrated that the basic saccadic orienting system is intact and, as such, individuals with ASD are normal in their basic automatic attention shifting ability.

In contrast, deficits in attention shifting and inhibition occurred in more complex executive tasks requiring a higher level of volitional cognitive control. In the memory-guided saccade task, participants were required to fixate a central target while a peripheral target appeared and then wait until this disappeared before moving their eyes to the remembered peripheral target location following the offset of the central target (Goldberg et al. 2002). Individuals with high-functioning autism showed a larger number of response suppression errors compared to controls. In addition, they have also displayed less accurate memory-guided saccades than controls (Luna, Doll, Hegedus, Minshew, & Sweeney, 2007). Both Goldberg et al. and Luna et al. found increased memory-guided saccadic latencies in the participants with ASD.

In antisaccade tasks where participants were required to look in the opposite direction to the location of a target, higher error rates for participants with ASD compared to controls were consistently reported (Goldberg et al., 2002; Minshew et al., 1999; Luna et al., 2007). These apparent deficits in higher level voluntary cognitive control of saccades were linked to abnormalities in prefrontal cortex and functional connectivity (Funahashi, Bruce, & Goldman-Rakic, 1993; Funahashi, Chafee & Goldman-Rakic, 1993). If feedback from higher order processes is weakened it becomes more difficult to voluntarily inhibit the automatic responses of the saccadic system to attend to a stimuli. This is consistent with the brain imagining study by Cherkassky et al. (2007), which found that reduced frontal activation and frontal-posterior connectivity is linked to reduced speed of processing in an executive task.

Eye Movements During Simple vs Complex Tasks

Recent eye-tracking studies have looked into cognitive mechanisms that may mediate any abnormalities in brain function and behavioural differences in ASD. Research discussed in this section so far has revealed a lack of gaze preference indicative of spontaneous false belief attribution during a theory-of-mind task, reduced processing time in simple visual perceptual tasks, and impaired response inhibition in executive function tasks requiring volitional control of eye movements. A few scene perception studies carried out in our eye-tracking lab have also shown that complex information processing deficits could be observed in eye-tracking measures.

Benson, Piper, and Fletcher-Watson (2009) recorded the eye movements of ASD and TD participants while they inspected a picture of a painting (“Unexpected Return”, see Figure 1.1) under two different task instructions. One of the instructions was a social instruction (estimate how long the unexpected visitor has been away from the family) and the other was a material instruction (estimate the material circumstance of the family). When TD controls looked at the picture, they modulated their eye movements according to these top-down instructions to look at more informative parts of the scenes. That is, they looked more and for longer at people and heads of people under the social instruction than the material instruction, and they looked more and for longer at objects under the material instruction than the social instruction. Participants in the ASD group, however, did not show such modulation of eye movements according to top-down task instructions, regardless as to the nature of the instruction. This lack of modulation of higher level cognitive influences on saccadic scanning for both social and nonsocial tasks indicates that cognitive processing deficits in ASD are not restricted to the social cognitive domain, but may be generalized for inferential processes across cognitive domains.

Figure 1.1
“Unexpected Return” painted in 1884 by the Russian artist Ilya Repin downloaded from: http://www.abcgallery.com/R/repin/repin46.JPG

Importantly, in Benson et al.’s study (2009), both task instructions may be considered complex in that they each require the participant to draw upon previous (top-down) knowledge and combine the novel (bottom-up) information gathered from the sampling of the scene in order to make a subjective value judgment. However, as the experiment was not specifically designed to test simple versus complex processing during scene inspection, we cannot conclude from that study that processing was exclusively impaired for complex scene perception tasks. Hence a more concrete visual task that places less demand on higher order inferential processes, whilst using the same stimulus materials, was needed to test whether the dissociation between intact simple information processing and impaired complex information processing exist.

A recent study by Benson, Castelhano, Au-Yeung, and Rayner (2012) compared eye movement patterns between ASD and TD participants for simple versus complex information processing using the same materials but different task instructions. Participants were presented with pairs of pictures side by side. For the complex task, they were instructed to decide which one of the two pictures looked weird (See Figure 1.2a). For the simple task, they were instructed to decide which picture had a detail missing (See Figure 1.2b). No between-group differences were found in accuracy of response, response time, or any of the eye movement measures for the simple information processing task. For the complex information processing task, both groups performed at ceiling in their accuracy for identifying the picture with the “weird” feature. However, participants with ASD took longer to respond manually.

A sequence analysis (Au-Yeung, Benson, Castelhano, & Rayner, 2011) conducted to look at the similarity of patterns of eye movements from that study, taking into account the spatial location, sequential information, and temporal duration of the eye movements and fixations, revealed that participants with ASD viewed the scenes differently from TD participants exclusively for the complex information processing task throughout the entire trial period. More in-depth eye movement analysis by Benson et al. revealed that participants with ASD took longer and made more fixations before they began fixating the “weird” target region compared to TD participants. Furthermore, and importantly, whereas TD participants immediately picked up what was weird as indexed by their longer first fixation duration in the “weird” target region than the “normal” target region, participants with ASD did not show this difference. This suggests that unlike TD participants, participants with ASD do not immediately detect what is weird in the scene when they first fixate the weird feature.

Figure 1.2a. Example stimuli for the "Which One's Weird" task. Picture on the left is the "normal" picture. Picture on the right is the "weird" picture. This picture was digitally manipulated so that the beach ball in midair was replaced by a baby.

Figure 1.2b. Example stimuli for the "Spot the missing detail" task. The stimuli pair could either be two normal pictures (top two) or two "weird" pictures (bottom two). The detail missing pictures are shown on the right of the picture pairs; the shadow of the woman in the background was digitally removed.

The above study indicated that the individuals with ASD are unimpaired in a simple processing task that involves basic visual pattern matching, but they show impairments that manifest in the patterns of eye movements in a complex processing task, in which ambiguous abstract decisions need to be made. This is in line with the findings of executive function tasks, in which impairments are only shown when coordination of higher order processes is involved. Furthermore, consistent with Senju et al.'s theory-of-mind study (2009), the ability to make an inference spontaneously is compromised in ASD, as indicated by their reduced prioritisation of attention to task-relevant stimuli in the Which One's Weird study.

In sum, eye-tracking methodology has provided a means of investigating on-line cognitive processing differences between ASD and TD individuals in different cognitive tasks. It is able to provide information about what is driving, capturing, and maintaining attention, and gives an indication about processing speed and difficulty, attention priority, time-course of processing, and strategies used by a viewer in a given task.

Future Directions

The aim of this thesis is to further explore eye movements during simple and complex information processing in ASD, across a range of processing domains. Complexity as defined by the Disordered Complex Information Processing Theory is a broad concept; therefore there is a need to identify factors that contribute to complexity, and to identify the effects that these factors have on processing in ASD. I proposed to do this in two ways: 1) by manipulation of task instructions, and 2) by manipulation of stimuli for existing experimental paradigms which have been tested on TD individuals, and which are known to produce robust effects. This has the advantage of providing information about normative cognitive processes and behavioural performance for comparison with individuals with ASD. Paradigms using scenes and text stimuli will be used, as it is important to establish that processing deficits (if any) should be apparent across cognitive domains. The need for the integration of multiple words and linguistic information at different levels (word, sentence, passage) makes reading an ideal task for investigating complex information processing, and furthermore, the systematic nature of text stimuli provides an opportunity to create manipulations that are consistent across trials (e.g., manipulating words that occurs in the same position within a sentence or passage).

In the upcoming empirical chapters of this thesis, four experiments are presented that attempt to test the influence of complexity on Theory-of-Mind Deficits, Weak Central Coherence, and Executive Dysfunction. Attempts were made in these experiments to manipulate complexity in different ways in order to determine the factors that drive complexity, and eye movements have been recorded to investigate on-line processing differences between ASD and control groups. High-functioning adults with ASD were chosen for these experiments because, by adulthood, major changes in brain development would have taken place during childhood and adolescence, and because an adequate level of language skills would be obtained for carrying out reading tasks as well as to comprehend task instructions for each task. The first experiment presented in Chapter Two investigates processing during non-perspective-taking versus perspective-taking in a scene perception task, and in relation to Theory-of-Mind Deficit Hypothesis. The second and third experiments (Chapters Three and Four) investigate the ability to use contextual information to disambiguate meaning during reading, and the influence of context on spotting anomalies at the local sentence level and the more global passage level, both in relation to the Weak Central Coherence Theory. Finally, the fourth experiment (Chapter Five) investigates how the explicitness/implicitness of task instructions and memory load affects memory performance for scene information in relation to Executive Dysfunction Theory.

Can complexity be defined as the need to take on a psychological perspective? A popular use of eye-tracking with ASD samples has been to examine social attention or the ability to make mental state inferences from social stimuli. However, differences in attention to social figures are sometimes based on passive viewing where no explicit task was given (Riby & Hancock, 2008; Speer, Cook, McMahon, & Clark, 2007; Senju et al. 2009), and as such do not give any information as to how individuals with ASD adapt when there are specific processing requirements. In addition, the heavy use of social only stimuli in past research into ASD may have given the false impression that abnormalities in performance only exist for the social domain, whilst other more domain generalised theories such as the Disordered Information Processing Model would suggest otherwise. The first study will investigate perspective-taking vs non-perspective-taking in ASD using non-social stimuli. In the study by Senju et al. (2009), because a “simple” non-perspective-taking equivalent task was not provided for comparison, it is unclear whether the lack of spontaneity in directing their attention to relevant stimuli resulted from a specific difficulty with mental state attribution, rather than a general difficulty for attending to task relevant stimuli. If perspective-taking increases complexity, then it is predicted that participants with ASD will have difficulty inferring what task relevant stimuli to attend to, based on a given psychological perspective, whereas they will be able to attend to task relevant stimuli when directly cued to by a non-perspective-taking instruction.

Do individuals with ASD have difficulties disambiguating meaning using contextual information? The lack of or delayed language development and/or the idiosyncratic use and understanding of language is a hallmark of ASD. The aim of the second study is to investigate whether individuals with ASD are able to understand irony, a type of figurative language that requires inference of ambiguous meaning of the text that is not communicated by the surface meaning of the text. If difficulties do exist in ASD for irony processing, eye movements should give a clue as to whether impeded performance is due to inability to use contextual information as suggested by weak central coherence, or whether processing does occur but is slowed specifically for irony language as it places a greater load on processing capacity.

Does anomaly detection during reading in ASD depend on the need to use context? A number of studies have employed simple visual search tasks to examine the ability to spot an anomalous target amongst visually similar distractors. While simple search processes are generally intact/enhanced in ASD, recent evidence has shown that this is not the case for anomalies in complex scenes, where a slowing of detection was found (Au-Yeung et al., 2011; Benson et al., 2012). To our knowledge, no eye movement studies have yet investigated whether anomalies are detected during reading in ASD. Weak Central Coherence would imply that the need to use contextual information would determine whether or not individuals with ASD are successful in spotting anomalies. The third study will examine the performance of text anomaly detection under context-dependent and context independent conditions. It is predicted that individuals with ASD should have difficulty with detecting context-dependent anomalies due to their inability to take contextual information into account. In contrast, individuals with ASD are expected to excel at spotting context-independent anomalies as they should be less distracted by contextual information in the passage, something that would normally hinder anomaly detection in TD individuals.

Does implicitness of task instruction and number processing load contribute to impaired memory performance in ASD? In the executive function literature reviewed, participants with ASD appear to have difficulty with tasks with an increasing number of features to be manipulated; this could be attributed to increase in working memory load, which impairs ASD performance (Hill, 2004), when the limited resource could not cope with excessive demand. By manipulating the task instruction of an existing neuropsychological assessment tool, I will investigate whether recall deficits in ASD previously reported in this task (Williams et al., 2005) could be explained by the number of elements to remember. The family pictures task (Wechsler, 1997) was designed to assess visual memory using four family pictures depicting characters in different locations carrying out different activities. Another possible factor that could lead to deficits in executive function tasks in ASD is the inability to spontaneously use organisational strategies to drive attention (Williams et al., 2005), perhaps due to a failure to acquire an implicit understanding of an experimenter's expectations of task requirements for tasks with arbitrary rules (White, 2013). Therefore, the original implicit instruction from the family pictures test (i.e., Remember as much as you can about this scene) used in this study, and which does not specify what in the scenes actually needs to be recalled, is compared to an equivalent instruction in which participants were explicitly told they would need to recall all relevant features of the scene. It is predicted that participants with ASD would be impaired at recall following the more complex implicit instruction but not the simple explicit instruction. Explicit instructions should provide a structure for individuals with ASD to follow, in contrast with requiring ASD individuals to spontaneously assess what is important in the scene implicitly.

In summary, the experiments in the current thesis are planned to examine some of the unanswered questions raised by previous research in relation to the influential cognitive theories of ASD. Evidence from each of the reviewed deficit domains including, Disordered Complex Information Processing, Theory-of-Mind, Weak Central Coherence, and Executive Dysfunction suggests that performance on cognitive tasks were complexity dependent. It is also suggested that there could be a common underlying brain deficit, that is, frontal posterior cortical underconnectivity. The following chapters will look at 1) Are individuals with ASD specifically impaired at a task requiring them to take on a psychological perspective? 2) Do individuals with ASD have difficulties disambiguating meaning using contextual information during reading? 3) Does contextual information affect anomaly detection during reading in ASD? And 4) how does implicitness of task instruction and processing load of a task affect memory performance in ASD? In all experiments, an attempt will be made to include simple and complex processing tasks by manipulation of stimuli and task instruction, in order to see if performance is complexity dependent. These studies will potentially provide clues about what factors are driving complexity in different domains. In addition, recording of eye movement measures will give us an indication of what, when, and how information is being processing in ASD, and will reveal any subtle information processing differences that might exist between TD and ASD populations that are not apparent in behavioural measures such as accuracy or reaction times.

Chapter Two

Cognitive Perspective-Taking during Scene Perception in Autism Spectrum Disorder

2.1 Introduction

The current study examines the eye movements of individuals with ASD compared to TD individuals during perspective-taking versus non-perspective-taking tasks. The original Theory-of-Mind Deficit Hypothesis (Baron-Cohen. et al., 1985) proposed that the inability to infer mental states of others underlies the social communicative deficits in ASD (Baron-Cohen, 2001). It is well known, however, that ASDs are not only defined by social communicative impairments, but also by repetitive, restricted, and stereotyped patterns of behaviours and interests (APA, 2013). Recent theoretical development has extended the original Theory-of-Mind Deficit Hypothesis by proposing that the social and communicative deficits observed in ASD result from a delay in the development of an empathizing system, whereas intact or superior skills in systemizing are thought to offer an account for non-social aspects of ASD, such as repetitive behavior or narrow interests. In this two-factor Empathizing-Systemizing theory (Baron-Cohen, 2009), the Systemizing dimension refers to the drive to construct and analyze systems and the Empathizing dimension refers to the ability to identify mental states in others and to produce appropriate emotional responses. It is argued that the dissociation between these two dimensions can act as a reliable indicator of whether or not someone has ASD. Furthermore, the theory would suggest that it would be impairments in the empathizing dimension that would lead to a reduced or absent ability for individuals with ASD to take on the perspective of another person.

Alternatively, the Disordered Complex Information Processing Theory (Minshew et al., 2008) proposed that the reduced capacity to process complex information across cognitive domains underpins ASD. Complex information processing tasks require one or more of the following: integration of multiple features, speed of processing, processing of large amounts of information and processing of novel stimuli or information. Minshew et al. (1997) found that individuals with ASD performed at a reduced level compared to TD individuals in a large battery of tasks designed to test higher-order cognitive processing, for example, ‘concept formation aspects of abstraction’, which involve self-initiation of a problem solving strategy, whereas performance was intact or enhanced in the same ASD sample for tasks that tested basic or mechanical abilities, for example ‘rule learning aspects of abstraction' which involve attribute identification and rule learning to produce responses to simple problems.

In summary, despite the different use of terminology in these two different theoretical contexts, both theories (Baron-Cohen, 2009; Minshew et al., 2008) predict that individuals with ASD should have problems dealing with tasks that are unsystematic or complex. An aspect of empathizing is perspective-taking, which is a complex task that requires activating and maintaining knowledge about what other people would be interested in, and making use of various contextual cues to infer the mental state of the other person. Thus, perspective-taking can be assumed to be challenging to individuals with ASD.

Pichert and Anderson (1977) studied perspective-taking in TD participants by asking them to read a story describing the interior of a house from either a homebuyer's or a burglar's perspective. They showed that adopting the psychological perspective of another person while reading a story resulted in increased memory for perspective relevant information. Kaakinen, Hyönä, and Viljanen (2011), examined the eye movements of TD adults during perspective-taking tasks. When TD individuals viewed scenes with a specific psychological perspective in mind, more and longer fixations were made to perspective-relevant than perspective-irrelevant areas in the scenes. Furthermore, while the first fixation was more likely to land on a visually salient than a non-salient target region irrespective of the relevance of a target, this saliency effect was quickly overridden by task instruction. In the present study, a modified version of the Kaakinen et al. (2011) paradigm was used to investigate perspective-taking in ASD. This is an important extension to previous work as it addresses whether deficits in perspective-taking, which is an aspect of theory-of-mind, are related to ASD.

Eye movements are known to reflect the moment-to-moment cognitive processes during the time-course of a task (Rayner, 2009), and as such they can reveal subtle processing differences between TD and ASD individuals that are not available from other behavioural measures such as response time and accuracy. A theory-of-mind study that recorded eye movements and verbal responses (Senju et al., 2009) found that adults with Asperger's Syndrome were able to pass standard verbal first-order and second-order belief attribution tasks, but, unlike the TD group, their eye movements revealed no spontaneous orienting to the relevant information in an implicit theory-of-mind task. In another study, Au-Yeung et al. (2011) presented pairs of scenes to investigate processing for a simple “spot the difference” task, and a more complex “which one’s weird” task. Eye-movement sequence analyses that took into account spatial location and the sequential and temporal nature of the eye fixations revealed that the eye movement patterns differed between TD and ASD participants exclusively for the complex task. A more thorough regions-of-interest analysis (Benson et al., 2012) showed that participants with ASD took longer to begin fixating the “weird” target region, and that they did not immediately grasp what was weird as soon as they fixated it, despite performing at ceiling in terms of the accuracy measure in that task. These studies suggest that while TD individuals are known to modulate their eye movements when instructed to make a higher-level inference, this modulation is less spontaneous and more effortful in ASD.

The current study aimed to investigate whether individuals with ASD can take the psychological perspective of another person, and recorded eye movements to examine whether there were processing differences between ASD and TD individuals during non-perspective-taking and perspective-taking tasks. Perspective-taking tasks required participants to infer the category of objects that the perspective characters would be interested in, and then interpret whether information in the scene (pictures of the inside rooms and the outside of houses) belonged to that category (Kaakinen et al., 2011). It was predicted that TD participants with a burglar schema in mind would be interested in valuable items in the house, whereas things that needed fixing in the house would be of interest to the participants with a repairman schema in mind. Consequently, participants should more rapidly attend to, and look longer at the schema-relevant items compared to the irrelevant items. The difference between schema-relevant and irrelevant items in the dependent eye movement measures is referred to the *relevance effect* in the current study. Two non-perspective-taking tasks, in which participants were explicitly told to look for a certain category of objects in the scene, were also devised. The non-perspective-taking tasks were designed to direct participants’ attention to the same targets as for the perspective-taking tasks, but without the need to adopt the psychological perspective of another person. Theory-of-Mind Deficits Hypothesis would predict individuals with ASD to be unable to take on the perspective of another because of an inability to empathize, which would be reflected as the lack of a relevance effect for the perspective-taking task in early eye movement measures, which give an indication of attention priority, as well as the global eye movement measures, which give an indication of processing across the entire trial duration. In the non-perspective-taking task, however, individuals with ASD are expected to demonstrate the relevance effect for all eye movement measures. The current study therefore extends Kaakinen et al.'s study (which investigated the effect of perspective-taking on eye movements in TD individuals) by investigating the effect of perspective-taking on eye movements in ASD, and in addition, comparing modulation of eye movements in a non-perspective-taking task between TD and ASD individuals.

In contrast, the Disordered Complex Information Processing Model would similarly predict that participants with ASD have more difficulty in the perspective-taking task due to the more complex higher level inferential processing involved as compared to the non-perspective-taking task. In that case, ASD individuals may not show a relevance effect in the perspective-taking task especially for the early processing measures, if it is the case that perspective-taking raises the task complexity. Relevance effects may, however, occur in the global processing measures, indicating that individuals with ASD need more time to complete the complex task, but that they do have the capacity to take on psychological perspectives. Similar to predictions for the Theory-of-Mind Deficits Hypothesis, the Disordered Complex Information Processing Theory (Minshew & Goldstein, 1998) predicts that both TD and ASD group should show the relevance effect in the non-perspective-taking task.

2.2 Method

Participants

The original participant sample consisted of 17 neurotypical men (*n* =13) and women (*n* = 4) in the TD group and 18 men (*n* = 15) and women (*n* = 3) in the ASD group. Typically developing participants were recruited from the local community. The participants with ASD were recruited from the Southampton Adult Asperger's Society, the Hampshire Autistic Society, the Autism Diagnostic and Research Centre, the National Autistic Society, and the Children on the Autistic Spectrum Parents' Association. Prior to the study, participants with ASD were clinically diagnosed in the UK under the criteria of International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (World Health Organisation, 1992) for an ASD. Diagnostic reports confirmed that participants with ASD were primarily diagnosed using standard diagnostic instruments including the Adult Asperger Assessment (Baron-Cohen, Wheelwright, Robinson, & Woodbury-Smith, 2005), Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 2001), and/or the Autism Diagnostic Interview–Revised (Lord, Rutter, & Le Couteur, 1994).

All participants completed the Autism-Spectrum Quotient (AQ: Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), and the Wechsler Abbreviated Scale of

Intelligence (The Psychological Corporation, 1999), which confirmed that the two groups were matched on all IQ-subsets. The ASD group scored disproportionately higher on the AQ than the TD group. Comparing ASD and TD adults who fall within the normal IQ range allows the identification of cognitive features that are unique to ASD and that are not attributable to intellectual disability (Minshew & Williams, 2008). Participants with missing data in any of the experimental conditions were excluded. This included a participant with ASD (female) due to calibration error and a participant with ASD (male) due to computer failure. Other participants, including a participant with ASD (male) with a history of head injury, a TD participant (male) scoring over the autism cut-off, and two participants (one TD and one with ASD, both female) who scored lower than 80 on all IQ-subsets were also excluded from the analysis. The final sample consisted of 15 TD participants and 14 ASD participants. The ASD sample included 13 individuals diagnosed with Asperger's Syndrome, and one individual with high-functioning autism. The participant with high-functioning autism were within the normal range for the IQ measures and did not significantly differ from the other participants in the ASD group, and hence were included in the study. The characteristics of the final sample are summarized in Table 2.1.

Table 2.1

Participant Characteristics

	TD			ASD				
Measure	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*t*	*p*
Age	26.5	8.3	18-49	29.8	11.1	18-50	.900	.376
Verbal IQ	112	8.8	95-122	109	17.9	77-137	.569	.577
Performance IQ	114	10.0	88-127	112	16.1	85-134	.435	.669
Full scale IQ	114	8.8	96-126	111	18.5	87-140	.441	.665
AQ	15.9	5.1	7-25	31.6	8.5	19-45	6.10	<.001

Materials

The stimuli were color photographs of two houses. For each house there was a set of 8 pictures See Figure 2.1 for an example and see Appendix A for the full set of stimuli. The pictures (1024 x 768 pixels) were taken using a digital camera and were then digitally manipulated to contain perspective relevant and irrelevant items. Each picture contained equal numbers of relevant and irrelevant target items (one, two, or three of each type) and there were no significant differences in the size of the two item types (valuable items: *M* = 39276 pixels; features needed that fixing: *M* = 32367 pixels; *p* = .446). For the burglar schema, the valuable items were the relevant targets and the features of the house that needed fixing were the irrelevant targets. This was reversed for the repairman schema. The pictures within each set were presented in a fixed order for all participants, always starting with a picture of the exterior of the house, followed by the interior pictures.

Figure 2.1. An example of a house scene. There are an equivalent number of interest items of each type. Each target was outlined by freehand with resulting regions of interest shown in yellow. The burglar targets were valuable items, including 1) the laptop and 2) the printer. The repairman targets were features that need fixing, including 1) the broken curtain rail and 2) the damaged radiator. It must also be noted that the valuable items were not restricted to technology items (a class of stimuli that individuals with ASD are known to favour) but also included non-technological items such as money, purses, handbags etc.

A pilot study was conducted to verify the appropriateness of the items for each perspective. Six TD individuals who did not participate in the actual experiment were given colored prints of the stimuli on paper and asked to circle the items that were relevant for a burglar or a repairman. The order of which perspective was presented first was counterbalanced across participants. The rating study verified that the relevant items on average were identified by participants 93% of the time, and there was no significant difference between the two perspectives (burglar: 97%, *SD* = 19; repairman: 89%, *SD* = 9), $t(21.5) = 1.59$; $p = .127$.

Apparatus

Participants viewed the stimuli binocularly at a viewing distance of 70 cm on a 19 inch monitor with a screen resolution of 1024 by 768 pixels and a refresh rate of 75 Hz. Eye movements were recorded monocularly for the right eye using an Eyelink 1000 eye-tracker (SR Research Ltd, Osgoode, Canada) at a sampling rate of 1000 Hz. A chin rest and a forehead support were used to maintain participants' head position. Participants were calibrated using a nine-point matrix where they were required to fixate each calibration point in a random sequence. This was repeated to validate that each fixation was within 0.5 degrees of visual angle of corresponding calibration points.

Design

The experiment was a mixed design with one between-participants factor: *Group* (ASD vs. TD) and two within-participant factors: *Item Type* (valuable items vs features that need fixing) and *Schema* (burglar vs. repairman for the perspective-taking task; 'Look for the valuable items' vs 'look for the features that need fixing' for the non-perspective-taking task).

Procedure

Ethics and Research Governance approval was obtained from the University of Southampton. Participants gave written consent and took part in all schema conditions following verbal task instruction from the experimenter. A calibration procedure preceded each set of picture trials. For the two non-perspective-taking tasks participants were instructed to "*look at the items of the house that are valuable", or "look at the features of the house that need fixing"*. For the two perspective-taking tasks, participants were instructed to *"look at the pictures and imagine that you are a burglar"* or *"look at the pictures and imagine that you are a repairman"*. Prior to the presentation of each picture, participants had to fixate a central dot. Recalibration was carried out if participant's point of gaze no longer matched the location of the fixation dot.

Participants viewed each picture set twice; i.e., if a participant started with the non-perspective-taking task they would view the pictures with one of the instructions (e.g., look for valuable items) and then be asked to view the same picture set with the other instruction (look for features that need fixing). A different set of pictures was presented to participants for the non-perspective-taking and perspective-taking tasks and the order of the two different picture sets and the order of the tasks were counterbalanced across participants. Each picture was presented for six seconds.

Following the eye-tracking task, all participants completed a pen and paper study. They were presented with a word list of 30 items twice and were instructed to tick the box next to a word if it referred to 'valuable items' or a 'feature of a house that needed fixing'. The order in which the two instructions were given was counterbalanced across participants. The word lists contained ten valuable items, ten features that needed fixing, and ten neutral items (e.g. a shoe box). The word list study confirmed that both groups of participants were equal in their ability to identify items that belonged to each category (valuable items: TD: *Mdn* = 10, ASD: *Mdn* = 10, $U(15, 14) = 98$, $p = .705$; features that need fixing: TD: *Mdn* = 10, ASD: *Mdn* = 10, $U(15, 14) = 103.5$, $p = .936$). Participants were debriefed at the end of the study.

Eye Movement Analysis

Fixations and saccades were identified using a velocity criterion of 30 degrees per second. Any fixations that spanned across screen changes or were shorter than 50 ms were discarded. Eyelink DataViewer (SR Research Ltd, Osgoode, ON, Canada) was used to create freehand regions of interest surrounding the shape of each target. For each dependent variable involving regions of interests, extreme data points were removed if they were two or more standard deviations away from an individual's mean over an entire condition (across eight pictures) for each type of target (< 3% data).

The data were analysed separately for the non-perspective-taking and perspective-taking tasks. For the non-perspective-taking task, a 2 (Schema: look for the valuable items vs. look for features that need fixing) × 2 (Item Type: valuable items vs. features that need fixing) × 2 (Group: ASD vs. TD) repeated measures ANOVA was computed for each dependent variable. For the perspective-taking task, a 2 (Schema: burglar vs. repairman) × 2 (Item Type: valuable items vs. features that need fixing) × 2 (Group: ASD vs. TD) repeated measures ANOVA was computed for each dependent variable. Significant interactions were followed up with pairwise *t*-tests; Bonferroni corrections to the *p*-values were applied to control for the possibility of inflated family-wise error rates.

2.3 Results

Baseline Eye Movement Measures

Baseline eye movement measures were computed across all trials and conditions for each group. There were no between-group differences in the mean total viewing time spent on the stimuli (TD = 4937 ms, ASD = 4925 ms), mean total number of fixations

(TD = 18.4, ASD = 17.3), mean fixation duration (TD = 282 ms, ASD = 314 ms), first saccade latency (TD = 233 ms, ASD = 254 ms), and saccade amplitude (TD = 6.00, ASD = 5.78), all *p*'s > .05. These findings indicate that any observed between-group differences in the regions of interest analysis in the following sections are unlikely to be the result of between-group differences in basic sampling and oculomotor control.

Global Eye Movement Measures

We analysed global eye movement measures, including, *total viewing time*, *total number of fixations*, and *mean fixation duration* within the predefined target areas (valuable items and items that needed fixing). These measures give an indication of the importance of the target in the scene related to the task at hand. Greater viewing time and a higher number of fixations means that more attention was allocated to the area and more processing of the contents was carried out (Benson et al., 2012). Descriptive statistics for the global measures are presented in Table 2.2.

Table 2.2

Descriptive Statistics for the Global Eye Movement Measures

			Item Type			
			Valuable items		Features that need fixing	
Measure	Schema	Group	M	SD	M	SD
Total viewing time (ms)	Look for valuable items	TD	2631.12	609.6	281.33	150.8
		ASD	2747.67	866.18	303.17	253.9
	Look for features that need fixing	TD	518.42	303.44	2080.6	739.5
		ASD	598.05	310.68	1973.27	653
	Imagine you are a burglar	TD	2291.63	819	385.39	241.4
		ASD	2204.74	978.97	371.67	278.1
	Imagine you are a repairman	TD	460.53	168.34	1968.21	516.7
		ASD	765.98	504	1794.39	835.4
Total number of fixations	Look for valuable items	TD	7.86	1.68	1.25	0.52
		ASD	7.56	2.55	1.29	0.84
	Look for features that need fixing	TD	2.35	1.3	5.97	1.14
		ASD	2.2	0.72	6.07	1.99
	Imagine you are a burglar	TD	7.22	2.64	1.5	0.94
		ASD	6.52	2.43	1.62	1.16
	Imagine you are a repairman	TD	1.99	0.82	6.46	1.96
		ASD	2.77	1.23	5.21	2.1
Mean fixation duration (ms)	Look for valuable items	TD	322.8	65.21	220.66	44.81
		ASD	390.71	178.81	140.68	71.17
	Look for features that need fixing	TD	213.26	38.79	320.44	60.67
		ASD	252.2	55.66	318.26	61.6
	Imagine you are a burglar	TD	319.14	53.84	237.42	47.55
		ASD	341.63	105.42	240.49	67.71
	Imagine you are a repairman	TD	229.83	45.8	308.37	81.14
		ASD	254.28	66.71	353.29	115.2

Total viewing time. In the *non-perspective-taking task*, there was a main effect of Schema, $F(1,27) = 15.9$, $p < .001$, $\eta_p^2 = .371$, indicating that overall, more time was spent on target regions when viewing the pictures with the ‘look for valuable items’ (M = 1490.82 ms) than with the ‘look for features that need fixing’ schema (M = 1292.58 ms). A main effect of Item Type, $F(1,27) = 42.95$, $p < .001$, $\eta_p^2 = .614$, showed that participants spent more time on valuable items (M = 1623.82 ms) than on features that need fixing (M = 1159.59 ms). More importantly, there was a Schema × Item Type interaction, $F(1,27) = 170.43$, $p < .001$, $\eta_p^2 = .863$, indicating that more time was spent on schema-relevant than irrelevant target regions for both the ‘look for valuable items’ ($t(28) = 15.15$, $p < .001$, $d = 2.813$) and the ‘look for features that need fixing’ schema ($t(28) = 8.91$, $p < .001$, $d = 1.655$).

Similarly, in the *perspective-taking task*, there was a main effect of Item Type, $F(1, 28) = 6.71$, $p = .015$, $\eta_p^2 = .199$, (valuable items: M = 1430.72 ms, features that need fixing: M = 1129.92 ms), and an interaction between Schema and Item Type, $F(1,28) = 112.08$, $p < .001$, $\eta_p^2 = .806$, indicating that more time was spent on schema-relevant than irrelevant target regions for both the burglar ($t(28) = 9.65$, $p < .001$, $d = 1.792$) and the repairman schema ($t(28) = 7.05$, $p < 001$, $d = 1.308$).

In sum, the results of the total viewing time show a clear relevance effect for both non-perspective-taking and perspective-taking schemas for both groups (see top left of Figure 2.2).

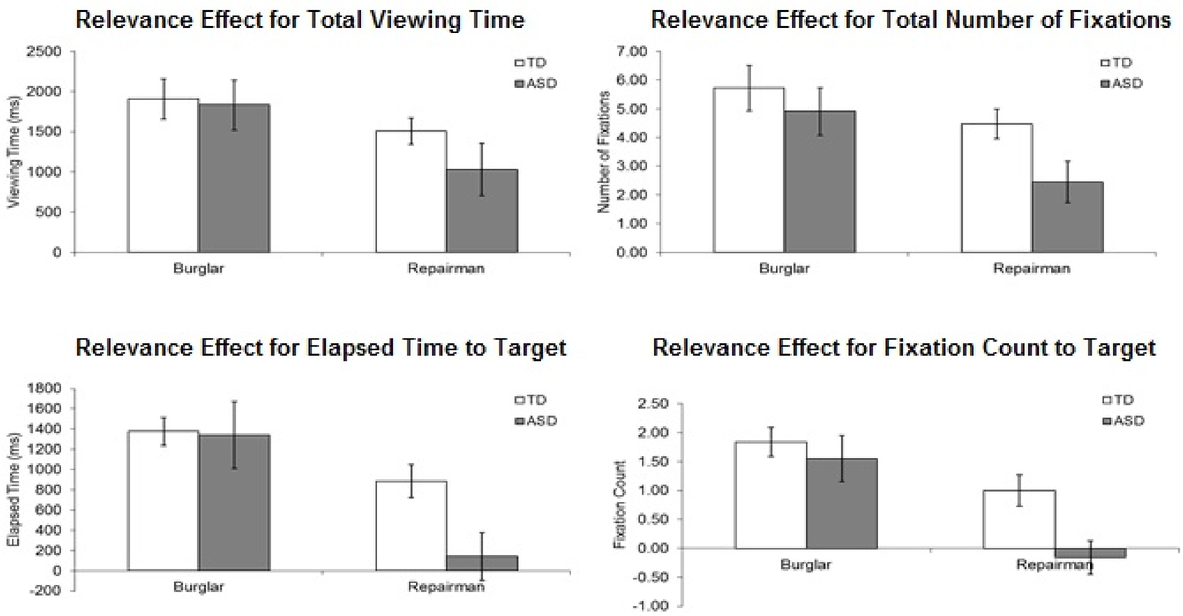

Figure 2.2. The magnitude of the relevance effect for total viewing time (top left), total number of fixations, (bottom left), elapsed time to target (top right), and fixation count to target (bottom right). Error bars represent *SEM*. Relevance effect is the difference in value between schema-relevant and irrelevant items for each of these dependent measures.

Total number of fixations. In the *non-perspective-taking task*, there was a main effect of Schema, $F(1,27) = 5.05$, $p = .033$, $\eta_p^2 = .158$, indicating that participants made more fixations on target regions for the 'look for valuable items' ($M = 4.49$) than the 'look for features that need fixing' schema ($M = 4.15$). A main effect of Item Type, $F(1,27) = 49.65$, $p < .001$, $\eta_p^2 = .648$, indicates that there were more fixations on valuables items ($M = 4.99$) than on features that need fixing ($M = 3.65$). A two-way interaction between Schema and Item Type, $F(1,27) = 188.01$, $p < .001$, $\eta_p^2 = .874$, indicates that more fixations were made on schema-relevant than irrelevant target regions for both the 'look for valuable items' ($t(28) = 14.20$, $p < .001$, $d = 2.636$) and 'look for features that need fixing' schemas ($t(28) = 10.32$, $p < .001$, $d = 1.916$).

In the *perspective-taking task*, a main effect of Item Type, $F(1,27) = 6.56$, $p = .016$, $\eta_p^2 = .195$, indicates that more fixations were made to valuable items ($M = 4.63$) than on features that need fixing ($M = 3.70$). A Schema × Item Type interaction, $F(1,27) = 146.84$, $p < .001$, $\eta_p^2 = .845$, shows that more fixations were made on schema-relevant than irrelevant target regions. However, there was also a marginal three-way interaction between Schema, Item Type and Group, $F(1, 27) = 3.89$, $p = .059$, $\eta_p^2 = .126$. Pairwise comparisons between the target types revealed that both groups made more fixations on schema-relevant than irrelevant target regions for the burglar (TD: $t(14) = 7.19$, $p < .001$, $d = 1.86$, ASD: $t(13) = 5.92$, $p < .001$, $d = 1.582$) and the repairman schema (TD: $t(14) = 8.73$, $p < .001$, $d = 2.253$, ASD: $t(13) = 3.35$, $p = .005$, $d = .896$). These results show that the magnitude of the relevance effect depends on the group and schema, such that the effect is smallest ($d = .896$) for the ASD group with repairman schema and greatest ($d = 2.253$) for the TD group with the repairman schema.

In line with the total viewing time measure, results for total number of fixations showed a clear relevance effect for both non-perspective-taking and perspective-taking schemas for both groups (see Figure 2.2 top right).

Mean fixation duration. In the *non-perspective-taking task*, there was a Schema × Item Type interaction, $F(1,27) = 42.16$, $p < .001$, $\eta_p^2 = .610$, indicating that participants made longer fixations on schema-relevant than irrelevant target regions across conditions and groups for both the 'look for valuable items' ($t(28) = 5.05$, $p < .001$, $d = .938$) and 'look for features that need fixing' schemas ($t(28) = 6.76$, $p < .001$, $d = 1.255$). In the *perspective-taking task*, a Schema × Item Type interaction, $F(1,27) = 37.29$, $p < .001$, $\eta_p^2 = .580$, indicated that participants made longer fixations on schema-relevant than irrelevant target regions for both the burglar ($t(28) = 6.06$, $p < .001$, $d = 1.125$) and the repairman schema ($t(28) = 5.27$, $p < .001$, $d = .978$). In sum, clear relevance effects for mean fixation duration were shown for both non-perspective-taking and perspective-taking schemas for both groups.

Early Eye Movement Measures

We also computed early processing measures for the predefined target areas, including *elapsed time* and *fixation count to target*, which give an indication of early orienting towards the target areas, and of how long participants spent exploring and processing other parts of the scene before a target captured the viewer's attention. *First fixation duration* gives an indication of recognition of the item as a target when it is initially attended to. Descriptive statistics for the early measures are presented in Table 2.3.

Elapsed time to target. In the *non-perspective-taking task*, there was a significant main effect of Item Type, $F(1,28) = 19.28$, $p < .001$, $\eta_p^2 = .417$, indicating that it took longer to look at features that need fixing ($M = 1502.60$ ms) than at valuable items ($M = 967.74$ ms). The main effect was qualified by a two-way interaction between Schema and Item Type, $F(1,27) = 79.28$, $p < .001$, $\eta_p^2 = .746$, indicating that participants landed sooner on schema-relevant than on irrelevant target regions. The three-way interaction between Schema, Item Type, and Group was also significant, $F(1,27) = 4.71$, $p = .039$, $\eta_p^2 = .149$. Pairwise comparisons revealed that the TD group were faster to fixate on schema-relevant than irrelevant target regions for the 'look for valuable items' schema ($t(14) = 7.97$, $p < .001$, $d = 2.058$), and marginally for the 'look for features that need fixing' ($t(14) = 2.35$, $p = .034$, $d = .607$), whereas the ASD group were only faster to fixate on schema-relevant than irrelevant target for the 'look for valuable items' schema ($t(13) = 4.50$, $p = .001$, $d = 1.202$) and not for the 'look for features that need fixing' schema ($t(13) = 1.53$, $p = .151$, $d = .408$).

For the *perspective-taking task*, a significant main effect of Item Type, $F(1,27) = 11.21$, $p = .002$, $\eta_p^2= .293$, shows that it took longer to land on features that need fixing ($M = 1592.03$ ms) than on valuable items ($M = 1170.22$ ms). A Schema × Item Type interaction, $F(1,27) = 92.39$, $p < .001$, $\eta_p^2 = .774$, indicated that overall participants were faster to fixate on schema-relevant than irrelevant target regions. In addition, a three-way interaction between Schema, Item Type, and Group that was approaching significance, $F(1,28) = 4.02$, $p = .055$, $\eta_p^2 = .130$ (modest effect), showed that elapsed time to schema-relevant and irrelevant target regions was modulated by Group. Follow-up comparisons clarified that TD participants were faster to fixate on schema-relevant than irrelevant target regions in both the burglar ($t(14) = 9.89$, $p < .001$, $d = 2.554$) and the repairman schema ($t(14) = 5.47$, $p < .001$, $d = 1.412$), whereas in the ASD group the difference between schema-relevant and irrelevant target regions was significant only for the burglar ($t(13) = 4.04$, $p = .001$, $d = 1.080$) but not for the repairman schema ($t(13) = .601$, $p = .558$, $d = .161$).

The TD group showed *relevance effects* for elapsed time to target in all schema conditions, whereas the ASD group showed *relevance effects* for the burglar and the non-perspective-taking counterpart 'look for the valuable items' schema, but not for the repairman schema and its non-perspective-taking counterpart 'look for the features that need fixing' schema (see Figure 2.2 Bottom Left).

Fixation count to target. In the *non-perspective-taking task*, there was a significant main effect of Schema, $F(1,27) = 5.06$, $p = .033$, $\eta_p^2 = .158$, with participants making more fixations before landing on a target region when viewing pictures from the 'look for valuable items' ($M = 2.15$) than the 'look for features that need fixing' schema ($M = 1.90$). A main effect of Item Type, $F(1,27) = 22.80$, $p < .001$, $\eta_p^2= .458$, indicated that participants made more fixations before landing on features that need fixing ($M =$

2.43) than on valuable items (*M* = 1.62). A main effect of Group, $F(1,27) = 6.68$, $p = .015$, $\eta_p^2 = .198$, showed that TD participants made more fixations (*M* = 2.16) before landing on a target region than the ASD participants (*M* = 1.88). These main effects were qualified by two interactions. A Schema × Item Type interaction, $F(1,27) = 60.21$, $p < .001$, $\eta_p^2 = .690$, indicated that overall, participants made fewer fixations before landing on schema-relevant than on irrelevant target regions. A significant three-way interaction between Schema, Item Type, and Group, $F(1,27) = 5.37$, $p = .028$, $\eta_p^2 = .166$, suggested that fixation count to schema-relevant and irrelevant target regions was modulated by group. Follow-up comparisons showed that fewer fixations were made before landing on a schema-relevant than on irrelevant target region for the ‘look for valuable items’ schema for both the TD ($t(14) = 8.42$, $p < .001$, $d = 2.175$) and ASD ($t(13) = .3.96$, $p = .002$, $d = 1.058$) groups. For the ‘look for features that need fixing’ schema the difference between the schema-relevant and irrelevant target regions was not significant in either group (ASD: $t(13) = .645$, $p = .530$, $d = .172$; TD: $t(14) = 1.28$, $p = .221$, $d = .331$).

For the *perspective-taking task*, there was a significant main effect of Schema, $F(1,27) = 5.27$, $p = .030$, $\eta_p^2 = .163$, with participants making more fixations before landing on a target region when viewing pictures from the burglar (*M* = 2.18) than the repairman schema (*M* = 2.01). A main effect of Item Type, $F(1,27) = 15.01$, $p = .001$, $\eta_p^2 = .357$, indicated that participants made more fixations before landing on features that need fixing (*M* = 2.41) than on valuable items (*M* = 1.77). These main effects were qualified by two interactions. A Schema × Item Type interaction, $F(1,27) = 56.93$, $p < .001$, $\eta_p^2 = .678$, indicated that overall, participants made fewer fixations before landing on schema-relevant than on irrelevant target regions. A significant three-way interaction between Schema, Item Type, and Group, $F(1,27) = 6.67$, $p = .016$, $\eta_p^2 = .198$, suggested that fixation count to schema-relevant and irrelevant target regions was modulated by group. Follow-up comparisons showed that fewer fixations were made before landing on a schema-relevant than on an irrelevant target region for the burglar schema for both the TD ($t(14) = 7.21$, $p < .001$, $d = 1.862$) and the ASD ($t(13) = .3.89$, $p = .002$, $d = 1.041$) groups. For the repairman schema, fewer fixations were made before landing on a schema-relevant than on irrelevant target region for the TD group, $t(14) = 3.68$, $p = .002$, $d = .0951$), but the difference between the schema-relevant and irrelevant target regions was not significant in the ASD group, $t(13) = .556$, $p = .587$, $d = .149$.

In the non-perspective-taking task, both groups showed clear relevance effects for the ‘look for valuable items’ schema, however, both groups showed an absence of a relevance effect for the ‘look for features that need fixing’ schema. In the perspective-taking task, both groups showed a relevance effect for the burglar perspective. However, for the repairman perspective, the relevance effect was only present for the TD group (see Figure 2.2 Bottom Right).

First fixation duration. In the *non-perspective-taking task*, there was a two-way interaction between Schema and Item Type, $F(1,27) = 26.52$, $p < .001$, $\eta_p^2 = .496$, suggesting that first fixation durations were longer on schema-relevant than on irrelevant target regions for both the ‘look for valuable items’, ($t(28) = 3.87$, $p = .001$, $d = .719$) and the ‘look for the features that need fixing’ schema, ($t(28) = 3.18$, $p = .004$, $d = .591$). In the *perspective-taking task*, there was a marginal main effect of Schema, $F(1,27) = 3.18$, $p = .086$, $\eta_p^2 = .105$, suggesting that first fixation durations were slightly longer when viewing the pictures with the burglar ($M = 268.02$ ms) than the repairman perspective ($M = 249.22$ ms). An interaction between Schema and Item type, $F(1,27) = 4.84$, $p = .037$, $\eta_p^2 = .152$, indicated that first fixation durations were significantly longer on schema-relevant compared to irrelevant target regions for the burglar schema ($t(28) = 2.79$, $p = .009$, $d = .009$), but not for the repairman schema ($t(28) = .127$, $p = .900$, $d = .024$).

The relevance effect on first fixation duration for the non-perspective-taking task was clear for both schemas, but was present only for the burglar schema in the perspective-taking task. This is consistent across participant groups and no between group difference was found for the first fixation duration measure.

Table 2.3

Descriptive Statistics for Early Eye Movement Measures

			Item Type			
			Valuable items		Features that need fixing	
Measure	Schema	Group	M	SD	M	SD
Elapsed Time to Target (ms)	Look for valuable items	TD	537.69	194.91	2449.84	905.1
		ASD	629.42	311.6	1683.61	815.8
	Look for features that need fixing	TD	1351.17	603.83	904.19	256.8
		ASD	1352.69	786.28	972.74	356
	Imagine you are a burglar	TD	683.62	286.7	2058.99	420.2
		ASD	896.82	494.99	2236.5	904.8
	Imagine you are a repairman	TD	1688.15	581.87	801.83	156.7
		ASD	1412.29	720.15	1270.81	706
Number of Fixations to Target	Look for valuable items	TD	1.12	0.17	3.6	1.06
		ASD	1.24	0.25	2.62	1.18
	Look for features that need fixing	TD	2.17	0.79	1.75	0.51
		ASD	1.93	0.77	1.74	0.39
	Imagine you are a burglar	TD	1.28	0.29	3.12	0.78
		ASD	1.39	0.36	2.94	1.15
	Imagine you are a repairman	TD	2.56	0.76	1.56	0.38
		ASD	1.87	0.64	2.03	0.55
First Fixation Duration (ms)	Look for valuable items	TD	274.73	79.11	206.87	42.26
		ASD	278.75	75.41	236.35	78.15
	Look for features that need fixing	TD	202.29	55.29	243.28	49.88
		ASD	236.03	46.5	259.59	59.39
	Imagine you are a burglar	TD	289.8	84.04	233.8	51.1
		ASD	302.04	122.15	246.43	63.08
	Imagine you are a repairman	TD	233.26	47.89	236.36	49.84
		ASD	262.52	100.11	263.75	127

2.4 Discussion

The current study explored whether or not individuals with ASD, like TD individuals (Kaakinen et al., 2011), were able to take on the perspective of another person during scene inspection. This is the first eye-tracking study to manipulate complexity in terms of non-perspective and perspective-taking tasks. Recently, Loth, Gomez, and Happé (2011) investigated the influence of event knowledge on attention and memory for context-relevant aspects of a scene and an effect of relevance was not found for either proportion of gaze time and number of fixations for TD or ASD groups, but was observed in the average fixation duration for both groups. In the current study, a modulation of eye movements in the global measures for both the non-perspective-taking and perspective-taking schemas was consistently observed for both participant groups. This means that task-relevant elements of a scene were more likely to receive attention, were inspected for longer, and were processed in more depth than the task irrelevant parts of a scene by all participants. We suspect that the differences in findings between the two studies could reflect methodological differences. Participants in the study by Loth et al. were not actively instructed to inspect the scene with the schemas in mind, and their stimuli contained a much larger array of objects with a much longer stimulus presentation time. These factors could have driven participants to explore non-context relevant aspects of the display more, therefore failing to show the robust relevance effects for all global measures observed in the current study. In contrast with the predictions based on the Theory-of-Mind Deficits Hypothesis, our results clearly indicate that, given direct instruction and enough time, participants with ASD show similar perspective-taking behaviour as TD individuals as reflected in global eye movement measures over the entire duration of the tasks. And, also in contrast with our original interpretation of Disordered Complex Information Processing Theory, there were subtle processing differences for the two different perspectives, which was not anticipated at the outset of the experiment.

The findings from our early eye-movement measures showed that individuals with ASD do not show initial orienting to, and processing of, target relevant items equally for the two different perspectives and across the two non-perspective-taking instructions. This suggests that complexity (Minshew et al., 2008) cannot be defined by the perspective-taking element of a task per se, but it could be accounted for by qualitative differences that might exist between the different perspectives. For the burglar schema and its non-perspective-taking equivalent ‘look for the valuable items’ schema, both TD and ASD showed a relevance effect in all three early measures, such that they spent less time and made fewer fixations to other parts of the scenes before orienting to schema-relevant compared to irrelevant targets. Furthermore, they spent more time fixating a relevant compared to an irrelevant target the first time they attended to it, suggesting they are able to immediately identify the relevant item for the burglar and the 'look for the valuable items' schema. In contrast, for the perspective-taking repairman schema and its non-perspective-taking equivalent "look for the feature that needed fixing" schema, participants with ASD showed an absence of a relevance effect for elapsed time and fixation count to target.

The difference between the two perspectives could be related to the fact that 'features that need fixing' tend to be structural features of the house at the background of the scene, whereas burglar relevant items tend to be foreground objects. In general, viewers prefer to look at foreground objects over background objects (Yarbus, 1967) because it is more likely that these objects contain potentially meaningful semantic information (Henderson, Malcohm, & Schandl, 2009). Therefore, even during the 'look for the features that need fixing' task or the repairman task, the 'valuable items' will inevitably attract attention initially, purely because they are at the foreground, and this may have contributed to a reduced relevance effect even for the TD group for the repairman perspective and the 'look for features that need fixing' schema. It could also be that individuals with ASD were slower in overcoming this default mode of initial attention by guidance of the task instructions than TD individuals. The following sections discuss two possibilities as to why this might be the case.

Pichert and Anderson (1977) suggested that some perspectives are harder to keep in mind than others due to unfamiliarity with the role. It is possible that in the present study, the novelty of the repairman and 'look for the features that needed fixing' schema made it harder to draw on prior knowledge on what targets are relevant to the tasks and therefore led to a greater exploration of irrelevant targets initially. It could also be that individuals with ASD have less experience with home repairs because more of them, in comparison to TD individuals, continue to live with caregivers who are likely to take care of household maintenance rather than living independently. This is however only a speculation, as no data were collected regarding the living arrangements of our participants.

Another explanation for the lack of a relevance effect in the repairman and the 'look for the features that needed fixing' schema observed in the ASD group relates to possible ambiguities in the categorization of the relevant items in the pictures. For example, when participants were asked to imagine they were a burglar, their role was clear to them, and they were able to quickly relate to the idea that a burglar would be interested in valuable items in a house. In a previous study by Kaakinen and Hyönä (2008) the burglar perspective proved to be a relatively consistent concept within a sample of college students. Kaakinen and Hyönä asked participants to list things that would be of interest to a burglar and found that there was considerable overlap in what kind of items were listed by different participants. However, a repairman's role might be more ambiguous because it could be interpreted as someone who fixes objects other than the structural features of the house. And similarly, 'features that need fixing' could refer to object features rather than structural features of the house. This means that there are potentially multiple ways to interpret the repairman task instructions or the items that might belong to that category.

In relation to the Theory-of-Mind Deficit Hypothesis and the extended Empathizing-Systemizing Theory (Baron-Cohen, 2009), the results from the current study clearly raise question as to whether deficits in ASD are restricted to theory-of-mind or empathizing, and also question whether a better explanation or working definition of theory-of-mind is now needed for future investigation of these concepts. Recently, Baron-Cohen (2009) suggested that the two dimensions (empathizing and systemizing) could be reduced to a single dimension defined by "the extent to which one is able to deal with degrees of unlawfulness in information" (p. 78). *Lawfulness of information* can be thought of as information that is rule based and which has a single predictable outcome. It is the process of systemizing that enables one to identify the lawful patterns behind many phenomena. In contrast, unlawfulness might be thought to refer to information that might be ambiguous, since the outcome may vary, and as such is less predictable. Hence identification of lawful patterns is more difficult for ambiguous information.

Thus, it might be this unlawfulness (ambiguity) of information to be processed, as put by Baron-Cohen (2009), which is posing extra difficulty for the ASD group for the repairman task in the current study. It is possible that ambiguity is one way to define complexity, leading processing to be slowed during ambiguous tasks. The eye movement data in the current study are particularly informative regarding the timing of processing differences, and they correspond with previous scene perception studies in which participants with ASD showed delayed orienting in a more ambiguous task, where participants had to decide "which one is weird" from a pair of almost identical scenes. An absence of such a delay was also observed using the same materials but with a simpler task that required participants to “spot the difference” between the two scenes (Au-Yeung et al., 2011; Benson et al., 2012).

The current study showed that the participants with ASD were clearly able to take the perspective of another person, which would not have been predicted by the original Theory-of-Mind Deficit Hypothesis. Importantly, it also appears that some task instructions may be more complex than others, regardless of whether or not there was a perspective-taking element. Although the current study was not set out to vary the different levels of ambiguity in different tasks, it seems that increasing ambiguity in the way information could be interpreted is resulting in an early processing delay in ASD in comparison to TD individuals. It is possible that this processing delay associated with ambiguity would not be restricted to empathizing tasks, but observed across a range of processing domains, as predicted by the Disordered Complex Information Processing Theory. The next study will continue to examine any differences in processing of ambiguous information in the linguistic domain during reading in ASD, and will investigate whether or not this is processing of ambiguous linguistic information is less efficient in ASD in comparison with TD individuals.

Chapter Three

Processing of Written Irony in Autism Spectrum Disorders

3.1 Introduction

The findings from the first experiment of this thesis reported in Chapter Two (Au-Yeung, Kaakinen, Benson, 2013) suggest that it is task ambiguity, rather than the perspective-taking element of the task, that was driving the observed differences in attention to task relevant stimuli between ASD and TD individuals during scene perception. The next two studies, one presented in the current chapter (Three) and one in the following chapter (Four), will examine the processing of contextual information during reading in relation to the Weak Central Coherence Theory of ASD. The current chapter will specifically explore whether the use of contextual information to disambiguate the meaning of text with multiple possible interpretations, namely, written irony, is processed on-line in ASD.

The Language Profile of ASD

Under the Pervasive Developmental Disorders (also known as Autism Spectrum Disorders or ASD) section of DSM-IV-TR (APA, 2000), Autistic Disorder is characterised by behavioural symptoms into three categories, including qualitative impairments in social interaction, qualitative impairments in communication, and restricted, repetitive, and stereotyped patterns of behaviour, interests, and activities. One of the stated communicative impairments could include either delay in, or a total lack of spoken language development. The diagnostic criteria of Asperger's Syndrome differs from Autistic disorder in that there should be no qualitative impairments in communication, and that there should be no significant clinical general delay in language. Nevertheless, it had been reported that even children with Asperger's Syndrome who were supposed to have no language delay by diagnostic standards showed some impairment in receptive language as defined by word and sentence comprehension (Noterdaeme, Wriedt, & Höhne, 2010). Recent revisions to the new DSM-V (APA, 2013) grouped the two different diagnoses into one unique diagnosis of Autism Spectrum Disorder, under the category heading of Neurodevelopment Disorders. Additionally, the three previous diagnostic domains were reduced to two: 1) social/communication deficits and 2) fixed interest and repetitive behaviours. It was suggested that although language delay could affect the presentation of clinical symptoms of ASD, language delay is not a unique or universal feature in ASD and hence social and communication deficits were more appropriately considered as a single set of symptoms. In relation to the current study, it is suggested that any language processing deficits should be linked to problems with pragmatic use of language, and not to the inability to acquire language in high-functioning individuals with ASD. Minshew, Goldstein, and Siegel (1995) assessed a large sample (n = 62) of verbal (VIQ > 70) high-functioning autistic participants on a battery of psychometric tests tapping language abilities. High functioning autistic individuals performed equivalently to TD controls in tasks demanding only simple procedural language skills but were impaired at linguistic tasks involving complex interpretive and inferential skills. This language profile fits with the findings from other cognitive domains, which all show disordered complex information processing abilities with spared basic abilities within the same domain of functioning in ASD (Minshew et al., 1997).

Weak central coherence refers to a processing style that is biased towards processing local details at the expense of global information and it was proposed as an explanation for the findings from language studies in ASD (Happé, 1999). At its extreme, weak central coherence gives rise to the idea of impaired integration of basic information, such as visual features, and perception of global forms. However, as mentioned in Chapter One, such deficits at the lower perceptual level have been refuted (Happé, 1999). Individuals with ASD are able to integrate features and perceive global forms such as letters (Plaisted et al., 1998), instead of perceiving meaningless line features. In fact, ability in simple reading tasks could sometimes be superior in ASD individuals compared to TD individuals. For example, ASD has been linked to hyperlexia, which refers to the discrepancy between word-level decoding and comprehension (Grigorenko, Klin, & Volkmar, 2003). Using various reading tasks, Frith and Snowling (1983) found that autistic children were intact at lexical and phonological processing. It has also been reported that people with ASD also automatically access the meaning of individual words, such that they show typical Stroop interference effects for both concrete and abstract printed words, and they also showed sensitivity to syntactic constraints (Eskes, Bryson, & McCormick, 1990; Frith & Snowling, 1983).

In contrast to findings from tasks tapping automatic access to meaning, it was also found that ASD participants performed worse than TD controls at using sentence context to pronounce the correct version of a homograph (especially when the homograph required its rarer pronunciation rather than its more common pronunciation), and that they made more errors than controls by filling in gaps of sentences and short stories with words that are syntactically appropriate but semantically inappropriate (Frith & Snowling, 1983; Happé, 1997; Joliffe & Baron-Cohen, 1999; López & Leekam, 2003). Individuals with ASD were also less accurate and slower in selecting the correct bridging sentence (amongst two distractor sentences) to fit between two sentences (a sentence describing a situation and a sentence describing an outcome) to make them coherent and related (Joliffe & Baron-Cohen, 1999). They were less accurate and slower at selecting the appropriate interpretation of an ambiguous sentence when the preceding context sentence called for the more rare interpretation, compared to when it called for the more common interpretation. These findings support an ASD deficit in integrating linguistic information when a high demand is placed on integration to establish higher-level meaning (Joliffe & Baron-Cohen, 1999), in particular, Gomot and Wicker (2012) proposed that it might be linked to a dysfunction in the ability to build flexible predictions, originating from impaired top-down influence over a variety of sensory and higher level information processing.

A more recent study by Nation, Clarke, Wright and Williams (2006) has also found that autistic children have good text reading accuracy (decoding nonwords, reading single words out of context, and reading connected text), but are impaired at reading comprehension. Some studies have suggested that reading comprehension deficits are not specifically linked to ASD. Snowling and Frith's findings (1986) revealed that more verbal students with autism did not differ from younger controls matched on decoding ability on homograph disambiguation, and it was also suggested that hyperlexia is more linked to verbal ability. Brock, Norbury, Einav, and Nation (2008) found no differences in the effect of sentence context on eye movements between their TD and ASD groups; however, a reduced effect of sentence context was linked to poorer language skills in both groups. These negative findings on verbal semantic coherence clearly pose some problems for the Weak Central Coherence Theory (Happé, 1999) explanation of ASD, which, recall, suggested that a detail focused cognitive processing style in individuals with ASD is what compromises the integration of information for higher-level meaning in open ended tasks.

Irony Processing in TD Individuals

Theories on irony comprehension. Traditionally, theories that have attempted to explain irony comprehension could be described as belonging to one of two types. The *Direct Access View* (Gibbs, 1986) on sarcasm assumes irony processing to be a one-stage process and suggests that the ironic meaning of an utterance is accessed directly under certain facilitating conditions (e.g. explicit mention in the previous context, social norm), and that the literal meaning of an utterance need not be computed. The proposition that a single interpretation is computed and maintained means that there should be no extra processing cost (as manifested in increased time) to interpret ironic statements. Furthermore, a single interpretation could even speed up processing further when strong contextual support is available.

Alternatively, the *Standard Pragmatic View* (Searle, 1993, as cited in Evans, 2010) assumes a two-stage process for irony comprehension. It defines irony as a form of figurative language that conveys the opposite of the literal surface meaning of an utterance. Readers must first compute the context-independent meaning of an utterance, and if a mismatch with the context is detected then the reader must reject the literal interpretation and compute its opposite meaning. Therefore the intended figurative interpretation is the only interpretation that is maintained. The *Graded Saliency Hypothesis* (Giora, 1995) also assumes a two-stage process for irony processing. Under this view irony is defined as a form of indirect negation which highlights how a specific state of affairs is different from expectation. It is assumed that the most salient interpretation of an utterance is accessed first. So for familiar irony, the ironic interpretation would be available and no extra inferential processing would be required. However, for unfamiliar irony, the more salient literal interpretation would be computed first, leading to extra processing cost when a mismatch with the context is detected and the utterance has to be re-interpreted as being ironic. However, the end result differs from the other two previously discussed theories in that both the explicit and implicit meaning of the utterance is maintained, so the dissimilarity between the two meanings can be computed.

Eye movement studies. This section considers some eye-tracking studies conducted on written irony in TD individuals to provide the basis for comparisons when studying irony processing in ASD. The current study is based on findings from Filik and Moxey (2010) who set out to test the three traditional theories outlined in the previous section by presenting TD participants with short passages of text containing an utterance which could either be interpreted as ironic or non-ironic depending on the preceding context. The setup of the experiment allowed examination of whether an unfamiliar ironic utterance leads to an extra processing cost compared to when the same statement is meant in a non-ironic way. It was found that participants spent longer reading the same statement when it was meant ironically than when it was meant non-ironically. The results suggests that, at least for unfamiliar materials, irony is harder to process because of the need for re-interpretation from the more salient literal interpretation of the statement.

Filik, Leuthold, Wallington, and Page (2014) further tested the theories of irony processing by carrying out another eye-tracking study to investigate how individuals process familiar and unfamiliar written irony compared to non-ironic control text. They found that TD individuals showed longer first-pass reading times and total reading times in the critical region (disambiguating word) and the post critical region (the remainder of the sentence after the disambiguating word) for unfamiliar ironic sentences compared to non-ironic control sentences. Longer *regression path time* (the summed duration of the fixations that occurred from the first fixation on a region until the participant moved their eyes out of that region progressively) in the post-critical region was also found for the unfamiliar ironic sentences. However, there were no reading time differences between the familiar ironic sentences and the non-ironic control sentences. This finding also supports the graded saliency hypothesis in suggesting that some extra processing is required for reanalysis of an unfamiliar ironic utterance but not for familiar irony.

Another recent eye-tracking study investigating processing of written irony (Kaakinen, Olkoniemi, Kinnari, & Hyönä, 2013) found that irony triggered a higher probability, and longer duration, of immediate re-reading of the ironic target utterance, and shorter look-backs to the context compared to when the target utterance was presented in a literal context. This pattern suggests that readers selectively re-read the ironic part of the text in order to re-interpret and confirm the ironic interpretation of the text.

From the few studies described, it is clear that, at least for the processing of unfamiliar irony, there is a higher processing demand in terms of the time it takes to re-interpret the text meaning. Evans (2010) suggested that figurative language may be more complex as it involves integration of incongruent semantic information. This proposition is of interest to our line of research, which investigates how individuals with ASD process complex information. The Disordered Complex Information Processing Theory (Minshew & Goldstein, 1998) predicts a disproportionate decline in the ability to process complex information across cognitive domains in ASD; this could extend to irony processing because irony processing is considered to be a “complex” language task, even for TD participants. The idea that ASD involves a deficit in integration of information is convergent with the Weak Central Coherence Theory.

Irony Processing in ASD

Behavioural and reaction times studies. One objective of the current study was to gain some insight into how individuals with ASD process irony, and compare this with what we know about neurotypical processing of irony. A further objective was to investigate which of the cognitive theories of ASD could account best for how individuals with ASD process this type of information. The *Parallel Constraint Approach* (Pexman, 2008) suggests that an individual rapidly processes multiple cues in parallel, in order to arrive at a coherent interpretation of an (ironic) utterance best fit, for the activated information. It can be inferred from the Parallel Constraint Approach that if individuals with ASD are insensitive to any one or some of these cues then this could disrupt irony comprehension. Some of these cues could include, but are not limited to, contextual information such as knowledge of an event outcome, the speaker's tone of voice, the listener's social exposure to ironic language, and an individual's ability to mentalise.

Previous studies on irony processing in ASD have yielded inconsistent findings by testing participants with varying diagnosis, verbal ability, and age group using different methodologies and stimuli. For example, it has been found that children and adolescents with high functioning autism or Pervasive Developmental Disorders Not Otherwise Specified were impaired compared to TD controls at interpreting ironies and metaphors, and this was related to their theory-of-mind and verbal abilities (de Villiers et al., 2011), although this was not the case for individuals with Asperger's Syndrome, who performed as well as TD controls on theory-of-mind tasks, metaphor understanding, irony judgments and explanations. These intact abilities were suggested to be attributable to the high verbal IQ of participants with Asperger's Syndrome (Diaz, 2010).

In an experiment carried out by Gyori (2004, 2006) it was found that individuals with ASD across a wide age range (9 to 43), and verbal IQ range (63-117), were less accurate than TD controls in responding to comprehension questions regarding whether stories were ironic or not, and they also took longer than TD controls to produce correct responses, which could be an indication of general processing impairments. Results for other manipulations in the study further revealed that participants with ASD were better at interpreting communicative utterances for negative contexts, which were deemed less ambiguous than positive contexts due to their relevance to the speaker's frustration. Participants with ASD were also better at interpreting stories where mental state terms were explicitly verbalised. It was concluded that individuals with ASD had a limited ability in the inferential aspect of theory-of-mind, but intact ability in the representational aspect of theory-of-mind. However, the author noted that some precautions are needed in interpreting these findings. Firstly, the performances of the ASD participants were still surprisingly higher than expected. Secondly, there was higher within group variance in the ASD group for reaction time measures. Thirdly, there was no correlation between understanding of false belief (1st and 2nd order) and irony. Coupled with the fact that the previous empirical study (Chapter Two; Au-Yeung et al., 2013) showed processing difficulties across non-perspective-taking and perspective-taking tasks in ASD, this suggests that theory-of-mind ability could not account for irony processing performance. It is speculated that problems with irony processing, if any, would be due to more domain general factors because abnormalities have been shown across cognitive domains. Hence the focus of this chapter will be to look at more generalised theories including Weak Central Coherence and Disordered Complex Information Processing.

Gyori (2006) suggested that perhaps some ASD participants used alternative non-theory-of-mind related heuristic strategies to complete the task. He named this the *reality-based short-cut strategy*, in which an individual perceives the contradiction between the literal meaning of the ironic utterance and the current state of affairs, and assumes the utterance to be meant nonliterally and opposite to the literal meaning, without the need to mentalise. To test this, Gyori designed a false irony task in a follow-up study, in which participants were presented with an ironically meant utterance. However, the ironic statement is actually literally true in the story context due to the speaker's belief going out of date (e.g., John asked his brother to help build a house, they promised to meet in the morning to do it. John waited all morning but his brother did not turn up. He left with disappointment. Without his knowledge, his brother went in the afternoon and worked on the house. They met another day and John said to his brother, "You have really helped me a lot"). It was prediced that if individuals with ASD who uses these strategies should interpret the statement literally (because they interpret it algorithmically on the basis of agreement with the story context), whereas genuine mentalisers should interpret the target utterance as ironic (because they interpret it in the context of the protagonist belief). However, it was found that a large portion of participants with ASD could pass the false irony task and a very limited number of participants showed the expected pattern of response in line with the proposed shortcut strategy. This lends doubt to the notion that individuals with ASD cannot make inferences about representational mental states in complex contexts. However, since no comparison group was tested, it is inconclusive as to whether participants with ASD were passing the test using the same strategy as TD participants, and whether or not they are more or less successful in comprehending the false irony.

Nevertheless, there were still other reports which support the idea that the nature of processing is different in ASD compared to TD individuals. For example, Pexman et al. (2011) found that although high-functioning children with ASD performed as accurately as TD controls in their ability to point to an object associated with a speaker's ironic intent in an irony comprehension task that minimized verbal and pragmatic demands, there were differences in judgement latencies, eye gaze, and humour evaluation. The findings suggested that irony was processed in a different way in the ASD group.

Eye-Tracking Study

The existing literature has mainly consisted of behavioural and reaction time to investigate ASD and irony processing. However, none of these studies were able to say anything about the time-course of information processing deficits, and little is known about how any deficit in ASD is related to any abilities to either notice and/or use contextual information in irony processing. The current study employed eye-tracking technology to explore whether individuals with ASD had particular deficits in processing reading materials containing irony.

To achieve this, a partial replication of Filik and Moxey's Study (2010), in which TD participants and participants with ASD read short passages containing an utterance that could either be interpreted ironically or non-ironically, depending on the preceding context, was carried out. Participants were then asked comprehension questions about their interpretation of the utterance. The following shows an example of the ironic and non-ironic version of the same stimulus.

Ironic

1. John and Mary were sitting in the newspaper office, reading through a huge pile of **hate** mail.
2. 'Obviously our readers liked your story', said John.
3. Mary was surprised that so **few** people liked her news article.

Non-ironic

1. John and Mary were sitting in the newspaper office, reading through a huge pile of **fan** mail.
2. 'Obviously our readers liked your story', said John.
3. Mary was surprised that so **many** people liked her news article.

The first sentence of a passage gives the context and determines whether the proceeding sentence should be interpreted as ironic or not. The first sentences for the ironic and non-ironic versions of the same passage differ only on one target word. The second sentence is an utterance by a character that could be interpreted ironically or literally depending on the preceding context. The second sentence remains the same for both the ironic and non-ironic version of the stimuli. The third sentence is consistent with the first and second sentence for the non-ironic condition when the utterance was meant to be read literally. However, in the ironic condition, the third sentence is only consistent with the first sentence but not the second sentence, where the utterance was meant to be taken ironically. The third sentence for the ironic and non-ironic versions also differed on one target word. The purpose of the third sentence was to catch any delayed disruption of irony processing.

Consistent with Filik and Moxey's findings (2010), a processing cost for unfamiliar irony processing is expected in the current study. It is predicted that TD participants would show longer re-reading times for the critical utterance in the second sentence, for the ironic compared to the non-ironic condition. It is also predicted that participants should spend more time re-reading the contextual information in the first sentence and the restatement of the contextual information in third sentence for the ironic condition compared to the non-ironic condition, in order to resolve the incongruent information between the context and the literal meaning of the utterance.

Weak Central Coherence Theory of ASD

An objective of the current study was to see whether the ASD data provided support for either of two current contemporary theories of ASD. Predictions for participants with ASD for each of these theories are described in the two following sections.

Weak Central Coherence Theory predicts that participant with ASD would not take into account contextual information whilst reading the sentences due to impaired global processing. The prediction therefore would be that the ASD participants should take the ironic utterance literally and ignore the factual inconsistency between the context and the ironic utterance. Impaired ability to comprehend the ironic statement should be reflected in reduced offline accuracy data in the comprehension task. Participants should show intact performance in the comprehension questions for the non-ironic condition, but accuracy scores should be disproportionately lower for the ironic condition compared to TD participants. Therefore, unlike TD participants, we would expect no difference in the way participants with ASD process ironic and non-ironic versions of the utterance, and this should be reflected by a lack of differences between the two conditions in reading times for the utterance in the second sentence. The inability to notice the inconsistency between the ironic utterance in the second sentence and the contextual information in the first sentence should also be reflected in the lack of difference between the time spent re-reading the contextual information in the first sentence and the restatement of the contextual information in the third sentence, between the ironic and non-ironic condition within the ASD group.

Disordered Complex Information Processing Theory of ASD

The Disordered Complex Information Processing Theory would predict that participants with ASD should have a generalised deficit in complex tasks with high requirements for on-line information processing (Minshew et al., 1995). Based on previous findings (Benson et al., 2012, Au-Yeung et al., 2013), it is expected that high-functioning individuals with ASD should not necessarily show impaired performance in their offline comprehension question responses specifically for the ironic condition, but rather that they should show intact performance for both ironic and non-ironic conditions, comparable to those of TD participants. However, if complexity could be defined as the figurativeness of the language, then on-line eye movement measures should reveal difficulties in interpreting ironic utterances over and above those experienced by TD individuals. For the purpose of this experiment, the non-ironic condition would be considered a simple task and the ironic condition a complex task, because the ironic condition theoretically involves an extra step: Readers must calculate the non-literal meaning of the ironic utterance, putting greater processing demand on participants. Participants with ASD might show disproportionately elevated re-reading for the contextual information in the first sentence and the third sentence, and the critical region of the ironic utterance in the second sentence, but this would not be predicted for the non-ironic condition compared to TD participants. Such a finding would indicate more effortful processing in order to resolve the inconsistency between contextual information and the literal surface meaning of the ironic utterance in order to make an adequate interpretation of the ironic utterance. Furthermore, there could be a difference in time-course in which irony is resolved between the groups. If ASD individuals take disproportionately longer to resolve the irony than TD individuals, we might expect to find the irony effect (significant difference between the ironic and non-ironic text type) to persist for longer in regions that follow the critical region, for the ASD group in the later measures (e.g., total viewing time).

3.2 Method

Participants

Forty two volunteers in total participated in the study; 20 in the TD group and 22 in the ASD group. Participants were clinically diagnosed prior to the study and recruited from the National Autistic Society website, Children on the Autism Spectrum Parents' Association, and a database of volunteers who had previously taken part in other studies at the University of Southampton. One participant with ASD was excluded from the analysis (female) due to calibration error in the majority of the trials. A participant (male) in the ASD group was excluded because he was unable to provide formal evidence of a clinical diagnosis. One other participant (male) in the ASD group did not complete the IQ assessment, and therefore was excluded from the study. One TD participant (male) and two participants (2 females) in the ASD group were excluded due to scoring below 90 on at least one measure in IQ subscales. The demographics of the final sample are presented in Table 3.1, which included 19 participants in the TD group (13 males, 6 females) and 18 participants in the ASD group (16 males, 2 females). The ASD group consisted of predominantly individuals with Asperger's Syndrome and one individual with high-functioning autism with IQ within the normal range who had already participated in the previous experiment and behaved no differently to other participants within the ASD. The two groups were matched as closely as possible with regards to the number of male and female participants and their age. However, due to the aforementioned unforeseen circumstances in which some of the participants had to be excluded, the ASD group has a slightly greater mean age than the TD group, but the majority within a similar age range (TD *mdn*: 21, ASD *mdn*: 28). The two participant groups were matched on all measures of IQ. The ASD group scored significantly higher on AQ compared to the TD group, confirming statistically greater levels of self reported autistic traits in the ASD group.

Table 3.1

Participant Characteristics

	TD			ASD				
Measure	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*t*	*p*
Age	23.8	5.6	18-35	32.4	11.2	20-52	2.92	.007
Verbal IQ	116	9.6	95-138	118	12.4	97-138	.358	.722
Performance IQ	117.	10.1	93-133	118	11.0	97-134	.165	.870
Full scale IQ	119	9.3	104-139	120	11.8	97-140	.347	.731
AQ	15.3	7.2	7-35	33.9	8.7	12-47	7.09	<.001

Materials

The experimental stimuli consisted of 36 short passages of text, each made up of three sentences. There were two versions of each passage, an ironic version and a non-ironic version. Some of the passages were modified stimuli from Filik and Moxey's study (2010) and some passages were new stimuli written and manipulated in the same way (See Appendix B for the full set of stimuli). The text was presented in the form of short passages with size 14 Courier New font to ensure equal spacing for each letter. Triple spacing between each line was used to ensure clear distinction between fixations on different lines of text. The text was presented in black on a white background on a screen with a dimension of 1024 x 768. Stimulus images were created using the multitext resource function in the Datasource tab of Experimentbuilder (SR Research Ltd, Osgoode).

The experimental stimuli were divided into two lists (A & B). Each list contained 18 ironic passages and 18 non-ironic passages. If the ironic version of a passage was in List A, then its non-ironic version would be in List B. An additional 32 filler passages were added to each list. These were identical for the two lists and were mixed in with the experimental stimuli and presented in random order. Each experimental passage was only seen once, either as ironic or non-ironic. Each participant viewed the stimuli from one of the lists. Participants also had four practice trials before being presented with the experimental stimuli and fillers. In total, each participant read 72 passages each. Comprehension questions were presented for a third of the stimuli. The inclusion of these was designed to gauge participants understanding of the intended meaning of the utterance. Participants were randomly selected to view one of the two stimulus lists.

Eye Movement Recording

Participants viewed the stimuli binocularly and eye movements were recorded monocularly for the right eye using an Eyelink 1000 eye tracker (SR Research Ltd, Osgoode) with a viewing distance of 70 cm. Participants placed their head on a chin rest and forehead support to stabilise their position throughout the experiment. Participants were calibrated using a nine-point matrix. A fixation dot was presented at the beginning of each trial indented to the left of the first word of each passage; participants were required to fixate this dot before the text appeared on screen. Once a participant's fixation matched the position of the dot, the experimenter pressed a key to display the stimulus on the screen. Participants were recalibrated if the fixation drifted away from the fixation dot in between trials.

Design

The experiment was a mixed design with a within-participant variable *Text Type* (Ironic vs Non-ironic) and a between-subject variable *Group* (TD vs ASD).

Procedure

Participants were seated in front of the computer monitor and read the participant instructions on the screen. They were told that they would be reading some short passages. They were instructed to read each passage carefully for comprehension and were calibrated on the eye-tracker. Participants were given four practice trials to familiarise themselves with the task. Once participants completed the practice trials the experimenter would ask the participants if they had any questions and if they understood what they had to do. After participants had their queries answered and indicated they understood the task, they were then presented with the experimental trials one at a time. Participants pressed a key when they finished reading each passage to trigger the next trial. When a comprehension question appeared on screen, participants were instructed to press the left button on the controller if they thought the answer to the question was 'no', and the right button for 'yes'.

3.3 Results

Comprehension Response Accuracy

A 2 (Text Type: Ironic vs Non-Ironic) x 2 (Group: TD vs ASD) ANOVA was computed on accuracy score to comprehension questions. There was a significant main effect of Text Type, $F(1,35) = 11.126$, $p = .002$, $\eta_p^2 = .241$: participants were significantly more accurate at answering comprehension questions in the non-ironic Text Type ($M = 5.376$, $SE = .153$) compared to the ironic Text Type ($M = 4.365$, $SE = .295$). There is no significant main effect of Group, $F(1,35) = 2.564$, $p = .118$, $\eta_p^2 = .068$, nor a significant interaction between Text Type and Group, $F(1,35) = 1.563$, $p = .220$, $\eta_p^2 = .043$, suggesting that both groups found it more difficult to interpret ironic utterances than non-ironic utterances. Importantly, participants with ASD performed similarly to TD controls in the ironic as well as non-ironic condition, which is inconsistent with the Weak Central Coherence assumption that individuals with ASD cannot take into account contextual information to interpret ironic utterances. The comprehension scores are presented in Table 3.2.

Table 3.2

Descriptive Statistics for Comprehension Accuracy

	Text Type			
	Ironic		Non-Ironic	
Group	*M* (%)	*SD*	*M* (%)	*SD*
TD	4.84 (80.67)	1.54	5.47 (91.17)	.84
ASD	3.89 (64.83)	2.03	5.28 (88.00)	1.02

Note. The maximum score for each Text Type is 6.

Data Trimming

For the eye movement data, any fixations that had duration of less than 50 ms were either removed, or were merged with a nearby fixation if that fixation was within one degree of the target fixation.

Regions of Interest

Each piece of text was auto-segmented into single word regions using Eyelink Dataviewer. Any punctuation marks that came after a word were merged into the same single word region as the word that preceded that punctuation, with the exception of opening quotation marks, which were included in the first word that followed those. The empty spaces (the size of one letter) that occurred in between words were included in the same single word region as the word that came directly after the space. Each single word region was 80 pixels in height. The blank spaces were divided between the lines of text equally, leaving no space in between single word regions on different lines of text. Each single word region also touched the edge of the regions for the words next to it, leaving no space in between single word regions on the same line. A fixation report file was exported from DataViewer and input into the Get Reading Measures program (available from the SR research online support forum). This program permitted the merging of single word regions into larger regions of interest, and also computed reading measures for each trial for each participant. Each passage was divided into seven regions of interest for analysis, as shown in the following example:

Ironic

1. /John and Mary were sitting in the newspaper office, reading through a huge pile of$_1$/ **hate** mail.$_2$/
2. /'Obviously our readers$_3$/ liked your story',$_4$/ said John.$_5$/
3. /Mary was surprised that$_6$/ so **few** people liked her news article.$_7$/

Non-ironic

1. John and Mary were sitting in the newspaper office, reading through a huge pile of$_1$/ **fan** mail.$_2$/
2. /'Obviously our readers$_3$/ liked your story',$_4$/ said John.$_5$/
3. /Mary was surprised that$_6$/ so **many** people liked her news article.$_7$/

Eye Movement Measures

We have adopted the definitions of the eye movement measures consistent with those provided by the Get Reading Measures program (SR research). Three eye movement measures have been reported in this study: *First pass reading time* is the summed duration of the fixations in a region of interest until the reader moved their eyes to fixate in another region that is either progressive or regressive to the current region, given that the first fixation on the current region was not made after any fixations on words later in the text. *Regression path reading time* is the summed duration of the fixations that occurred from the first fixation on a region until the participant moved their eyes out of that region progressively. Therefore, regression path reading times included all the fixations in a region and the regressive fixations on words in the previous portion of the text, given that the first fixation on the region in question was not made after the reader had fixated on words in later portions of the text. *Total reading time* is the summed duration of all the fixations in a region. Therefore, first-pass reading times gives an indication of early processing; regression path reading times also reflects early processing difficulty and re-inspection of the text in an effort to recover from difficulty; and total reading times provides a measure of overall processing (Filik & Moxey, 2010).

A 2 (Text Type: Ironic vs Non-Ironic) x 2 (Group: TD vs ASD) repeated measures ANOVA was computed for each eye movement measure (F_1). A by-item analysis was also computed for each measure (F_2).

Context region (2). This region is located in the first sentence and contains the text where the context of the passage is set and it determines whether or not the utterance that follows should be read as ironic or non-ironic. The descriptive statistics for this region are presented in Table 3.3. It was expected that no effects of irony should be apparent in the first-pass measure as no incongruent irony utterance has been encountered as yet. Evidence of re-analysing the text in the context region in order to resolve the inconsistency between the context and the ironic utterance in the later sentence might be shown in elevated total reading time in the ironic compared to the non-ironic condition.

Table 3.3

Descriptive Statistics for Eye Movement Measures (ms) in the Context Region (2) in the First Sentence

			Text Type			
			Ironic		Non-Ironic	
Region	Measure	Group	*M*	*SD*	*M*	*SD*
Context (2)	First-pass	TD	1006.91	210.45	1035.49	188.51
		ASD	1039.22	478.33	1161.37	440.78
	Total time	TD	1460.06	406.58	1419.70	390.23
		ASD	1884.35	984.61	1962.32	832.51

First-pass reading times. As expected, there was no significant main effect of Text Type, $F_1(1, 35) = .295$, $p = .095$, $\eta_p^2 = .078$ (an effect size indicating a small effect, despite a *p-value* of less than .10 suggests a trend towards significance), $F_2(1, 70) = .029$, $p = .866$, $\eta_p^2 < .001$, no significant main effect of Group, $F_1(1, 35) = .548$, $p = .464$, $\eta_p^2 = .015$, $F_2(1, 70) = 10.2$, $p = .002$, $\eta_p^2 = .127$, and no significant interaction between Text Type and Group, $F_1(1, 35) = 1.14$, $p = .294$, $\eta_p^2 = .031$, $F_2(1, 70) = .096$, $p = .757$, $\eta_p^2 = .001$.

Total reading times. There was no significant main effect of Text Type, $F_1(1,35) = .207$, $p = .652$, $\eta_p^2 = .006$, $F_2(1, 70) = .001$, $p = .972$, $\eta_p^2 = .001$. However, there was a significant main effect of Group both by-subject and by-item, $F_1(1, 35) = 4.60$, $p = 039$, $\eta_p^2 = .116$, $F_2(1, 70) = 46.6$, $p < .001$, $\eta_p^2 = .400$, showing that participants with ASD spent more time overall reading the text compared to TD participants. There was no significant interaction between Text Type and Group, $F_1(1, 35) = 2.049$, $p = .161$, $\eta_p^2 = .055$, $F_2(1, 70) = .073$, $p = .787$, $\eta_p^2 = .001$. The results for total time in the context region show no apparent effect of the irony manipulation by the TD or the ASD group, as neither group expended more effort to re-inspect the context region in the ironic compared to the non-ironic condition. This neither supports that participants with ASD were unable to use contextual information as suggested by the Weak Central Coherence Theory, nor does it support that participants with ASD were experiencing extra difficulty with resolving the inconsistency between the contextual information and the ironic utterance.

Pre-critical region (3). This is the beginning text of the second sentence preceding the critical region that contains the critical utterance. As for the context region, no effect of irony was expected in the first-pass as at this point no ironic information has been encountered yet. For the total reading time, if participants with ASD were less able to detect the irony than the TD group, then only the TD group should spend more time to re-inspect ironic sentences. In contrast, if the ASD group were able to detect the irony but had more difficulty resolving the ironic sentences, then total time for the ironic Text Type should be disproportionately greater for the ASD group. Table 3.4 shows the descriptive statistics.

Table 3.4

Descriptive Statistics for Eye Movement Measures (ms) in the Second Sentence

			Text Type			
			Ironic		Non-Ironic	
Region	Measure	Group	*M*	*SD*	*M*	*SD*
Pre-critical (3)	First-pass	TD	412.11	133.52	402.49	152.32
		ASD	432.53	180.35	457.06	212.39
	Total time	TD	585.39	157.09	539.51	178.09
		ASD	832.24	437.10	785.47	371.53
Critical (4)	First-pass	TD	708.49	159.50	685.31	172.85
		ASD	782.55	326.41	752.61	335.59
	Regression path	TD	871.51	149.74	802.55	207.09
		ASD	921.49	553.20	901.17	500.54
	Total time	TD	950.66	182.35	859.34	243.07
		ASD	1237.98	553.51	1164.59	443.51
Spill-over (5)	First-pass	TD	466.00	120.73	446.04	116.71
		ASD	525.84	244.40	530.95	245.67
	Regression path	TD	574.52	184.65	574.99	203.57
		ASD	765.12	559.83	667.04	455.68
	Total time	TD	634.16	189.37	564.44	182.31
		ASD	862.84	364.60	820.70	369.58

First-pass reading times. As expected**,** there was no significant main effect of Text Type, $F_1(1, 35) = .288$, $p = .595$, $\eta_p^2 = .008$, $F_2\ (1, 70) = .880$, $p = .352$, $\eta_p^2 = .012$, and no significant main effect of Group, $F_1(1, 35) = .471$, $p = .497$, $\eta_p^2 = .013$, $F_2(1, 70) = 14.0$, $p < .001$, $\eta_p^2 = .166$. There was also no significant interaction between Group and Text Type, $F_1(1, 35) = 1.51$, $p = .227$, $\eta_p^2 = .041$, $F_2(1, 70) = 4.20$, $p = .044$, $\eta_p^2 = .056$ (a small effect in F_2 indicate no further tests were warranted despite *p*-value of slightly less than .05. Furthermore, no interaction at first-pass is expected in the pre-critical region as no ironic information would have been encountered yet).

Total reading times. There was a significant main effect of Text Type by-subject, $F_1(1,35) = 4.52$, $p = .041$, $\eta_p^2 = .114$, $F_2(1, 70) = .448$, $p = .505$, $\eta_p^2 = .006$, showing that participants spent more time in total re-reading the text in the pre-critical region in the ironic compared to the non-ironic Text Type. Furthermore, there was a significant main effect of Group both by-subject and by-item, $F_1(1, 35) = 6.23$, $p = .017$, $\eta_p^2 = .151$, $F_2(1, 70) = 56.7$, $p < .001$, $\eta_p^2 = .447$, again showing that participants with ASD spent longer reading the text in the pre-critical region than participants with TD. There was no significant interaction between Text Type and Group, $F_1(1, 35) < .001$, $p = .984$, $\eta_p^2 < .001$, $F_2(1, 70) = .001$, $p = .974$, $\eta_p^2 < .001$. The results from the pre-critical region show that both groups went back to re-inspect the beginning of the critical sentence in the ironic condition.

Critical region (4). This is the critical region which contains the text of the ironic/non-ironic utterance depending on the contextual information in the Context Region (2). While it was expected that the effect of irony would be present in the critical region for at least the TD group, it is likely that the effect will show up in the later measures, and not the early measures, (Filik & Moxey, 2010). This is because it is unlikely that readers would resolve unfamiliar irony immediately. Rather, some re-inspection of the critical text might be required. It was expected that the TD group would spend more time in the ironic condition re-reading the text in the critical region. If participants with ASD were unable to detect the irony, there would be no difference in total time between the two Text Types within this group. If participants with ASD were able to detect the irony but had more difficulty processing it, then they may show disproportionately longer reading times specifically for the ironic condition. The descriptive statistics are presented in Table 3.4.

First-pass reading times. As expected, there was no significant main effect of Text Type, $F_1(1, 35) = 1.62$, $p = .212$, $\eta_p^2 = .044$, $F_2(1, 70) = .056$, $p = .813$, $\eta_p^2 = .001$, no significant main effect of Group, $F_1(1, 35) = .728$, $p = .399$, $\eta_p^2 =.020$, $F_2(1, 70) = 15.9$, $p < .001$, $\eta_p^2 = .185$, and no significant interaction between Group and Text Type, $F_1(1, 35) = .026$, $p = .872$, $\eta_p^2 = .001$, $F_2(1, 70) = .035$, $p = .853$, $\eta_p^2 < .001$.

Regression path reading times. There was no significant main effect of Text Type, $F_1(1, 35) = 1.237$, $p = .274$, $\eta_p^2 = .034$, $F_2(1, 70) = .306$, $p = .582$, $\eta_p^2 = .004$, no significant main effect of Group, $F_1(1, 35) = .372$, $p = .546$, $\eta_p^2 = .011$, $F_2(1, 70) = 6.15$,

p = .016, η_p^2 = .081, and no significant interaction between Text Type and Group, F_1(1, 35) = .367, p = .548, η_p^2 = .010, F_2(1, 70) = .157 , p = .693, η_p^2 = .002.

Total reading times. There was a significant main effect of Text Type by-subject, F_1(1, 35) = 9.81, p = .003, η_p^2 = .219; F_2(1, 70) = 1.144, p = .289, η_p^2 = .016, showing that participants spent longer re-reading the text in the critical region when the text is intended ironically compared to when it is intended non-ironically. There was also a significant main effect of Group both by-subject and by-item, F_1(1, 35) = 5.82, p = .021, η_p^2= .142;, F_2(1, 70) = 47.0, p < .001, η_p^2 = .402, showing that participants with ASD spent more time re-reading the text overall in the critical region compared to TD participants. There was no significant interaction between Text Type and Group, F_1(1, 35) = .116, p = .735, η_p^2 = .003, F_2(1, 70) = .002, p = .962, η_p^2 < .001. The results for the critical region are presented in Figure 3.1. In line with the results from the pre-context region, both groups showed a later effect whereby they re-inspect the text in the critical region specifically for the ironic condition, and there was no evidence of reduced ability to detect the irony by participants with ASD, or greater processing difficulty specifically related to the irony condition.

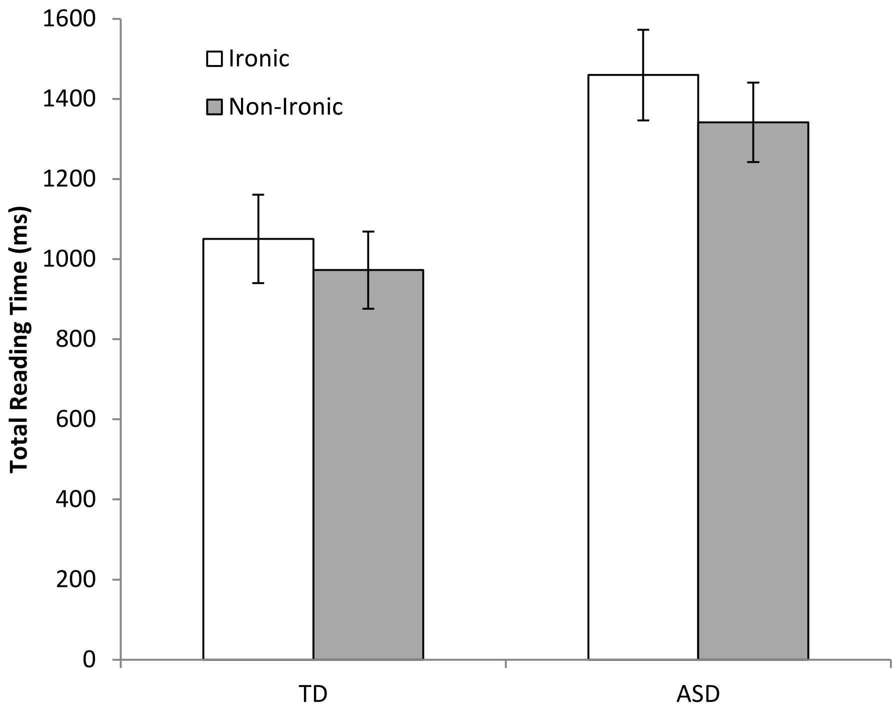

Figure 3.1. Total reading times for the critical region (4). Error bars represent ± *SEM.*

Spill-over region (5). This region includes the end of the second sentence that stated which character in the story made the utterance. The descriptive statistics are presented in Table 3.4. There was evidence of a marginal effect of irony for TD individuals on regression path and total time in the region that extends past the critical region into the end portion of the sentence. This was also shown by Filik and Moxey (2010). The prediction for the spill-over region therefore follows that of the critical region. Only the TD group, but not the ASD group, should show the effects of irony if participants with ASD were not able to detect the irony. However, if participants with ASD were able to process the irony but require more processing effort, then they may show elevated reading times specifically for the ironic condition.

First-pass reading times. There was no significant main effect of Text Type, $F_1(1, 35) = .143$, $p = .707$, $\eta_p^2 = .004$, $F_2\ (1, 70) = .090$, $p = .765$, $\eta_p^2=.001$, no significant main effect of Group, $F_1(1, 35) = 1.47$, $p = .233$, $\eta_p^2 = .040$, $F_2\ (1, 70) = 26.6$, $p < .001$, $\eta_p^2 = .275$. There was also no significant interaction between Group and Text Type, $F_1(1, 35) = .409$, $p = .527$, $\eta_p^2 = .012$, $F_2\ (1, 70) = 1.70$, $p = .197$, $\eta_p^2 = .024$.

Regression path reading times. There was no significant main effect of Text Type, $F_1(1, 35) = 1.52$, $p = .226$, $\eta_p^2 = .042$, $F_2(1, 70) = .450$, $p = .505$, $\eta_p^2 = .006$, no significant main effect of Group, $F_1(1, 35) = 1.40$, $p = .244$, $\eta_p^2 = .039$, $F_2(1, 70) = 13.7$, $p < .001$, $\eta_p^2 = .163$, and no significant interaction between Text Type and Group, $F_1(1, 35) = 1.55$, $p = .221$, $\eta_p^2 = .042$, $F_2(1, 70) = .780$, $p = .380$, $\eta_p^2 = .011$.

Total reading times. There was a marginal main effect of Text Type, $F_1(1, 35) = 3.93$, $p = .055$, $\eta_p^2 = .101$ (modest effect), $F_2(1, 70) = .281$, $p = .598$, $\eta_p^2 = .004$, which suggests that participants spend slightly longer re-reading in the ironic compared to the non-ironic Text Type, in line with Filik and Moxey, (2010). There was a significant main effect of Group both by-subject and by-item $F_1(1, 35) = 7.16$, $p = .011$, $\eta_p^2 = .170$, $F_2(1, 70) = 80.9$, $p = .001$, $\eta_p^2 = .536$, showing that participants with ASD spent more time reading the text in the spill-over region compared to the TD group. There were no significant interactions between Text Type and Group, $F_1(1, 35) = .239$, $p = .628$, $\eta_p^2 = .007$, $F_2(1, 70) = 1.46$, $p = .232$, $\eta_p^2 = .020$. Both participant groups showed a spill-over effect for the irony condition in the region of text following the critical region. Again, confirming results from the pre-critical region and the critical region that both groups re-inspect the second sentence when the statement is meant ironically compared to when it was meant non-ironically.

Pre-context region (6). This is the beginning portion of the third sentence preceding the restatement of the contextual information. It is possible that having once reached the context restatement region, and noting the inconsistent contextual information and the literal meaning of the ironic statement, participants would expend more effort to re-read the third sentence in order to resolve the irony. Again, lack of detection by the ASD participants would lead to only TD participants showing the irony effect. Whilst if participants with ASD were able to perform the task but had slightly greater difficulty in doing this, then elevated reading times for this sentence would be expected. The descriptive statistics are presented in Table 3.5. Regression path analysis was only completed for the Context Restatement Region as it was expected that participants would only make regressions to check the consistency between the previous sentence and the current sentence once they had encountered text that is informative of the meaning of the previous statement.

Table 3.5

Descriptive Statistics for Eye Movement Measures (ms) in the Third Sentence

			Text Type			
			Ironic		Non-Ironic	
Region	Measure	Group	*M*	*SD*	*M*	*SD*
Pre-context (6)	First-pass	TD	493.44	179.58	496.92	181.77
		ASD	554.54	269.88	587.18	278.76
	Total time	TD	673.6	247.98	602.52	236.3
		ASD	924.8	388.92	826.14	353.34
Context Restatement (7)	First-pass	TD	876.93	220.2	819.07	243.98
		ASD	876.87	359.7	918.86	382.56
	Regression path	TD	1498.01	436.53	1222.03	386.2
		ASD	2323.92	1543.84	2128.69	1444.08
	Total time	TD	1050.23	267.57	972.51	262.59
		ASD	1459.65	631.58	1341.27	538.08

First-pass reading times. There were no significant main effect of Text Type, $F_1(1, 35) = .358$, $p = .554$, $\eta_p^2 = .010$, $F_2(1, 70) = .706$, $p = .404$, $\eta_p^2 = .010$. There was also no significant main effect of Group, F_1 (1, 35) = 1.18, $p = .285$, $\eta_p^2 = .033$, F_2(1, 70)

= 11.1, p = .001, η_p^2 = .137, and no significant interaction between Text Type and Group, F_1 (1, 35) = .233, p = .632, η_p^2 = .007, F_2(1, 70) = 2.08, p = .153, η_p^2 = .029.

Total reading times. There was a significant main effect of Text Type by-subject, F_1(1, 35) = 4.45, p = .042, η_p^2 =.113, F_2(1, 70) = .433, p = .513, η_p^2 = .006. This effect shows that participants spent more time in total reading the beginning of the third sentence in the ironic Text Type compared to the non-ironic Text Type. There was also a significant main effect of Group both by-subject and by-item, F_1(1, 35) = 6.33, p = .017, η_p^2 = .153, F_2(1, 70) = 79.8, p < .001, η_p^2 = .533, which showed that participants with ASD spent significantly more time reading the beginning of the third sentence regardless of Text Type. There was no significant interaction between Text Type and Group, F_1(1, 35) = .117, p = .734, η_p^2 = .003, F_2(1, 70) = .850, p = .360, η_p^2 = .012.

Results from this region analysis has shown that the effect of irony extends to the third sentence in the pre-context region, before the restatement of the context, for both participant groups, whereby participants spent more time going back to re-read the restatement of the context.

Context restatement region (7). This is the end portion of the third sentence where the contextual information in the context region (2) is restated. Detection and attempts to make sense of the incongruent information between the context and the ironic utterance might be reflected in elevated reading times in this region. Again, non-detection by individuals with ASD would mean only the TD group will show the irony effect in the reading times measure, whereas greater difficulty with processing ironic information would likely produce greater reading times in individuals with ASD. The descriptive statistics are presented in Table 3.5.

First-pass reading times. There was no significant main effect of Text Type, F_1(1, 35) = .064, p = .801, η_p^2 = .002, F_2 (1, 70) = .011, p = .918, η_p^2 < .001, no significant main effect of Group, F_1(1, 35) = .268, p = .608, η_p^2 = .008, F_2 (1, 70) = 7.59, p = .007, η_p^2 =.098 (small effect), and no significant interaction of Text Type and Group, F_1 (1, 35) = 2.55, p = .119, η_p^2 = .068, F_2 (1, 70) = .927, p = .339, η_p^2 = .013.

Regression path reading times. There was a significant main effect of Text Type by-subject, F_1(1, 35) = 7.01, p = .012, η_p^2 = .0167, F_2(1, 70) = 2.374 , p = .128, η_p^2 = .033. There was also a significant main effect of group both by-subject and by-item.

$F_1(1, 35) = 6.31$, $p = .017$, $\eta_p^2 = .153$, $F_2(1,70) = 68.7$, $p < .001$, $\eta_p^2 = .495$, showing that participants with ASD spent longer re-reading previous portion of the passage which they reached this region. There was no significant interaction between Text Type and Group, $F_1(1, 35) = .206$, $p = .653$, $\eta_p^2 = .006$, $F_2(1, 70) = .539$, $p = .465$, $\eta_p^2 = .008$.

Total reading times. There was a significant main effect of Text Type by-subject, $F_1(1, 35) = 8.00$, $p = .008$, $\eta_p^2 = .186$, $F_2(1, 70) = 1.35$, $p = .249$, $\eta_p^2 = .019$. This suggests that participants spent more time re-reading the restatement of the context for the ironic Text Type compared to the non-ironic Text Type. There were significant main effects of group both by-subject and by-item, $F_1(1, 35) = 7.28$, $p = .011$, $\eta_p^2 = .172$, $F_2(1, 70) = 115$, $p < .001$, $\eta_p^2 = .621$. This shows that participants with ASD spend more time reading the restatement of the context regardless of the Text Type. There were no significant interactions between Text Type and Group, $F_1(1, 35) = .344$, $p = .561$, $\eta_p^2 = .010$, $F_2(1, 70) = .049$, $p = .826$, $\eta_p^2 = .001$. The results for the context restatement region are presented in Figure 3.2.

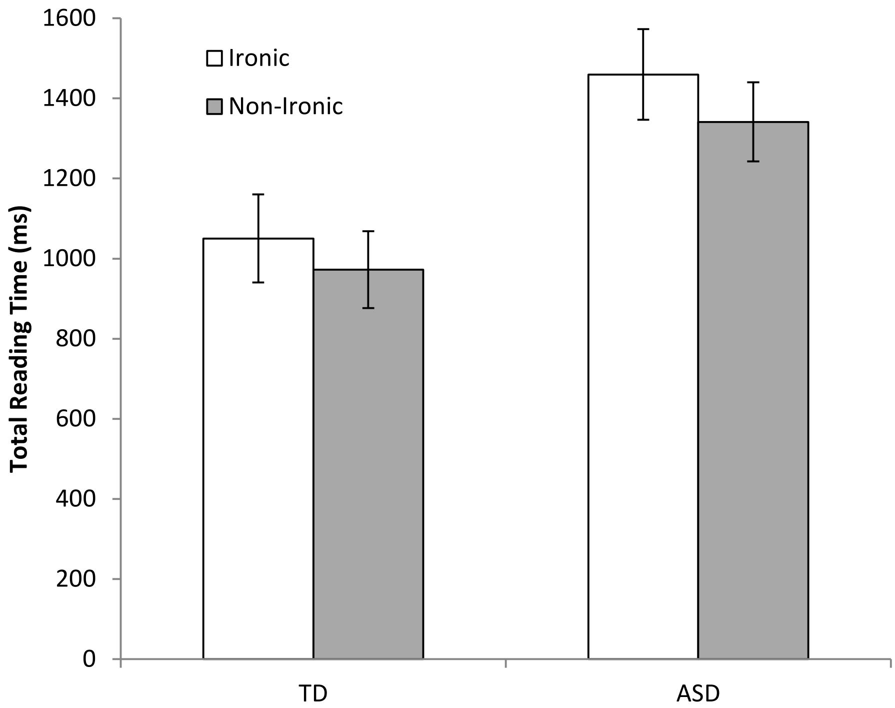

Figure 3.2. Total reading times for the context restatement region (7). Error bars represent ± *SEM.*

Evidence from both regression path reading times and total reading times show that both participant groups expended more effort re-reading the restated context information, and text preceding it, in the ironic compared to the non-ironic condition. In summary, and in contrast with predictions from current literature, participants with ASD did not show an inability to detect irony based on the contextual information provided, nor any specific processing difficulty associated with the ironic text.

3.4 Discussion

In summary, the current study examined the time-course of irony processing in both TD individuals and individuals with ASD. Consistent with the findings of previous eye movement studies conducted with TD readers (Filik & Moxey, 2010; Kaakinen et al., 2013) both our TD participants and participants with ASD produced longer total reading times in the second sentence containing the irony utterance, longer total reading times in the third sentence, and more regressions, in the ironic compared to the non-ironic condition. This fits with predictions of two stage theories of irony processing (Standard Pragmatic View Searle, 1993, as cited in Evans, 2010; or Graded Saliency Hypothesis, Giora, 1995) in that, at least for unfamiliar irony, there is an extra processing demand which involves reinterpretation of the meaning of the utterance so that the ironic interpretation becomes available to the readers. This is consistent across participant groups. The only difference between the two groups was that participants with ASD showed prolonged reading times compared to the TD participants across the ironic and non-ironic Text Type conditions. No between-group differences were found for the accuracy of comprehension question responses.

Weak Central Coherence

I will first evaluate the results against the predictions generated from the Weak Central Coherence Theory, which predicted that individuals with ASD would ignore the context information and, as such, fail to notice the irony and hence maintain the literal non-ironic interpretation of the utterance. Our results do not support this view. Firstly, impaired ability to correctly interpret the intended meaning of the ironic utterance should lead to a disproportionate decline in accuracy in the comprehension questions that followed an ironic text, in the ASD group. However, the results showed that although both participant groups were less accurate in responding to the ironic comprehension question compared to the non-ironic questions, participants with ASD did not show a disproportionately poorer performance than the TD participants for the ironic condition. This lack of difference between the groups could not be due to the ironic sentence being too easy, as both groups had more difficulty with the ironic condition. The lack of difference could also not be due to practice effects, as only a small proportion of the experimental stimuli were followed by comprehension questions.

Secondly, if participants with ASD were interpreting both ironic and non-ironic versions of the utterance literally, then there should be no differences between the two Text Types in reading times for the critical utterance. In fact, the results showed that participants with ASD, like TD participants, spent more time in total reading the text in the critical region for the ironic compared to the non-ironic condition.

Thirdly, the inability to notice the inconsistency between the ironic utterance and the contextual information should have been reflected as a lack of a difference in reading times in the context region and the context restatement region between ironic and non-ironic conditions within the ASD group. What was actually found was that neither participant group spent more time reading the contextual region for the ironic compared to the non-ironic condition. Therefore it is unlikely that the lack of difference between the two text types for the contextual region within the ASD group is due to inability to notice the irony. Furthermore, it was found that both participant groups spent more time re-reading previous portions of the text, and spent more total time reading the text in the context restatement region. This means that participants with ASD, like TD participants, did notice the inconsistency between the ironic utterance and the context when it was restated, and consequently went back to try and resolve this inconsistency.

Disordered Complex Information Processing

I also tested the assumption that if, complexity increases with figurativeness, then individuals should show elevated difficulty with processing ironic language as compared to TD individuals. In the current study, the non-ironic condition can be considered the simpler task and ironic condition can be considered as a more complex task. It was expected that our high-functioning sample of participants with ASD would show comparable performance in accuracy with TD controls for the offline comprehension questions in both ironic and non-ironic conditions. The results are in line with this prediction. For the eye movement measures, it was expected that participants with ASD would require substantially more effort to process and integrate incongruent information in the discourse than the TD group in order to achieve the same level of accuracy for irony comprehension. This should lead to elevated re-reading for the contextual information in the first sentence, the critical ironic utterance in the second sentence, and the restatement of the contextual information in the third sentence for the ironic condition specifically. However, this was not actually the case. What was found was that both groups showed the typical disruption when processing ironic text. There were significant main effects of Text Type with no interaction between Text Type and Group for total reading time, and regression path reading times measures, including (and after) the critical region, suggesting that ironic meaning is not automatically accessed for both participant groups, but reinterpretation of the text meaning has to be carried out. This indicates that participants with ASD did not experience a specific difficulty with processing irony, which is supposedly more figurative and complex as opposed to literal non-ironic text, and that they show qualitatively the same pattern as the TD group.

An unexpected finding in the current study was that there was prolonged reading times for both the ironic and non-ironic Text Type conditions in the ASD group compared to the TD group. However, although not predicted here, this finding is consistent with the findings of the study by Gyori (2006), which also report that, even if differences were present between groups, these differences were not isolated for the ironic condition. In Gyori's study where a sentence-by-sentence self-paced reading task was employed, participants read several context sentences followed by a target utterance that was either ironic or literal. During this task, participants were required to press a button after reading each sentence to trigger the presentation of the next sentence. Participants then had to respond to a forced choice question that was related to whether an interpretation of the target utterance was true or not. It was found that both ASD and TD participants consistently showed prolonged reaction times to the interpretation question for an ironic condition compared to a literal condition. However, and consistent with the current study, participants with ASD had greater reading times for all context sentences and the target utterance, as well as greater reaction times to the interpretation question, across literal and ironic conditions compared to TD participants. The current study extends Gyori's findings to show that participants with ASD are not just simply poorer reader per se in terms of their ability in word recognition, such that they were taking longer to identify each word, instead, their prolonged reading times were a consequence of greater re-reading of the passage overall.

These findings suggests that, even if participants with ASD required extra processing effort for making decisions about the appropriate interpretation of the meaning of the materials presented to them, such difficulty does not seem to be specific to ironic materials.

Taken together, the participants with ASD in the current study, and in previous studies (e.g. Gyori, 2006), do not seem to have a processing deficit specifically associated with ironic language. For example, they do not appear to show difficulty with the extra step of having to compute the ironic meaning from the surface meaning of an utterance, or in using contextual information to aid interpretation. The question that remains then is, what causes the prolonged processing time in ASD, regardless of the figurativeness of the language? One explanation for the current findings could be that individuals with ASD were taking extra time to be sufficiently assured that their interpretation of the sentence was correct. Only when this was complete do the participants with ASD feel able to terminate the display to move on to either a comprehension question or the next passage. Alternatively, it could be that participants were taking longer to integrate contextual information across different sentences in the passage regardless of text type conditions.

It is also possible that outside laboratory settings, children with ASD might find interpreting figurative language like irony difficult to detect and respond to appropriately in everyday social interaction and communication, which are dynamic and rely on fast detection and interpretation of multiple cues (Pexman, 2008). The fact that our adult participants with ASD were able to comprehend irony suggests though that learning to understand this figurative language is attainable through exposure. Persicke (2012) found that it is possible to train children with ASD to comprehend multiple untrained metaphors through multiple exemplar training. This is also likely to generalise to ironic language because irony could theoretically be comprehended through simple heuristic rules. As such, comprehending irony might not be as complex for ASD participants as previously thought. Gernsbacher and Pripas-Kapit (2012) criticised various studies that reported non-literal language processing deficits and pragmatic language deficits in ASD for failing to take into account language comprehension ability, when in actual fact the ASD group were performing worse in both literal and non-literal tasks, and for pragmatic and non-pragmatic language tasks (Ozonoff & Miller, 1996). Various studies conducted by Norbury (2014) found that comprehension ability, but not autistic status, determines the ability to understand non-literal language such as metaphors and idioms and ambiguous terms.

One limitation of the current study is that language comprehension ability has not been assessed using standardised measures. Despite this, verbal IQ was well matched between groups and our ASD group were able to perform as well as controls on comprehending ironic and non-ironic text. There might be various explanations for the longer re-reading times in the ASD group, and language comprehension ability could be one of them. It might be that it is comprehension ability and not autism is driving the results, but it could also be argued that comprehension deficit is part and parcel of the ASD profile, albeit to different degrees across the spectrum.

Another explanation for longer reading times could be related to the age differences between the two groups. It is reported that older adults (65+) (Paterson, McGowan, & Jordan, 2013) compared to younger adults (18-30) took longer to read, make more and longer fixations, and more regressions even though good comprehension level is shown in both age groups. However, none of our participants exceeded 52 years of age. Therefore it is unlikely that the slightly older age range in the ASD group had a profound effect on our results. The results from the current study are also generally consistent with the previous study (Chapter Two; Au-Yeung et al., 2013), which suggested that individuals with ASD were slower to arrive at an appropriate interpretation for an ambiguous task where they had to decide what information was relevant for a scene perception task. There is no evidence that individuals with ASD had problems taking into account contextual information from the current study.

The next experiment will continue to investigate whether the influence of context is normal in ASD. The next study will examine whether the time course for detection of anomalous, rather than ambiguous information, is the same or different in ASD compared to TD participants. Furthermore, anomalies will be manipulated in the text passages so that they are either detectable when the context of the passage was attended to, or independent of the passage context and detectable by reading the sentence alone, which allows further examination of contextual integration during reading in ASD.

Chapter Four

Eye Movements during Anomalous Text Reading in Autism Spectrum Disorder

4.1 Introduction

The previous study found that there were no differences in the time course to detect irony statements using contextual information in a reading comprehension task. Continuing on from that study, the current study aimed to investigate how individuals with ASD differ from TD individuals in their ability to spot anomalies in text comprehension, both at a local and a global level. Weak Central Coherence Theory suggests that individuals with ASD would be enhanced at spotting anomalies at the local level (independent of context) but impaired at the global level (dependent on context).

A detail focused processing style in favour of local information processing in people with ASD has been demonstrated in cognitive tasks using visual stimuli and verbal stimuli (e.g., Plaisted et al., 1999; Booth & Happé, 2010; see Section 1.4 for a review of these studies). It is expected that this local processing bias in ASD individuals should also be evident in the ability to spot anomalies that are dependent on the need to use contextual information. This study was therefore designed to investigate processing differences between TD individuals and individuals with ASD when reading text containing anomalies, compared to when reading text without anomalies. Problems with detecting anomalies have been found in scene perception tasks in ASD. For example, Joliffe and Baron-Cohen (2001) found that individuals with ASD were slower and less accurate at identifying the odd object (incongruent within the context of the scene) and less accurate in describing the scenes compared to TD participants, suggesting impairment in visual conceptual coherence.

In an eye-tracking study by Benson et al. (2012), participants were asked to look for an oddity in one of a pair of identical pictures (with one dissimilar target region) for what was defined as a complex processing task. Participants with ASD were as accurate as TD participants to identify the ‘weird’ picture; however, response time data showed that they were slower to make a response, and eye movement data revealed that they made more fixations before looking to the ‘weird’ target. Furthermore, the first fixation duration on the target region showed that the ASD group failed to immediately identify that the weird target was weird. To our knowledge, the aforementioned study is the only eye-tracking study that has investigated how individuals with ASD process anomalies during scene viewing. The time-course of anomaly processing during reading tasks has not been investigated in the ASD population using eye-tracking. The current study aims to do this.

Event-Related Potentials Studies for Anomaly Processing

Despite the lack of eye-tracking studies in this area, there have been various studies looking at brain responses to reading anomalous text materials in ASD. *Event-related-potentials* (*ERP*s) refer to the voltages the brain generates in response to stimuli (Sur & Sinha, 2009). In particular, ERP's produced at "later" time frames (post 100 ms) are named 'cognitive ERPs' as they are a reflection of information processing or how a person evaluates the stimulus. The N400 response is a negative wave that is present between 300 to 600 ms after the stimulus onset and is linked to semantic incongruity. The larger the N400 response, the less expected a word was assumed to be presented at the end of a sentence. A P600 response has also been linked to semantic anomalies, and this is thought to reflect monitoring of the veridicality of a sentence (van Heeten, Kolk, & Chwilla, 2005). Spotting an anomaly requires an individual to make an inference about whether or not a word is appropriate within a sentence or a passage of text. This was shown for example by Van Berkum, Hagoort, and Brown (1999) who presented TD participants with sentences containing a critical word that is either semantically coherent or anomalous in relation to the wider discourse (but acceptable to the local sentence containing the anomaly). In the following example, "quick" at the end of the sentence is the critical word for the discourse-coherent condition, whereas "slow" is the critical word for the discourse-anomalous condition.

> "As agreed upon, Jane was to wake her sister and her brother at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told the brother that he was exceptionally **quick/slow**."

Van Berkum et al. (1999) also presented participants with single sentences containing a local semantic anomaly. In the following example, "grave" is the critical word for the sentence coherent condition and pencil is the critical word for the sentence-anomalous condition:

> "Gloomily the men stood around the **grave/pencil** of the president."

It was found that both discourse-dependent semantic anomalies and sentence-dependent local semantic anomalies elicited a similar and large N400 effect compared to the coherent conditions. This finding was attributed to problems with integrating the anomalous critical word into the wider discourse and within the local sentence context, and it was suggested that this reflects functionally the same integration process, and thus supports a lack of distinction between the integration of a word in its local sentence-level and in its global discourse-level semantic context, at least in TD individuals.

In another ERP study, Ring, Sharma, Wheelwright, and Barratt (2007) showed TD participants and a small sample of participants with Asperger's Syndrome (n = 7) either semantically congruent or semantically incongruent sentences (both syntactically congruent). Typically developing participants showed the N400 response selectively for incongruent stimuli, whereas participants with Asperger's Syndrome demonstrated the N400 response for both congruent and incongruent stimuli (e.g. There are one hundred pennies in a pound/The blind man was led by a guide *flower*). This suggests participants with Asperger's Syndrome might be carrying out excessive semantic processing on the congruent stimuli due to impaired use of preceding sentence context to predict the outcome of sentences.

There are a few methodological drawbacks in Ring et al. (2007)'s study. Firstly, no IQ measures were taken. Secondly, word-by-word presentation of stimuli in both studies means that only immediate effects, after encountering a word for the first and the only time, could be measured, which is not normally the case in most everyday reading conditions in which readers are able to return to re-read the text. It could be that when allowed sufficient time for processing, individuals with ASD would show an effect of context in anomaly detection. Indeed there are suggestions that individuals with ASD are less immediate in processing contextual anomalies. Another ERP study by Pijnacker, Geurts, van Lambalgen, Buitelaar, and Haggoort (2010) found that participants with Asperger‘s Syndrome (n = 12) showed similar N400 effects to TD participants, but these were absent in participants with high-functioning autism (n = 6). However, all groups showed a late positive component at 600 to 900 ms latency for the incongruent condition compared to the congruent condition, which suggests a less automatic and more effortful attempt to make sense of the anomalous sentence. Although again presentation in this task is word-by-word and therefore provides limited information about the time course at which the anomaly and its context are processed in normal reading conditions.

Eye Movements during Processing of Anomalous Text in TD Individuals

The time-course of how TD individuals process text containing anomalous material had been widely researched. Ferguson and Sanford (2008) recorded the eye movements of TD participants when they are reading text materials containing sentence anomalies that violated real-world knowledge. In the following example, "fish" is the target word in the non-anomalous real-world-consistent condition, and “carrots” is the target word in the anomalous real-world inconsistent condition.

> “If cats are hungry they usually pester their owners until they get fed.
> Families could feed their cat a bowl of **fish/carrots** and it would gobble it down happily.
> Cats are loving pets when you look after them well.”

It was found that the anomaly in the real-world inconsistent condition elicited prolonged first-pass reading times, regression path times, and total reading times in the critical region containing the target word, compared to the real-world consistent condition. This indicated that world knowledge is accessed rapidly and automatically recruited to aid interpretation. Furthermore, these anomalies are also detected rapidly, and trigger more effortful processing in an attempt to resolve the anomaly.

The original Barton and Sanford (1993) study investigated how global goodness of fit influenced anomaly detection in a paragraph of text. Typically developing participants were given a text passage to read with an anomalous term that varied between participants, as in the following example:

> “There was a tourist flight travelling from Vienna to Barcelona. On the last leg of the journey, it developed engine trouble. Over the Pyrenees, the pilot started to lose control. The plane eventually crashed right on the border. Wreckage was equally strewn in France and Spain. The authorities were trying to decide where to bury the survivors.” (p.479).

In Barton and Sanford’s investigation (1993), it was found that the overall detection rate for the anomaly was 30%. In a series of later experiments it was shown that the better the fit of the anomalous term to expectation based on the context of the text, the more likely readers would be to engage in shallow processing and, therefore, the more likely they would be to miss the anomaly. This is consistent with the idea of central coherence (Frith, 1989) which assumes that TD individuals strive to incorporate incoming information in its context for meaningful coherent representation, and at the expense of processing detailed information.

Hannon and Daneman (2004) replicated Barton and Sanford’s study and found that the results extended to new text stimuli and were not restricted to the ‘bury the survivors’ scenario. Furthermore, individual differences in reading skills (as measured by a standardised test of reading comprehension) affected the likelihood of anomaly detection. Less skilled readers performed worse at detecting anomalies than skilled readers, which suggests that the less skilled readers are more likely to engage in shallow semantic processing, trading detailed processing of the local meaning with global thematic representation of the whole text.

Daneman, Lennertz, and Hannon (2007) carried out an eye-tracking study to examine the time course of anomaly detection using variations of the same stimuli from Hannon and Daneman's study. Eye movement measures reported in Daneman et al.'s study included *first-pass reading times*, which as described in the previous chapter, is the time spent fixating the target words during the first encounter of these words, and before the reader moves to the next word. They also reported *number of first-pass fixations*, which is the number of fixations that landed on the target words during this first encounter. Both of these measures are indices of early detection and processing and as such were used to determine whether the detection of the anomaly was immediate. Daneman et al. also reported *look-back fixation times*, defined as the time spent making regressive fixations to the target words that were made after the reader initially fixated and moved on from the target words, and *the number of look-back fixations*, which was the number of re-fixations on the target words. Both of these measures gave an index of delayed detection and processing of the anomalies. The findings showed that there were no differences for both early measures between the anomalous and non-anomalous condition. On the other hand, participants spent more time and made more fixations looking back at the target words in the anomalous condition compared to the non-anomalous condition. This suggests that detection of the anomaly was an effortful and delayed process that occurred later during re-reading of the text, and that the anomaly was not immediately detected on the first encounter of the anomalous target word.

Eye Movements During Processing of Anomalous Text in ASD

The current experiment used modified stimuli from previous anomaly studies (Barton & Sanford, 1993; Daneman et al., 2007; Hanon & Daneman, 2004) and new stimuli created and manipulated in the same way to test hypotheses derived from the Weak Central Coherence Theory of ASD. Participants will be presented with passages of text with or without anomalies. Two different types of anomalies were devised: one type of anomaly occurred at the global level in which detection of the anomaly is dependent on the context of the passage and another type where the anomaly occurred at the local sentence level and in which detection of the anomaly is independent of the context of the passage. (van Berkum et al., 1999). It was expected that participants with ASD would show differential performance for anomaly detection at these two levels if they do not experience the influence of context to the same degree as TD participants.

Passage Anomalies. These are anomalies that cannot be detected when the sentence containing the anomaly is read on its own, but can be detected when the contextual information of the rest of the passage is taken into account. For this type of anomaly, Weak Central Coherence Theory would predict a different performance for individuals with ASD compared to performance for the sentence anomalies. For passage anomalies, the impaired ability to take context into account should result in the anomalies being less detectable for individuals with ASD compared to TD individuals. An example of a passage anomaly is shown as follows:

> "After three years of hard work on his degree in Oriental Studies, Scott finally graduated from university. After his graduation, he received a job offer to work in Japan for a year. He was really excited about this and he was planning to take the opportunity to travel around Tokyo, one of the most vibrant cities in East Asia. However, Scott was worried that his inability to speak **Chinese/Japanese** would stop him from communicating with people. He really wanted to be able to make new friends out there."

In this example, the critical anomalous target word is "Chinese" and the non-anomalous target word is "Japanese". The story leading up to the critical word is about Scott, a graduate who was planning to work in Japan. One would assume that Scott would be worried if he could not speak Japanese, the mother tongue of Japan, in order to communicate with people in Japan if he is working there. Hence when the text in the anomalous condition states that Scott was worried that his inability to speak "Chinese" would stop him from communicating with people in Japan, it contradicts the previous factual content of the story. Typically developing readers may find this type of anomaly easier to spot if they are attentive to the contextual information of the passage. However, individuals with ASD may find this type of anomaly harder to spot if they tend not to take into account contextual information and integrate the information as they read through the passage.

Sentence Anomalies. These are local semantic anomalies that can be detected when the sentence containing it is read on its own (van Berkum et al., 1999) and therefore do not require the context of the passage to make it anomalous. However, the semantic good fit of the anomalous term with the overall theme of the passage could make the anomaly difficult to detect for TD individuals (Barton & Sanford, 1993). Therefore, if individuals with ASD have weak central coherence and difficulty with processing information within its global context, then the effect of context on weakening the detection of the sentence anomaly should be reduced in ASD. In other words, the ASD group may be better at detecting sentence anomalies compared to TD participants. The following passage is an example of a sentence anomaly:

> "Jonathan was bitten by a poisonous spider during a hiking trip on a mountain in South California. Shortly after being bitten, Jonathan developed severe cramps and muscle pain in his stomach. He felt extremely nauseous and began to vomit uncontrollably. He tried to shout for help but there was no one around. He desperately needed to be treated with **venom/antidote**, because his condition could be fatal. He was extremely worried."

In the example above, the critical anomalous target word is "venom" and the non-anomalous target word is "antidote". The story in the text leading up to the critical target word talks about a character named Jonathan being bitten by a poisonous spider and how he is desperate for medical treatment, which provides a semantic good fit with the term 'venom' and this might lead typical readers to miss the anomaly due to their drive to build a coherent representation of the discourse. However, since the anomaly can be detected just by reading the sentence containing the critical word alone ("He desperately needed to be treated with **venom/antidote"**) by noting that you don't normally treat people with venom, then individuals with ASD, who are assumed to neglect contextual information, may be more likely to detect the anomalous target word than their counterpart TD individuals.

Eye movements were measured online to provide an index of the time course of anomaly detection and any difficulty associated with this task. Specifically, for the sentence anomaly condition, enhanced anomaly detection in ASD may be observed as longer reading times on the critical target word in the anomalous condition compared to the normal condition, with a greater magnitude difference than the TD group. For the passage anomaly condition, inability to detect anomalies in ASD may be observed as a lack of difference between reading times on the critical target word between the anomalous condition and the normal condition, or a smaller magnitude difference compared to the TD group.

4.2 Method

Participants

Thirty eight volunteers in total participated in the study; 20 in the TD group and 18 in the ASD group. The participants in the ASD group were of similar demographics as those in the first and second experiment. Participants with ASD were clinically diagnosed prior to the study and recruited from the National Autistic Society, Children on the Autism Spectrum Parents' Association, and a database of volunteers who had already previously taken part in other studies at the University of Southampton. We included participants with Asperger's Syndrome and with high-functioning autism with normal to above average IQ (IQ > 90). Two participants from the ASD group and one from the TD group were excluded due to scoring lower than 90 on at least one of the IQ subsets. One participant in the ASD group was excluded due to an inability to supply evidence of a formal diagnosis of ASD. Three TD participants were also excluded due to the inability to achieve satisfactory eye movement calibration. The final sample included 15 participants with ASD and 16 TD participants. These were group matched on all IQ measures. All participants were within the adult age range but the ASD group had a slightly higher age mean compared to the TD group, as for the Irony Study (Chapter Three; Au-Yeung, Kaakinen, Liversedge, & Benson, in press). The ASD group scored significantly higher on the AQ demonstrating greater levels of self-reported autistic traits. (The participants' characteristics are presented in Table 4.1). The majority of participants within the ASD group were individuals with Asperger's Syndrome, but also included one individual with high-functioning autism with IQ within the normal range who had already participated in the previous experiment and behaved no differently to other participants within the ASD group.

Table 4.1

Participants' Characteristics

	TD			ASD				
Measure	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*t*	*p*
Age	24.6	5.8	18-35	32.2	11.4	20-52	2.592	.017
Verbal IQ	116	9.9	95-138	119	12.5	97-138	.678	.503
Performance IQ	117	10.8	93-133	120	10.3	97-134	.671	.507
Full scale IQ	118	9.7	104-139	122	11.6	97-140	.841	.407
AQ	14.9	7.5	7-35	35	6.3	19-45	7.980	<.001

Materials

Twenty four passages of text consisting of between five to seven sentences were created, and used as the experimental stimuli. Three passages were modified from stimuli used in previous studies (Barton & Sanford, 1993; Daneman et al., 2007, Hanon & Daneman, 2004) and the rest were created by the experimenter. There were two types of anomalies. For twelve of the passages, the anomalous target word was inconsistent with the context of the entire passage, but was not anomalous when the sentence containing the target word was read in isolation from the rest of the passage. These are termed Passage Anomalies. For the other twelve passages, the anomalous target word was designed to have a global good fit with the context of the passage but was anomalous within the context of the sentence containing it when read in isolation. These are termed Sentence Anomalies. A non-anomalous version of each passage was further created to be used as baseline. Non-anomalous versions of the passages were identical to the anomalous versions other than the target word, which was replaced with a word that was consistent with the context of the passage for Passage Anomalies or consistent with real world knowledge for Sentence Anomalies. Examples of passages containing the two different types of anomalous target words along with their non-anomalous normal control target words are provided in the Introduction Section in this chapter (see Appendix C for the full set of stimuli). To ensure that any potential effects of the anomalous target words on eye movements were not due to their word length or word frequency, the target words in the anomalous and normal condition were also matched as close as possible in word length [Anomalous: *M* = 6.92, SD = 2.34, Normal: *M* = 7.17, *SD* = 2.75, *t* (46) = .340, *p* = .736], and frequency (counts per million words) [Anomalous: *M* = 92.92, *SD* = 294, Normal: *M* = 100, *SD* = 222, *t*(46) = .097, *p* = .923], as taken from the CELEX corpus (Baayen, Piepenbrock, & Guliker, 2001).

Four stimuli lists were created for the experiment. Each list consisted of 24 passages that included 12 anomalous text passages and 12 non-anomalous text passages. Within the 12 anomalous passages, 6 of those were sentence anomalies and the other six were passage anomalies. For the 12 non-anomalous passages, six of those were control passages for the sentence anomalies and six were control passages for the passage anomalies. Participants viewed all 24 passages in a stimuli list, but only one of the two versions of a passage appeared in any one stimuli list, therefore participants were presented with either the anomalous or the non-anomalous version of the same passage. The passages were presented in randomised order for each participant.

The passages were entered into the DataSource of ExperimentBuilder and an image for each passage was created using the multi-text function. The size of each image was 1024 x 768 pixels. The text was presented in black, size 14 Courier New font, with equal character spacing, on a white background. Each line of the passage was separated by triple spacing to facilitate recording of eye movements in different lines of text.

Eye movement recording

Participants viewed the stimuli binocularly and eye movements were recorded monocularly for the right eye using an Eyelink 1000 eye tracker (SR Research with a viewing distance of 70 cm. Participants placed their head on the chin rest and forehead support to stabilise their position throughout the experiment. Participants were calibrated using a nine-point matrix. A fixation dot was presented at the beginning indent to the left of the first word of each passage. Participants were required to fixate this dot before the text appeared on the screen. Once participant fixated the position of the dot, the experimenter pressed a key to display the stimuli on the display screen. Participants were recalibrated if the fixation drifted away from the fixation dot in between trials.

Design

The experiment was a mixed design with two within-participant variables *Anomaly Type* (Passage vs Sentence) *Target* (Anomalous vs Normal) and one between-participant variable *Group* (TD vs ASD).

Procedure

Participants were seated in front of the computer monitor and first read the instructions that were displayed on the screen. They were told that they would be reading some short stories. They were instructed to read each passage carefully and that they would be answering two questions after each passage. Once participants verbally indicated that they had finished reading and understood the instructions, they were calibrated on the eye-tracker and presented with the text passages one at a time. Participants pressed a button on a button controller when they had finished reading each passage. The button press triggered the presentation of the question screen. The questions were simple forced-choice yes-no questions about factual contents of the passage unrelated to the anomalies to ensure participants were attending to the information of the passage and reading for comprehension. Participants pressed the left button for a ‘no’ answer and the right button for a ‘yes’ answer. The button press then executed the next trial.

4.3 Results

Data Trimming

One trial from a participant with ASD was deleted due to the participant pressing the response button before finishing reading to the end of the passage. A single trial from a different participant with ASD was deleted because of calibration error. Therefore, in total less than .6% of trials were excluded for the ASD group and none were excluded for the TD group. Any fixations that were shorter than 50 ms were removed, or were merged with a nearby fixation if that fixation was within one degree of the target fixation.

Regions of Interests Analysis

Each piece of text stimuli was auto-segmented into single word regions using Eyelink Dataviewer. Each punctuation mark that comes after a word was merged into the same single word region as that word. The empty spaces (the size of one letter) that are between words were included in the same single word region as the word that comes directly after the space. Each single word region was 80 pixels in height, leaving no space in between single word regions on different lines of text. Each single word region also touched the edge of the regions for the words next to it, leaving no space in between single words regions on the same lime.

A fixation report file was exported from DataViewer and inputted into the Get Reading Measures program (available from the SR research online support forum) which allows merging of single word regions into larger regions of interest and computes reading measures for each trial for each participant. Each passage was divided into six different types of regions of interest for analysis. These regions are described in relation to the following example passage:

> Jonathan was bitten by a poisonous spider during a hiking trip on a mountain in South California. Shortly after being bitten, Jonathan developed severe cramps and muscle pain in his stomach. He felt extremely nauseous and began to vomit uncontrollably. He tried to shout for help but there was no one around. He desperately needed to be treated with *venom/antidote*, because his condition could be **fatal**. He was extremely **worried**.

The *Critical Word Region* is "venom" for the anomalous version of the above passage or "antidote" for the normal version of the above passage, as shown in italic. The *Critical Sentence Region* for the above passage is underlined and it contains the critical word. The *Spill-Over Region* would usually be the word after the critical word, but in the case of the above passage it will be the words "because his condition", shaded in grey. This is due to the fact that the word after the critical word ("because") in this example is a function word, therefore the spill-over region extends to include up to and including the next progressive word in the passage that is not a function word. The *Critical Sentence End Region* is the last word of the critical sentence before the sentence is closed by a full stop. In the case of the example passage, it is the word "fatal" shown in bold and underlined. In cases where the last word of the critical sentence is a function word, the region will extend to include the words up to and including the next word in the passage that is not a function word. Note that in some cases this region may overlap with the critical word or the spill-over region. The *Passage End Region* is the last word in the passage. In the case of the example passage above this is the word "worried" shown in bold. In cases where the last word of the passage is a function word, the region will extend to include the words up to and including the next word in the passage that is not a function word. The *Context Sentences* include all the sentences that come before the critical sentence.

A three-way 2 (Anomaly Type: Passage vs Sentence) x 2 (Condition: Anomalous vs Normal) x 2 Group (ASD vs TD) ANOVA was first computed. After that, two separate ANOVAs with Condition (Anomalous vs Normal) as within-participant factors and Group (ASD vs TD) as between-participant factors were ran for the passage type and the sentence type anomalies separately, as it was predicted that the two participant groups would perform differently for the two types of anomaly tasks (Passages vs Sentences).

Furthermore, a different set of stimuli are used for the two anomaly types (see Appendix C).

Critical Word Region. If participants with ASD are more likely to detect anomalies in the sentence anomaly condition as predicted by Weak Central Coherence Theory, they should show greater reading times for the critical region compared to the TD participants. In contrast, if participants with ASD are less able to detect anomalies in the passage anomaly condition, they should show shorter reading times for the critical region compared to the TD participants.

First-pass, regression path, and total reading times are reported for the critical word region (See Table 4.2). These measures provide an indication of whether participants were able to detect the anomaly as the anomalous critical word was initially fixated, and whether the anomalous word would lead to disruption of processing, as shown by regression back to previous portions of the text once the anomaly was noticed, and the overall time processing the critical word. Detection and difficulty processing the target word in the anomalous condition should produce greater reading times compared to the normal condition.

Table 4.2

Descriptive Statistics for the Critical Word Region

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
		Passage Anomaly				
First-pass	TD	219.42	55.18	190.58	59.36	28.84
	ASD	230.19	82.01	188.23	73.28	41.96
Regression path	TD	393.90	197.76	258.49	75.42	135.41
	ASD	330.81	147.55	440.99	500.39	-110.18
Total time	TD	374.24	126.79	178.32	55.30	195.92
	ASD	382.31	288.43	230.69	181.03	151.62
		Sentence Anomaly				
First-pass	TD	245.70	48.16	235.93	60.21	9.77
	ASD	258.22	79.37	231.78	53.92	26.44
Regression path	TD	329.28	135.42	326.14	112.99	3.14
	ASD	611.32	578.88	287.61	98.51	323.71
Total time	TD	390.64	118.53	254.67	61.14	135.96
	ASD	670.26	500.81	274.02	128.36	396.24

First-pass reading times. For the three-way ANOVA, there was a significant main effect of Anomaly Type by-subject, $F_1(1, 29) = 13.571$, $p = .001$, $\eta_p^2 = .319$, and by-item, $F_2(1, 43) = 7.378$, $p = .009$, $\eta_p^2 = .146$, a significant main effect of Condition by-subject, $F_1(1, 29) = 10.871$, $p = .003$, $\eta_p^2 = .273$, and by-item, $F_2(1, 43) = 4.496$, $p = .040$, $\eta_p^2 = .095$, suggesting that across the two anomaly types (Passage and Sentence), participants spent longer at first-pass reading the Critical Word Region in the anomalous condition compared to the normal condition. None of the other main effects or interactions were significant; all *p*s > .05 (see Figure 4.1a and 4.1b). Next, two separate ANOVAs are reported for each Anomaly Type.

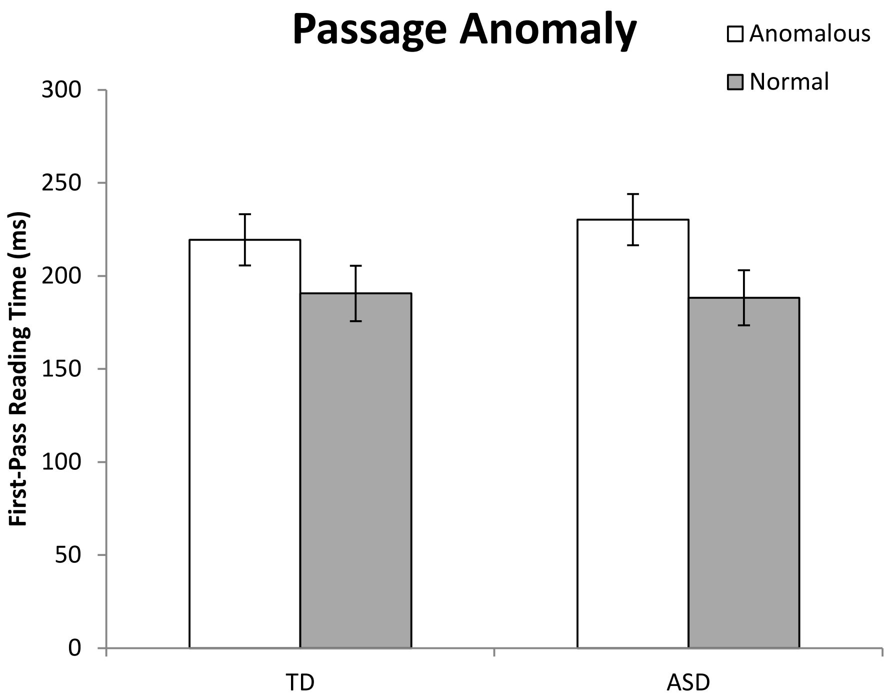

Figure 4.1a. First-pass reading times for the Critical Word Region of the passage anomaly condition. Error bars represent + *SEM*.

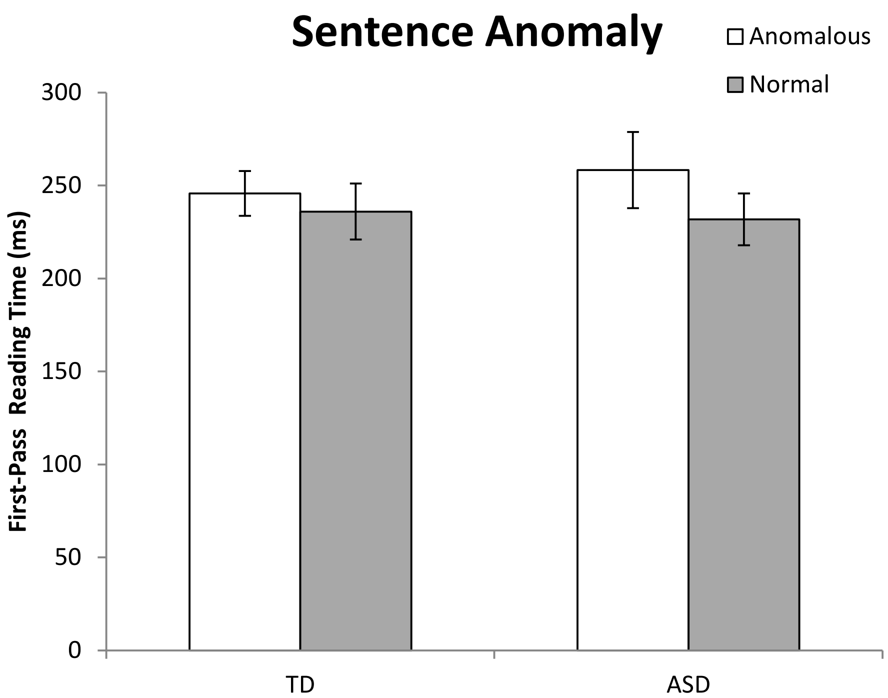

Figure 4.1b. First-pass reading times for the Critical Word Region of the sentence anomaly condition. Error bars represent + *SEM*.

Passage. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 8.007$, $p = .008$, $\eta_p^2 = .216$, and by-item , $F_2(1, 21) = 4.653$, $p = .043$, $\eta_p^2 = .181$, showing that participants spent longer during first-pass reading in the anomalous condition compared to the normal condition. There was no significant main effect of Group by-subject, $F(1, 29) = .040$, $p =.842$, $\eta_p^2 = .001$, or by-item, $F_2(1, 22) = .015$, $p = .904$, $\eta_p^2 = .001$, and no significant interaction between Condition and Group by-subject, $F_1(1, 29) = .275$, $p = .604$, $\eta_p^2 = .009$, or by-item, $F_2(1, 22) = .909$, $p = .351$, $\eta_p^2 = .042$.

Sentence. There was no significant main effect of Condition by-subject $F_1(1, 29) = 1.886$, $p = .180$, $\eta_p^2 = .061$, or by-item, $F_2(1, 22) = .728$, $p = .403$, $\eta_p^2 = .032$, no significant main effect of Group by-subject, $F(1, 29) = .056$, $p = .814$, $\eta_p^2 = .002$, or by-item, $F_2(1, 22) = .064$, $p = .803$, $\eta_p^2 = .003$, and no significant interaction between Condition and Group by-subject, $F_1(1, 29) = .399$, $p = .533$, $\eta_p^2 = .014$, or by-item, $F_2(1, 22) = 1.311$, $p = .265$, $\eta_p^2 = .056$.

Regression path reading times. The three-way ANOVA revealed a tendency towards a significant main effect of Condition by-subject, $F_1(1, 29) = 2.986$, $p = .095$, $\eta_p^2 = .093$, and by-item, $F_1(1, 43) = 3.347$, $p = .074$, $\eta_p^2 = .072$, which was qualified by a significant interaction between Anomaly Type, Condition, and Group, by-subject, $F_1(1, 29) = 8.468$, $p = .007$, $\eta_p^2 = .226$, and by-item, $F_2(1, 43) = 8.856$, $p = .005$, $\eta_p^2 = .171$ (see Figure 4.2a and 4.2b).

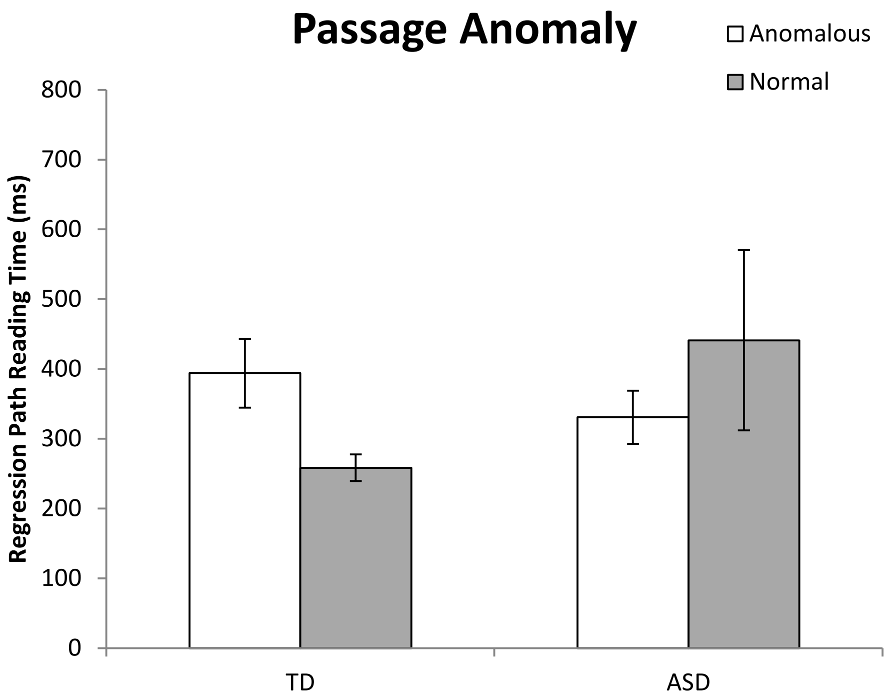

Figure 4.2a. Regression path reading times for the Critical Word Region of the passage anomaly condition. Error bars represent + *SEM*.

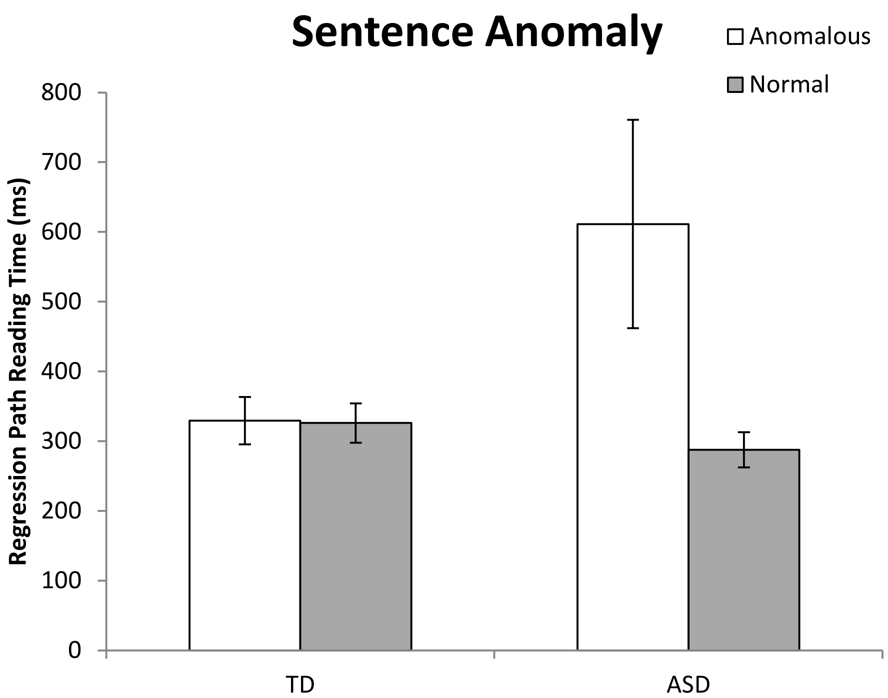

Figure 4.2b. Regression path reading times for the Critical Word Region of the sentence anomaly condition. Error bars represent + *SEM*.

Passage. There was no significant main effect of Condition by-subject, $F_1(1, 29) = .037$, $p = .849$, $\eta_p^2 = .001$, or by-item, $F_2(1, 21) = 479$, $p = .496$, $\eta_p^2 = .022$, and no significant main effect of Group by-subject, $F_1(1, 29) = .630$, $p =.434$, $\eta_p^2 = .021$, or by-item, $F_2(1, 22) = .525$, $p = .477$, $\eta_p^2 = .024$. There was a trend towards a significant interaction between Condition and Group by-subject, $F(1, 29) = 3.486$, $p = .072$, $\eta_p^2 = .107$, which is also marginally significant by-item, $F_2(1, 21) = 4.292$, $p = .051$, $\eta_p^2 = .170$. This modest effect for both subject and item analysis means that follow-up analyses were carried out. Pairwise comparisons ($\alpha = .025$) within each group showed that TD participants had greater regression path reading times in the anomalous condition compared to the normal condition, and this was significant by-subject $t_1(15) = 2.716$, $p = .016$, and approaching significance by-item, $t_2(22) = 2.079$, $p = .050$, but there was no difference between the two conditions for the ASD group by-subject, $t_1(14) = .880$, $p = .393$ or by-item, $t_2(22) = .875$, $p = .392$.

Sentence. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 4.773$, $p = .037$, $\eta_p^2 = .141$, and a tendency towards significance by-item, $F_2(1, 22) = 3.070$, $p = .094$, $\eta_p^2 = .122$. Participants spent more time re-reading in the anomalous condition than the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = 2.393$, $p = .133$, $\eta_p^2 = .076$, or by-item, $F_2(1, 22) = 4.613$, $p = .117$, $\eta_p^2 = .108$. There was a significant interaction between Condition and Group by-subject, $F_1(1, 29) = 4.592$, $p = .041$, $\eta_p^2 = .137$, and by-item, $F_2(1, 22) = 4.613$, $p = .043$, $\eta_p^2 = .173$. Pairwise comparisons between group showed that there was no difference between the two conditions for the TD group, $t_1(15) = .068$, $p = .947$, $t_2(22) = .106$, $p = .916$. For the ASD group, there was a trend towards greater regression path times for the anomalous condition compared to the normal condition by-subject, $t_1(14) = 2.208$, $p = .044$, and by-item, $t_2(11.964) = 2.000$, $p = .069$.

Total reading times. The three-way ANOVA revealed that there was a significant main effect of Anomaly Type by-subject, $F_1(1, 29) = 8.528$, $p = .007$, $\eta_p^2 = .227$, and by-item $F_2(1, 44) = 5.613$, $p = .022$, $\eta_p^2 = .113$. There was also a significant main effect of Condition both by-subject, $F_1(1, 29) = 55.436$, $p < .001$, $\eta_p^2 = .657$, and by-item, $F_2(1, 44) = 22.331$, $p < .001$, $\eta_p^2 = .337$. There was a significant main effect of Group by-item $F_2(1, 44) = 5.795$, $p < .020$, $\eta_p^2 = .116$, but not by-subject, $F_1(1, 29) = 2.426$, $p < .130$,

η_p^2 = .077. There was also a trend towards a significant interaction between Condition and Group by-subject, $F_1(1, 29) = 3.341$, $p = .078$, $\eta_p^2 = .103$, but not by-item, $F_2(1, 44) = 2.151$, $p = .150$, $\eta_p^2 = .047$. There was also a significant interaction between Anomaly Type, Condition, and Group by-subject, $F_1(1, 29) = 5.404$, $p = .027$, $\eta_p^2 = .157$, and by-item, $F_2(1, 44) = 4.708$, $p = .035$, $\eta_p^2 = .097$ (see Figure 4.3a and 4.3b).

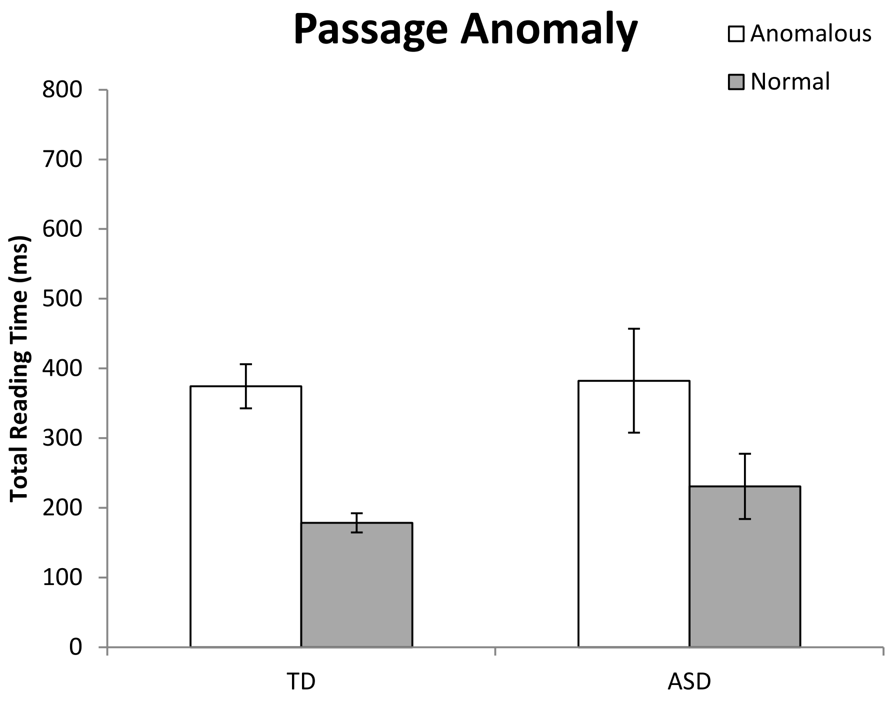

Figure 4.3a. Total reading times for the Critical Word Region of the passage anomaly condition. Error bars represent + *SEM.*

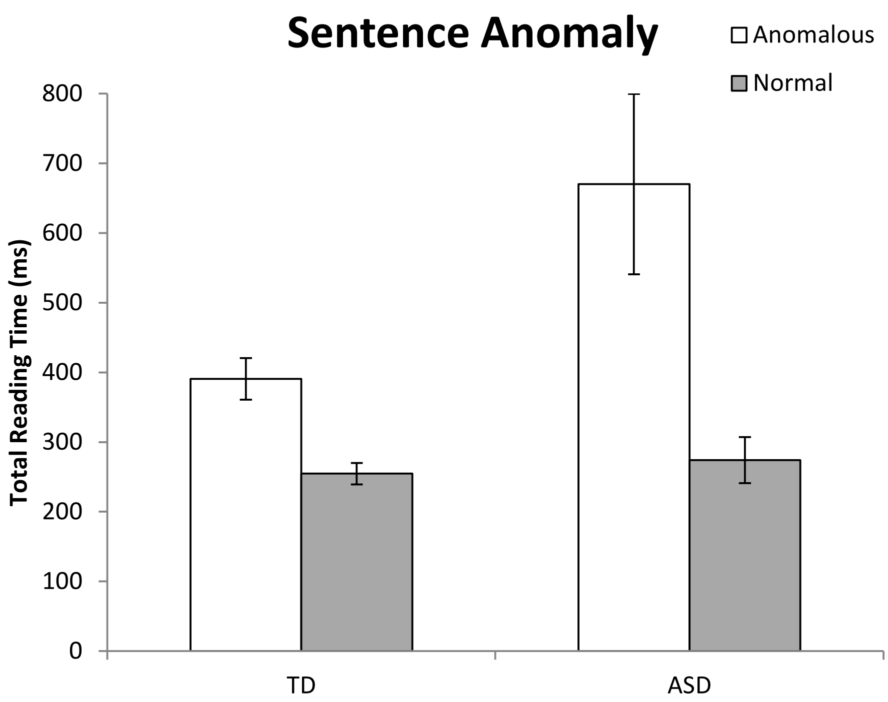

Figure 4.3b. Total reading times for the Critical Word Region of the sentence anomaly condition. Error bars represent + *SEM.*

Passage. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 35.426$, $p < .001$, $\eta_p^2 = .550$, and by-item, $F_2(1, 22) = 10.455$, $p = .004$, $\eta_p^2 = .322$. Participants spent more time overall reading in the anomalous condition compared to the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = .268$, $p = .608$, $\eta_p^2 = .009$, or by-item, $F_2(1, 22) = .754$, $p = .395$, $\eta_p^2 = .033$. There was no significant interaction by-subject, $F_1(1, 29) = .575$, $p = .454$, $\eta_p^2 = .019$, or by-item, $F_2(1, 22) = .818$, $p = .376$, $\eta_p^2 = .036$.

Sentence. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 23.305$, $p < .001$, $\eta_p^2 = .446$, and by-item $F_2(1, 22) = 12.333$, $p = .002$, $\eta_p^2 = .359$. Participants spent more time overall reading in the anomalous condition compared to the normal condition. There was a trend towards a significant main effect of Group by-subject, $F_1(1, 29) = 3.794$, $p = .061$, $\eta_p^2= .116$, which was significant by-item, $F_2(1, 22) = 5.047$, $p = .035$, $\eta_p^2 = .187$. This was qualified by a significant interaction between Condition and Group by-subject, $F_1(1, 29) = 5.574$, $p = .025$, $\eta_p^2 = .161$, which also approached significance by-item, $F_2(1, 22) = 3.894$, $p = .061$, $\eta_p^2 =.150$. Pairwise comparisons within each group ($\alpha = .025$) showed that the TD group spent significantly longer overall reading in the anomalous condition compared to the normal condition by-subject, $t_1(15) = 4.570$, $p < .001$, and marginally by-item, $t_2(22) = 2.214$, $p = .037$. The ASD group also spent significantly longer overall reading in the anomalous condition compared to the normal condition by-subject $t_1(14) = 3.62$, $p = .003$, and by-item, $t_2(12.918) = 3.068$, $p = .009$. Examination of the data suggested that the interaction was likely to be due to the magnitude difference of the anomaly effect between the TD and ASD, in which participants with ASD spent more time in total reading the critical word region in the anomalous condition (see Figure 4.3b).

Summary. Results for the Critical Word Region show that both participant groups spent longer during first-pass reading of the critical word in the anomalous condition compared to the normal condition across anomaly types. However, when calculated separately, this was only significant for the passage condition but not the sentence condition. TD participants showed more immediate re-reading for the anomalous condition compared to the normal condition for the passage type anomalies, but no difference between the two conditions was found for the ASD group. In contrast, for the sentence type anomalies, there was a tendency for ASD participants to spend more time immediately re-reading the anomalous condition compared to the normal condition. Overall, TD and ASD participants both spent more time reading the critical word region when it was anomalous compared to when it was normal across the two Anomaly Types, although the magnitude of the anomaly effect is greater for the ASD group for the sentence anomaly type.

Spill-Over Region. Increased first-pass reading time on the word following a target word was associated with processing difficulty in integrating the target word into sentence context (Rayner, Warren, Juhasz, & Liversedge, 2004). Therefore similar effects were expected for this region as those predicted for the Critical Word Region. First-pass reading time was reported for the Spill-Over Region to determine if the effect of anomaly detection spills-over to the next word in the sentence (see Table 4.3 for descriptive statistics).

Table 4.3

Descriptive Statistics for the Spill-Over Region

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
		Passage Anomaly				
First-pass	TD	308.84	86.27	278.97	89.14	29.87
	ASD	320.55	114 .59	318.46	141.62	2.09
		Sentence Anomaly				
First-pass	TD	335.96	133.20	296.69	138.90	39.27
	ASD	298.21	137.62	341.89	197.03	-43.68

First-pass reading times. The three-way ANOVA revealed no significant main effects and interactions by-subject or by-item, all *p*s > .10.

Passage. There was no significant main effect of Condition by-subject $F_1(1, 29) = .552$, $p = .464$, $\eta_p^2 = .019$ or by-item $F_2(1, 22) = .113$, $p = .740$, $\eta_p^2 = .005$, no significant main effect of Group by-subject, $F(1, 29) = .603$, $p = .444$, $\eta_p^2 = .020$, or by-item, $F_2(1, 22) = .016$, $p = .902$, $\eta_p^2 = .001$, and no significant interaction between Condition and Group by-subject, $F(1, 29) = .417$, $p = .524$, $\eta_p^2 = .014$, or by-item $F_2(1, 22) = 1.06$, $p = .314$, $\eta_p^2 = .046$.

Sentence. There was no significant main effect of Condition by-subject, $F_1(1, 29) = .006$, $p = .941$, $\eta_p^2 < .001$, or by-item, $F_2(1, 22) = .002$, $p = .964$, $\eta_p^2 < .001$, no significant main effect of Group by-subject, $F(1, 29) = .006$, $p = .937$, $\eta_p^2 < .001$, or by-item, $F_2(1, 22) = .036$, $p = .852$, $\eta_p^2 = .002$, and no significant interaction between Condition and Group by-subject, $F(1, 29) = 2.00$, $p = .168$, $\eta_p^2 = .065$, or by-item $F_2(1, 22) = .918$, $p = .384$, $\eta_p^2 = .040$.

Summary. Results for the Spill-Over Region indicate that the effect of anomaly detection did not extend to the word that followed directly after the target during first-pass reading.

Critical Sentence End Region. Difficulty in resolving the anomaly might also be shown in the end portion of the sentence containing the anomaly. The end of a sentence is important as it has been described as the wrap-up region in which integrative processes occur (Rayner, Kambe, Duffy, 2000). Any increase in difficulty with integrative processing as a result of encountering an anomaly should produce greater reading times in this region. First-pass reading time was reported to determine if the difficulty with integrating the anomalous term into the context is apparent when the last word of the sentence containing the anomaly was read. The descriptive statistics for this region are presented in Table 4.4.

Table 4.4

Descriptive Statistics for the Critical Sentence End Region

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
		Passage Anomaly				
First-pass	TD	243.10	85.27	230.60	61.32	12.50
	ASD	242.11	78.96	247.62	131.39	-5.51
		Sentence Anomaly				
First-pass	TD	282.17	87.53	249.74	72.48	32.43
	ASD	248.45	84.98	225.50	82.30	22.95

First-pass reading times. The three-way ANOVA revealed no significant main effects or interactions by-subject or by-item, all *p*s > .10.

Passage. There was no significant main effect of condition by-subject, $F_1(1, 29) = .025$, $p = .876$, $\eta_p^2 = .001$, or by-item, $F_2(1, 22) = .024$, $p = .878$, $\eta_p^2 = .001$, no significant main effect of group by-subject, $F(1, 29) = .105$, $p = .748$, $\eta_p^2 < .004$, or by-item, $F_2(1, 22) = .023$, $p = .881$, $\eta_p^2 = 001$, and no significant interaction between condition and group by-subject, $F(1, 29) =.165$, $p = .687$, $\eta_p^2 = .006$, or by-item $F_2(1, 22) = .417$, $p = .525$, $\eta_p^2 = .019$.

Sentence. There was no significant main effect of condition by-subject $F_1(1, 29) = 1.555$, $p = .222$, $\eta_p^2 = .051$, or by-item, $F_2(1, 22) = .015$, $p = .902$, $\eta_p^2 =.001$, no significant main effect of group by-subject, $F(1, 29) = 2.24$, $p = .145$, $\eta_p^2 = .072$, or by-item, $F_2(1, 22) = 1.35$, $p = .258$, $\eta_p^2 = .058$, and no significant interaction between condition and group by-subject, $F(1, 29) = .046$, $p = .832$, $\eta_p^2 = .002$, or by-item, $F_2(1, 22) = .175$, $p = .680$, $\eta_p^2 = .008$.

Summary. The results for the Critical Sentence End Region have shown that anomaly detection did not produce problems with integrative wrap-up processes when readers read the final word of the critical sentence.

Critical Sentence Region. For the sentence anomaly condition, it was expected that detection of the anomaly would drive participants to spend more time re-reading the critical sentence. Therefore if participants with ASD are better at detecting sentence anomaly, then they should spend more time reading the critical sentence in the anomalous condition compared to TD participants, but there should be no between-group difference in the non-anomalous condition. For the passage anomaly, we would expect the opposite pattern for the two groups. If ASD participants are poorer at detecting passage anomaly than TD participants, then we should see less re-reading of the critical sentence in the ASD group compared to the TD group.

First-pass, regression path, and total reading times in the entire critical sentence which contains the critical word were analysed to determine if anomaly detection occurred immediately when the sentence was read through the first time, or whether disruption occurred after the anomalous critical sentence was encountered, leading to re-reading of previous portions of the text, and whether more time was spent overall to process the anomalous critical sentence. The descriptive statistics for this region are presented in Table 4.5.

Table 4.5

Descriptive Statistics for the Critical Sentence Region

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
Passage Anomaly						
First-pass	TD	2090.18	704.46	1779.97	501.83	310.21
	ASD	2039.83	857.80	1866.64	874.14	173.19
Regression path	TD	2641.71	1187.38	2119.82	796.76	521.89
	ASD	2641.57	1372 .21	2468.78	1572.82	172.79
Total time	TD	2965.85	903.51	2057.97	687.40	907.88
	ASD	3262.53	1991.51	2557.54	1271.92	704.99
Sentence Anomaly						
First-pass	TD	2476.29	1175.35	2093.77	634.40	382.52
	ASD	2100.58	1282.54	2408.98	1611.64	-308.40
Regression path	TD	3302.69	996.70	2575.39	649.89	727.30
	ASD	3477.53	1693.82	2791.77	1540.29	685.76
Total time	TD	3591.39	1123.89	2724.75	881.54	866.64
	ASD	5031.96	3546.29	3131.74	1415.77	1900.22

First-pass reading times. The three-way ANOVA revealed a significant main effect of Anomaly Type both by-subject, $F_1(1, 29) = 9.35$, $p = .005$, $\eta_p^2 = .244$, and by-item, $F_2(1, 44) = 4.36$, $p = .043$, $\eta_p^2 = .090$. There was also a significant interaction between Group and Condition by-item, $F_1(1, 44) = 5.72$, $p = .021$, $\eta_p^2 = .115$, but not by-subject, $F_2(1, 29) = 2.38$, $p = .134$, $\eta_p^2 = .076$. The data is illustrated in Figure 4.4a and 4.4b.

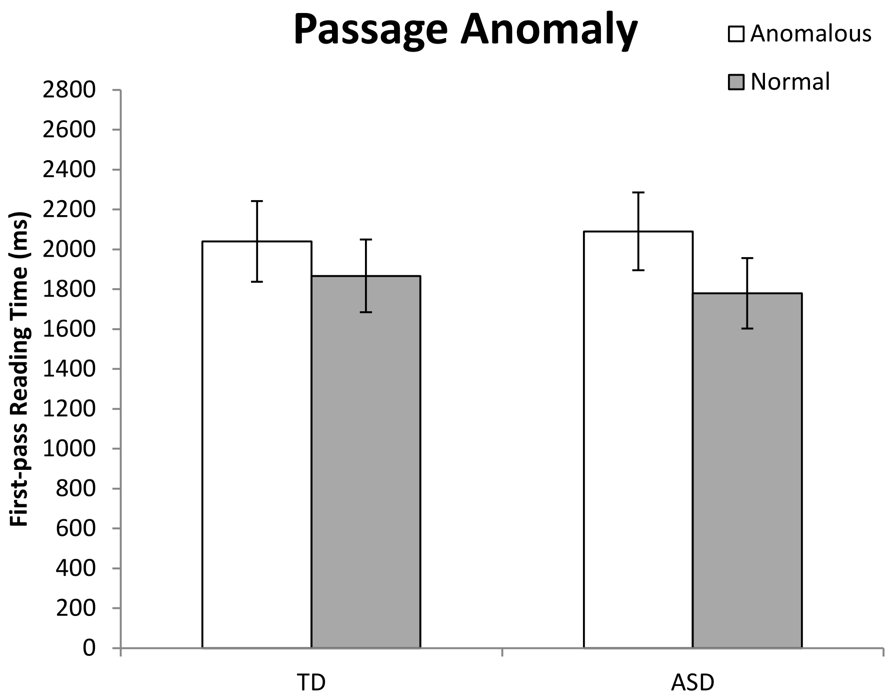

Figure 4.4a. First-pass reading times for the Critical Sentence Region of the passage anomaly condition. Error bars represent ± *SEM.*

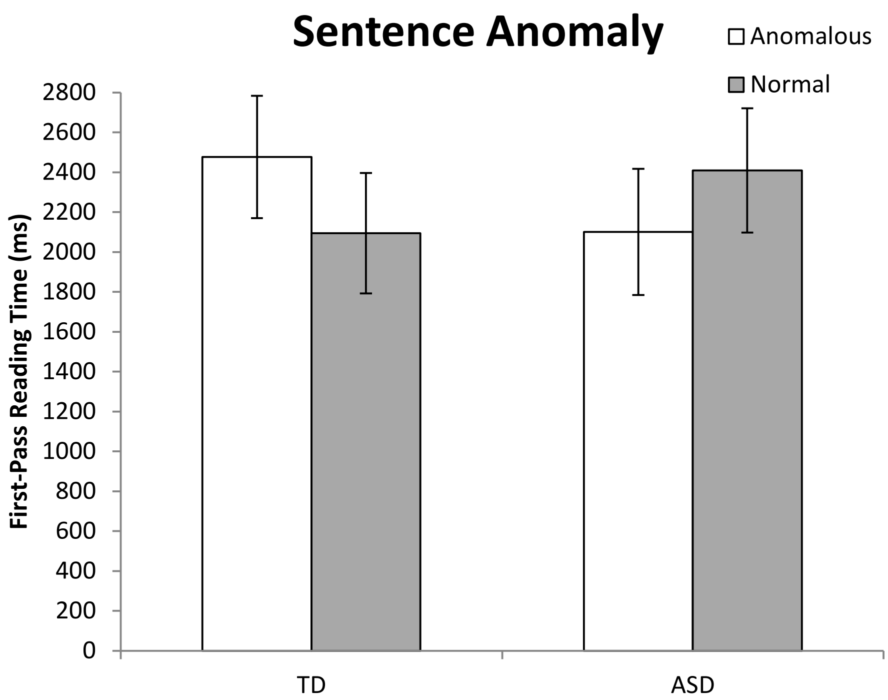

Figure 4.4b. First-pass reading times for the Critical Sentence Region of the sentence anomaly condition. Error bars represent ± *SEM.*

Passage. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 5.36$, $p = .028$, $\eta_p^2 = .156$, but not by-item, $F_2(1, 22) = .584$, $p = .467$, $\eta_p^2 = .024$. Participants spent longer reading initially in the anomalous condition than the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = .005$, $p = .942$, $\eta_p^2 < .001$, or by-item, $F_2(1, 22) = 1.08$, $p = .310$, $\eta_p^2 = .047$. There was no significant interaction by-subject, $F_1(1, 29) = .431$, $p = .517$, $\eta_p^2 = .015$, or by-item, $F_2(1, 22) = 2.04$, $p = .167$, $\eta_p^2 = .085$.

Sentence. There was no significant main effect of Condition by-subject, $F_1(1, 29) = .027$, $p =.871$, $\eta_p^2 = .001$, or by-item, $F_2(1, 22) = .002$, $p = .967$, $\eta_p^2 < .001$. There was no significant main effect of Group by-subject, $F_1(1,29) = .007$, $p = .936$, $\eta_p^2 <.001$ or by-item, $F_2(1, 22) = .505$, $p = .485$, $\eta_p^2 = .022$. There was no significant interaction by-subject, $F(1, 29) = .2.32$, $p = .138$, $\eta_p^2 = .074$, or by-item, $F_2(1, 22) = 3.69$, $p = .068$, $\eta_p^2 = .144$.

Regression path reading times. The three-way interaction revealed a significant main effect of Anomaly Type by-subject, $F_1(1, 29) = 32.5$, $p < .001$, and by-item, $F_2(1, 44)$ 8.95, $p = .005$, $\eta_p^2 = .169$, a significant main effect of Condition, by-subject $F_1(1, 29) = 22.4$, $p < .001$, $\eta_p^2 = .436$, and by-item, $F_2(1, 44) = 6.27$, $p = .016$, $\eta_p^2 = .125$ The data is illustrated in Figure 4.5a and.4.5b.

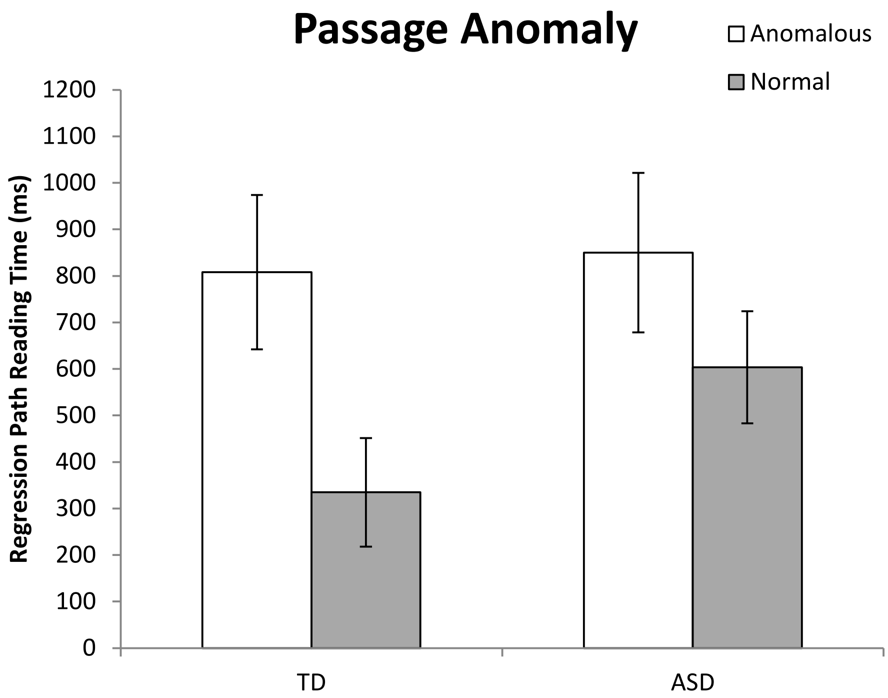

Figure 4.5a. Regression path reading times for the Critical Sentence Region for the passage anomaly condition. Error bars represent <u>+</u> *SEM*.

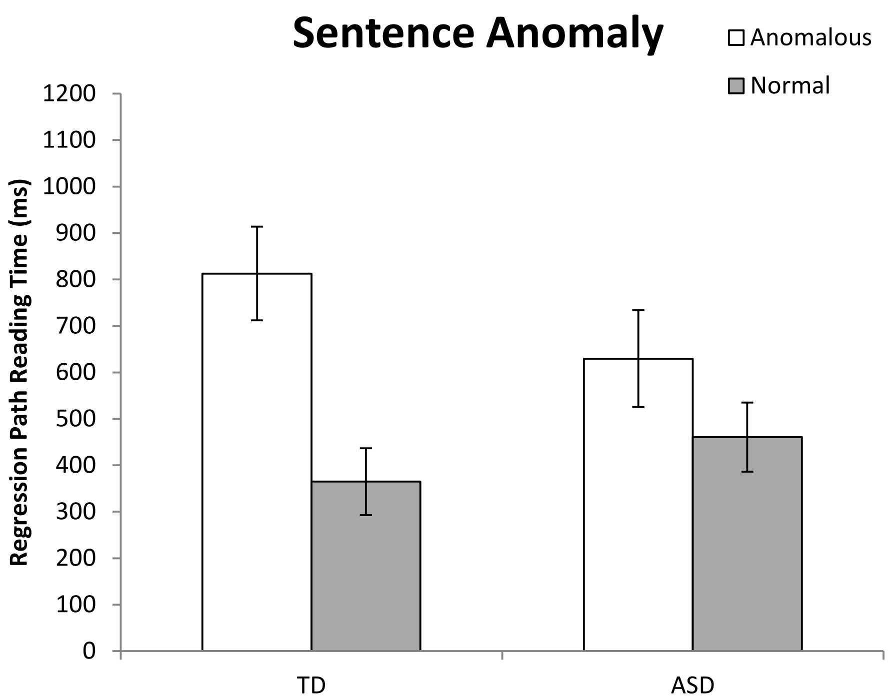

Figure 4.5b. Regression path reading times for the Critical Sentence Region for the sentence anomaly condition. Error bars represent <u>+</u> *SEM*.

Passage. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 4.29$, $p = .047$, $\eta_p^2 = .129$, but not by-item, $F_2(1, 22) = 2.07$, $p = .164$, $\eta_p^2 = .086$. Participants spent longer re-reading in the anomalous condition compared to the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = .173$, $p = .681$, $\eta_p^2 = .006$ or by-item, $F_2(1, 22) = .239$, $p = .629$, $\eta_p^2 = .011$. There was no significant interaction by-subject, $F_1(1, 29) = 1.08$, $p = .307$, $\eta_p^2 = .036$, or by-item, $F_2(1, 22) = .461$, $p = .504$, $\eta_p^2 = .021$.

Sentence. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 35.291$, $p < .001$, $\eta_p^2 = .549$ and this approached significance by-item, $F_2(1, 22) = 4.23$, $p = .052$, $\eta_p^2 = .161$. Participants spent longer re-reading in the anomalous condition than the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = .195$, $p = .662$, $\eta_p^2 = .007$, or by-item, $F_2(1, 22) = .958$, $p = .338$, $\eta_p^2 = .042$. There was no significant interaction by-subject, $F_1(1,29) = .031$, $p = .863$, $\eta_p^2 = .001$, or by-item, $F_2(1, 22) = .041$, $p = .842$, $\eta_p^2 = .002$.

Total reading times. The three-way ANOVA revealed a significant main effect of Anomaly Type by-subject, $F_1(1, 29) = 18.2$, $p < .001$, $\eta_p^2 = .386$, and by-item, $F_2(1, 44) = 9.10$, $p = .004$, $\eta_p^2 = .171$, a significant main effect of Condition by-subject, $F_1(1, 29) = 30.5$, $p = .001$, $\eta_p^2 = .513$ and by-item, $F_2(1, 44) = 11.9$, $p = .001$, $\eta_p^2 = .213$, and a significant main effect of Group by-item $F_2(1, 44) = 9.211$, $p = .004$, $\eta_p^2 = .173$, which was non-significant by-subject, $F_1(1, 29) = 1.78$, $p = .192$, $\eta_p^2 = .058$. The data is illustrated in Figure 4.6a and 4.6b)

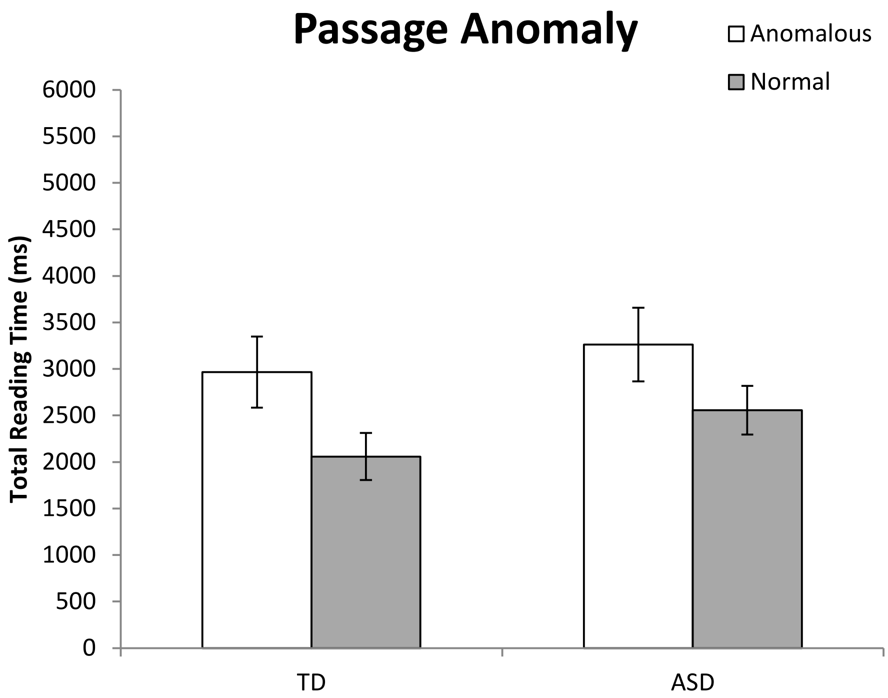

Figure 4.6a. Total reading times for the Critical Sentence Region for the passage anomaly condition. Error bars represent ± *SEM.*

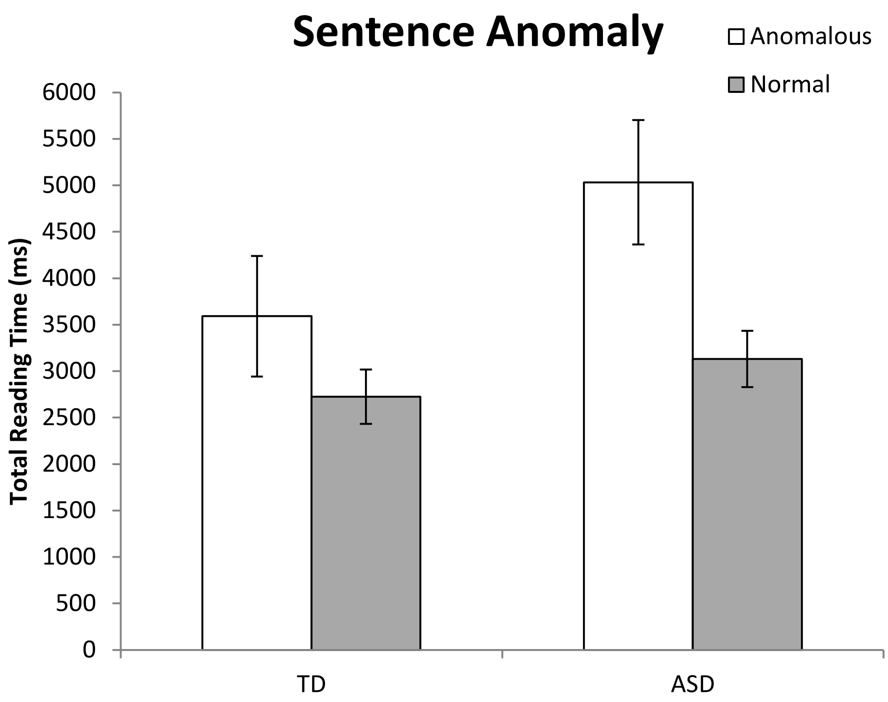

Figure 4.6b. Total reading times for the Critical Sentence Region for the sentence anomaly condition. Error bars represent ± *SEM.*

Passage. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 26.0$, $p < .001$, $\eta_p^2 = .472$, and by-item, $F_2(1, 22) = 7.839$, $p = .010$, $\eta_p^2 = .263$. Participants spent significantly more time overall reading in the anomalous condition compared to the normal condition. There was no significant main effect of group by-subject, $F_1(1, 29) = .825$, $p = .371$, $\eta_p^2 =. 028$, but there was a significant main effect of Group by-item, $F_2(1, 22) = 6.73$, $p = .017$, $\eta_p^2 = .234$. There was no significant interaction by-subject, $F_1(1, 29) = .411$, $p = .527$, $\eta_p^2 = .014$, or by-item, $F_2(1, 22) = .684$, $p = .417$, $\eta_p^2 = .030$.

Sentence. There was a significant main effect of Condition by-subject, $F_1(1, 29) = 14.29$, $p = .001$, $\eta_p^2 = .330$, and by-item $F_2(1, 22) = 6.05$, $p = .022$, $\eta_p^2 = .216$. Participants spent longer overall reading in the anomalous condition than the normal condition. There was no significant main effect of Group by-subject, $F_1(1, 29) = 2.20$, $p = .149$, $\eta_p^2 = .070$, but there was a significant main effect of Group by-item, $F_2(1, 22) = 5.24$, $p = .032$, $\eta_p^2 = .192$. There was also no significant interaction by-subject, $F_1(1, 29) = 1.99$, $p = .169$, $\eta_p^2 = .064$, nor by-item, $F_2(1, 22) = 1.90$, $p = .182$, $\eta_p^2 = .080$.

Summary. Results for the Critical Sentence Condition showed that for all participants the effect of anomaly detection is apparent in early processing eye movement measures, for example during first-pass reading times for passage anomalies. Evidence for difficulties in resolving the anomaly were shown in regression path measures, made from the Critical Sentence Region, as well as in total reading time for both Anomaly Types. Importantly, as for the Critical Word Region, participants did not show superior detection for the sentence anomalies.

Context Sentences. Because detection of the passage anomalies requires participants to notice the inconsistency between the anomaly and the preceding context of the passage it should be expected that, if TD participants were more likely to detect the passage anomaly compared to ASD participants, they should spend more time re-reading the sentences prior to the critical sentence containing the anomaly. Total reading time was reported for the context sentences in order to find out if participants spent more time in total processing the text preceding the critical sentence containing the anomalous critical word. Descriptive statistics are presented in Table 4.6).

Table 4.6

Descriptive Statistics for the Context Sentences

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
Passage Anomaly						
Total time	TD	2147.51	676.64	2109.99	637.07	37.52
	ASD	2668.84	1800.24	2366.43	1059.96	302.41
Sentence Anomaly						
Total time	TD	1903.66	516.90	1833.38	602.81	70.28
	ASD	2240.83	1393.88	2054.06	906.67	186.77

Total reading times. **A** three-way ANOVA revealed that there was a significant main effect of Anomaly Type, by-subject, $F_1(1, 29) = 27.1$, $p < .001$, $\eta_p^2 = .483$, and by-item $F_2(1, 44) = 4.37$, $p = .042$, $\eta_p^2 = .090$. There was also a significant main effect of Group by-item, $F_2(1, 44) = 8.39$, $p = .006$, $\eta_p^2 = .160$, but non-significant by-subject, $F_1(1, 29) = .947$, $p = .338$, $\eta_p^2 = .032$.

Passage. There was no significant main effect of Condition by-subject, $F_1(1, 29) = 2.10$, $p = .158$, $\eta_p^2 = .068$, or by-item, $F_2(1, 22) = .512$. $p = .482$, $\eta_p^2 = .023$. There was no significant main effect of Group by-subject, $F_1(1, 29) = 1.00$, $p = .326$, $\eta_p^2 = .033$, but a significant main effect of Group by-item, $F_2(1, 22) = 5.48$. $p = .029$, $\eta_p^2 =.199$. There was no significant interaction by-subject, $F_1(1, 29) = 1.28$, $p = .268$, $\eta_p^2 = .042$, or by-item, $F_2(1, 22) = .667$. $p = .423$, $\eta_p^2 = .029$.

Sentence. There was no significant main effect of Condition by-subject, $F_1(1, 29) = 1.05$, $p = .314$, $\eta_p^2 = .035$, or by-item, $F_2(1, 22) = 1.00$, $p = .327$, $\eta_p^2 = .044$. There was no significant main effect of Group by-subject, $F_1(1, 29) = .850$, $p = .364$, $\eta_p^2 = .028$, or by-item, $F_2(1, 22) = 3.03$, $p =.096$, $\eta_p^2 = .121$ (modest effect). There was no significant interaction by-subject, $F(1, 29) = .216$, $p = .646$, $\eta_p^2 = .007$, or by-item, $F_2(1, 22) = .371$, $p = .548$, $\eta_p^2 = .017$.

Passage End Region. As for the Critical Sentence End Region, difficulty in resolving and integrating the anomaly into the context might also be shown at the end of passages, where these wrap-up processes occurs (Rayner et al., 2000), in terms of greater reading times. Regression path reading time for the last word of the passage was analysed in order to determine if participants spent more time re-reading the passage in the anomalous condition (see Table 4.7 for descriptive statistics).

Table 4.7

Descriptive Statistics for the Passage End Region

		Condition				
		Anomalous		Normal		
Measure	Group	*M*	*SD*	*M*	*SD*	Mean Differences
		Passage Anomaly				
Regression path	TD	1289.80	1017.18	962.88	574.29	326.92
	ASD	2648.74	2640.74	2861.61	3601.67	-212.87
		Sentence Anomaly				
Regression path	TD	1080.40	660.17	990.55	555.44	89.85
	ASD	3572.24	4151.23	2192.57	2337.52	1379.67

Regression Path Reading Times. Three-way ANOVA revealed there was a significant main effect of Group by-subject, $F_1(1, 27) = 7.85$, $p = .009$, $\eta_p^2 = .225$, and by-item, $F_2(1, 42) = 11.2$, $p = .002$, $\eta_p^2 = .211$. The data is illustrated in Figure 4.7a and 4.7b).

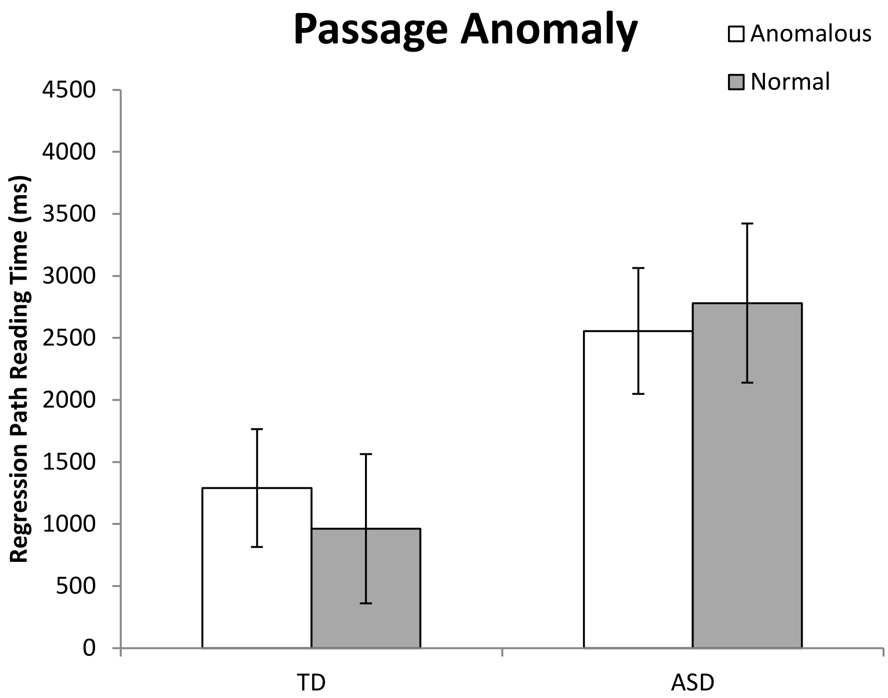

Figure 4.7a. Regression path reading times for the Critical Sentence Region for the passage anomaly condition. Error bars represent + *SEM.*

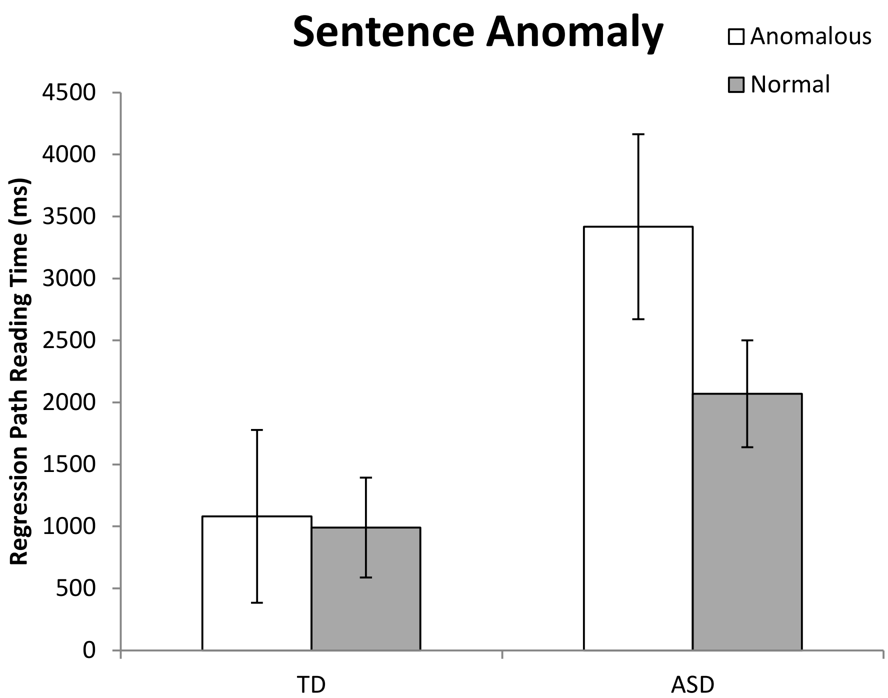

Figure 4.7b. Regression path reading times for the Critical Sentence Region for the sentence anomaly condition. Error bars represent + *SEM.*

Passage. There was no significant main effect of Condition by-subject, $F_1(1, 28) = .009$, $p = .926$, $\eta_p^2 < .001$, or by-item $F_2(1, 21) = .225$, $p = .640$, $\eta_p^2 = .011$. There was a significant main effect of Group by-subject, $F_1(1,28) = 7.18$, $p = .012$, $\eta_p^2 = .204$ and by-item, $F_2(1, 21) = 8.33$. $p = .009$, $\eta_p^2 = .284$. This showed that the ASD group spent more time re-reading the passage than the TD group regardless of whether the passage contains an anomaly or not. There was no significant interaction by-subject, $F_1(1, 28) = .257$, $p = .616$, $\eta_p^2 = .009$, or by-item, $F_2(1, 21) = .018$. $p = .895$, $\eta_p^2 = .001$.

Sentence. There was no significant main effect of Condition by-subject, $F_1(1, 28) = 2.14$, $p = .155$, $\eta_p^2 = .071$, or by-item, $F_2(1, 21) = 1.15$, $p = .296$, $\eta_p^2 = .052$. There was a significant main effect of Group by-subject, $F_1(1, 28) = 6.439$, $p = .017$, $\eta_p^2 = .187$, and this was approaching significance by-item, $F_2(1, 21) = .4.22$, $p = .053$, $\eta_p^2 = .167$. This result shows that the ASD group spent more time re-reading than the TD group. There was no significant interaction by-subject, $F_1(1, 28) = 1.63$, $p = .212$, $\eta_p^2 = .055$, or by-item, $F_2(1, 21) = .207$, $p = .654$, $\eta_p^2 = .010$.

Summary. Results for the Passage End Region analyses show that participants with ASD spent more time re-reading the passage compared to TD participants across conditions and anomaly types.

Comprehension task

Descriptive statistics for the accuracy score to the comprehension questions are presented in Table 4.8. A three-way ANOVA , 2 (Anomaly Type: (Passage vs Sentence) x 2 (Conditions : Anomalous vs Normal) x 2 (Group: TD vs ASD), revealed that there was a significant main effect of Anomaly Type $F_1(1, 29) = 62.3$, $p < .001$, $\eta_p^2 = .682$, a significant main effect of condition, $F_1(1, 29) = 14.8$, $p = .001$, $\eta_p^2 = .338$, and a significant interaction between Anomaly Type and Condition, $F_1(1, 29) = 16.4$, $p < .001$, $\eta_p^2 = .361$.

Table 4.8

Comprehension Score

	Condition				
	Anomalous		Normal		
Group	*M* (%)	*SD*	*M* (%)	*SD*	Mean Difference
			Passage		
TD	9.06 (75.50)	2.32	11.06 (92.17)	0.77	-2.00
ASD	8.27 (68.92)	1.94	10.27 (85.58)	1.16	-2.00
			Sentence		
TD	8.00 (66.67)	2.50	8.13 (67.75)	2.66	-0.13
ASD	7.27 (60.58)	2.31	7.33 (61.08)	2.13	-0.06

Passage. There was a significant main effect of Condition, $F(1, 29) = 26.0$, $p < .001$, $\eta_p^2 = .473$, showing that participants were generally more accurate in answering comprehension question about facts in the passages following presentation of a normal passage (*M* = 10.68, *SD* = 1.05) compared to an anomalous passage (*M* = 8.68, *SD* = 2.15). However, there was no significant main effect of Group, $F(1, 29) = 3.07$, $p = .090$, $\eta_p^2 = .096$, nor was there an interaction between Condition and Group, $F(1, 29) < .001$, $p = 1.00$, $\eta_p^2 < .001$.

Sentence. There was no significant main effect of Condition, $F(1, 29) = .087$, $p = .770$, $\eta_p^2 = .003$, no significant main effect of Group, $F(1, 29) = .898$, $p = .351$, $\eta_p^2 = .030$, and no interaction between Condition and Group, $F(1, 29) = .008$, $p = .929$, $\eta_p^2 < .001$.

Results from the comprehension question analyses showed that comprehension accuracy was worse for the anomalous condition compared to the normal condition for the passage anomaly type, and that this difference was not present in the sentence condition. However, there was no difference in accuracy in answering the comprehension questions between the two groups.

4.4 Discussion

In the current eye-tracking experiment, participants read passages of text with or without anomalies. Some texts contained context-dependent passage anomalies, while others contained context-independent sentence anomalies. Overall, the regression path reading time measure for the critical word region showed that TD participants were more efficient at detecting context-dependent passage anomalies, while participants with ASD were more efficient at detecting context-independent sentence anomalies. Another significant finding in regression path reading time measures for the passage end region showed that participants spent significantly greater time re-reading the passage from that region.

The Weak Central Coherence Theory predicts that individuals with ASD should show differences in performance for the two types of anomaly detection, due to abnormal use of contextual information. However, the ability to use context in ASD might be affected by whether anomalies rely on keeping the context of a passage of text in mind whilst reading, or whether anomalies could be detected at a single sentence level. It was therefore predicted that detection of passage anomalies would be harder for the ASD group, as a reduced ability to integrate contextual information would mean that it should be harder to detect information that contradicts the context. For the sentence anomaly, it was expected that a reduced contextual influence would mean that detection of sentence anomalies would be facilitated in the ASD group, as the ASD group would be less likely to build a coherent mental representation of the discourse based on the context of the passage, compared to the TD group.

The findings from the current study broadly supported these predictions, and showed evidence that the ASD group was more efficient at detecting sentence anomalies and less efficient at detecting passage anomalies compared to the TD group. For the passage type anomalies, the TD participants spent more time immediately re-reading in the critical word region and in the text that comes before this region in the anomalous condition, compared to the normal condition, while this difference between the two conditions was not significant for the ASD group. However, the total reading times results showed a lack of interactions between Group and Condition but a significant main effect of Condition, suggesting that ASD participants were disrupted by the passage anomaly and that they attempted to resolve the anomaly at a later time compared to TD participants.

For sentence type anomalies, participants with ASD spent more time immediately rereading in the critical word region and the text that comes before it in the anomalous condition compared to the normal condition, but the TD participants did not show this effect of immediate re-reading. The TD participants, however, showed the anomaly effect at the total reading time measure, albeit to a smaller degree compared to the ASD group. These findings suggest that participants with ASD were disrupted by the anomalous critical word and subsequently attempted to resolve the anomaly by immediately rereading the text to recover from the disruption, whereas, this was not the case for TD participants, who tended to detect and resolve the sentence anomaly at a later time.

The results here support the prediction that when the task requires participants to take into account contextual information for detecting complex passage anomalies, in order to spot the consistency between the anomaly and the rest of the context, individuals with ASD would have more difficulty noticing the anomaly. However, when context information of the passage is not required, as for spotting simple sentence anomalies, and where passage context would perhaps hinder detection, the ASD group are better at noticing the anomaly, compared to the TD controls. This finding is consistent with the Weak Central Coherence Theory in that individuals with ASD showed enhanced local processing and impaired global processing.

The finding of less efficient detection of context dependent passage anomalies in ASD during reading is also consistent with scene perception studies in which detection of anomalies were required. Benson et al. (2012) found that participants with ASD took longer to fixate a weird target feature in one of two otherwise identical complex scenes, which are displayed at the same time, and once they fixated the target they did not immediately recognise the anomaly. Similarly, Joliffe and Baron-Cohen (2001) found that individuals with ASD performed worse at a top-down processing task requiring them to detect incongruent objects from a group of line drawings of objects and people that made up a scene: and furthermore, in a second experiment, participants with ASD were slower and less accurate at identifying the odd object and less accurate in describing the scene compared to TD participants, again supporting the Weak Central Coherence prediction that they are less sensitive to context. The current findings for context dependent passage anomalies are also consistent with a previous ERP study (Pijnacker et al., 2010). In this study, it was found that in highly constrained sentences that were designed to strongly drive semantic expectations about the upcoming final word (e.g. "Finally the climbers reached the top of the mountain/tulip"), participants with high functioning autism did not show the usual N400 response when they encountered a context incongruent anomaly. Instead, they showed a delayed response of a late positive component at 600 to 900 ms latency for the incongruent condition compared to the congruent condition, which suggests a less immediate processing of contextual anomalies.

It must be noted here, though, that for the sentence anomalies in the current study, the sentences that contained the anomaly were not designed to be constrained in the same way as the sentences used in the study by Pijnacker et al. (2010), and furthermore, some of the anomalies in the current study are embedded within the context of a passage of text, which was designed to suppress the detection of the anomaly by global coherence. Hence, if participants with ASD were less sensitive to the contextual influence of the greater passage, they should be more adept at spotting the context-independent sentence anomaly. In tasks that do not require the use of context and in fact where using context will hinder performance, Weak Central Coherence Theory predicts that individuals with ASD will show a local processing bias and enhanced performance for these tasks. The Disordered Complex Information Processing Theory also predicts that in simple tasks where no complex information processing is required, individuals with ASD should show either a pattern of enhanced, or at least spared, performance. One of the criteria of complex information processing tasks is that they involve integration of multiple features rather than reliance of one or two features (Minshew et al., 2008). The finding that participants with ASD are more immediate in their detection of context-independent sentence anomalies during reading is in line with the predictions of both of these theories. Consistent with Disordered Complex Information Processing Theory, studies using less context dependent scene perception tasks, (e.g., a bottom-up processing task employed by Joliffe, and Baron-Cohen [2001) where participants had to look for similarities and detect an incongruent object from a group of objects from the same category], participants with ASD were unimpaired. Benson et al. (2012) also found unimpaired performance in ASD in a simple spot the difference task where participants had to decide which one of two pictures had a feature missing.

The current study, as well as the aforementioned studies (e.g. Benson et al., 2012; Joliffe & Baron-Cohen, 2001), indicates that conceptual coherence is weaker in ASD compared to TD individuals. Some studies have also shown that this weakness extends to visual perceptual coherence. Using more simple stimuli, enhanced performance as reflected by faster response times had been consistently found in visual detection type tasks such as visual search, block design, and embedded figures tasks (e.g. Keehn et al., 2009; Plaisted et al., 1998; Shah & Frith, 1993; see Chapter One for a thorough review of these tasks). However, a study by Plaisted et al. (1999) provided evidence that top-down task demands could modulate the presence of a local processing bias, and whether or not individuals with ASD attended to global context. In the Navon task, participants are required to respond to a target letter that could appear at the local level (small letters), at the global level (large letter made up by other small letters), or at both levels. In the divided attention task where no specific instruction was given as to which level participants should attend to it was found that TD children responded faster and more accurately when the target was at the global level than when it was at the local level, whereas children with autism responded faster and more accurately when the target was at the local level than when it was at the global level, consistent with the idea of a local processing bias in children with autism. However, in the selected attention condition in which participants were instructed to respond to targets at a specific level, both participant groups showed a global bias, responding faster to global targets than to the local targets in this task. The study suggests the individuals with ASD do not have a problem with perceiving global information, but a preferential bias for information presented at the local level, unless they are explicitly primed by specific task instructions. The structure of the divided attention task is similar to the current study in that no specific instruction was given to take note of the contextual information. When the anomalies were not directly presented as the main focus of the task, individuals with ASD were less efficient at detecting context dependent passage anomalies and more efficient at detection of context independent anomalies.

There were some similarities in how the two groups in the current study responded to anomalies. For example, both groups spent longer reading the text within the anomalous Critical Sentence Region compared to the normal control condition during first-pass for the passage anomaly, although this effect was not present for the sentence anomaly. Also, all participants made more regressions and spent longer re-reading the text in, and preceding, the Critical Sentence Region for the anomalous condition, compared to the normal condition.

In previous research, Van Berkum et al (1999) has found that both discourse-dependent semantic anomalies, and sentence-dependent local semantic anomalies, have elicited larger N400 ERP effects compared to the coherent conditions. This finding has been attributed to problems with integrating an anomalous critical word in both the wider discourse and within the local sentence context too. It was suggested that the similar N400 effects observed for both discourse-dependent and sentence-dependent anomalies reflects functionally the same integration processes, and supports a lack of distinction between the integration of a word at a local sentence-level and at a global discourse-level semantic context in TD individuals. Interestingly, van Berkum et al. (1999) also found a subtle difference between the two types of anomaly effects. In the sentence-dependent condition, the ERPs related to the anomaly effect had a slightly delayed onset (290-300 ms latency) compared to the discourse-dependent effect (280-290 ms latency). This again fits with the current findings that the main effects of Condition for first-pass reading times in the critical word regions and the critical sentence region are only significant for the passage type but not the sentence type anomaly condition. This finding implies that context dependent anomalies are detected more quickly than context independent anomalies, perhaps due to the fact that passage context gives participants a more direct cue as to the inappropriateness of the anomalies.

It is also interesting to note that the analysis in the Passage End Region across Anomaly Types (passage vs sentence) and across conditions (anomalous vs normal) in the current study showed that participants with ASD spent reliably longer making regressions and re-reading overall. This finding of prolonged reading times in ASD is consistent with the findings in the previous study on irony comprehension in Chapter Three (Au-Yeung et al., in press), where longer reading times in the ASD group compared to the TD group were found across both ironic and non-ironic conditions. As discussed in the previous chapter, age is a confounding variable as our ASD participants are slightly older than the TD participants, and it is possible to consider that increased age might offer an account for the rereading observed in the current study in the ASD group. Nevertheless, as none of the participants in the current study were close to the over 65 years old threshold in the majority of eye-tracking research looking at aging (Paterson et al., 2013), an alternative explanation had been offered for the prolonged reading times. The explanation was that it was possible that participants with ASD had to recheck what they had read before they have the confidence to press the button to proceed to answering the comprehension questions, in order to ensure that they have made sense of the passage. There seem to be some compatibility between this prolonged reading and Ring et al.'s ERP findings (2007), in which regardless of stimuli conditions (congruent or incongruent), participant with ASD show the N400 response indicating excessive processing were carried out even when the stimuli is congruent.

In Chapter Three (Au-Yeung et al., in press), it was also found that participants with ASD showed no difference compared to TD participants in their ability to comprehend ironic utterances based on contextual information provided by the passage.

The study suggests that individuals with ASD were able to use context to disambiguate the meaning of sentences with multiple interpretations. This seems to be in contradiction with the findings of the current study whereby ASD participants seem less efficient at spotting anomalies relating to the context of the whole passage. It is speculated here that this difference in performance, for the study reported in the previous chapter, and for the current study, is due to the implicit nature of the task demand imposed for the current study. While in both this study and the previous study, participants were explicitly instructed to read for comprehension and to answer comprehension questions relating to the text, the actual aim of the current study was to see whether participants could detect anomalies within the text, and this information was not revealed to the participants until after completion of the experiment. Furthermore, the comprehension questions in the comprehension task in the current study were not related to the anomaly; rather, they were related to the factual content of the passages. In contrast, the comprehension questions to the passages for the experimental conditions (non-ironic and ironic condition) in the irony study presented in Chapter Three (Au-Yeung et al., in press) were specifically designed to tap into whether participants had correctly interpreted an utterance in the text. In this way, the task requirement for the irony study could be considered as more explicit and the current study more implicit, because the participants can deduce the real requirement of the irony experiment, which is to disambiguate the utterance, from the comprehension question despite the fact that no reference were made to irony in the instructions at the beginning of the experiment.

Another possible explanation for the difference in the passage and sentence anomalies in ASD could be related to Executive Dysfunction Theory. It could be that detection of passage anomalies requires participants to voluntarily keep track of the context of the passage, and this could produce a greater demand on working memory load, while sentence anomaly detection did not do have this requirement. Autism had been linked to problems with executive dysfunction in which one of the components is working memory. Some of these factors relating to executive dysfunction, for example, increasing the explicitness/implicitness of task instruction, and manipulating working memory load, will be investigated in the next chapter using a scene memory task.

In summary, the current study examined passive detection of the anomalies in passages of text in TD and ASD participants. Specifically, two types of anomalies were presented. One type was at the global passage level, for which detection was dependent on being able to take into account the passage context. The other type at the local sentence level and were independent of the passage context, rather, taking into account the contextual information would cause a hindrance to detection of the anomaly. It was found that participants with ASD were less efficient at detecting the passage anomaly and more efficient at detection the sentence anomaly compared to TD participants. This is in line with the Weak Central Coherence proposal of enhanced local processing and impaired global processing which is related to atypical use of contextual information.

Chapter Five

Eye Movements and Memory for Scenes in Autism Spectrum Disorder

5.1 Introduction

The aim of the final study of this thesis is to explore the nature of executive dysfunction in ASD by manipulating the task instructions of an existing neuropsychological test for complex scene memory. The study will examine whether memory deficits in ASD, as reported in scene perception study, could be accounted for by the implicitness of the task instructions, or by increasing working memory load driven by task instructions.

Executive Dysfunction in ASD

Executive function describes a range of abilities associated with frontal lobe processing, including components such as planning, inhibition, cognitive flexibility and working memory. As discussed in the literature review in Chapter One, the idea of executive dysfunction in ASD originated from the observed similarities in behavioural symptoms between individuals with ASD and individuals with prefrontal lobe damage, and it was proposed that ASD is a result of atypical functioning of the prefrontal cortex (Damasio & Maurer, 1978). However, there have been alternative reasons put forward to account for the performance of individuals with ASD on the executive function tasks reported in the literature.

Recently, the *Triple I Hypothesis* (White, 2013) proposed that individuals with ASD have impairments in inferring implicit information and that they are unable to form an implicit understanding of the experimenter's expectation. Hence, the performance on some executive tasks, according to this theory, is impaired because the instructions do not provide the individual with enough explicit cues about the task requirements. White (2013) evaluated previous findings on executive functions in ASD and pointed out that individuals with ASD had consistent difficulties on structurally open-ended executive tasks that lack explicit instructions and involve arbitrary rules (e.g. Hayling Sentence Completion task), but they showed unimpaired performance in executive function tasks that are explicit, logical, and constrained, and which give little room for misinterpretation of the task demand (Stroop task).

The current thesis has already touched on the distinct performance between explicit and implicit tasks in ASD within the perspective-taking domain. For example, Senju et al. (2009) demonstrated that individuals with ASD were able to pass the classical first and second-order theory-of-mind tasks but eye movement data during an implicit theory-of-mind task showed a lack of spontaneous mental state attribution (also see Au-Yeung et al., 2013; Chapter One). In the memory domain, individuals with ASD have shown deficits in free recall (Gaigg, 2008), but intact performance in cued recall (Phelan, 2010). These findings imply that when task complexity is increased, by increasing the implicitness of the task, memory performance will be impaired, due to less efficient use of self-directed organization strategies to aid memory when the task instruction is open-ended, abstract, and requires an individual to figure out the task requirement that is not explicitly stated (Minshew & Goldstein , 2001; White, 2013).

Hill (2004) also evaluated findings from various executive function tasks including planning, cognitive flexibility, and inhibition. From this review it was speculated that task complexity could explain ASD performance. Hill noted that inhibition task performance appeared to be worse for tasks with arbitrary rules and no clear aim, and this converges with White's (2013) Triple I Hypothesis. Hill also pointed out that individuals with ASD were worse than controls at a planning task called the Stockings of Cambridge, but this decrement in performance was restricted to trials with longer sequences, and this finding differed from patients with frontal lesions who were impaired compared to TD controls on a variation of the same task. Furthermore, performance on a mental flexibility task that demanded an intra-dimensional/extra-dimensional shift showed that individuals with ASD were impaired only for later, more difficult stages of the task.

Recently, it has been proposed that ASD deficits could be explained by increasing working memory load (Barendse et al., 2013). Given that working memory had been described as one of the core components of executive function; it is likely that any tasks that are excessively demanding on working memory capacity will also be affected.
A study by Minshew and Goldstein (2001) has also reported that visual memory performance is dependent on complexity, as defined by increasing the number of elements to be monitored within a task. In that study, high functioning individuals with autism showed intact performance for the lowest level of a maze learning task but required disproportionately more trials than TD participants to learn the mazes as the number of choice-points increased. In another review, Minshew et al. (2008) suggested that the amount of information to be processed in a unit of time could define complexity. They provided an example of dual task performance, which showed that individuals with ASD were unimpaired when completing two simple tasks separately including digit span and motor tracking; however, their performance declined disproportionately when both

tasks were performed simultaneously, while TD controls did not show such a decline. Taken together, the aforementioned literature (Minshew et al., 2008, Minshew & Goldstein, 2001) suggests that increasing the number of elements to be monitored in a task could impair memory recall performance if individuals with ASD have a reduced information processing capacity and a slower speed of processing.

Family Pictures Task

The Family Pictures task is part of the Wechsler Memory Scale Third Edition (WMS-III: Wechsler, 1997) and consists of subtests that tap learning, memory, working memory in immediate and delayed recall conditions, in both auditory and visual modalities. The Family Pictures subtest was designed to be the visual equivalent to the logical memory subtest. In the logical memory subtest, examinees are required to verbally recall a story that was read out by an examiner. In the Family Picture subtest, an examinee is introduced to seven characters that form a family in an illustrated family picture. These characters include the grandmother, grandfather, mother, father, daughter, son, and the dog. The examinee is then shown four scenes consecutively for ten seconds each. The four scenes include the garden scene, the meal scene, the picnic scene, and the department store scene. Each of the scenes contains four of the characters in different spatial locations, each carrying out different activities related to the theme of the scene. After inspecting all the pictures, an examinee is required to immediately recall the characters, their spatial location, and the activities they were carrying out scene by scene. After a delay of 30 minutes, the examinee is retested again with the same recall procedure. The Family Pictures subtest is intended to be a test of spatial memory for visually presented materials and information (Tulsky, 2003). However, it has commonly been criticised for being unclear on what type of memory function it actually assesses, because the pictures are presented visually, but the information can be encoded verbally and must be recalled verbally (Mitrushina, 2005; Lichtenberger, Kaufman, & Lai, 2002), so it is thought to tap multiple aspects of memory.

Indeed, research with clinical samples such as those with epilepsy (Dulay et al., 2002) found that performance on the Family Pictures task was best predicted by Logical Memory, another subtest of the WMS-III (Wechsler, 1997) that measures auditory-verbal memory ability and requires immediate and delayed verbal recall of short stories. Similarly, Chapin, Busch, Naugle, and Najm (2009) found that Family Pictures performance was significantly predicted by performance on the Logical Memory task as well as the Faces subtest which tests face recognition, indicating that the Family Pictures task measures both verbal and visual memory.

Further evidence that the Family Pictures task was at least partially determined by verbal ability comes from Lum, Contri-Ramsden, and Ullman (2013). It was predicted that, if the Family Pictures subtest actually measures declarative memory for visual but not verbal information, then children with specific language impairments (SLI; defined as clinically significant language impairments but with at least average nonverbal intelligence and unimpaired sensory functioning) should show equivalent performance in Family Pictures compared to controls. However, it was instead found that children with SLI performed significantly worse at the Family Pictures task compared to TD controls. Furthermore, their performance on the Family Pictures task was best predicted by a measure of verbal working memory (central executive component score which takes into account performance on listening recall, backwards digits, and counting recall). These findings indicate that this task puts demand on working memory capacity to transfer visual information into verbal codes.

Performance on the Family Pictures Subtest in ASD

Given that the Family Pictures is not a pure measure of visual working memory, it creates a problem when used to calculate the visual index score in the Wechsler Memory Scale (WMS) assessment. Hence it has been removed from the newer fourth version of the WMS (Wechsler, 2009). Nevertheless, the WMS had been used to assess memory function of patients in clinics during neuropsychological assessments, for example, as part of the diagnostic process for ASD to rule out other possible disorders. Williams, Goldstein, and Minshew (2005) tested adults with Autistic Disorder on the WMS-III. These participants with ASD were reported to have delayed and disordered language development, although they had Verbal and Full-scale IQ > 80. It was reported that participants with ASD performed significantly worse than controls in measures that supposedly tap visual memory for both immediate and delayed conditions of the Family Pictures subtest, the Faces subtest, and spatial span; but that they showed intact performance in tasks designed to tap verbal working memory, such as logical memory, verbal pairs, and letter number sequencing.

However, there are several issues with this study by Williams et al. (2005). Firstly, only the scaled scores were reported, thus it is not known whether participants with ASD struggled with recalling particular elements of the scenes, such as remembering which characters were in the scene, where they were located in the scene and what activities they were carrying out, or whether perhaps the large number of features to be remembered as a combination of all these scene elements resulted in impairments in performance. Secondly, in general the visual tasks seem to be more complex than the verbal tasks, in that they have less obvious organisational structure. While the verbal tasks consist of list sequences, or passages of words that limit what needs to be recalled, visual tasks could be thought to be more open-ended. In the Family Pictures task for instance, participants were asked to remember as much as they could in the scenes, and no specific cues were given as to what participants should attend to. Therefore, it could be speculated that impaired performance in the ASD group might be related to inability to decide what is important in a scene to remember, rather than visual memory impairment per se.

Thirdly, while the Family Pictures task was thought to be a "complex" visual memory task, no "simple" visual memory tasks were provided for comparison, and for, which according to the Disordered Complex Information Processing Theory (Minshew & Goldstein, 1998), individuals with ASD should demonstrate unimpaired performance. Finally, as mentioned earlier, although the stimuli were presented visually in the Family Pictures subtest, the task also puts a strain on working memory capacity and requires participants to transfer visual presentation into verbal codes. So, since the ASD sample in that study had delayed/disordered language development despite performing as well as controls on the verbal recall and being matched on IQ, the results might just be a reflection of the presence of language impairment and not of ASD per se. Higher functioning individuals such as those with Asperger's might be unaffected due to intact verbal ability.

Current Study

The current study extends the study by Williams et al. (2005) with a particular focus on the Family Pictures task. The aim of the current study was to attempt to manipulate the complexity of the task instruction using the original set of picture stimuli, to see if performance declines as a result of increased complexity. Based on reviews of previous work (Hill, 2004; Minshew et al., 2008; White, 2013), two candidate variables that are likely to affect ASD performance on memory and executive function tasks have been identified. These are outlined below.

Explicitness of Task Instruction. It has been suggested in previous literature that, individuals with ASD would be intact at a cued task with clear aims, but impaired at arbitrary tasks with no clear aims and lacking in organisational structure (White, 2013).

The original Family Pictures task as carried out by Williams et al. (2005) provides the same instruction for all four pictures shown in the task, which merely instructs participants to remember as much as they can about the scene. However, the instruction does not provide explicit cues to direct participants' attention to specific parts of the scene, much like a free-viewing instruction. As such, the original instruction in the Family Pictures task can be seen as implicit as it requires the viewers to decide what parts of the scenes are important. In the current study, an explicit instruction and an implicit instruction were presented to participants to test if participants with ASD had specific difficult with implicit tasks. The explicit instruction was designed to prompt participants directly to inspect all relevant information (Remember which characters are in the scene, their location, and their activities), whereas the implicit instruction requires participants to decide what is the relevant information in the scene without explicit cues (e.g., Remember as much as you can about this scene). If memory performance can indeed be explained by explicitness/implicitness of the task instruction, and if an implicit task instruction is more complex for individuals with ASD, then individuals with ASD should show equivalent recall performance for the explicit task but be impaired at the implicit task, compared to TD individuals. For the eye movement measures, it is expected that both participant groups would modulate their eye movements to the areas of the scenes relevant for recall for the explicit instruction condition. These included the faces of the characters, their bodies, and the objects they were interacting with. However, participants with ASD should have difficulty modulating their eye movements in terms of orienting to and fixating relevant features for the implicit task instruction condition compared to the control group.

Number of elements to remember. Reviews of previous research also suggested that number of elements or steps involved in a task is positively associated with complexity (Hill, 2004; Minshew et al., 2008). Three instructions were therefore designed for the current study, each with an increasing number of elements of the scene to remember. One instruction required participants to remember which characters are in the scene (C task). The next instruction adds an extra element and required participants to remember which characters are in the scene and their location (CL task). Finally, the next instruction further adds an element, requiring participants to remember which characters are in the scene, their location, and their activities (CLA task, also coded as the explicit task). If increasing the number of elements increases complexity, then we should find that participants with ASD show unimpaired recall for the tasks with fewer elements to remember, and impaired recall for the tasks with more elements to remember. Furthermore, eye movement data should reveal a differential pattern for participants in the later task only, as reduced processing capacity would lead them to be less able to divide attentional resources within a limited amount of time to sample all of the relevant scene features in accordance with task instructions as a greater number of elements was required to be remembered.

5.2 Method

Participants

There were a total of 39 volunteers in the original sample (20 TD and 19 ASD). Two participants were excluded from the data analysis because one participant with ASD had not received a formal diagnosis and another participant with ASD was also diagnosed with dyslexia and was unable to complete some of the assessments required. Therefore, the final TD group comprised 20 adults (14 males, 6 females) aged 18 to 51 years. They were recruited through word of mouth from the local community. The final ASD group comprised of 17 adults (13 males, 4 females) aged 18 to 52 years with Autism Spectrum Disorder (ASD), including predominantly individuals with Asperger’s Syndrome and one High-Functioning Autism, previously clinically diagnosed using standardized diagnostic instruments. The participants with ASD were recruited from the Southampton Adult Asperger’s Society, the University of Southampton, the Hampshire Autistic Society, the Autism Diagnostic and Research Centre, the National Autistic Society’s website, and the Children on the Autistic Spectrum Parents' Association. For the purpose of eye movement recording, only individuals with normal or corrected to normal vision were selected to take part.

All participants completed the 50-items Autism-Spectrum Quotient questionnaire (Baron-Cohen, Wheelwright et al., 2001). Higher AQ scores imply more autism-like traits, and as expected, participants in the ASD group scored significantly higher than participants in the TD group, which confirmed that the ASD group self-reported disproportionately more autistic traits than the TD group. Participants’ characteristics are summarised in Table 5.1.

Table 5.1

Participants' Characteristics

	TD			ASD				
Measure	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*t*	*P*
Age	25.2	8.1	18-51	32.2	11.2	18-52	1.872	.070
Verbal IQ	116	9.6	95-138	117	13.0	97-138	.200	.843
Performance IQ	116	11.8	88-133	115	16.5	75-134	.168	.868
Full scale IQ	118	10.3	96-139	118	15.3	87-140	.039	.969
AQ	15.6	7.1	7-35	34.4	6.2	19-45	8.454	< .001

Participants also completed the Wechsler Abbreviated Scale of Intelligence (WASI: The Psychological Corporation, 1999); there were no significant between-group differences in Verbal IQ, Performance IQ, and Full-Scale IQ. The mean age for the ASD group was marginally greater than the TD group but this was not significant and the two groups fell within a similar adult age range.

Stimuli

The scenes for the experiment were four coloured pictures taken from the Family Pictures subtest in the WMS-III (Wechsler, 1997), which have been used as part of the neuropsychiatric screening process to examine memory functions. Each scene depicted four characters out of a total of seven possible family members including the grandmother, the grandfather, the mother, the father, the daughter, the son and the dog. The four characters were in different locations of the scene and engaging in different activities. The theme of the four scenes included a department store scene, a garden scene, a meal scene and a picnic scene. The original scenes from WMS-III were scanned and were formatted in Adobe Photoshop Elements, but the contents of the scenes remained unchanged. The width and height ratio of the edited scenes were kept the same as the originals but were re-sized to fill as much of a 1024 x 768 pixels canvas as possible. The dimensions of each scene covering the canvas were 1024 x 608 pixels and each scene was placed in the centre on the canvas. Empty space above and at the bottom of the scene were filled with a black background. Examples of the scenes can be found in the WMS-III Stimulus book.

Apparatus

Participants viewed the stimuli binocularly on a 21 inch monitor with a resolution of 1024 by 768 pixels. The experiment was created using Experiment Builder (SR Research Ltd, Osgoode, Canada) and eye movements were recorded monocularly for the right eye using an Eyelink 1000 eye-tracker at a sampling rate of 1000 Hz. A chin rest and a forehead support were used to maintain participants' head position at a viewing distance of 70 cm from the monitor. Participants were calibrated using a nine-point matrix prior to each experimental condition, where participants were required to fixate the calibration points in a sequence. This was then repeated to validate that each fixation was within 0.5 degrees of visual angle of each corresponding calibration point.

Design

The four pictures were presented with a different task instruction each. The four pictures were presented in a randomized order whilst the task instructions were presented in a set order, as shown below. Abbreviated names for the task instructions are shown in brackets. C stands for characters, CL stands for characters and location, and CLA stands for characters, location, and activities.

1. Remember as much as you can about this scene (Implicit Free-Viewing task).
2. Remember which characters are in the scene (C task, one element to be remembered).
3. Remember which characters are in the scene and where they are (CL task, two elements to be remembered).
4. Remember which characters are in the scene, where they are, and what they are doing (Explicit CLA task, three elements to be remembered).

For the Implicit Free-Viewing task, the instruction does not directly prompt participants to remember specific elements of the scene. This implicit instruction is presented first to avoid participants adopting viewing patterns for the more explicit instructions in this implicit condition. In the C, CL, CLA tasks, participants were directly instructed to attend to specific elements of the scene and the number of elements to remember increased progressively. In the C task one element, participants had to remember the characters in the scene. In the CL task, participants were required to remember two elements including the characters and their locations. Finally, in the CLA task, participants were required to remember three elements of the scene, including the characters, their locations, and the activities they were carrying out. Note that the CLA task is also named the explicit task and provides a comparison for the implicit task where no direct instruction with relation to remembering the specific categories of elements in the scene was given.

Two comparisons were made in the current study. The first comparison were a mixed design, with Task (implicit versus explicit) as the within participants variables, and Group as the between participants variable. The second comparison were also a mixed design but with Task (one versus two versus three elements to remember) as the within participants variables, and Group as the between participants variable. Two memory measures were recorded; these were immediate recall and delayed recall. The dependent variables for the recall tasks were therefore recall scores for character, location, and activity. For the eye movement analysis, the dependent variables were total viewing time, number of fixations, elapsed time to target, and fixation count to target, for the head, body, and object interest areas in the scenes.

Procedure

Participants gave consent to participate in writing. The participants read some general instructions about the eye-tracking experiment which made it clear that they would be viewing four family scenes, each under a different task instruction, and that it was important for them to keep the instruction in mind while viewing the scenes as they would be asked some questions about the scenes the at end of the experiment. Participants were introduced to what each of the family members looked like by initially presenting a picture of the family members on screen. The experimenter pointed to and named each character in the family picture. After that, the experimenter pointed to each character again and this time asked the participant to name the characters, in order to ensure that participants recognized each of the characters in the family.

Eye-tracking task. For the eye movement recording participants were seated in a dark room facing the monitor. Before the presentation of each picture, a fixation dot appeared at the centre of a white screen and participants were asked to look at this dot. This allowed the experimenter to see whether the eye-tracker was capturing the location of participant's fixation accurately and therefore recalibrate if necessary. Once the participants' point of fixation matched this dot satisfactorily, the experimenter pressed the "Enter" key to initiate each trial. Participants were given a task instruction on the display screen and pressed a button to indicate when they had finished reading this, which then triggered the presentation of the scene. The scenes were presented for 10 seconds each, according to the procedures of the original Family Pictures subtest (Wechsler, 1997).

Immediate recall task. Once participants had viewed all four scenes, they were shown four quadrants labeled 1, 2, 3, and 4 on the computer screen filling the area in which the scene was presented (see Figure 5.1).

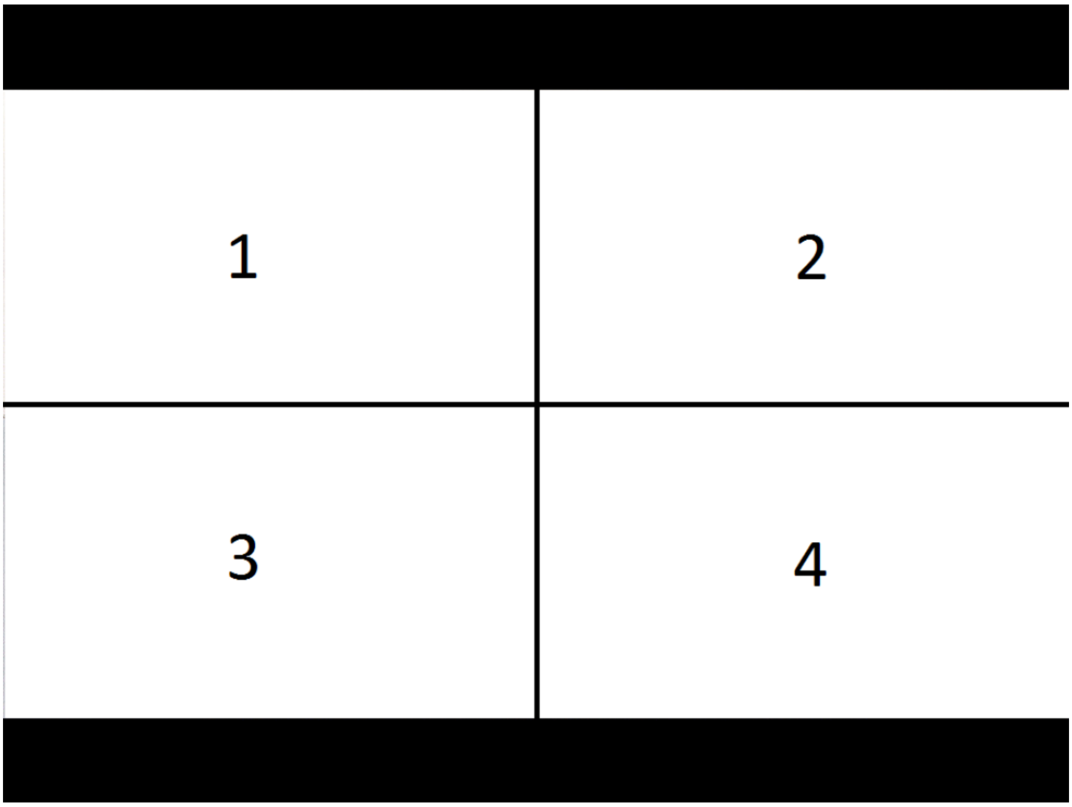

Figure 5.1. Testing Grid for immediate recall and delay recall.

The experimenter prompted the participant to recall each of the scenes by saying, “In the (first, second, third, fourth) scene you saw, the family was having a picnic/was in the department store/was in the garden/was having a meal” in the order the scenes were shown to the participants. For each of the scenes, the experimenter asked the participant, “Who was in the [*department store, garden, meal and a picnic*] scene”? Once the participant had named the characters they thought were the scene, the experimenter pointed to the testing grid on the screen and said, “Pretend this is the [*name of the scene*]. You said [*name the character identified by the participant*] was in this scene. On the screen, point to where that character was in the picture”. The experimenter then said “Now tell me what [*name the character identified by the participant*] was doing”. This was repeated for each character named by the participant. Then the experimenter asked “Were there any other characters in this scene?” If the participant said there were additional characters in the scene, the participant was asked the characters' location, and activities they were engaging in. The experimenter proceeded to prompt recall about the other scenes when the participant said there were no other characters in the first scene. After recall was completed for each of the scenes, the experimenter told the participant that they would be asked questions about these scenes again later and that they should try to remember them.

Delayed recall task. After a break of approximately 30 minutes where participants engaged in another unrelated task, participants were again prompted to recall the family scenes they were shown earlier. The procedure of delayed recall was the same as for the immediate recall condition in which participants had to try and recall which characters were in the scenes, where they were, and what they were doing. Inclusion of both immediate and delayed recall condition will reveal whether impaired memory performance in ASD, if any, is related working memory deficits and inability to modulate attention to the stimuli according to task instructions, or decline in long term memory.

At the end of the experiment participants were debriefed and given a monetary reward. The experiment lasted approximately 30 minutes.

5.3 Results

Immediate Recall Results

The original method for calculating scale scores in the WMS-III (Wechsler, 1997) across all the trials was not used in the current experiment as the task instructions had been varied for each of the picture trials. Therefore, and because each scene was presented for the same duration, the raw scores are reported for each condition. The scores for immediate recall are presented in Table 5.2. Participants received one point for each of the characters correctly recalled, and one point if the location of the character was correctly recalled. The maximum score for the activity was two points: one for correctly identifying the action and a second point for correctly identifying the object of the action.

Table 5.2.

Immediate Recall Scores

		Character		Location		Activity		Total	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit Free-viewing	TD	3.45	0.60	2.50	1.36	4.75	2.22	10.70	3.76
	ASD	3.53	0.62	3.29	0.99	4.29	2.17	11.12	3.44
C	TD	3.45	0.69	2.55	1.36	2.25	2.22	8.25	3.54
	ASD	2.82	0.88	1.71	1.26	1.76	1.35	6.29	2.59
CL	TD	3.30	0.80	2.35	1.46	2.75	2.15	8.40	3.66
	ASD	3.06	0.90	2.47	1.33	3.24	2.36	8.76	3.91
Explicit CLA	TD	3.55	0.69	3.20	1.11	5.05	2.33	11.80	3.65
	ASD	3.29	0.92	2.76	1.09	3.76	2.36	9.82	3.83

The immediate recall results for both implicit vs explicit comparison and number of elements comparisons are illustrated in the Figure 5.2.

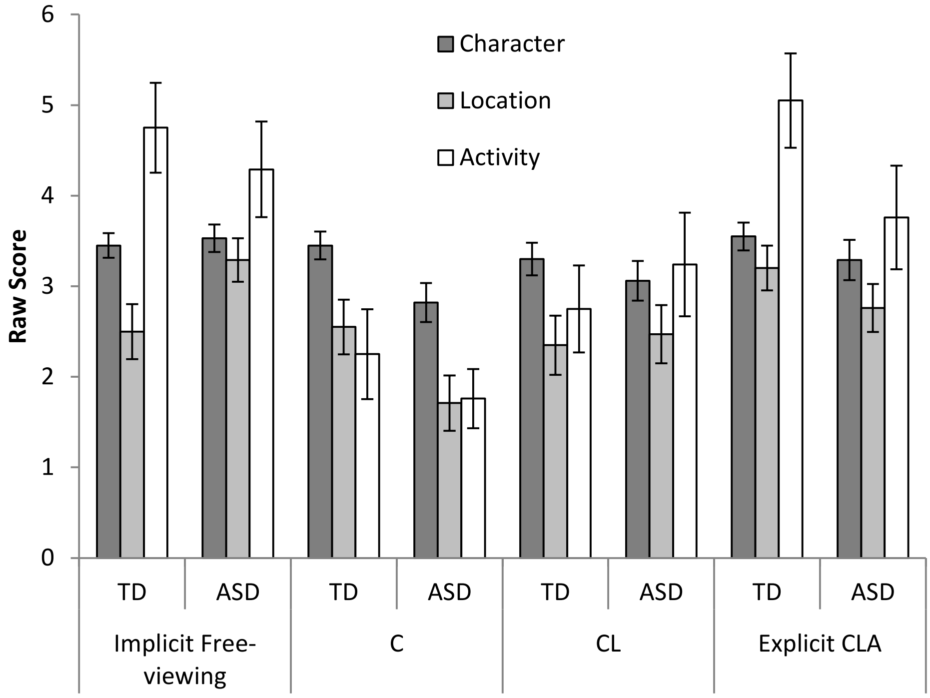

Figure 5.2. Raw scores for immediate recall for each scene element for each task. Error bars represent ± *SEM*.

Implicit vs explicit. It was predicted that the ASD group would show disproportionately greater impairment in recall performance for the implicit task compared to the explicit task, in comparison to TD participants. Scores for each element (character, location, and activity) are analysed separately to see if any differences in immediate recall is associated with a certain element. Some suggestion from previous research (Riby & Hancock, 2008) indicates that individuals with ASD look less at faces during free-viewing of social scenes, therefore one possibility is that for the implicit task they would be worse at recalling characters compared to TD participants. Consequently, location score and activity scores would be lower too for the ASD group compared to the TD group, because these scores are only scored as being accurate if the correct character is associated with the correct location or the correct activity.

A three-way 2 (Task: Implicit vs Explicit) x 3 (Elements: Character, Location, Activity) x 2 (Group: TD vs ASD) ANOVA was carried out on immediate recall scores for different element of the scenes to investigate whether performance varied across tasks and group. Only significant effects are reported in this section and for all subsequent three-way ANOVAs. There was a significant main effect of Elements, $F(2, 70) = 35.8$, $p < .001$, $\eta_p^2 = .505$, indicating that immediate recall score varied between different elements. This is because for each picture, the maximum character score is four, the maximum location score is four, whereas the maximum activity score is 8. There was also a significant interaction between Element and Group, $F(2, 70) = 4.43$, $p = .016$, $\eta_p^2 = .112$, suggesting that immediate recall scores for the different Elements varied between the two participant groups.

To further investigate how the number of elements varied for each group a 2 (Task: Implicit vs Explicit) x 2 x (Group: TD vs ASD) ANOVA was carried out on the immediate recall scores for each element of the scenes to be remembered separately.

Character. There was no significant main effect of Task, $F(1, 35) = .219$, $p = .643$, np2 = .006, no significant main effect of Group, $F(1, 35) = .225$, $p = .638$, $\eta_p^2 = .006$, and no significant interaction between Task and Group, $F(1, 35) = 1.35$, $p = .254$, $\eta_p^2 = .037$.

Location. There was no significant main effect of task, $F(1, 35) = .133$, $p = .718$, $\eta_p^2 = .004$, no significant main effect of Group, $F(1, 35) = .360$, $p = .553$, $\eta_p^2 = .010$, but there was a significant interaction between Task and Group, $F(1, 35) = 6.90$, $p = .013$, $\eta_p^2 = .165$, suggesting that difference between location immediate recall score for the two tasks varied dependent on groups. Pairwise comparisons with Bonferroni correction ($\alpha = .025$) indicated that there was a trend that the TD group was scoring higher for the explicit task compared to the implicit task, however this was not significant, $t(19) = 2.15$, $p = .044$. There was no significant difference between the two tasks within the ASD group, $t(16) = 1.59$, $p = .132$. The results show that the direction of the interaction is not as predicted, that is, that the ASD group would have more difficulty for the implicit task compared to the explicit task. Furthermore, because the pairwise comparison was not significant the interaction could be due to variability and Type One Error.

Activity. There was no significant main effect of Task, $F(1, 35) = .050$, $p =. 824$, $\eta_p^2 = .001$, Group, $F(1, 35) = 2.53$, $p =.121$, $\eta_p^2 = .067$, and no interaction between Task and Group, $F(1, 35) = .658$, $p = .423$, np2 = .018.

Summary. Contrary to the prediction, the findings for immediate recall indicated that varying the explicitness of task instruction produced similar patterns in recall of the different elements within each participant group. Participants with ASD were not particularly poorer at immediate recall compared to TD participants when given an implicit instruction.

Number of elements. For TD participants, it was expected that recall scores for each element would be modulated by the task instructions; in other words, they should display better recall scores when then the task instructions specifically demanded that participants remember those elements. So, recall scores for the location element should be higher for the CL and CLA task compared to the C task. Also, recall score for the activity element should be higher for the CLA task compared to the CL and C task. For the ASD participants, it is predicted that they would perform worse than the TD group as the number of elements to remember increases. Specifically, participants with ASD may show lower recall scores for the location element for the CL and CLA task, and they should also show lower recall score for the activity element for the CLA task compared to TD participants.

A three-way 3 (Task: C, CL, CLA) x 3 (Element: Character, Location, Activity) x 2 (Group: TD vs ASD) ANOVA was computed. There was a significant main effect of Task, $F(2, 70) = 11.6$, $p < .001$, $\eta_p^2 = .249$, a significant main effect of Element $F(2, 70) = 9.73$, $p < .001$, $\eta_p^2 = .218$, and a significant interaction between Task and Element, $F(4, 140) = 9.56$, $p < .001$, $\eta_p^2 = .215$, indicating that immediate recall scores for different elements varied according to the task instruction.

To further investigate how the immediate recall for each element varied within each participant group and across tasks in which participants were instructed to remember an increasing number of elements, a 3 (Task: C, CL, CLA) x 2 (Group: TD, ASD) ANOVA was conducted for each element.

Character. There was no significant main effect of Task, $F(2, 70) = 1.54$, $p = .221$, $\eta_p^2 = .042$, but there was a significant main effect of Group, $F(1, 35) = 4.58$, $p = .039$, $\eta_p^2 = .116$, suggesting that participants in the TD group ($M = 3.43$, $SE = .119$) achieved higher character scores than the ASD group ($M = 3.06$, $SE = .129$) overall across the three tasks. There was no significant interaction between Task and Group, $F(2, 70) = .777$, $p =.464$, $\eta_p^2 = .022$.

Location. There was a significant main effect of Task, $F(2, 70) = 4.13$, $p = .020$, $\eta_p^2 = .106$, showing increased location scores as the number of elements to remember increased across tasks (C: $M = 2.128$, $SE = .217$, CL: $M = 2.41$, $SE = .231$, CLA: $M = 2.98$, $SE = .181$). There was no significant main effect of Group, $F(1, 35) = 2.687$, $p = 110$, *np2* = .071, and no interaction between Task and Group, $F(2, 70) = 1.28$, $p = .285$, $\eta_p^2 = .035$.

Activity. There was a significant main effect of Task, $F(2, 70) = 15.5$, $p < .001$, $\eta_p^2 = .307$, suggesting that activity scores increased as the number of task elements to remember increased (C, $M = 2.01$, $SE = .309$, CL: $M = 2.99$, $SE = .371$, CLA: $M = 4.41$, $SE = .386$). There was no significant main effect of Group, $F(1, 35) = .707$, $p = .406$, $\eta_p^2 = .020$, and no interaction between Task and Group, $F(2, 70) = 2.099$, $p = .130$, $\eta_p^2 = .057$.

Summary. The results show that as the number of elements to remember increased, location and activity scores increased across all participants. This was what was expected, as the later task directly requested participants to remember the location of the characters (CL task), and the activities that they were carrying out (CLA task). A significant group difference was found, where the ASD group scored significantly lower on the character score compared to the TD group across the C, CL, and CLA tasks, regardless of the number of elements to remember. This is inconsistent with the prediction that participants with ASD would show incrementally impaired recall performance for increasing numbers of elements to remember. Analyses on delayed recall scores are presented next to check if the effects found for immediate recall were consistent, and to see if they extended to delayed recall.

Delayed Recall Results

The scores for delayed recall are presented in Table 5.3. Predictions for this measure follow that of immediate recall, and this analysis verifies whether any differences observed for immediate recall are reliable and persist across time.

Table 5.3
Delayed Recall Raw Scores

		Character		Location		Activity		Total	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit Free-viewing	TD	3.45	0.69	2.35	1.53	4.30	2.45	10.10	4.23
	ASD	3.47	0.62	2.88	1.11	4.29	2.52	10.65	3.64
C	TD	3.35	0.88	2.60	1.39	2.15	2.37	8.10	3.81
	ASD	2.88	1.05	2.12	1.36	1.82	1.70	6.82	2.94
CL	TD	3.45	0.69	2.30	1.59	2.60	1.98	8.35	3.42
	ASD	3.18	0.73	2.35	1.37	3.76	2.46	9.29	3.95
Explicit CLA	TD	3.35	1.04	3.05	1.32	4.80	2.19	11.20	4.19
	ASD	3.41	0.80	2.71	1.31	4.18	2.35	10.29	3.77

The delayed recall results for both implicit vs explicit comparison and number of elements comparisons are illustrated in the Figure 5.3.

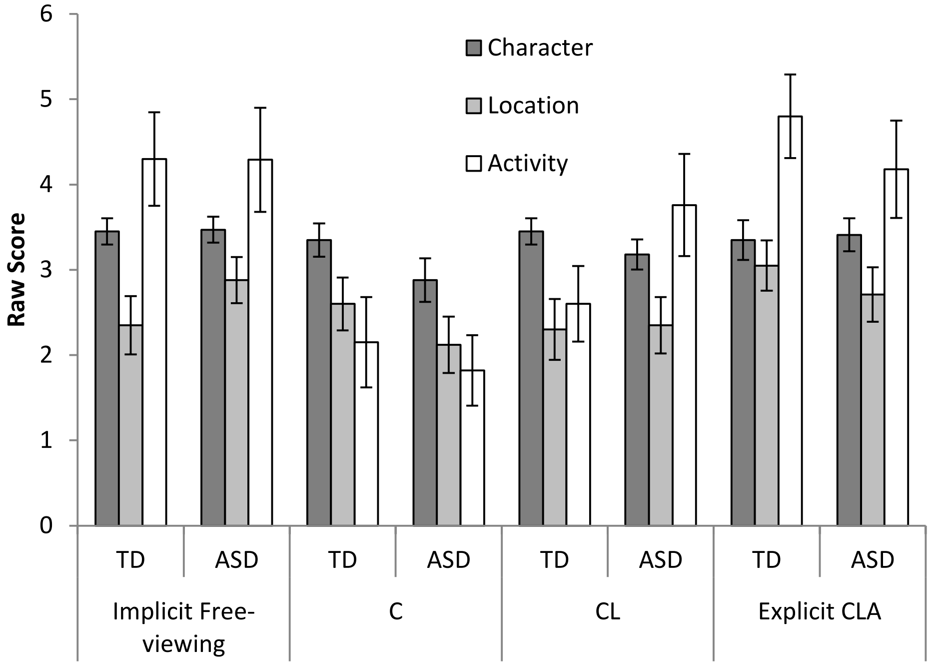

Figure 5.3. Raw score for delayed recall for each scene element for each task. Error bars represent ± *SEM*.

Implicit vs explicit. A three-way 2 (Task: Implicit vs Explicit) x 3 (Elements: Character, Location, Activity) x 2 (Group: TD vs ASD) ANOVA was carried out on delayed recall scores for different element of the scenes to investigate whether performance varied across tasks and group. A three-way ANOVA revealed significant main effect of Elements, $F(2, 70) = 36.9$, $p = .001$, $\eta_p^2 = .513$, indicating that recall score varied for the different elements. None of the other main effects and interactions were significant, *p*s > .10. A 2 (Task; Implicit vs Explicit) x 2 (Group: TD vs ASD) ANOVA was carried out on the recall scores for each element separately.

Character. There was no significant main effect of Task $F(1, 35) = .190$, $p = .666$, $\eta_p^2 = .005$, Group $F(1, 35) = .045$, $p = .834$, $\eta_p^2 = .001$, and no significant interaction between Task and Group, $F(1, 35) = .013$, $p = .911$, $\eta_p^2 < .001$.

Location . There was no significant main effect of Task, $F(1, 35) = .811$, $p = .374$, $\eta_p^2 = .023$, no significant main effect of Group, $F(1, 35) = .081$, $p = .778$, $\eta_p^2 = .002$, and no interaction between Task and Group, $F(1, 35) = 2.27$, $p = .141$, $\eta_p^2 = .061$.

Activity. There was no significant main effect of Task, $F(1, 35) = .120$, $p = .731$, $\eta_p^2 = .003$, Group, $F(1, 35) = .319$, $p = .576$, $\eta_p^2 = .009$ and no interaction between Task and Group, $F(1, 35) = .314$, $p = .579$, $\eta_p^2 = .009$.

Summary. The results for delayed recall revealed that, as for immediate recall, explicitness of the task instruction did not influence how the two different groups performed.

Number of elements. A three-way 3 (Task: C, CL, CLA) x 3 (Element: Character, Location, Activity) x 2 (Group: TD vs ASD) ANOVA was computed. There was a significant main effect of Task, $F(2, 70) = 8.66$, $p < .001$, $\eta_p^2 = .198$, a significant main effect of Elements, $F(2, 70) = 11.3$, $p < .001$, $\eta_p^2 = .243$, and these main effects were qualified by a significant interaction between Task and Element, $F(4, 140) = 10.6$, $p < .001$, $\eta_p^2 = .232$. This interaction showing that delayed recall scores varied across task depending on the element that had to be remembered. To further investigate how the delayed recall score for each of the elements varied within each participant groups and across tasks in which participants were instructed to remember increasing number elements, a 3 (Task: C, CL, CLA) x 2 (Group: TD, ASD) ANOVA was conducted for each element.

Character. There was no significant main effect of Task, $F(2, 70) = 1.01$, $p = .369$, $\eta_p^2 = .028$, Group, $F(1, 35) = 1.52$, $p = .224$, $\eta_p^2 = .042$, or interaction between Task and Group, $F(2, 70) = .958$, $p = .388$, $\eta_p^2 = .027$.

Location. There was no significant main effect of Task, $F(2, 70) = 1.77$, $p = .178$, $\eta_p^2 = .048$, Group, $F(1, 35) = .975$, $p = .330$, $\eta_p^2 = .027$, and no interaction between Task and Group, $F(2, 70) = .357$, $p = .701$, $\eta_p^2 = .010$.

Activity. There was a significant main effect of Task, $F(2, 70) = 14.9$, $p < .001$, $\eta_p^2 = .299$, showing that activity score increase as the number of elements to remember increases across task, (C: $M = 1.99$, $SE = .345$, CL: $M = 3.18$, $SE = .365$, CLA: $M = 4.49$, $SE = .374$). There was no significant main effect of Group, $F(1, 35) = .021$, $p = .885$, $\eta_p^2 = .001$, and no interaction between Task and Group, $F(2, 70) = 2.19$, $p = .120$, $\eta_p^2 = .059$.

Summary. The delayed recall results for varying the number of elements to remember slightly differed from the immediate recall findings. Only activity scores (but not location scores) increased as the number of elements to remember increased, reflecting the fact that participants were only directly asked to remember the activities of the character in the CLA task. For the immediate recall condition the ASD group had lower character scores compared to the TD group across all three tasks (C, CL, CLA), however this main effect of group is not significant in the delayed recall condition. The results for delayed recall are inconsistent with the prediction that participants with ASD will show increasingly impaired recall performance as the number of elements to remember increased.

Baseline Eye Movement Measures

Baseline eye movement measures were calculated across the four conditions for eye movements made during the whole trial period. There were no between-group differences in total viewing time, $t(35) = .315$, $p = .755$, total number of fixations, $t(35) = .310$, $p = .759$, mean fixation duration, $t(35) = .853$, $p = .400$, first saccade latency, $t(35) = .763$, $p = .450$, or saccade amplitude, $t(35) = 1.41$, $p = .168$, indicating that there are no between-group differences in basic sampling and oculomotor control that could be driving any observed experimental effects. See Table 5.4 for the descriptive statistics.

Table 5.4

Descriptive Statistics for Baseline Eye Movement Measures.

Measure	Group	*M*	*SD*
Total Viewing Time (ms)	TD	8212.14	382.76
	ASD	8252.54	396.96
Number of Fixations	TD	30.54	4.53
	ASD	29.99	6.29
Mean Fixation Duration (ms)	TD	279.77	47.74
	ASD	301.91	104.18
First Saccade Latency (ms)	TD	219.03	60.89
	ASD	233.48	52.92
Saccade Amplitude (°)	TD	4.38	0.65
	ASD	4.71	0.78

Regions of Interest Analysis

Three types of regions of interest were created using the DataViewer freehand interest area tool. The heads of the characters, their bodies, and the objects related to their activities were outlined separately for the regions of interest analysis. Two global eye movement measures including total viewing time and number of fixations were reported. Global eye movement measures are a reflection of the importance of different targets in the scene in relation to the task being carried out. The greater the total viewing time and the number of fixations indicates more attention allocation and more effortful processing to the targets being attended to, and this is generally linked to better memory for those targets (Kaakinen et al., 2011). Two early eye movement measures were also reported, these included elapsed time to target and fixation count to target. These early eye movement measures can inform about early orienting towards the targets. Short elapsed time and low fixation count meant that a viewer spent less time exploring and processing other parts of the scene before a target captured their attention, and this is an indication of attentional priority for that target.

For the explicit versus implicit comparison, it was predicted that TD participants would show the same modulation of eye movements to the different targets across explicit and implicit tasks. It was expected that participants with ASD would show the same modulation of eye movements as TD participants to the different targets when an explicit instruction was given, but not when an implicit instruction was given. This means that the ASD group might spend less time inspecting, and make fewer fixations to, the task relevant targets, as well as taking longer and making more fixations in other regions before they fixate the task relevant targets, for the implicit task. As for the recall predictions, it was expected that participants with ASD may give less attention to faces and prioritise faces less compared to TD participants for the implicit task (Riby & Hancock, 2008), and instead focus on other features such as bodies of the characters and objects in the scene. In other words, the ASD group was expected to display shorter total viewing time, a smaller number of fixations, along with greater elapsed time and fixation count before first fixating the head interest areas compared to TD participants, and to show the reverse pattern for bodies and objects.

For the number of elements comparison, it was predicted that TD participants would modulate their eye movements depending on the number and type of elements they were asked to remember to the three different tasks, namely, the C task, CL task, and the CLA task. Specifically, participants should give more attention and priority to faces (greater total viewing time and number of fixations to heads, shorter elapsed time and smaller fixation count to begin to fixate heads) for the C task compared to the CL task and CLA task in which participants were directly instructed to allocate attention to people, objects, or activities in order to remember these other elements in the scene. In addition, participants should also give more attention and priority to object interest areas for the CLA task (which require participants to remember what activity the characters are engaging in) compared to the C and CL tasks. It was expected that participants with ASD would show ineffective strategies when inspecting the scenes that would become more apparent as the number of elements to remember increased, as this was thought to put a greater demand on processing capacity. Specifically, ASD participants would show the same attention and priority as TD participants for heads for the C task, but an an impairment in modulating and dividing attention to other regions for the CL and CLA tasks compared to TD participants.

Total viewing time. The descriptive statistics for total viewing times in each condition are presented in Table 5.5.

Table 5.5.

Descriptives Statistics for Total Viewing Time (ms)

		Head		Body		Object	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit	TD	2209.20	1303.05	1052.55	916.50	2260.95	1079.96
Free-viewing	ASD	2225.59	1628.08	935.41	854.34	2297.53	810.72
C	TD	3782.95	1847.44	744.55	689.97	1135.05	896.09
	ASD	3773.53	2399.99	1045.00	776.91	780.59	708.20
CL	TD	3574.05	1919.40	1006.85	834.41	1239.95	950.10
	ASD	2555.71	1987.18	1231.06	1019.54	1376.59	967.20
Explicit CLA	TD	2181.80	985.16	1218.55	778.63	1630.50	836.43
	ASD	2031.12	1536.46	1413.00	1182.23	2008.00	1328.25

The results for total viewing time are illustrated in Figure 5.4.

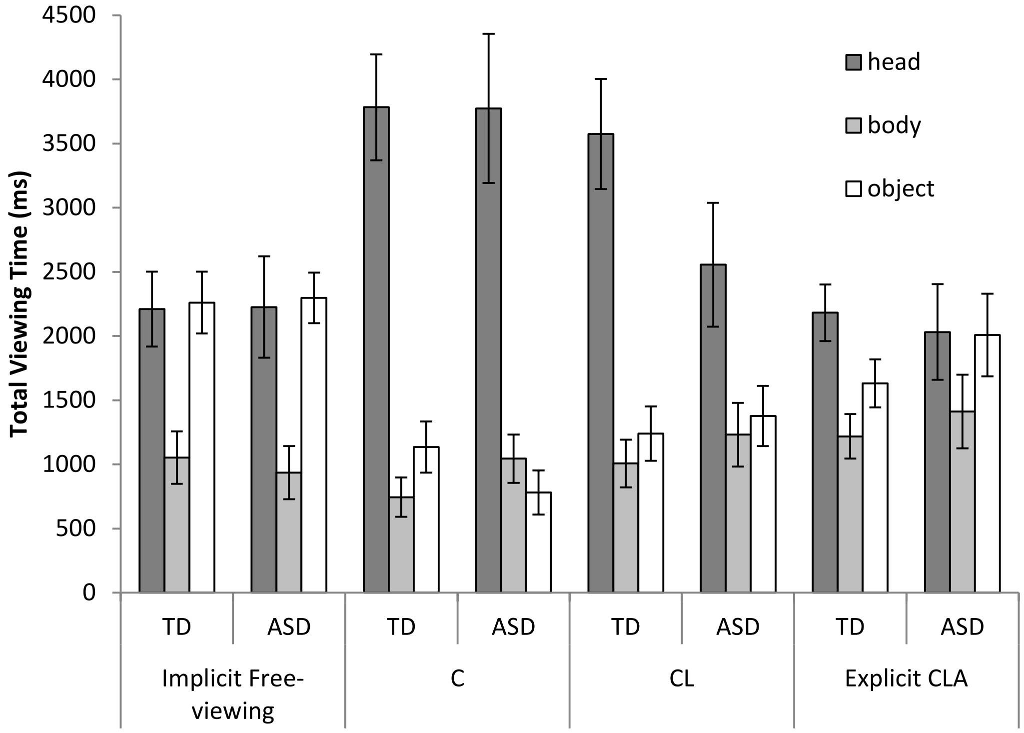

Figure 5.4. Total viewing time for each region of interest for each task. Error bars represent ± *SEM*.

Implicit vs explicit. A three-way 2 (Task: Implicit vs explicit) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA was computed. Only significant effects are reported here, and this applies to all three-way ANOVAs for subsequent eye movement measures analysed. There was a significant main effect of Interest Area, $F(2, 70) = 11.7$, $p < .001$, $\eta_p^2 = .250$. Specifically, participants spent more time on heads (M = 2161 ms, SE = 178) and objects (M = 2049 ms, SE = 112) than on bodies (M = 1155 ms, SE = 129) across the implicit and explicit tasks. None of the other main effects and interactions was significant. To further investigate how the amount of time spent in each region varied across task and participant group, a 2 (Task: explicit vs implicit) x 2 (Group: TD, ASD) ANOVA was conducted for each interest area.

Head. There was no significant main effect of Task $F(1, 35) = .161$, $p = .691$, $\eta_p^2 = .005$, no main effect of Group, $F(1, 35) = .036$, $p = .852$, $\eta_p^2 = .001$, and no significant interaction between Task and Group, $F(1, 35) = .091$, $p = .785$, $\eta_p^2 = .003$.

Body. There was no significant main effect of Task, $F(1, 35) = 3.57$, $p = .067$, $\eta_p^2 = .093$, no significant main effect of Group, $F(1, 35) = .022$, $p = .882$, $\eta_p^2 = .001$, and no interaction between Task and Group, $F(1, 35) = .836$, $p = .367$, $\eta_p^2 = .023$.

Object. There was no significant main effect of Task, $F(1, 35) = 3.25$, $p =.080$, $\eta_p^2 = .085$ (small effect size), no main effect of Group, $F(1, 35) = .853$, $p = .362$, $\eta_p^2 = .024$, and no interaction between Task and Group, $F(1, 35) = .446$, $p = .508$, $\eta_p^2 = .013$.

Summary. The overall result for total viewing time showed similar viewing times between the ASD and the TD group in the three interest areas regardless of implicitness of previewing task instructions.

Number of Elements. A three-way 3 (Task: C, CL, CLA) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA was computed. There was a significant main effect of Interest Area, $F(4, 140) = 39.4$, $p < .001$, $\eta_p^2 = .530$ and a significant interaction between Task and Interest Area, $F(4, 140) = 9.52$, $p < .001$, $\eta_p^2 = .214$, indicating that the amount of time spent in different interest areas varied across tasks. To further investigate how the amount of time spent in each region varied across tasks with increasing number elements to remember and within each participant groups, a 3 Task (C, CL, CLA) x 2 (Group :TD, ASD) ANOVA was conducted for each interest area.

Head. There was a significant main effect of task, $F(2, 70) = 9.50$, $p < .001$, $\eta_p^2 = .213$, which showed that the amount of time spent fixating the heads decreased as the number of elements to remember increased across tasks (C: $M = 3778$ ms, $SE = 349$, CL: $M = 3064$ ms, $SE = 322$, CLA : $M = 2106$ ms, $SE = 209$). There was no significant main effect of Group, $F(1, 35) = .956$, $p = .335$, $\eta_p^2 = .027$, and no significant interaction between Task and Group, $F(2, 70) = 1.01$, $p = .371$, $\eta_p^2 = .028$.

Body. There was no significant main effect of Task, $F(2, 70) = 2.60$, $p = .081$, $\eta_p^2 = .069$ (small; effect size), no significant main effect of Group, $F(1, 35) = 1.44$, $p = .238$, $\eta_p^2 = .039$, and no significant interaction between Task and Group, $F(2,70) = .044$, $p = .957$, $\eta_p^2 = .001$.

Object. There was a significant main effect of Task, $F(2, 70) = 7.72$, $p = .001$, $\eta_p^2 = .181$, which showed that the amount of time spent fixating the objects increased as the number of elements to remember across tasks increased (C: $M = 958$ ms, $SE = 135$; CL: $M = 1308$ ms, $SE = 158$; CLA: $M = 1819$ ms, $SE = 180$). There was no significant main effect of Group, $F(1, 35) = .080$, $p = .780$, $\eta_p^2 = .002$, and no significant interaction between Task and Group, $F(2, 70) = 1.43$, $p = .246$, $\eta_p^2 = .039$.

Summary. The results showed that as the number of elements to remember increased, less time was spent looking at the head interest areas and more time was spent looking at the object interest areas, reflecting the difference in allocation to and processing of different scene elements in relation to different demands across tasks. The C task only required participants to remember the characters whereas the CLA task required participants to remember the characters as well as activities carried out by the characters. Therefore, and in contrast with the predictions, participants with ASD showed no impairments for the implicit task, and they were able to modulate their eye movements to the task relevant targets according to the specific task instructions, requiring them to remember an increasing number of elements in the scenes.

Number of Fixations. The descriptive statistics for total number of fixations are presented in Table 5.6.

Table 5.6

Descriptive Statistics for Total Number of Fixations

		Head		Body		Object	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit Free-viewing	TD	8.20	4.55	4.35	3.03	8.15	3.31
	ASD	7.76	5.62	4.18	3.23	7.82	3.56
C	TD	11.25	4.97	3.55	2.67	4.45	3.38
	ASD	11.82	7.03	4.76	3.27	3.53	3.18
CL	TD	11.25	5.76	4.10	2.79	4.80	3.47
	ASD	7.53	5.33	4.88	3.35	4.82	2.96
Explicit CLA	TD	6.65	3.92	5.20	2.67	6.40	3.27
	ASD	6.53	4.90	5.47	4.47	7.00	4.27

Results for the number of fixations are illustrated in Figure 5.5.

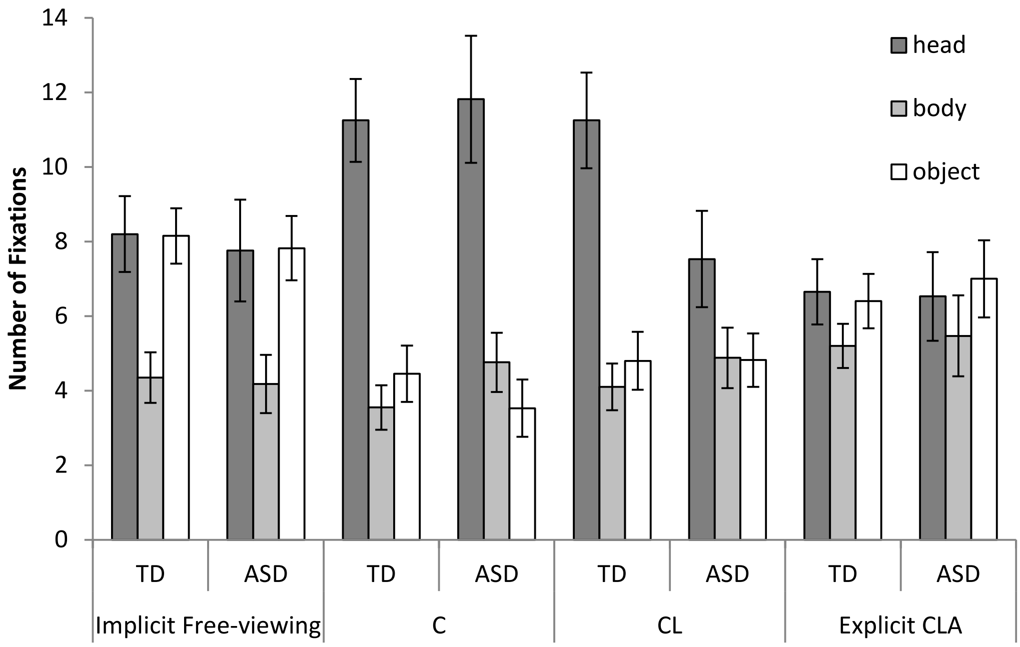

Figure 5.5. Number of fixations for each region of interest for each task. Error bars represent ± *SEM*.

Implicit vs explicit. A three-way 2 (Task: Implicit vs explicit) x 3 (Interest Area (Head, Body, Object) x 2 (Group :TD vs ASD) ANOVA revealed a significant main effect of Interest Area, $F(2, 70) = 7.87$, $p = .001$, $\eta_p^2 = .184$. None of the other main effects and interactions involving Task and Group were significant. In line with the total viewing time measure, participants made more fixations to the heads (*M* = 7.29, *SE* = .598) and objects (*M* = 7.34, *SE* = .461) than the bodies (*M* = 4.80, *SE* = .451) across the two tasks. A 2 Task: explicit vs implicit) x 2 (Group: TD, ASD) ANOVA was conducted for each interest area to further examine whether, and how the number of fixations in each interest area varied across tasks and groups.

Head. There was no significant main effect of Task, $F(1, 35) = 1.91$, $p = .176$, $\eta_p^2 = .052$, no significant main effect of Group, $F(1, 35) = .054$, $p = .818$, $\eta_p^2 = .002$, and no significant interaction between Task and Group, $F(1, 35) = .024$, $p = .877$, $\eta_p^2 = .001$.

Body. There was no significant main effect of Task, $F(1, 35) = 2.72$, $p = .108$, $\eta_p^2 = .072$, no significant main effect of Group, $F(1, 35) = .003$, $p = .957$, $\eta_p^2 = .001$, and no significant interaction between Task and Group, $F(1, 35) = .117$, $p = .735$, $\eta_p^2 = .003$.

Object. There was no significant main effect of Task, $F(1, 35) = 2.97$, $p = .093$, $\eta_p^2 = .078$, no significant main effect of Group, $F(1, 35) = .022$, $p = .883$, $\eta_p^2 = .001$, no significant interaction between Task and Group, $F(1, 35) = .385$, $p = .539$, $\eta_p^2 = .011$.

Summary. The overall results for number of fixations mirrored those for total viewing time. Number of fixations in each region for both groups did not vary dependent on the explicitness of task instruction.

Number of elements. A three-way 3 (Task: C, CL, CLA) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA was computed. In line with total viewing time measure, a three-way ANOVA revealed a significant main effect of Interest Area, $F(2, 140) = 30.5$, $p < .001$, $\eta_p^2 = .466$, and a significant interaction between task and Interest area , $F(4, 140) = 8.95$, $p < .001$, $\eta_p^2 = .204$, indicating that the number of fixations made in different interest areas varied across tasks. To further investigate how the number of fixations made in each interest area varied across tasks with increasing number elements to remember, and participant groups, a 3 (Task: C, CL, CLA) x 2 (Group: TD, ASD) ANOVA was conducted for each interest area.

Head. In line with the total viewing time measure, there was a significant main effect of Task, $F(2, 70) = 8.35$, $p = .001$, $\eta_p^2 = .193$. Participants made progressively fewer fixations to the head interest areas as the number of elements to remember increased across tasks (C: *M* = 11.5, *SE* = .990, CL: *M* = 9.39, *SE* = .918, CLA: *M* = 6.59, *SE* = .725). There was no significant main effect of Group, $F(1, 35) = 1.02$, $p = .320$, $\eta_p^2 = .028$, and no significant interaction between Task and Group, $F(2, 70) = 1.80$, $p = .172$, $\eta_p^2 = .049$.

Body. There was no significant main effect of Task, $F(2, 70) = 1.62$, $p = .205$, $\eta_p^2 = .044$, Group, $F(1, 35) = 1.09$, $p = .303$, $\eta_p^2 = .030$, and no interaction between Task and Group, $F(2, 70) = .246$, $p = .783$, $\eta_p^2 = .007$.

Object. In line with the total viewing time measure, there was a significant main effect of Task, $F(2, 70) = 6.52$, $p = .003$, $\eta_p^2 = .157$, which showed that participants made an increasing number of fixations to the object interest areas as the number of elements to remember increased across tasks (C: *M* = 3.99, *SE* = .543, CL: *M* = 4.81, *SE* = .536, CLA: *M* = 6.70, *SE* = .620). There was no significant main effect of Group, $F(1, 35) = .020$, $p = .889$, $\eta_p^2 = .001$, and no significant interaction between Task and Group, $F(2, 70) = .497$, $p = .610$, $\eta_p^2 = .014$.

Summary. The two groups also showed similar distributions of fixations across different tasks where the number of elements to remember varied. As the number of elements to remember increased, the number of fixations on the heads decreased, whereas the number of fixations on objects increased. This again reflects the effect of the task demand in the same way as for the total viewing time measure. Therefore, and again in contrast with the prediction, participants with ASD were not impaired at distributing their fixations to different target elements for the implicit task, and for task with an increasing number of elements to be remembered.

Elapsed time to target. Descriptive statistics for Elapsed Time to Target are presented in Table 5.7.

Table 5.7

Descriptive Statistics for Elapsed Time to Target (ms)

		Head		Body		Object	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit	TD	1327.84	1372.60	1341.84	1345.81	1319.40	1374.95
free-viewing	ASD	1122.50	1166.93	1846.67	2098.49	2365.76	2205.39
C	TD	836.20	1105.51	2670.26	2846.29	3131.39	2217.23
	ASD	791.35	468.32	1402.44	2062.28	2366.33	2596.46
CL	TD	679.26	275.08	2217.83	2781.66	1755.56	2143.66
	ASD	1281.06	1578.56	1970.29	2818.32	1116.82	1680.05
Explicit CLA	TD	1678.90	2292.23	1295.45	1323.01	1860.55	1990.11
	ASD	1079.19	918.67	1905.69	2126.37	1318.53	1756.61

The results for elapsed time to target are presented in Figure 5.6.

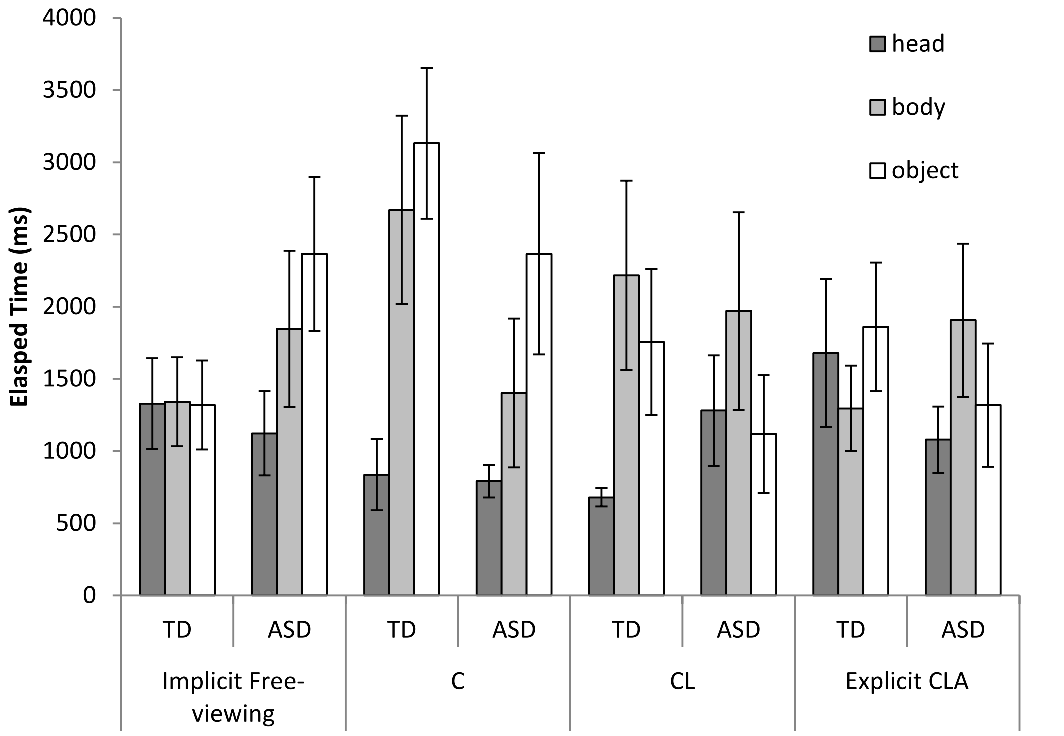

Figure 5.6. Elapsed time to target for each region of interest for each task. Error bars represent ± *SEM*.

Implicit vs explicit. A three-way 2 (Task: Implicit vs explicit) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA revealed that none of the main effects and interactions were significant all *p*s > .05.

Summary. Results for the elapsed time analyses showed that explicitness of instruction does not influence how long the two participant groups take to begin fixating the different interest areas.

Number of elements. A three-way 3 (Task: C, CL, CLA) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA revealed a significant main effect of Interest Area, $F(2, 48) = 4.03$, $p = .024$, $\eta_p^2 = .144$, showing that participants took less time to look at a head interest area (M = 1093.13 ms, SE = 192.46) for the first time compared to a body (M = 2012.41 ms, SE = 292.32) or an object interest area (M = 1880.03 ms, SE = 250.83). To further investigate how the time taken to first fixate each interest area varied across tasks with increasing numbers of elements to remember, and within each participant group, a 3 (Task: C, CL, CLA) x 2 (Group: TD, ASD) ANOVA was conducted for each interest area.

Head. There was no significant main effect of Task $F(2, 66) = 2.11$, $p = .129$, $\eta_p^2 = .060$, no significant main effect of Group, $F(1, 33) = .012$, $p = 914$, $\eta_p^2 = .001$, and no significant interaction between Task and Group, $F(2, 66) = 2.54$, $p = .087$, $\eta_p^2 = .071$.

Body. There was no significant main effect of Task $F(2, 62) = .460$, $p = .633$, $\eta_p^2 = .015$, no significant main effect of Group, $F(1, 31) = .329$, $p =.571$, $\eta_p^2 = .010$, and no significant interaction between Task and Group, $F(2, 62) = 1.49$, $p = .235$, $\eta_p^2 = .046$.

Object. There was a significant main effect of Task, $F(2, 58) = 3.829$, $p = .027$, $\eta_p^2 = .117$, indicating that participants were slower to first fixate an object target region in the C task (M = 2772 ms, SE = 433) compared to the CL (M = 1577 ms, SE = 364) and CLA task (M = 1552, SE = 346). There was no significant main effect of Group, $F(1, 29) = .853$, $p = .363$, $\eta_p^2 = .029$, and no significant interaction between Task and Group, $F(2, 58) = .012$, $p = .988$, $\eta_p^2 < .001$.

Summary. The results showed that when participants were asked to remember only the characters in the scene (C task), they were slower to fixate an object than when they were asked to also remember the location and the activity of each character. This pattern was consistent across the two participant groups. The results for elapsed time indicate that individuals with ASD were not impaired in their ability to prioritise attention to task relevant stimuli, both when an implicit instruction was given, and when there were increasing numbers of elements to remember.

Fixation Count to target. Descriptive statistics for Fixation Count to Target are presented in Table 5.8.

Table 5.8

Descriptive Statistics for Fixation Count to Target

		Head		Body		Object	
Task	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit free-viewing	TD	4.89	4.37	4.95	5.08	4.50	3.72
	ASD	4.06	3.89	6.60	7.03	7.47	6.93
C	TD	3.20	2.95	9.16	9.41	10.22	7.18
	ASD	3.47	1.55	4.69	4.70	8.43	8.05
CL	TD	2.95	1.43	6.22	7.51	5.56	5.67
	ASD	4.35	3.84	5.82	6.96	3.82	4.86
Explicit CLA	TD	6.05	7.22	5.00	4.36	6.65	6.56
	ASD	3.63	2.03	5.88	5.82	4.88	5.89

Results for fixation count to target are illustrated in Figure 5.7

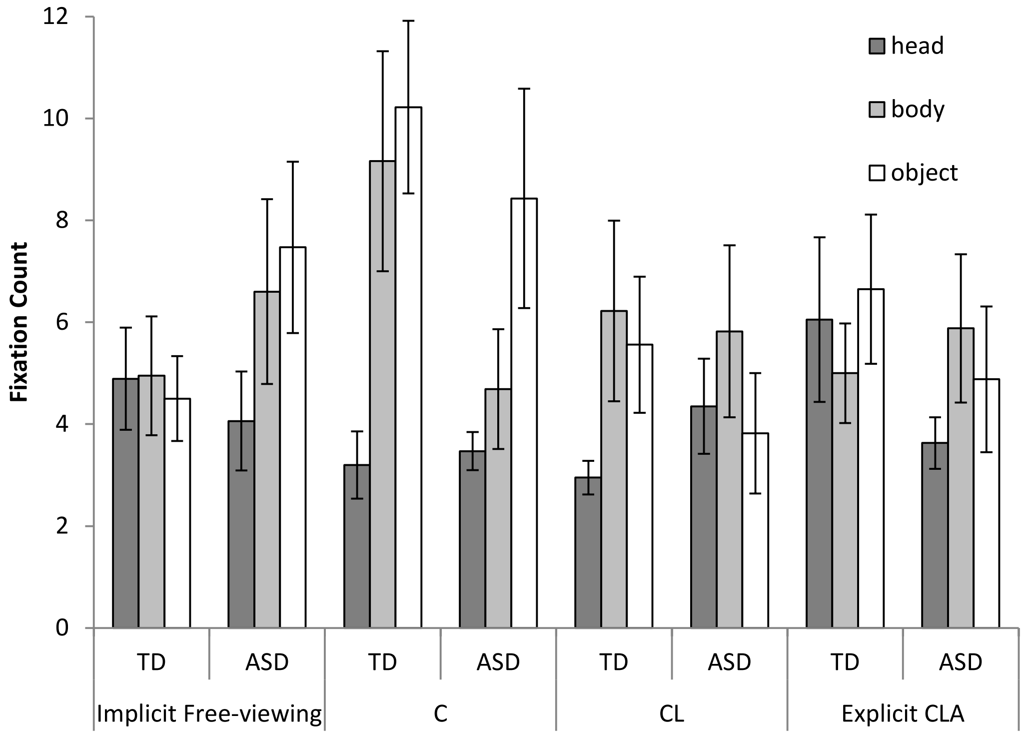

Figure 5.7. Fixation count to target for each region of interest for each task. Error bars represent ± *SEM*.

Implicit vs explicit. A three-way 2 (Task: Implicit vs explicit) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA revealed that none of the main effects and interactions were significant, *p*s >.05, suggesting that fixation count to each interest area for each group did not vary dependent on the tasks.

Summary. Results for the fixation count to target analyses are consistent with the elapsed time findings, and show that implicitness of instruction does not influence the number of fixation made by the two participant groups before they fixated the different interest areas for the first time.

Number of elements. A three-way 3 (Task: C, CL, CLA) x 3 (Interest Area: Head, Body, Object) x 2 (Group: TD vs ASD) ANOVA revealed that there was a significant main effect of Interest Area, $F(2, 48) = 3.27$, $p = .047$, $\eta_p^2 = .120$, showing that participants made fewer fixations before looking at a head interest area ($M = 4.11$, $SE = .54$) for the first time compared to a body ($M = 6.47$, $SE = .79$) or an object interest area ($M = 6.25$, $SE = .75$). To further investigate how the fixation count before reaching each interest area varied across tasks with increasing numbers of elements to remember, and within each participant group, a 3 (Task: C, CL, CLA) x 2 (Group: TD, ASD) ANOVA was conducted for each interest area.

Head. There was no significant main effect of Task, $F(2, 66) = 1.78$, $p = .176$, $\eta_p^2 = .051$, no significant main effect of Group, $F(1, 33) = .137$, $p = .713$, $\eta_p^2 = .004$, and no significant interaction between Task and Group, $F(2, 66) = 2.97$, $p = .058$, $\eta_p^2 = .083$.

Body. There was no significant main effect of Task, $F(2, 62) = .459$, $p = .632$, $\eta_p^2 = .015$, no significant main effect of Group, $F(1, 31) = 1.03$, $p = .318$, $\eta_p^2 = .032$, and no significant interaction between Task and Group, $F(2, 62) = 1.65$, $p = .200$, $\eta_p^2 = .051$.

Object. In line with the elapsed time measure, there was a significant main effect of Task, $F(2, 58) = 4.20$, $p = .020$, $\eta_p^2 = .126$, which showed that participants made more fixations before fixating an object region for the first time in the C task ($M = 9.21$, $SE = 1.38$) compared to the CL ($M = 5.13$, $SE = .991$) and CLA task ($M = 5.61$, $SE = 1.16$). There was no significant main effect of Group, $F(1, 29) = .887$, $p = .354$, $\eta_p^2 = .030$, and no significant interaction between Task and Group, $F(2, 58) = .002$, $p = .998$, $\eta_p^2 < .001$.

Summary. The results showed that when participants were asked to remember only the character in the scene (C task), they made more fixations before fixating an object than when they were asked to also remember the locations, and the activity of each character. This pattern is consistent across the two participant groups. Once again the results indicate that, in the ASD group, there were no impairments in modulating attentional priority, as reflected in initial eye movement orienting measures, to task relevant stimuli when an implicit instruction was given, and when there was an increasing number of elements to remember.

5.4 Discussion

In this experiment, participants were instructed to view each of four scenes from the family picture subtest from the WMS (Wechsler, 1997) under different task instructions. There were two different manipulations within these task instructions: one, the explicit/implicitness of the task instruction, and two, increasing the number of elements participants were told to remember. Both immediate and delay recall measures showed that neither the implicitness of the task instruction, nor increasing the number of elements to be remembered elicited poorer performance in participants with ASD compared to TD participants. Furthermore, all early and global eye movement measures showed that participants with ASD modulated their attention priority and fixation distributions in a similar way to TD participants.

Recent reports in the literature have suggested that executive dysfunction in ASD is modulated by task complexity, which could be driven by an impairment in inferring implicit information (White, 2013) as well as by increasing demands on working memory and processing capacity (Hill, 2004; Minshew et al., 2008). It was predicted in the current study that individuals with ASD would show poorer recall performance for an implicit task instruction compared to an explicit task instruction; and furthermore, it was also predicted that the ASD group would modulate their eye movements effectively (by looking at relevant items in the scenes) for the explicit task instruction but not for the implicit task instruction, compared to TD participants. However, recall performance and eye movement data have indicated that explicit and implicit instructions were just as effective in prompting both participants groups to attend to the relevant information in the scene, and to support equal recall performance across the explicit and implicit tasks in both the immediate and delayed recall conditions across the two groups. Importantly, participants with ASD do not seem to be worse at the implicit task compared to the TD group, even though it was thought that the implicit task would not provide organisational structure or direct cues to point participants towards specific parts of the scenes that are important.

The findings in relation to the the explicit versus implicit comparison are in contradiction to the findings of Williams et al. (2005), where only the implicit instruction was used. One reason for this could reflect the lower verbal ability (*M* = 109) of the ASD group in the Williams et al. study, compared to verbal ability in the ASD group in the current study (*M* = 117). Williams et al. used participants exclusively diagnosed with Autistic Disorder, who were reported to have a history of language delay, whereas the ASD sample of the current study comprised of individuals with high-functioning autism or Asperger's, with the majority having a diagnosis of Asperger's Syndrome, which by diagnostic definition in the DSM-IV-TR (APA, 2000) do not show any language development delay. It must be noted that the new DSM-V (APA, 2013) has amalgamated the separate diagnoses into one category of Autism Spectrum Disorder and no longer considers differences defined by verbal ability, and this could pose difficulties for future research, if these language delay differences impact on brain development and processing strategies in different subsets of Autism. Since the Family Picture tasks depend upon verbal working memory (Dulay et al., 2002), and transferring visuo-spatial information into verbal codes (Lum, et al., 2013), lower verbal abilities in the ASD group in Williams et al.'s study could be the factor that might be driving impaired recall performance in that study.

Another possibility for the different findings between the current study and the study by Williams et al. (2005) is that the original implicit instruction (remember as much as you can about the scene) was used for all four pictures in the study by Williams et al., while the implicit instruction in the current study was only imposed on for the first picture presented to the participants. Therefore, it could be argued that the task used in the study by Williams et al. put a greater demand on working memory capacity compared to the current study, since the request was to remember as much as possible for all four pictures presented. In the current study, although the implicit instruction was intended to increase the task complexity, it could be that the number of trials for each instruction condition was not enough to elicit any differences.

It was also predicted that if increasing the number of elements to remember in the pictures contributes to increasing the complexity of this executive function task, then both immediate and delayed recall performance of individuals with ASD should incrementally decrease for task with higher number of elements to remember. However the findings do not support this. Recall scores were modulated by task across both groups, and the activities score was consistently higher for the CLA task which required participants to remember characters locations and activities across immediate and delayed recall. Participants with ASD were able to selectively remember and maintain attention on specific parts of the environment, and this experiment has shown that they can be cued to do so.

Interestingly, participants with ASD achieved lower character scores compared to TD participants across the three task instruction conditions (C, CL, CLA) in immediate recall; but the two groups produced equivalent performance for delayed recall. This is inconsistent with the impaired recall performance in participants with ASD found in both immediate and delayed recall for the original Family Pictures task (Williams et al., 2005). One reason for this difference in performance for the ASD group across the two recall conditions could be that participants with ASD were able to adopt the organisation strategies based on the immediate recall instructions, which helped them to encode and integrate the information better for longer term storage. Another possibility is that participants with ASD were more reluctant to give an answer if they were unsure and could have been less willing to make guesses. However, since no differences were found for the recall scores of the other elements (location and activity) which were only counted if they were associated with the correct character, it is suggested that the difference found in immediate recall in the current study are not a result of a reluctance to guess in the ASD group, but perhaps the result of Type I Error.

The global eye movement measures (total viewing time and number of fixations) indicated that both participant groups distributed their attention to each region in a similar way depending on the number of elements to remember. Specifically, they spent more time and made more fixations inspecting the head regions for the C task, which has the least number of elements to remember, and where participants were only required to remember which characters were in the scene compared to the later tasks where additional elements to remember. In contrast, longer viewing times and more fixations were dedicated to the objects when participants were told to remember the characters, their locations and the activity they were carrying out in the CLA task. The early eye movement measures (elapsed time and fixation count to target) indicated that both groups also prioritised which regions of the scene to attend to first according the task instructions in a similar way. Both groups were faster to attend to objects when they were instructed to remember the locations and activities the characters were carrying out, compared to when they only had to remember which characters were in the scene. This is inconsistent with the prediction that individuals with ASD would not be able to modulate their eye movements for tasks with higher complexity, as defined by increasing number of elements to remember, and that executive task performance is dependent on working memory load (Barendse et al., 2013; Minshew and Goldstein, 2001).

In the current study, the participants with ASD were able to modulate their eye movements in the face of having an increasing number of elements to remember, and their performance did not show the expected decline as the number of elements increased. As with the explicitness manipulation, the lack of between-group differences for the "number of elements" manipulation could also be due to an insufficient number of picture trials for each task instruction, with only one picture trial per task instruction. Perhaps because of this, the task demand was too low to elicit impairments as a result of reduced processing capacity within ASD. Furthermore, although the task demands were greater for instructions requesting a higher number of elements to remember, the amount of scene information remained unchanged for each scene (4 characters, each in a different location, and carrying out an activity), and the time constraint of 10 seconds was consistent for all pictures. Because processing capacity and speed of processing is thought to be affected in ASD (Minshew et al., 2008), perhaps imposing more trials, with more features in the scene, and more restricted time constraints to complete the task would elicit differences between the ASD and the TD group. For example, in the maze learning task by Minshew and Goldstein (2001), increasing the number of choice point elements with 6, 10, or 14 as the different conditions resulted in participants with ASD requiring a significantly higher number of trials for them to learn the mazes with 10 and 14 choice points.

In sum, the current study investigated whether online cognitive processing as reflected by eye movements, and recall performance on a scene memory task, was influenced by increasing task complexity, as defined by implicitness of task instruction, and increasing working memory load imposed by the task instruction. The findings from the current study suggest that increasing the implicitness of task instruction and increasing the number of elements to remember in the WMS-III Family Pictures task did not elicit a recall performance decline in individuals with ASD. Eye movement data showed that they the ASD group were able to modulate and prioritise attention to the appropriate information according the task instruction just as well as TD controls. It is speculated that one thing that can be drawn from the current study is that these factors (implicitness of task instruction and number of elements to be remembered) when manipulated in isolation do not place sufficient task demands to affect online processes and memory function in ASD, at least in the context of this paradigm in which number of trials are restricted. It may be that a combination of these factors, as in the study reported by Williams et al. (2005), would increase complexity to a threshold enough to elicit between group differences. The current study focussed on executive function in ASD and highlighted the difficulty in defining complexity within this processing domain. In that respect the study is in line with the previous perspective-taking study and the language processing studies in the current thesis.

Chapter Six

General Discussion

This purpose of this thesis was to examine eye movements during complex information processing in ASD. Four influential cognitive theories of ASD, including the Disordered Complex Information Processing Theory, Theory-of-Mind Deficits Hypothesis, Weak Central Coherence, and Executive Dysfunction, were outlined in the literature review in Chapter One. The common theme drawn from reviewing the literature for each theory is that performance on a wide range of cognitive tasks is complexity dependent. It is also suggested that strengths and deficits across cognitive tasks testing theory-of-mind, central coherence, and executive functions could share the same neural mechanisms. In the empirical chapters (Chapter Two to Five), task instructions and stimuli of existing paradigms from previous research were manipulated in order to investigate the conditions in which processing difficulties or advantages occur in ASD, and it was thought that findings from these experiments could provide information as to what the defining features of complexity across different processing domains.

Non-invasive eye-tracking methodology was employed to record the eye movements of participants during the presentation of the stimuli in each of the paradigms used in the experiments of the current thesis. The purpose of this was to provide online moment-by-moment measures of how participants are processing information as they complete the tasks, and to provide information as to what is driving, capturing, and maintaining attention during completion of each task (Liversedge & Findlay, 2000). A direct comparison of eye movements between TD individuals and individuals with ASD has the potential to uncover similarities and differences in cognitive processing between these two participant groups for a range of tasks and across a range of cognitive processing domains. Such direct examination of on-line processing differences is not possible using more traditional methods that have relied on off-line methods, or have involved recording overall reaction times or accuracy. Tasks across a variety of cognitive domains were employed, as it had been suggested that reduced capacity to process complex information should be apparent across cognitive domains, whereas tasks with simple processing demands should result in normal or enhanced performance within each domain in ASD (Minshew & Goldstein, 1998). This dissociation between intact simple information processing, and impaired complex information processing was postulated to be the result of underconnectivity between frontal-posterior cortical regions in the brain.

And it is thought that this underconnectivity also underlies deficits in theory-of-mind, central coherence, and executive functions. Underconectivity was thought to be the result of preserved or overgrown local neural connections along with underdevelopment of connections within and between higher cortical systems (Just et al., 2012; Just, et al. 2013).

The ASD participant sample in the current thesis was comprised of high-functioning individuals with ASD. This sample was selected for a number of reasons. The experiments required participants to have sufficient language ability to comprehend task instructions, and this criterion allows the identification of unique cognitive processing features that are attributable to autism and which do not reflect differences in verbal intelligence between TD participants and participants with ASD. Additionally, only participants within the adult age range were tested because major changes in brain development that occurred during childhood and adolescence would have taken place by adulthood. As such an adult sample provides a relatively stable participant population with reduced variability in cognitive processing ability that could be related to on-going brain maturation or developmental differences. Finally, in a high functioning adult sample there are no differences in IQ measures compared to a control group, but there are clear differences in everyday functioning, such as their social communication ability. Thus, the interest was in the subtle processing differences for cognitive tasks that would potentially impact on the ability to function in everyday life.

The sections that follow will discuss the findings from each of the experimental studies in the current thesis in relation to the four questions raised in the Introduction (Chapter One). Question #1: Can complexity be defined as the need to take on the psychological perspective of another person? Question #2: Do individuals with ASD have difficulties disambiguating meaning using contextual information? Question #3: Does anomaly detection during reading in ASD depend on the need to use context? And Question 4: Does implicitness of task instruction and the number of features to be remembered contribute to impaired memory performance in ASD? One aim in the design of the experiments in the thesis was to manipulate task to look for differences in processing and performance when the task was defined as a simple processing task compared to when it was a complex processing task using the same materials in each experiment. The behavioural and eye movement results will be discussed in relation to the cognitive theories and the impact of complexity on performance is also discussed..

Finally, some of the limitations of the studies will be highlighted, and any possible impact that the findings could have at the clinical and theoretical level will be proposed.

6.1 Can Complexity be Defined as the Need to Take on a Psychological Perspective?

The Theory-of-Mind Deficit Hypothesis and its extension, Empathising-Systemizing Theory (Baron-Cohen, 2009), suggest that specific deficits in ASD should emerge for tasks requiring an individual to take on the cognitive perspective of another person where they may need to infer what category of targets that person would be interested in within a scene. The same theory also predicts that performance of individuals with ASD should be intact for non-perspective-taking tasks, where participants are directly cued to attend to a category of relevant targets. In the first empirical study (Chapter Two; Au-Yeung et al., 2013) of this thesis, participants viewed house scenes with either non-perspective-taking (i.e., look for valuable items/features of the house that need fixing) or perspective-taking instructions (i.e., imagine that you are a burglar/repairman) while their eye movements were recorded. It was proposed that, if the participants with ASD were unable to take on the perspective of others, as predicted by the original Theory-of-Mind Deficit Hypothesis, then they would not show a relevance effect (the preference to look at schema-relevant compared with schema-irrelevant targets) in their eye movements across the entire trial in their global eye movement measures. On the other hand, it could be that individuals are able to take on the perspective of others, but the inclusion of a Theory-of-Mind element makes the perspective-taking task more complex, and the lack of this element makes the non-perspective-taking task simpler in terms of the processing required. Therefore if theory-of-mind is one of the elements that defines complexity within the Disordered Complex Information Processing Model, then a slowing of processing should be seen exclusively for the perspective-taking tasks, as reflected in early eye movement measures, (e.g., in how soon they start attending to the relevant targets in ASD), and this effect should be absent in the simple non-perspective taking task.

The global eye movement measures revealed typical relevance effects in ASD participants comparable to those in TD participants, meaning that they spent more time and made more fixations overall to task relevant targets in the scenes for both non-perspective-taking and perspective-taking tasks. Thus, the findings from the global eye movement measures do not support the original Theory-of-Mind Deficit Hypothesis, because participants with ASD were clearly able to take on the perspective of others.

The early eye movement measures revealed that, for the non-perspective-taking "look for the valuable items" task and burglar perspective task, the ASD group showed typical relevance effects. However, subtle processing differences were observed between the groups that were related to initial orienting to and processing of schema-relevant items for the non-perspective-taking "look for the features that need fixing" task and the repairman perspective-taking task. There was an absence of a relevance effect in the elapsed time and fixation count to target measures for the ASD group for the repairman perspective and its non-perspective-taking equivalent instruction. This finding implies that the ASD group were slower to decide which items to attend to in that task. Thus, this slowing in processing for this task in the ASD group could not have been driven by the need to take on the theory-of-mind element. Rather, some other differences between the burglar and repairman tasks and between their non-perspective-taking equivalent tasks must have driven this difference.

For example, in a previous study by Kaakinen and Hyönä (2008), the burglar perspective proved to be a relatively consistent concept within a sample of college students. The knowledge about the role of the burglar, which is to steal, and their interest in valuable items is relatively consistent across participants in previous studies (e.g. Kaakinen & Hyönä, 2008; Pichert & Anderson, 1978). However, a repairman's role might be more ambiguous because it could be interpreted as someone who fixes objects other than the structural features of the house. This means that there are potentially multiple ways to interpret the repairman task instructions or the items that might belong to that category, and individuals with ASD took longer to decide which is the appropriate interpretation of the task instruction for that perspective. The findings in the first empirical study strongly suggest that resolving ambiguity, rather than the need to take on a psychological perspective, may be a defining feature of complexity for participants with ASD, and it is this ambiguity that is driving the slowing of processing for the repairman perspective in ASD.

The implication of a lack of specific perspective-taking deficit in the findings reported in Chapter Two (Au-Yeung et al., 2013), for the Empathising-Systemising Theory, is that empathising should not be considered as a unique dimension within this theory. The findings support Baron-Cohen's (2009) speculation that the two dimensions could be further reduced to one dimension which is characterised by the unlawfulness of the information to be processed. The findings from the first experiment in this thesis support this proposal. When an instruction is ambiguous, as was the case in repairman perspective-taking task and the non-perspective-taking equivalent “look for the features that need fixing” task, it is then more difficult to find lawful and systematic ways to drive attention and appropriate behaviour. The lack of a strong cue to guide behaviour means that a top-down inference has to be made, and in order to resolve an ambiguity it is necessary to recruit higher regions in the brain (frontal areas) that are involved in problem solving. If the feedback network is underconnected in ASD, it is likely that more default viewing patterns, driven by lower level processes will prevail at the beginning of scene viewing. An example would be the preference for foreground objects due to the higher likelihood of these objects containing meaningful semantic information, compared to background objects (Henderson et al., 2009; Yarbus, 1967). Consequently, it will take longer for top-down inferences to override lower level strategies in order to direct a viewer with ASD to attend to appropriate task relevant scene targets.

Because processing deficits in ASD do not seem to be related exclusively to the social domain, the experiment reported in the next chapter investigated more domain general cognitive explanations of ASD such as Weak Central Coherence as well as Disordered Complex Information Processing, and whether or not using contextual information to disambiguate the meaning of a statement with multiple possible interpretations would pose difficulty for individuals with ASD during processing of text stimuli.

6.2 Do Individuals with ASD have Difficulties Disambiguating Meaning Using Contextual Information?

Previous research (e.g. Leekam & Lopez, 2003) has suggested that individuals with ASD have particular difficulty using contextual information to disambiguate meaning. Comprehension of written irony requires a reader to make use of the discourse context. It is necessary to negate the literal meaning of an utterance, which is incoherent with the context, to reach the ironic meaning. The need to process ambiguous information in relation to context in irony comprehension leads to the prediction that individuals with ASD would have difficulty processing irony. In the second empirical study of this thesis (Chapter Three; Au-Yeung et al., in press), eye movements of TD adults and adults with ASD were recorded when they read passages containing utterances that could either be interpreted as ironic or non-ironic depending on the passage context. For this experiment the non-ironic condition was considered to be a simple processing task as the reader could simply accept the surface literal meaning of the sentence to form a correct interpretation even without the contextual information. The ironic condition was considered the complex processing task as participants must note the inconsistency between the passage context and the literal meaning of the critical sentence, and then, reject the literal interpretation of the text and compute the ironic meaning.

The Weak Central Coherence Theory predicts that individuals with ASD would not take into account the contextual information and therefore they should be less accurate in answering comprehension questions regarding the interpretation of the critical sentence for the ironic condition compared to the non-ironic condition. For the eye movement measures, it was predicted that individuals with ASD would not show the typical irony effect that is, longer re-reading times for the contextual information as well as the critical sentence for the ironic text compared to the non-ironic text. Instead, they would show equivalent reading times across the two text types in accordance with the Weak Central Coherence Theory prediction that they would read the ironic utterance literally (i.e., as if it was non-ironic).

Based on the Disordered Complex Information Processing Model and previous findings (Benson et al., 2012, Au-Yeung et al., 2013), high-functioning individuals with ASD were expected to show intact performance for the off-line comprehension questions for both ironic and non-ironic conditions. If figurativeness of the language increases task complexity, then disproportionate difficulty in interpreting ironic statements should be revealed in the eye movements of individuals with ASD in terms of elevated re-reading for the contextual information and the critical sentence in the ironic condition, and also a difference in the time-course such that the irony effect persists for longer into the text that follows the critical sentence. Such findings would provide evidence for more effortful processing in ASD in order to resolve the irony.

Participants with ASD performed as well as TD controls in their comprehension accuracy for both ironic and non-ironic conditions, with both groups scoring lower for the ironic condition compared to the non-ironic condition. Eye movement data showed that both participant groups spent more time overall reading the statement in the critical region and the text in the context restatement region for the ironic compared to the non-ironic condition, suggesting that more effortful processing is required for ironic text compared to when text was required to be interpreted literally. The results therefore indicated that individuals with ASD were able to use contextual information to compute the non-literal interpretation of ironic text. However, there was a general slowing in processing that showed that individuals with ASD spent more time overall than TD controls re-reading the passages, across ironic and non-ironic conditions. This is in line with a previous study of irony processing in ASD during reading, but that study only measured response time and accuracy (Gyori, 2006). The findings seem to suggest an absence of any specific deficit related to irony processing in ASD, and the use of contextual information appears to be no different to TD individuals, as opposed to the prediction generated by our interpretation of the revised Weak Central Coherence Theory (Happé, 1999) and Disordered Complex Information Processing Theory.

It was speculated that the prolonged reading times across conditions could be due to participants with ASD taking longer to recheck the text to be sufficiently self-assured about their interpretation of the text before proceeding to the next piece of text or comprehension questions. This reading study, along with the previous scene study (Chapter Two) suggests that the slowing in processing in ASD could relate to extra time needed to be able to be assured that any original interpretation that was made is correct. Furthermore, it seems that in general, processing discourse information is more difficult for individuals with ASD, regardless of the ambiguity of a statement due to its inconsistency with the contextual information. It is possible that this could be due to the amount of information contained in passages of text, which needed to be processed, rather than single sentences, putting a strain on a limited processing capacity in ASD, another factor that was suggested to define complexity. Thus, although the eye movement measures indicate that the detection of the irony occurs at the same time in the ASD group as the TD group, the increased reading times in the ASD group for ironic and non-ironic text suggests that the participants with ASD had to complete some additional processing of the text. This need for extra processing time to finalise their interpretation seems to be consistent with the first study in Chapter Two (Au-Yeung et al., 2013), in which participants took longer to start fixating task relevant target for more ambiguous task instructions irrelevant of whether a theory-of-mind element was involved. Moreover, the current study provides further evidence that the need to take on a perspective does not necessarily increase the complexity of a task, as participants with ASD were clearly able to understand other mental states in terms of realizing the true meaning of ironic utterances.

Considering the Weak Central Coherence proposal that individuals with ASD have a detailed focused processing style (Happé, 1999), it might be that individuals with ASD find it harder to integrate multiple pieces of information in discourse into a coherent whole, and as a result, the influence of context is weaker in ASD. In the next experiment, this issue of whether contextual influence is reduced in ASD during reading was investigated through anomaly detection during a reading comprehension task with longer paragraphs of text.

6.3 Does Anomaly Detection during Reading in ASD Depend on the Need to Use Context?

The empirical study in Chapter Four further investigated whether individuals with ASD processed contextual information differently in comparison to TD individuals, and how context affects anomaly detection during reading for a comprehension task. Previous scene perception research has found that individuals with ASD were slower and sometimes less accurate at identifying anomalous objects within a scene context compared to TD individuals (Au-Yeung et al., 2011; Joliffe & Baron-Cohen, 2001; Benson et al., 2012). An eye movement study (Benson et al., 2012) showed that participants with ASD took more time and made more fixations in other parts of the scenes before fixating an anomalous target in one of two otherwise identical scenes, and, once they fixated the target they did not immediately recognise the anomaly, as reflected by a lack of difference between the first fixation duration to the target region for the anomalous scene and the equivalent region for the non-anomalous scene. However, no difference between ASD and TD individuals in performance was found in a simpler task, using the same materials, where participants had to spot a missing feature in one of two otherwise identical scenes. That task did not require taking note of the context of the scene. The study suggests that the need to process contextual information in scenes could also be considered to be a factor that increases complexity.

The third experiment (reported in Chapter Four of this thesis), investigated whether a similar pattern of findings would also occur when the task was to detect anomalies during reading. Participants read passages of text containing context dependent passage level anomalies or context independent sentence level anomalies. Weak Central Coherence Theory would predict that if individuals with ASD do not take into account contextual information, then it should be harder for them to detect passage anomalies compared to TD individuals. This should be reflected as a reduced magnitude difference in reading times on the critical target word between the anomalous condition and the normal condition for the ASD participants compared to the TD participants. In contrast, detection of sentence anomalies does not rely on taking into account passage contextual information, and reliance on passage contextual information could potentially hinder detection of sentence level anomalies through a focus on the formation of a coherent, schema mediated representation of the discourse. Thus, it was predicted that by not taking into account contextual information, individuals with ASD would detect anomalies as rapidly or even exhibit enhanced anomaly detection for context independent sentence level anomalies compared to TD individuals. Enhanced anomaly detection in ASD should be reflected as longer reading times on the critical target word in the anomalous condition compared to the normal condition, or at least a greater magnitude difference should be seen in the ASD participants compared to the TD participants. For this study, the context independent sentence anomaly condition could be considered the simpler processing task, as processing of the greater contextual information was not required. In contrast, the passage anomaly condition, where detection of the sentence anomaly depended on the context of the passage, could be considered the more complex processing task, as the detection of the anomaly required integration of passage context information.

As predicted, it was found that TD participants spent longer re-reading the text in the critical region and the text that comes before it immediately on encountering the anomalous critical word for the passage condition. This anomaly effect for regression path times was not significant for the ASD group. However, both groups showed the anomaly effect for the total viewing time for the critical region, thus indicating that detection of anomalies in sentences where the passage context had to be taken into account is less efficient in ASD. In contrast, for the context independent sentence type anomalies, it was found that participants with ASD spent longer re-reading the text in the critical region and the text that comes before it immediately on encountering the anomalous critical word for the sentence condition, and, conversely, this anomaly effect for regression path times was not significant for the TD group. However, the anomaly effect was significant for both groups in total reading times, albeit to a smaller degree for the TD participants. This finding indicates that participants with ASD were more efficient at detecting context independent sentence anomalies than TD participants. This finding does lend support to the Weak Central Coherence Theory (Happé, 1999), which proposes that individuals with ASD have a preferred processing style that is detailed focused, and that processing of context is not as automatic as it is for TD individuals when ASD individuals are not explicitly instructed to do this. The findings from the anomaly study show that this preference in ASD is what hinders performance in the more complex context dependent passage anomalies, and also accounts for the enhanced performance in the simpler context independent sentence anomalies.

As mentioned in the previous subsection (6.2), the reason why processing contextual information could be considered complex is that it requires an individual to integrate multiple pieces of information from a discourse, and this could put a strain on any limited working memory capacity in individuals with ASD. Since the rate of information transfer is thought to be slower in ASD due to underconnectivity between frontal and posterior regions, this means that the influence of context would become effective at a later time, and could explain why detection of context dependent passage anomalies is apparent at later reading measures (total reading time) rather than earlier measures in ASD. Thus, the findings could be accounted for by a number of theories that propose problems with integration of multiple processes or information in ASD, including the Weak Central Coherence theory as well as the Disordered Complex Information Processing Model.

An additional finding, and one which is similar to that obtained from the Irony Study in Chapter Three (Au-Yeung et al., in press), is that participants with ASD spent longer re-reading the whole text. This prolonged reading is consistent with slowing of processing in ASD as proposed by Minshew et al. (2008). It is speculated that the overall slowing observed in the ASD group could be induced by the presence of comprehension questions following each of the passages, and that (and similar to the irony reading study) participants with ASD needed to do more rechecking of the text to be self-assured that their interpretation of the text was correct, and that enough information had been gathered before they felt confident enough to proceed to the questions. This speculation remains to be empirically tested.

The final experiment continued on from the anomaly study to investigate the two factors that are thought to increase task complexity in a memory for scenes task, and which have been thought to underlie some of the executive dysfunctions observed in ASD. These factors are related to ambiguity of task instructions and processing load, which have already been touched upon in this discussion.

6.4 Does Implicitness of Task Instruction and the Number of Features to be Remembered Contribute to Impaired Memory Performance in ASD?

Reviews of previous literature (Hill, 2004:White, 2013) have proposed that the presence of executive dysfunction in ASD is driven by arbitrary rules provided by open-ended task instructions, and by increasing elements in a task sequence, putting excessive processing demands on the limited working memory capacity in individuals with ASD (Minshew et al., 2008). The WMS-III (Wechsler, 1997) Family Pictures task is a neuropsychological assessment for memory function that requires the examinee to encode visual information of characters, their location and their activities, in everyday scenes, and then to recall these elements verbally immediately after inspection and following a delay. Individuals with ASD were found to show poorer memory performance compared to TD controls in this task and it was speculated that this was due to impaired use of organisation strategies in ASD (Minshew & Goldstein, 2001; Williams et al., 2005).

In the final empirical study of this thesis (Chapter Five), the Family Pictures task was adopted but modified so that the scenes were presented on a computer screen. Furthermore, task instructions were manipulated for each of the four family pictures used in the original assessment. The first instruction required participants to remember as much as they could about the scene – and this was called the implicit free-viewing instruction, as no specific cues were given as to which elements of the scene that participants had to attend to. The second instruction required participants to remember the characters in the scene, and this task demand was then increased for the third instruction, which was to remember the characters as well as their locations. Finally, the fourth instruction again added another element to be remembered, requiring participants to remember the characters, their locations and the activities the characters were carrying out in the scenes. The fourth instruction was also called the "explicit" instruction as it specified all the elements needed to be remembered in the scene, and provided a comparison condition for the implicit instruction which required participants to remember as much as they could about the scene.

Two comparisons were made in this study. Firstly, the performance of ASD and TD participants was compared on the explicit and the implicit task, and it was hypothesised that the implicit task would be more complex than the explicit task due to the lack of provision of any organizational strategy in the implicit task (White, 2013; Williams et al., 2005). Equivalent recall performance was predicted for the explicit task between the ASD and TD groups but impaired memory performance was predicted for the implicit task in ASD compared to TD individuals. Eye movements were expected to be modulated such that fixations would be made on relevant parts of the scenes under explicit instruction for both groups, whereas the ASD group were expected to show less modulation in terms of orienting to and fixating relevant parts of the scenes for the implicit task instruction condition compared to the control group.

Secondly, performance of the two groups was compared for the three task instructions with increasing working memory load. It was hypothesised that the task instruction requiring more elements of the scene to be remembered was more complex, as this should put a greater strain on any limited processing capacity in ASD (Hill, 2004; Minshew et al., 2008). It was expected that participants with ASD would show a decrease in recall performance for when increased numbers of elements were required to be remembered. Furthermore, it was expected that the eye movement data would reveal a differences in patterns of fixations between the two groups for tasks in which greater numbers of elements had to be remembered, since reduced processing capacity should lead individuals with ASD to be less able to divide attentional resources in order to sample all of the relevant scene features during a time restriction.

The findings from the study revealed no consistent differences in recall performance across immediate and delayed recall, and no significant differences in eye movement patterns between the ASD and TD participants. The common findings across participant groups were that recall performance, overall attentional distribution (i.e., global eye movement measures), and initial attentional priority (i.e., early eye movement measures) varied depending on the elements that were required to be remembered for each task. No between-group differences were found across both the implicit and the explicit tasks. The results overall do not support that the two factors manipulated in this study, namely, implicitness of a task instruction and increasing number of elements to be remembered impeded memory performance in individuals with ASD. Furthermore, the eye movement data indicated that individuals with ASD used similar organization strategies across all four tasks instructions to those employed by TD individuals.

However, it could be the case that the manipulations designed to increase task complexity in this study failed to achieve that aim. Specifically, one reason for the null findings in the current study could relate to the pictures used in the study, rather than the task instructions. Because only one picture was used for each task instruction, any difficulties imposed by the implicit task instruction and the task instructions imposing greater memory load could be compensated for by the fact that there was a very limited amount of information in each picture. In an earlier study, Williams et al. (2005) used the implicit instruction (i.e., remember as much as you can about the scene) for all four pictures of the paradigm. Therefore that study could be considered as being more complex compared to the memory for scenes study in this current thesis, in that Williams et al.'s study imposed a greater working memory load requirement for all pictures. Another possibility for differences in findings could be that Williams et al. only included individuals with a diagnosis of Autistic Disorder and as such these participants would have had disordered or delayed language development, whereas the majority of the participants with ASD in the current study were diagnosed with Asperger's Syndrome and therefore would not have any clinically significant delay in language development. However, it must be noted that only participants with IQ above 80 were included and the average verbal IQ of Williams et al.'s ASD sample was 108 and this was matched with their TD controls. Therefore it is unclear how much the language delay would have contributed to differences in findings, if at all.

To summarise, the experiments in this thesis have investigated how viewing patterns and performance for tasks in different cognitive processing domains could be affected by complexity imposed by the task instruction and stimuli. Throughout these experiments, complexity was defined in various ways according to suggestions from previous literature relating to theory-of-mind deficits, Weak Central Coherence and Executive Dysfunction as well as the definition outlined in the Disordered Complex Information Processing Model. The following section discusses the overlap between these theories and addresses the problems with current definitions of complexity in cognitive processing tasks in that the given definition is not always valid when directly tested.

The Problem of Complexity

Within the Disordered Complex Information Processing Model, complex information processing tasks were suggested to involve integration of multiple features, speed of processing, processing of large quantities of information, and processing of novel materials (Minshew et al., 2008). Research looking into other cognitive theories of ASD, namely Theory-of-Mind, Weak Central Coherence, and Executive Dysfunction, have also shown that complexity may play a key role in task performance in ASD. The question is: what are the features within different cognitive tasks that serve to increase complexity and produce processing differences between TD and ASD individuals?

Researchers investigating within the theory-of-mind domain have speculated that poor performance on theory-of-mind tasks in ASD was not due to specific deficits in attributing mental states *per se*, but in difficulties dealing with transience and predictability of social stimuli (Reed, 1994). The transience of social stimuli might require fast speed of processing to be able to quickly detect and process the social cues in the environment, which are dynamic, often non-verbal, with implicit rather than explicit rules. Failure to follow such cues would make responding either appropriately or effectively difficult in ASD. The findings from the first experiment (Chapter Two; Au-

Yeung et al., 2013) clearly show that the individuals with ASD experience a slowing in processing that is not limited to the perspective-taking conditions that could be considered social in that task. The slowing was instead associated with more ambiguous task instructions (perspective-taking or not) with the possibility of multiple interpretations of items in the stimuli that might belong to one of the categories. This resulted in more exploration of the features/objects relevant to both possible categories. The reduction in processing capacity that affects the rate of information transfer in ASD means that individuals with ASD would experience difficulty when there is a requirement for using top-down influence to infer the correct interpretation in ambiguous tasks.

Furthermore, the unpredictable nature of social stimuli is akin to dealing with novel materials during every social encounter. The updated version of the Theory-of-Mind deficit hypothesis, also called the Empathizing-Systemizing Theory (Baron-Cohen, 2009) proposed that empathizing, due to its unlawfulness, lies on the opposite end of a continuum to systemizing, and so tasks high on that end of the dimension, such as perspective-taking, could be seen as more complex for ASD populations. However, it is not perspective-taking *per se* that impairs performance in ASD, as the findings from the first experiment (Chapter Two; Au-Yeung et al., 2013) have shown. One perspective might be more complex than another, depending on any ambiguity associated with the interpretation the task instruction.

Previous research had shown that weak central coherence is specifically characterized by a difficulty to use context to disambiguate meaning (Lopez & Leekam, 2003). Such a finding could be argued to be attributable to problems with integrating multiple items of information. An example of this is in tasks that require the reading of homographs featuring rare or frequent pronunciation within sentences, in which ASD have been shown to make fewer context appropriate pronunciations and fewer self-corrections when a rare pronunciation rather than a common one would have been correct. These kinds of findings also fit with the Disordered Complex Information Processing Model, which also predicts difficulty in tasks where there are multiple features to be integrated and where novel information has to be processed (Minshew et al., 2008). Minshew and Meyer (2002) had explained weak central coherence in terms of a higher order cognitive deficit in abstract reasoning and the pattern of responses produced by participants with ASD were described as resulting from a failure to integrate context into interpretation. The cognitive style of individuals with ASD has also been described as detail focussed, in which local processing of information is enhanced at the expense of active organisation of information into meaningful wholes (Happé, 1999; Minshew & Meyer, 2002). However, it has also been shown that this preference is task dependent in visual perceptual tasks. When no instruction is given as to whether the focus needs to be at the local or global level, participants with ASD show a processing advantage for local information, whereas processing of global information seems to be unimpaired when a specific instruction is given to attend to the wider context (Plaisted et al., 1999). This processing style is further observed during a reading comprehension task where anomalies are embedded and detection of these anomalies is implicit, as measured using eye tracking (Chapter Four) in this thesis. In line with the visual perceptual tasks (Plaisted et al., 1999; Benson et al., 2012), detection of targets was immediate by individuals with ASD when processing of context was not required, as reflected by more time spent immediately rechecking the text as soon as the anomalous target was encountered. In contrast the ASD group was less efficient when the task required that it was necessary that context be taken into account, and this was reflected by a lack of effects in immediate reading, but increased re-reading as reflected by the total reading time measure. A detail focused processing style might also explain the increased re-reading across conditions observed in both reading studies in the current thesis, and could be attributed to over-activation of lower visual areas predicted by the fronto-posterior cortical underconnectivity hypothesis, although this idea is speculative. Increased time spent reading and re-reading could also be due to a tendency to be less confident about the interpretation of the discourse, or because of being unsure as to whether enough information has been gathered to proceed to comprehension questions. This could perhaps be tested in the future using a confidence judgement task which rates the level of confidence participants have for their answers to the comprehension questions using a Likert Scale.

Minshew and Meyer (2002) also suggest that abstract reasoning deficits in ASD can also help to explain findings from a wealth of research based around executive dysfunction in ASD, which include difficulties with planning, organizing, shifting sets, and forming new concepts. For example, White (2013) has proposed that executive dysfunction is modulated by implicitness/explicitness of task demands, and that individuals with ASD have trouble forming an implicit understanding of what is required of them in executive tasks. Other studies from the literature such as Hill (2004) have suggested that increasing the number of elements to be processed in cognitive tasks produces more difficulty for participants with ASD. Implicit tasks require participants to form their own representation of the task requirements, and this is akin to processing novel information, and, an increase in the number of elements to be processed puts a heavier demand on a limited processing capacity. However, the manipulation of task instructions in terms of their implicitness and number of elements to be remembered in the memory for scenes experiment (Chapter Five) did not produce the expected between-group difference, and it is suggested that the definition of complexity can be problematic and needs better operational definition in the future.

The current thesis has highlighted the difficulty with defining complexity, and the conditions in which complex information processing deficits would be expected to be exhibited across different processing domains in ASD. One problem that has arisen from the research literature concerns the wide range of terminologies used by different research groups to describe similar processes. For example, while Minshew and Goldstein (1998) describe individuals with ASD to be intact or even excel at “simple” processing tasks, these tasks could also be referred to as “local” processing tasks by researchers focusing on the Weak Central Coherence Theory (Happé, 1999). Similarly, “systemizing” as defined by researchers following the Theory-of-Mind Deficit Hypothesis (Baron-Cohen, 2009) could be explained within the Disordered Complex Information Processing Model as rule based learning or simple processing in ASD. Complex information processing across cognitive domains, which individuals with ASD were supposed to be impaired at as described by Minshew and Goldstein (1998), (e.g., abstract reasoning), have also been referred to as contextual processing, or as demanding intact higher order executive functions. It has recently been proposed (Just et al. 2013) that deficits that have been related to the theories outlined above could all be accounted by a common underlying neurobiological mechanism, namely, frontal-posterior underconnectivity. Complex information processing deficits may occur when the frontal brain regions are required to successfully perform a task to support higher levels of abstraction, where reduced frontal-posterior cortical connectivity may restrict the frontal contribution and delay its influence on behaviour. Furthermore, this frontal-posterior underconnectivity could lead to an increase in the autonomy of the posterior regions, producing greater activity in those regions, which could underlie the enhancements in visual processes observed in ASD. The current thesis has provided evidence of how underconnectivity may be reflected in eye movement behaviours of individuals with ASD. For example, underconnectivity could be reflected in eye movements being directed by lower level rule based strategies resulting in an increase in time to make fixations to task relevant targets according to top-down instructions, as seen in Experiment 1. During reading, underconnectivity could result in the observed lack of immediate re-reading when encountering a contextual anomaly, and this slowed processing could explain the finding that a delayed contextual influence was observed in later re-reading of the anomalous target word (i.e., total reading time). Also, due to the late context influence governed by frontal brain areas, contextual independent anomalies were spotted soon, as reflected by immediate re-reading (i.e., regression path reading time) of the anomalous target and the text prior to it in ASD. Last but not least, greater re-reading observed across conditions in all reading tasks could reflect rechecking to confirm that any interpretation made of the discourse information is correct, which could also be linked to reduced top-down influences as a result of underconnectivity.

In sum, the studies of the current thesis support that complex information processing deficits are not restricted to social processing or theory-of-mind, but instead relate to the ambiguity of task instruction resulting in delayed orienting to task relevant stimuli during scene perception tasks. In a reading comprehension task, an observed processing deficit was linked to implicit integration of contextual information, which impairs the detection of passage context dependent anomalies and enhances detection of context independent sentence anomalies, in line with the dissociation between intact simple and impaired complex information processing. However, some questions remain as to what produces greater re-reading across reading paradigms and whether this is a result of cortical underconnectivity and slowing of integration of large amounts of discourse information. Furthermore, as shown in the memory for scenes task, increasing implicitness of task instruction and working memory load does not always produce group differences, and this may be because of an insufficient amount of information in the stimuli to raise complexity.

6.5 Potential Limitations

Diagnosis and Language

In the empirical studies of this thesis, our ASD samples consisted of individuals who had previously received formal clinical diagnoses of ASD. The majority of the participants that took part in these studies were classified as Asperger's Syndrome, and a few were classified as high-functioning individuals with autism. The term "high-functioning autism" generally refers to individuals with Autistic Disorder with normal to above average IQ (IQ > 70). The difference in diagnostic criteria is that Autistic Disorder includes a lack of (or delayed) language development, while Asperger's Syndrome does not (APA [DSM-IV], 2000). This raises the question as to whether or not any differences between the ASD and the TD group could be driven by a particular subgroup of participants with ASD, for example, language impairment in high-functioning individuals with autism. It has been suggested that the difference between Autistic Disorder and Asperger's Syndrome is severity dependent (Meyer & Minshew, 2002), with information processing capacity and functional connectivity falling as the severity of autism increases (Minshew & Williams, 2007; 2008). Due to the small sample size, it was not possible to make a clear comparison between subgroups in the studies of the current thesis. It was not possible to form further sub-groups as defined by, for example, age, or diagnostic group, or language ability, to allow for comparisons. It should be noted though that even with a relatively small sample it was still possible to obtain the expected experimental effects, such as the perspective effect (Kaakinen et al., 2011), the irony effect (Filik & Moxey, 2010), and the anomaly effect (Daneman et al., 2007), using a within-participant design. However, the reasoning for using a sample with mixed diagnosis is based on the assumption that all individuals on the autism spectrum share a common pathophysiology of cortical underconnectivity and reduced information-processing capacity, albeit affected to different levels of severity (Minshew & Williams, 2008).

The recent publication of the new DSM-V (APA, 2013) has meant that all of the previous separate diagnoses are merged into a single diagnostic category of Autism Spectrum Disorder with the diagnostic distinction marked by language ability removed, in line with research implicating common underlying factors in ASD in brain mechanisms and cognitive processes. Mayes, Calhoun and Crites (2001) have shown that communication problems, including impaired conversational speech and repetitive stereotyped or idiosyncratic speech were present in both high-functioning children diagnosed with Autistic Disorder and Asperger's Syndrome with normal intelligence. Furthermore, Mayes and Calhoun (2001) found no difference in autistic symptoms and expressive language between children with Autistic Disorder or Asperger's Syndrome, suggesting that speech delay is irrelevant to later functioning of children with Autistic Disorder or Asperger's Syndrome, with intelligence within the normal range indicating that the separate diagnosis might be unjustified. Meyer and Minshew (2002) evaluated the literature on neurocognitive profiles and found that within the normal range of intelligence, individuals with Asperger's Syndrome and high-functioning autism did not show a clear distinction in their performance in tasks across various cognitive domains, including theory-of-Mind tasks, visual perceptual tasks, and executive function tasks.

Any minor between-group differences tended to diminish after intellectual ability and severity were taken into account. Since there is not sufficient evidence for the two distinct diagnoses and speech delay did not distinguish between high-functioning autism and Asperger's Syndrome (Mayes et al., 2001), using a mixed sample of participants with diagnostic title of Asperger's Syndrome or high-functioning autism within the normal to above range of IQ should not have affected the findings in the current thesis.

In the current thesis, lower functioning individuals (including those with Autistic Disorder who had significant language delay and impairments) were not tested. In addition, those participants who did not reach the minimal IQ threshold were excluded. This exclusion criterion was adopted partly to ensure that participants were able to follow instructions to perform the tasks in the experiments, but also to ensure that any group differences that were observed were solely due to autism and could not be accountable for by differences in intellectual ability (Minshew & Goldstein, 2008). Minshew and Williams (2008) have argued that, in lower-functioning individuals, brain connections maybe so severed, and processing capacity so limited, that no meaning can be attached to sensory information in that population. Consequently, this limitation on processing capacity could be characterised as mental retardation for lower functioning individuals.

Even though the participants with Asperger's Syndrome, by diagnostic definition, would not have experienced any language delay, research has nevertheless reported that receptive language could be an area that is affected in individuals with Asperger's Syndrome (Noterdaeme, Wriedt, & Höhne, 2010). There are debates as to whether research findings regarding some of the cognitive processing deficits in ASD are actually unique to ASD or are common across individuals with other language impairments. Some studies (see review by Norbury, 2013) have shown that both ASD individuals with language impairments and non-ASD individuals with language impairments had trouble resolving ambiguities during sentence comprehension. Could it be that differences between ASD and TD participants in the current thesis were due to language ability and not ASD? This highlights a shortcoming of the empirical studies in this thesis, namely that language comprehension ability was not formally assessed. Nonetheless, participant groups were matched on verbal, non-verbal, and full-scale IQ, and performance in comprehension questions for the two reading tasks (Chapters Three and Four) revealed no difference in performance between the ASD and the TD group. Therefore, arguably, differences in language comprehension ability do not appear to be driving the findings presented in this thesis.

Age Differences

In the reading studies presented in Chapter Three (Au-Yeung et al., in press) and Four, the ASD group had a slightly larger mean age compared to the TD group. Potentially this might mean that age could be a possible confound for the results in those experiments. Previous research has shown that eye movements during reading were affected by age (Paterson, McGowan, & Jordan, 2013). Older adults (age 65+) took longer to read, make more and longer fixations, and make more regressions compared to younger adults (age 18 to 30), but both group had good comprehension. One might argue that age could account for the common finding of greater overall reading time and re-reading found in both reading studies in the current thesis in ASD, however, this is doubtful, as none of the participants in the ASD group were close to old enough to be classified as an older adult as defined by the eye movement research in ageing, above.

Another question is whether age could account for the results of the scene memory study (Chapter Five), as in that study the ASD group also had a higher mean age than the TD group. Ageing is known to be related to memory decline and also to influence eye movement behaviour (Shih, Meadmore, & Liversedge, 2012). Counterintuitively, the findings in the scene memory study suggested that participants with ASD, despite having a slightly higher mean age, performed as well as controls overall on recall The ASD group also showed similar overall eye movement behaviour as TD controls. This finding, again, confirms that age is unlikely to be driving the results in this study.

Linking Brain Activity with Eye Movements

The empirical studies in this thesis utilised eye movements as an indication of on-line cognitive processing for simple and complex cognitive tasks. It is speculated that the brain mechanism underlying complex information processing deficits in ASD is frontal-posterior cortical underconnectivity. However, the current studies do not allow direct linking of eye movement behaviour with brain mechanisms for the specific tasks. Future studies comparing individuals with ASD and TD individuals for cognitive tasks should attempt to combine the measures of brain activity and eye-tracking techniques to directly link brain mechanisms with how information is attended to and processed on-line, in order to establish whether underconnectivity gives rise to the slowing of processing observed in the eye-movement studies of the current thesis.

It is speculated that underconnectivity could result in the the observations in the current thesis, including delays in initial orienting to task relevant targets in scene perception tasks, dissociation between delayed contextual anomaly detection and enhanced context independent anomaly detection, and increased re-reading across conditions during text comprehension. For example, theoretically, if both eye movements and brain activity were measured concurrently during stimuli presentation, delay in initial orienting to task relevant targets in a scene perception task should co-occur with delays in activation of frontal regions. Similarly, the observed increased re-reading across conditions in the reading comprehension tasks should co-occur with increased activity of posterior regions. Decreased frontal activity and increased posterior activity have previous been shown in sentence comprehension task with fMRI studies (Just, Cherkassky, Keller, & Minshew, 2004). Furthermore, frontal-posterior cortical asynchrony as reflected by lower functional connectivity may be observed concurrently with immediate re-reading and detection of context independent anomalous terms as well as delayed re-reading of context dependent anomalous terms. There is evidence from a previous study (Damarla et al., 2010) that frontal-posterior underconnectivity does not only underlie performance in complex processing tasks but it also underlies performance in an embedded figure visual detection task, in which ASD participants show intact behaviour performance. Damarla et al. found reduced activation in the frontal areas but greater activation in the visuospatial areas, as well as lower functional connectivity between frontal and parietal-occipital regions in participants with ASD, compared to TD controls. Perhaps this greater autonomy in posterior regions as a result of reduced frontal input could explain greater attention to details, and more detailed processing of discourse information across conditions in both the Irony Study (Chapter Three; Au-Yeung et al., in press) and the Anomaly Study (Chapter Four).

Reading

The current thesis examined some relatively unexplored areas of ASD in eye movement research. Eye-tracking studies looking at reading in ASD are rare in the literature and this is surprising considering that social communicative and language difficulties are well known in ASD. The two studies in Chapters Three and Four investigated the processing of complex information during reading. This is important as complex information processing deficits were believed to be present regardless of cognitive domain, and therefore deficits should be revealed based on the task demand imposed by the task regardless as to whether the information is presented in text format or scenes. However, there has, to date, been limited research in terms of more basic reading effects in ASD (e.g., word frequency effects), which would be important to shed light on ASD performance on simple processing tasks. These areas of reading should be explored in future research to ensure deficits in processing complex text information were not due to more basic reading deficiencies.

6.6 Conclusion

In conclusion, the overall findings from this thesis have shown that there is a slowing in processing of complex information in ASD. In the scene perception task (Experiment One), slowness in processing was exhibited as a prolonged time taken, with an increased number of fixations made, before directly attending to task relevant targets for more ambiguous task instructions. The eye movement data from Experiment One indicate problems with choosing appropriate interpretation of objects that is relevant to the repairman perspective and its non-perspective-taking equivalent instruction, rather than resulting from prolonged fixations across the duration of the task, inattention to, or perseveration on certain objects. In Experiment Two, the eye movement measures showed clearly that the participants with ASD detect irony at the same time course as the TD participants, but they spend more time re-reading the text material before responding, after they had already read all of it, again most likely to confirm interpretation. This means that participants with ASD are not simply taking longer to read because they are perseverating at each word or because they have longer overall fixation durations. In an implicit anomaly detection reading study (Experiment Three), the slowing in participants with ASD was demonstrated as a delayed influence of contextual information, resulting in more efficient context independent anomaly detection, but on the other hand, less efficient context dependent anomaly detection. The eye movement measures revealed that there were differences in processing that, once again, were not because individuals with ASD were generally slower at performing all types of tasks. Additionally in Experiment Three, the participants with ASD re-read the text from the end of the passages prior to responding, in line with Experiment Two. Overall, the studies have found that online processing differences were specifically restricted to certain conditions in high-level cognitive tasks during scene perception and reading. While complexity, as defined in various ways, sometimes but not always predicts the outcome of the studies in the current thesis, it is suggested here that some other factor, such as when there is a need to make an implicit decision based on ambiguous contextual information, will be what results in the observation of processing differences in ASD. The empirical studies reported here have shown that current theories that underpin ASD, such as Weak Central

Coherence and Disordered Complex Information Processing Theory, can sometimes both account for some of the findings, but also that there is some convergence between the different theories.

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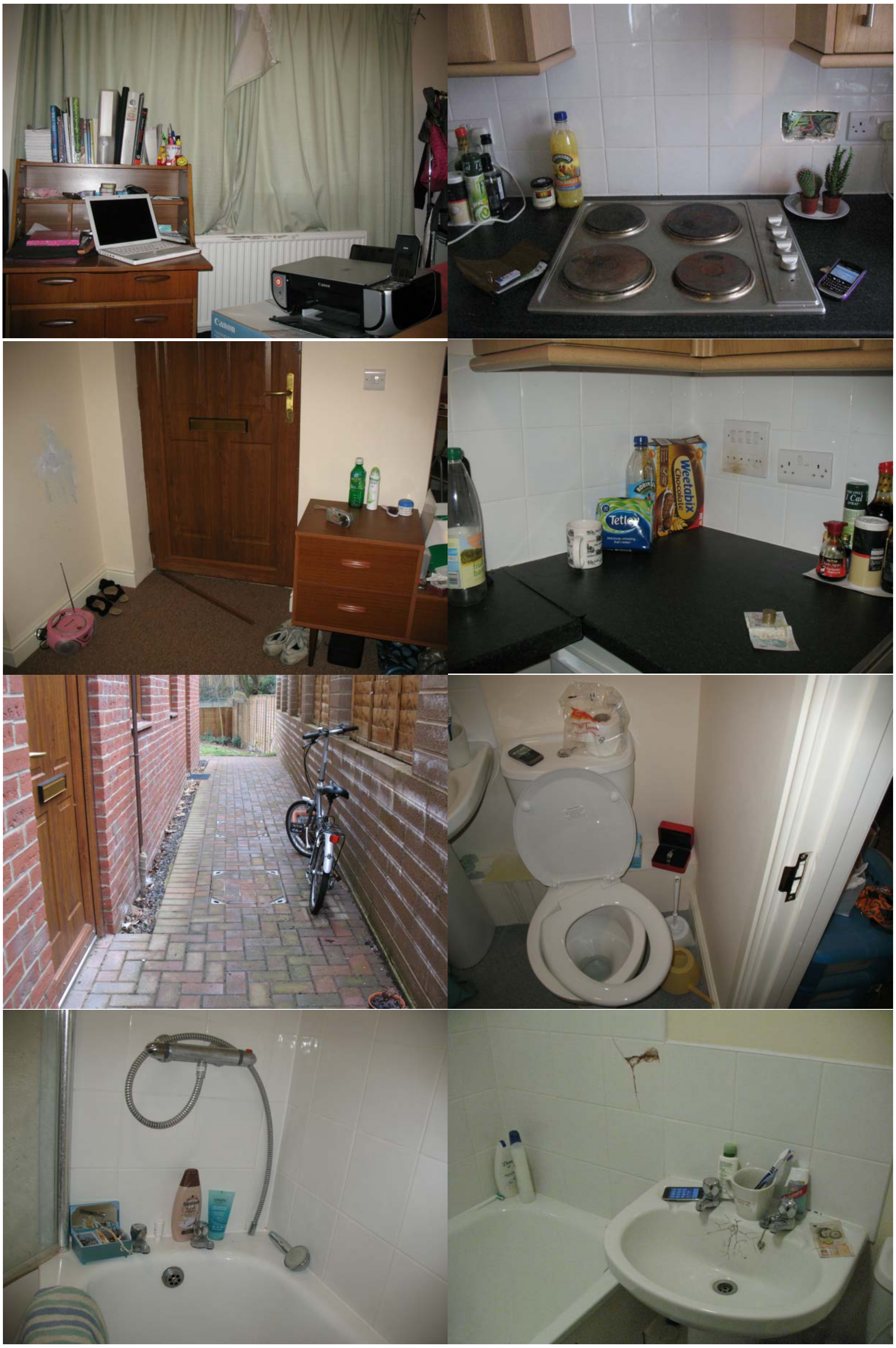
Appendix A
Stimuli for Chapter Two (Perspective-Taking Study)
Set A



Set B

Appendix B

Stimuli for Chapter Three (Irony Study)

IRONIC_1 /John and Mary were sitting in the newspaper office, reading through a huge pile of/ hate mail./ ‘Obviously our readers/ liked your story’,/ said John./ Mary was surprised that/ so few people liked her news article./

NON-IRONIC_1 /John and Mary were sitting in the newspaper office, reading through a huge pile of/ fan mail./ ‘Obviously our readers /liked your story’,/ said John./ Mary was surprised that/ so many people liked her news article./

IRONIC_2 /Sylvia looked round at/ the empty function hall, before walking over to Jane./ ‘Clearly people/ were keen on coming to your party’,/ giggled Sylvia./ Jane couldn’t believe that/ the party turned out so unpopular./

NON-IRONIC_2 /Sylvia looked round at the/ crowded function hall, before walking over to Jane./ ‘Clearly people/ were keen on coming to your party’,/ giggled Sylvia./ Jane couldn’t believe that/ the party turned out so popular./

IRONIC_3 /Miss Edwards was looking at/ the long list of ‘F’s on the exam results board./ ‘I see your students/ have got good grades’,/ exclaimed her colleague./ Miss Edwards was surprised that/ her students did so badly./

NON-IRONIC_3 /Miss Edwards was looking at/ the long list of ‘A’s on the exam results board./ ‘I see your students/ have got good grades’,/ exclaimed her colleague./ Miss Edwards was surprised that/ her students did so well./

IRONIC_4 /Joe evaluated/ the small number of tickets sold for Justin’s concert./ ‘I see people/ are desperate to listen to you sing’,/ he said./ Justin was shocked that/ so few people wanted to hear his latest songs./

NON-IRONIC_4 /Joe evaluated/ the large number of tickets sold for Justin’s concert./ ‘I see people/ are desperate to listen to you sing’,/ he said./ Justin was shocked that/ so many people wanted to hear his latest songs./

IRONIC_5 /Emma scanned the shelves at Ann’s book launch;/ the book hadn’t sold well./ ‘I see people/ have rushed in to buy your new book’,/ Emma exclaimed./ Ann was amazed that/ nobody was interested in her new book./

NON-IRONIC_5 /Emma scanned the shelves at Ann’s book launch;/ the book had sold well./ ‘I see people/ have rushed in to buy your new book’,/ Emma exclaimed./ Ann was amazed that/ everyone was interested in her new book./

IRONIC_6 /It was Valentine's Day and /Jamie had received no cards./ 'It appears the girls/ really fancy you',/ laughed his flatmate./ Jamie wondered why/ the girls found him unattractive./

NON-IRONIC_6 /It was Valentine's Day and /Jamie had received many cards./ 'It appears the girls/ really fancy you',/ laughed his flatmate./ Jamie wondered why/ the girls found him attractive./

IRONIC_7 /The politician had taken his assistant along to his conference;/ there were almost no other attendees there/. 'Clearly people/ want to hear you speak',/ mused the assistant./ The politician was/ not well liked by the citizens of his city./

NON-IRONIC_7 /The politician had taken his assistant along to his conference;/ there were hundreds of other attendees there./ 'Clearly people/ want to hear you speak',/ mused the assistant./ The politician was/ very well liked by the citizens of his city./

IRONIC_8 /It was results day and/ Michael got the lowest grade in class again./ 'I see you/ are very smart',/ commented his best friend./ Michael had always been/ academically weak./

NON-IRONIC_8 /It was results day and/ Michael got the highest grade in class again./ 'I see you/ are very smart',/ commented his best friend./ Michael had always been/ academically gifted./

IRONIC_9 /Cheryl noticed there were/ no flowers by Lisa's bed./ 'I see your boyfriend /really cares about you being in hospital',/ she exclaimed./ Lisa knew that /her boyfriend didn't care about her being ill./

NON-IRONIC_9 /Cheryl noticed there were/ some flowers by Lisa's bed./ 'I see your boyfriend/ really cares about you being in hospital',/ she exclaimed./ Lisa knew that /her boyfriend cared about her being ill./

IRONIC_10 /A group of health volunteers were visiting a village/ with lots of underweight children./ 'It seems that these villagers /are very well fed',/ said one of the volunteers./ The villagers had been/ starving for years./

NON-IRONIC_10 /A group of health volunteers were visiting a village/ with lots of overweight children./ 'It seems that these villagers /are very well fed',/ said one of the volunteers./ The villagers had been/ overeating for years./

IRONIC_11 /Paul peeked into his son Billy’s bedroom;/ Billy was completely absorbed in his computer game./ ‘I knew my son/ would be revising hard for his exam’,/ Paul said to his wife./ Billy had spent days/ procrastinating about the exam./

NON-IRONIC_11 /Paul peeked into his son Billy’s bedroom;/ Billy was completely absorbed in his history textbook./ ‘I knew my son/ would be revising hard for his exam’,/ Paul said to his wife./ Billy had spent days/ preparing for the exam./

IRONIC_12 /Alice looked at the/ huge piles of leftovers after her dinner party./ ‘I see people/ enjoyed their food’,/ said Bill./ Alice was/ embarrassed that people didn’t like her food/.

NON-IRONIC_12 /Alice looked at the/ stack of empty plates after her dinner party./ ‘I see people/ enjoyed their food’,/ said Bill./ Alice was/ overjoyed that people liked her food./

IRONIC_13 /Bob peered into his friend’s/ empty fishing net./ ‘I see you/ have caught lots of fish today’,/ he laughed./ The six hours of fishing/ had proved to be a disappointing day./

NON-IRONIC_13 /Bob peered into his friend’s/ bulging fishing net./ ‘I see you/ have caught lots of fish today’,/ he laughed./ The six hours of fishing/ had proved to be a rewarding day./

IRONIC_14 /Sandra looked at the/ huge pile of cakes left on the cake stall./ ‘I see that the children/ appreciate your baking’,/ she exclaimed to Hannah./ Hannah was/ upset at what the children thought of her cakes./

NON-IRONIC_14 /Sandra looked at the/ remnants of/ the cakes left on the cake stall. ‘I see that the children/ appreciate your baking’,/ she exclaimed to Hannah./ Hannah was/ pleased at what the children thought of her cakes./

IRONIC_15 /The boyfriend of the waitress noticed that/ nobody was leaving a tip./ ‘I see people/ are happy with the service’,/ he smirked./ The waitress was/ disappointed that people thought she did a bad job./

NON-IRONIC_15 /The boyfriend of the waitress noticed that/ everyone was leaving a tip./ ‘I see people/ are happy with the service’,/ he smirked./ The waitress was/ satisfied that people thought she did a good job./

IRONIC_16 /The vineyard owner spoke to the site manager/ about the low productivity./ ‘I see your grape pickers/ are highly motivated’,/ he exclaimed./ The owner knew that/ his grape pickers were lazy workers./

NON-IRONIC_16 /The vineyard owner spoke to the site manager/ about the high productivity./ ‘I see your grape pickers/ are highly motivated’,/ he exclaimed./ The owner knew that/ his grape pickers were hard workers./

IRONIC_17 /Mandy walked into her daughter’s bedroom,/ it was messy./ ‘I can see that you/ take cleanliness very seriously’,/ she said to her daughter./ Mandy knew/ her daughter never made an effort to clean her room./

NON-IRONIC_17 /Mandy walked into her daughter’s bedroom,/ it was immaculate./ ‘I can see that you/ take cleanliness very seriously’,/ she said to her daughter./ Mandy knew/ her daughter always made an effort to clean her room./

IRONIC_18 /The train manager showed the transport minister round/ the empty carriage./ ‘I see people/ support your plea to use public transport’,/ he mused./ The citizens/ were very reluctant to use public transport./

NON-IRONIC_18 /The train manager showed the transport minister round/ the packed carriage./ ‘I see people/ support your plea to use public transport’,/ he mused./ The citizens/ were very eager to use public transport./

IRONIC_19 /The guests/ were completely silent when Dave delivered the punch line in his best man’s speech./ ‘I see people/ appreciate your sense of humour’,/ teased the groom./ The guests found/ the best man’s joke rather dull./

NON-IRONIC_19 /The guests/ fell about laughing when Dave delivered the punch line in his best man’s speech./ ‘I see people/ appreciate your sense of humour’,/ teased the groom./ The guests found/ the best man’s joke rather funny./

IRONIC_20 /The football manager walked onto the pitch/ to boos from the stands./ ‘Clearly people/ are glad that you have been kept on’,/ mused the coach./ The fans were/ outraged that the football club had stuck with the same manager./

NON-IRONIC_20 /The football manager walked onto the pitch/ to cheers from the stands./ ‘Clearly people/ are glad that you have been kept on’,/ mused the coach./ The fans were/ grateful that the football club had stuck with the same manager./

IRONIC_21 /The councillor looked at/ the unimpressed faces of the crowd who had turned out to see the firework display./ ‘Clearly people/ liked your idea of setting the display to music,’/ he exclaimed to his advisor./ The crowd thought/ the show was absolutely awful./

NON-IRONIC_21 /The councillor looked at/ the delighted faces of the crowd who had turned out to see the firework display./ ‘Clearly people/ liked your idea of setting the display to music,’/ he exclaimed to his advisor./ The crowd thought/ the show was absolutely awesome./

IRONIC_22 /Maggie looked at/ the very short list of volunteers to help with her raffle./ ‘Clearly people/ are willing to give up their spare time’,/ exclaimed the coordinator./ People were/ indifferent about helping out at the raffle./

NON-IRONIC_22 /Maggie looked at/ the very long list of volunteers to help with her raffle./ ‘Clearly people/ are willing to give up their spare time’,/ exclaimed the coordinator./ People were/ enthusiastic about helping out at the raffle./

IRONIC_23 /The market researcher was with her supervisor,/ lots of people were refusing to take part in the survey./ ‘Clearly people/ are really keen to help you’,/ exclaimed the supervisor./ It was evident to the researcher that/ people were unwilling to participate./

NON-IRONIC_23 /The market researcher was with her supervisor,/ lots of people were queuing to take part in the survey./ ‘Clearly people/ are really keen to help you’,/ exclaimed the supervisor./ It was evident to the researcher that/ people were willing to participate./

IRONIC_24 /The actor was/ disappointed by the lack of award nominations./ ‘I see people/ enjoyed your last film’,/ remarked his girlfriend./ The actor knew that/ his last film was a failure./

NON-IRONIC_24 /The actor was/ delighted by the flurry of award nominations./ ‘I see people/ enjoyed your last film’,/ remarked his girlfriend./ The actor knew that/ his last film was a success./

IRONIC_25 /Bill surveyed the huge pile of/ unmarked essays in front of Lisa./ ‘I see you/ have worked hard on the marking’,/ he mused./ Lisa had spent/ barely any time getting the marking done./

NON-IRONIC_25 /Bill surveyed the huge pile of/ marked essays in front of Lisa./ ‘I see you/ have worked hard on the marking’,/ he mused./ Lisa had spent/ a very long time getting the marking done./

IRONIC_26 /Sally looked at Julie’s dinner plate;/ she was having burger and chips for dinner again./ ‘It looks like you/ are taking your weight loss very seriously’,/ remarked Sally./ Julie was/ ignoring the diet plan her nutritionist gave her./

NON-IRONIC_26 /Sally looked at Julie’s dinner plate;/ she was having tuna and salad/ for dinner again./ ‘It looks like you/ are taking your weight loss very seriously’,/ remarked Sally./ Julie was/ following the diet plan her nutritionist gave her./

IRONIC_27 /Mary went to see Tom’s first attempt at stand-up comedy, and gazed around at/ the audience who were silent./ ‘Clearly people/ enjoyed your show’,/ she mentioned afterwards./ Tom could not believe he had delivered/ such a poor first performance./

NON-IRONIC_27 /Mary went to see Tom’s first attempt at stand-up comedy, and gazed around at/ the audience who looked amused./ ‘Clearly people/ enjoyed your show’,/ she mentioned afterwards./ Tom could not believe he had delivered/ such a good first performance./

IRONIC_28 /Martin’s sales pitch had stunned everyone,/ the atmosphere was very negative./ ‘I see people/ liked your idea’,/ laughed Bill./ Martin could sense that/ people were disappointed about the new idea./

NON-IRONIC_28 /Martin’s sales pitch had stunned everyone,/ the atmosphere was very positive./ ‘I see people/ liked your idea’,/ laughed Bill./ Martin could sense that/ people were passionate about the new idea./

IRONIC_29 /The new art exhibition was/ failing to draw in the crowds./ ‘Obviously the local people/ appreciate modern art’,/ said Jason./ He knew that/ the locals wouldn’t like the new collection./

NON-IRONIC_29 /The new art exhibition was/ succeeding to draw in the crowds./ ‘Obviously the local people/ appreciate modern art’,/ said Jason./ He knew that/ the locals would like the new collection./

IRONIC_30 /The new deal on the travel agent website was/ not attracting people to buy holiday packages./ ‘Obviously people/ are excited by these offers',/ said Joyce./ Joyce's boss was aware that/ nobody was keen to go on holiday./

NON-IRONIC_30 /The new deal on the travel agent website was/ really attracting people to buy holiday packages./ 'Obviously people/ are excited by these offers',/ said Joyce./ Joyce's boss was aware that/ everyone was keen to go on holiday./

IRONIC_31 /The dogs at the dog training class/ were running riot./ 'Obviously the dogs/ are responding well to training,/ remarked Rachel./ The new trainer was/ dismayed that the dogs were so oblivious to her commands./

NON-IRONIC_31 /The dogs at the dog training class/ were sitting obediently./ 'Obviously the dogs/ are responding well to training',/ remarked Rachel./ The new trainer was/ pleased that the dogs were so responsive to her commands./

IRONIC_32 /Andrew looked round the meeting room at/ all the frowning faces./ 'Clearly people/ are convinced by your argument',/ muttered his secretary./ Andrew got the feeling that/ his colleagues disagreed with his ideas./

NON-IRONIC_32 /Andrew looked round the meeting room at/ all the smiling faces./ 'Clearly people/ are convinced by your argument',/ muttered his secretary./ Andrew got the feeling that/ his colleagues agreed with his ideas./

IRONIC_33 /The IT manager had received/ a lot of stupid questions about the new computer system./ 'Clearly people/ understood your explanation',/ mused his assistant./ The manager was astonished that/ nearly everyone was confused about what he said./

NON-IRONIC_33 /The IT manager had received/ a lot of good feedback about the new computer system./ 'Clearly people/ understood your explanation',/ mused his assistant./ The manager was astonished that/ nearly everyone was clear about what he said./

IRONIC_34 /The doctor surveyed/ the anxious face of his patient on the ward./ 'I see your patient/ is reassured by your surgical skills',/ said the nurse./ The doctor knew that/ his patient felt insecure about his competence./

NON-IRONIC_34 /The doctor surveyed/ the relaxed face of his patient on the ward./ 'I see your patient/ is reassured by your surgical skills',/ said the nurse./ The doctor knew that/ his patient felt confident about his competence./

IRONIC_35 /Two cashiers in the supermarket surveyed/ the shop floor with only a few customers./ ‘Clearly people/ cannot get enough of our products’,/ one of the cashiers commented./ The other cashier wondered why/ the products were so unappealing./

NON-IRONIC_35 /Two cashiers in the supermarket surveyed/ the shop floor with long queues of customers./ ‘Clearly people/ cannot get enough of our products’,/ one of the cashiers commented./ The other cashier wondered why/ the products were so appealing./

IRONIC_36 /James looked at pictures of/ the ugly girls who entered the beauty pageant./ ‘I see the girls/ are very good looking in the competition this year.’/ he said to his friend./ He was/ not impressed with the selection of competitors this year./

NON-IRONIC_36 /James looked at pictures of/ the pretty girls who entered the beauty pageant./ ‘I see the girls/ are very good looking in the competition this year.’/ he said to his friend./ He was/ very impressed with the selection of competitors this year./

Appendix C

Stimuli for Chapter Four (Anomaly Study)

Note. First word in bold is non-anomalous, second word in bold is anomalous.

Passage Anomalies

1. Andrea was the only child in her family and she was having a very hard time following her parent’s decision to split up. Andrea’s mum wanted her to live with her at Andrea’s grandparent’s place. On the other hand, her dad wanted her to live with him and his new partner. They had been arguing over who should get custody of their **son/daughter** for weeks. Andrea gets on better with her dad than her mum, but she dislikes her dad’s new partner. She didn’t know what she should do.

2. Bobby was completely devastated after being dumped by his girlfriend. To console himself after the break up, he had spent every evening in the pub drinking alone. In an effort to forget about his problems and avoid his feelings, he would drink pint after pint of alcohol to get himself through each night. He would not go home until he was completely **drunk/sober**. His friends suggested he should go and see a counselor but he was just too embarrassed about his drinking problem.

3. Margaret was in hospital because she was very ill. For the past month her granddaughter Hollie had been to visit her every Sunday. Hollie knew that Margaret had been very lonely since her husband died several years ago. One weekend, Hollie was invited by her best friend to see their favourite band on tour. She was very excited about this rare opportunity but it also meant that she would miss visiting her **grandmother/grandfather** on Sunday. She didn’t want to be a bad granddaughter.

4. A disastrous storm had hit a South Pacific city. The strong wind had destroyed many buildings and the government had called for emergency evacuation of all inhabitants. However, hazardous road conditions had made it hard to escape the city. There was heavy rainfall and blown over trees blocking the roads. Many unfortunate civilians died during this **hurricane/earthquake** due to falling roofs and scaffoldings. The governors of the city were deciding how to accommodate the remaining homeless citizens.

5. Joyce finally finished her degree at university, and her entire family was celebrating with her. They decided to throw a party at home for her and bought her a massive chocolate cake as a treat. They also bought her lots of

presents. Joyce was really happy that she had so many people to celebrate her **graduation/birthday** with her. It was one of the happiest days in her life.

6. Julia hates flying on aeroplanes. The first time she took a flight to go on holiday, she experienced horrible turbulence, which frightened her a lot. This has made her develop a fear for flying which she has had ever since. Julia’s best friend has invited her to fly to America next year for a reunion. Julia really wants to go but she is absolutely terrified that she would become **air/sea** sick. She is contemplating an alternative means of transport.

7. Liang, a recent arrivee from China, was having problems adapting to Canada. She could not speak English or French. She enjoyed spicy foods and found Canadian food very bland. She asked for help but people either ignored her or regarded her as stupid. Liang felt very much like a **foreigner in/native of** Canada. Frustrated by her entire move to Canada, she sat down and cried.

8. A dead body of an eighteen year old girl was found in the bathroom of an apartment last night. A young man who lives close by has been arrested on suspicion of murder. The police had found CCTV footage showing that the young man was lurking near the home of the girl yesterday. When the young man was questioned, he completely denied the charges. However, the police were convinced that he was **guilty/innocent** of killing the girl. They launched a further investigation to look for witnesses of the incident.

9. After three years of hard work on his degree in Oriental Studies, Scott finally graduated from university. After his graduation, he received a job offer to work in Japan for a year. He was really excited about this and he was planning to take the opportunity to travel around Tokyo, one of the most vibrant cities in East Asia. However, Scott was worried that his inability to speak **Japanese/Chinese** would stop him from communicating with people. He really wanted to be able to make new friends out there.

10. Selena, a recently married nineteen year old girl, was pregnant with her first baby. Being a college dropout and without a job Selena was still living at her parents’ house with her husband who was also unemployed. Her parents were asking her move out as there wouldn’t be enough space once the child was born. She had thought about applying for a council apartment but the waiting list was long. She never thought that being a **new/single** mother would be so troublesome. Her baby was due soon.

11. Tommy and his brother were playing football in their living room. Their mother had told them not to play ball games indoors as she was worried that they might break the expensive furniture. However, they didn’t listen to her. Tommy kicked the ball very hard and accidentally smashed the television. Tommy knew he would be in big trouble when his mother came home and found out what he did to the **screen/computer**. He was thinking of blaming it on his brother because he really didn’t want to get grounded.

12. A town was well-known for its spring water. Many locals had jobs bottling and selling the water to tourists. The lead pipes that delivered the water were old and needed replacing as high levels of lead are known to be toxic. However, the mayor decided to cut back on public spending and neglected the maintenance of the water system. After drinking the water contaminated with **metal/mercury**, many tourists became ill. The mayor was asked by a journalist to justify his decision-making.

Sentence Anomalies

1. Once again Amanda was studying all night for exams. She went to the canteen at her university and picked up her third extra large coffee. She then drank her black coffee and entered the library. However, when she sat down she found she could not focus. She was so hyperactive that she couldn’t even stay seated. Amanda was feeling jittery due to her excessive consumption of **stimulants/sedatives** contained in caffeinated drinks. She was desperate to concentrate on her revision.

2. A planned terror attack broke out in Islamabad, the capital city of Pakistan. A bomb had been set off on a bus causing ten civilian deaths. Fourteen passengers on the bus were also severely wounded. The paramedics rushed to the location of the incident and attempted to save the **injured/deceased** using resuscitation. The police also arrived shortly and arrested a male suspect in relation to the bombing. He was taken to the police station for questioning.

3. A woman has been diagnosed with a rare form of cancer in its advanced stage. Her doctor said she only had six months to live as her condition is deteriorating without medication. Devastated by the news, the woman’s husband went searching for a cure. He found out there is a new treatment that could **improve/worsen** his wife’s condition. However, it’s currently being tested and not available to patients. He wrote to the researchers to beg them to try the medication on his wife as a last resort.

4. Ethan, a sixth form student, is taking an important maths exam tomorrow, and he has done no revision whatsoever. If he doesn't make his grade, he will not be going to the university he wanted to go to. Knowing he won't be able to learn the exam materials in time, he wrote some formulas on his hand. He doesn't want to disappoint his parents by getting a **bad/good** grade, but he knows that cheating in an exam is prohibited. He doesn't want to get in trouble with the teachers.

5. Gordon has been with his girlfriend for nearly seven years. He is almost thirty years old and people were constantly asking him when he planned to get married. He decided that now is the right time to settle down with his girlfriend. Gordon bought an expensive ring from the jewellers and booked a posh restaurant for the evening of Valentine's day. He planned to propose to his girlfriend during their **celebration/wedding** dinner. He is very nervous and excited at the same time.

6. Denis loved collecting old toys. His room was filled with second hand toys from charity shops. Action figures, train sets, plush toys, and board games were just a few of the hundreds of items he owned. However, his collection got so big that the rest of the house was also packed with his belongings. His obsession with worthless old toys had caused great inconvenience to his family, who considered his possessions as **rubbish/treasures**. He had been told countless times by his mother to get rid of his toys.

7. A crash involving a kindergarten school bus happened on the motorway on a Monday morning. All the children were unharmed but the sixty year old bus driver was very seriously hurt. It was clear that fast action was needed. The ambulance picked up the bus driver and rushed away from the scene to quickly get him some medical treatment in the **hospital/nursery**. The situation was very serious and featured on the national news the same evening.

8. Jessica was a talented gymnast hoping to represent her country at the World Championships. Each athlete had to undergo a drug test prior to participating. Unfortunately, the drug test came back positive for Jessica and the anti-doping committee were considering banning her from the competition. Jessica was forced by her coach to take steroids that caused **enhancements/impairments** in performance. Jessica felt that she was innocent.

9. Lawrence was recruiting a new office assistant for his company. His best friend Paul had applied for the position. However, there was another applicant who was much more

qualified than Paul. Lawrence knew that as an interviewer he should try to be **impartial/biased**, but he didn't want to disappoint Paul. He felt sorry for Paul, who's been unemployed for a long time and desperately needs money.

10. There was a tourist flight travelling from Vienna to Barcelona. On the last leg of the journey, it developed engine trouble. Over the Pyrenees, the pilot started to lose control. The plane eventually crashed right on the border. Wreckage was equally strewn in France and Spain. The authorities were trying to decide where to bury the **dead/survivors** from the plane crash. The families of the passengers were devastated about their losses.

11. Rory had always wanted his own pet since he was a young boy. His parents had bought him a goldfish once before but it had only lived for a couple of months. They also kept a hamster for a few years because it was easy to look after, but Rory didn't really like hamsters. What he really wanted was a **dog/cat**, as people always describe them as man's best friend. Rory had been nagging his mum everyday but she wasn't sure that he was responsible enough to look after an animal by himself.

12. Jonathan was bitten by a poisonous spider during a hiking trip on a mountain in South California. Shortly after being bitten, Jonathan developed severe cramps and muscle pain in his stomach. He felt extremely nauseous and began to vomit uncontrollably. He tried to shout for help but there was no one around. He desperately needed to be treated with **antidote/venom**, because his condition could be fatal. He was extremely worried.