Investigating the effects of perceptual processing on visual working memory in individuals with autism spectrum disorder : an event-related potential study

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**INVESTIGATING THE EFFECTS OF PERCEPTUAL
PROCESSING ON VISUAL WORKING MEMORY IN
INDIVIDUALS WITH AUTISM SPECTRUM DISORDER:
AN EVENT-RELATED POTENTIAL STUDY**

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DEDICATION

This PhD research thesis is dedicated to the memory of my late parents.

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ABSTRACT

Recent neuroimaging and electrophysiological research has shown that autism spectrum disorder (ASD) is a neural systems disorder characterised by atypical connectivity between brain networks (Minshew & Keller, 2010). Such atypical connectivity underlies an impairment in the visual working memory (VisWM) for complex information (Williams, Goldstein & Minshew, 2006). Although research has reported differences in perceptual processing as well as the working memory network of ASD (Williams et al., 2006), there is no published literature to our knowledge on the effects of such differences on the topography of effects of complex information processing in the VisWM of these individuals with ASD. While individuals with ASD have been shown to prefer local to gestalt processing (Minshew and Keller, 2010), there has been no published literature on perceptual closure processes. Perceptual closure, which involves the filling in of details to form a complete image, underlies gestalt processing (Kimchi, 1992). This study investigated how such differences in visual perceptual reasoning may impact the processing of complex information in the VisWM of individuals with ASD. Study 1 and Study 2 used an event-related potential (ERP) VisWM paradigm to examine differences in perceptual closure and the effect of coherence on object-to-scene binding in the VisWM of ASD. The effect of a perceptual training on perceptual closure for ASDs was then examined in Study 3.

Nineteen ASD and 17 typically developing (TD) male adolescents from 13 to 16 years old participated in Study 1 and 2. Study 1 looked at the differences in perceptual processing between the adolescents with ASD and TD adolescents. Specifically, the perceptual closure processes involved in object recognition were examined. Perceptual closure involves the interplay between local and global processing, which has been found to be different in individuals with ASD. In this study, perceptual closure processes were indexed by closure negativity (N_{CL}), an ERP component generated within the visual association cortex.

Fragmented images were presented to the TD adolescents and adolescents with ASD.

Adolescents with ASD were found to need a slightly higher level of completion before the fragmented object was recognised. When the ERP components were examined, adolescents with ASD and TD adolescents were found to have similar generation of early visual components (P1 and N1) and the N_{CL} in the occipito-temporal regions. However, differences in prefrontal activations were found. While the TD adolescents showed prefrontal and posterior activations in the perceptual closure process, the individuals with ASD showed mainly temporal/parietal and posterior activations. Prefrontal regions have been shown to be involved in gist or low frequency processing. These areas have also been implicated in model selection and comparison processes. This is consistent with previous research that showed a reduced frontal-posterior connectivity in individuals with ASD. This engagement of prefrontal regions could explain the TD adolescents' ability to recognise fragmented objects at a lower level of closure, where gestalt processing is critical.

Having established that the interplay of global and local processing is present even in the earlier perceptual closure processes, Study 2 set out to investigate how such perceptual differences could impact on the ability of individuals with ASD to use coherence within an image to optimise their VisWM. In Study 2, slow-wave shifts showed that the VisWM network in adolescents with ASD and TD adolescents differed depending on the coherence of the scene. Although both groups showed better accuracy for intact than for scrambled scenes, TD adolescents recruited more higher-order attentional or cognitive processes when processing gestalt images. They also showed higher activation in the right brain regions, where gestalt processing occurs.

Following the differences found in perceptual closure process and VisWM, Study 3 investigated if perceptual closure could be improved with the use of metacognitive strategies that encourage more gestalt processing and use of category comparisons. Seventeen male

adolescents with ASD from 13 to 16 years old participated in Study 3. There were 9 participants in the training group and 8 participants in the control group. The differences in the two groups' ability to identify fragmented images did not reach statistical significance. The two group did not differ in the number of correct images identified on their pre- and post-measures. However, the mean level of identification was significantly different before and after training for both groups. Both groups could identify the fragmented images at a less complete level. No significant differences in the two groups' accuracy and reaction times were found on the VisWM tasks. The experiment would need to be replicated with a larger sample with an event-related potential design to investigate if differences in scalp activations are found following training. It could be that the differences may not be reflected at a behavioural level.

Implications of the current findings suggest that interplay of global and local processing impacts on lower-level and higher-level visual processing. This in turn affects the VisWM processes and performance of individuals with ASD. The use of a perceptual training program for improving VisWM using coherence as a metacognitive strategy is an area that can be considered in ameliorating some of the difficulties resulting from the atypical perceptual processing of individuals with ASD.

CHAPTER I: INTRODUCTION

Introduction

Being able to detect quickly and accurately changes in people and their movements are important when adapting to social situations. For example, we need to quickly process changes in the location of a person amidst other people and objects, in order to approach him to start a conversation. To be able to detect these changes in social as well as non-social scenes, we need to retain, accumulate and integrate the perceived visual information (Hollingworth, 2006). This is done by our visual working memory (VisWM). Our VisWM allows us to remember and update the spatial locations of people and objects.

This research study focuses on how differences in visual perceptual processing may impact on how such complex information are processed in the VisWM of individuals with autism spectrum disorder (ASD). These differences may affect the online monitoring processes needed to interpret complex stimuli within real-world contexts and contribute to some of the observed social deficits in ASD (Minshew & Keller, 2010).

What is Autism Spectrum Disorder?

ASD is a neurodevelopmental disorder characterised by a triad of impairments. Individuals with ASD have difficulties in the areas of social interaction and social communication. They also show repetitive behaviours and/or stereotyped interests (American Psychiatric Association, 2013). Using the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR), individuals could be diagnosed with four separate disorders: autistic disorder, Asperger's disorder, childhood disintegrative disorder, or pervasive developmental disorder not otherwise specified (American Psychiatric Association, 2000). With the current DSM-5, individuals diagnosed with one of the four pervasive developmental disorders (PDD) from DSM-IV would still meet the criteria for ASD in DSM-5. ASD affects approximately 2.25% of children (Zablotsky, Black, Maenner, Schieve, &

Blumberg, 2015). In Singapore, prevalence has increased from 2-4 per 10,000 school-aged children in the 1980s to currently 50-60 per 10,000 (CPG, 2010). Given this increase in prevalence of ASD, research into the causes and interventions for ASD is necessary.

Currently, the diagnosis of ASD is still largely based on behavioural symptoms. Although cognitive and behavioural theories have attempted to explain the impairments characterising ASD, they are still not able to adequately provide a unified account of the behavioural manifestations. A recent review on the cognitive and behavioural characteristics proposed six broad autism phenotypic traits (Dawson, 2002). These traits include face processing, social affiliation, motor imitation, feature binding, executive function, and language ability. The main cognitive theories of ASD: the Theory of Mind deficit hypotheses, the Weak Central Coherence theory, and the Executive Dysfunction theory, proposed explanations of the broad spectrum of symptoms seen in ASD. The Theory of Mind deficit hypotheses proposed that the social interaction and social communication impairments seen in ASD are caused by a defective innate cognitive mechanism to explain and predict behaviour by imagining what goes on in the mind of others (Baron-Cohen, Leslie, & Frith, 1985). Face processing is one such component underlying the theory of mind. However, this theory does not account for the repetitive and restricted behaviours seen in ASD. The Executive Dysfunction theory explains the impairments seen in ASD as due to deficits in their executive functioning ability (e.g. Ozonoff et al., 1991a). Executive functioning is an umbrella term for functions including planning, working memory, impulse control, inhibition and shifting sets, and initiation and monitoring of action. A cross-cultural study on Chinese and US pre-schoolers has found that differences in executive functioning predicted theory of mind in both cultures (Sabbagh et al., 2006). Studies have shown the impact of executive functioning on adaptive functioning in ASD (e.g. Wallace et al., 2016). However, the theory does not account for the atypical perceptual processing characteristics of individuals with

ASD. The Weak Central Coherence theory of ASD proposed that the perceptual and behavioural impairments characteristic of ASD are due to an inability to integrate many information sources into one unified whole (Frith, 1989). The Weak Central Coherence theory has proposed that the three areas of impairments that characterised ASD could be understood as an integration deficit. For example, impairments in social interactions are attributed by the Weak Central Coherence theory as an inadequate integration of various concurrent social information. In any social interaction, an ASD individual would have to monitor and integrate different aspects of social information including the content and context of the dialogue, the speaker's tone of voice, the speaker's facial expression and body language, etc. Thus, as the information becomes more complex and multiple, the individual with ASD's difficulty would increase. The Weak Central Coherence theory provides a possible explanation for the observed clinical symptoms of ASD. However, it does not indicate what possible cognitive or biological mechanisms underlie this integration deficit (Schipul, Keller, & Just, 2011). To date, no single deficit, whether it is theory of mind, executive functioning, or weak central coherence, can explain adequately all the core behavioural and cognitive symptoms of ASD.

Autism Spectrum Disorder as a Neural Systems Disorder

Recent advances in neuroimaging research have identified a possible biological mechanism underlying the behavioural manifestations of ASD (Schipul et al., 2011), suggesting that it is a neural systems disorder characterised by atypical connectivity between and within task-related brain regions (Belmonte, Allen, et al., 2004; Belmonte, Cook, et al., 2004; Minshew & Keller, 2010). This disrupted connectivity hypothesis proposes that individuals with ASD have weak connectivity between distant brain regions and increased connectivity within local regions. Together, these global underconnectivity and local

overconnectivity contribute to the social, cognitive, and behavioural characteristics of ASD (Belmonte, Cook, et al., 2004).

Atypical connectivity in ASD has been supported by both neuroanatomical and neuroimaging research. A review of the developmental neuroanatomy of ASD showed that brain overgrowth is found in the early development of ASD individuals. This brain overgrowth is likely due to a lack of neural pruning, and may lead to abnormalities in neural pattern where there is extensive local inter-connectivity at the expense of long-range connectivity (Courchesne et al., 2007). Neuroimaging research on functional connectivity in ASD has also consistently found reduced frontal-posterior synchronisation of activation across different types of tasks, although they tend to occur in more complex tasks, especially those that involve frontal participation. These included tasks on language (Kana, Keller, Cherkassky, Minshew, & Just, 2006; Mizuno et al., 2011), executive function (Just, Cherkassky, Keller, Kana, & Minshew, 2007), social processing (Kana, Keller, Cherkassky, Minshew, & Just, 2009; Schipul et al., 2011), working memory (Koshino et al., 2005; Koshino et al., 2008b), and visuospatial processing (Damarla et al., 2010). Known as the Underconnectivity theory of ASD (Just et al., 2007; Just, Keller, Malave, Kana, & Varma, 2012), it postulates that individuals with ASD have reduced functional connectivity between frontal and posterior cortical areas. As a result, psychological processes that rely on such integrated functioning of frontal and posterior brain networks may not be carried out in an optimal manner. Psychological processes which involve more complex information processing that require integration of various sources of information or processing are usually more affected (Minshew, Goldstein, & Siegel, 1997). Figure 1-1 is an example of reduced network synchronisation in ASD during set-shifting.

Atypical Connectivity in ASD and its relation to VisWM

VisWM is one such psychological process that typically involves complex information processing. Behavioural studies have shown that individuals with ASD have impaired working memory. Although their working memory performance on simple tasks was comparable to typical individuals (Steele, Minshew, Luna, & Sweeney, 2007), their performance on more complex tasks was impaired (Minshew & Goldstein, 2001). There are also emerging neuroimaging results which showed that working memory impairments in ASD were associated with atypicality in frontal lobe functioning, particularly in the prefrontal cortex (PFC)(Silk et al., 2006). Further studies also showed that the spatial working memory of individuals with ASD are found to be poorer, especially on tasks that require higher cognitive load and flexibility (Goldberg et al., 2005). The more complex the spatial working memory task is, the more obvious the memory deficit (Barendse et al., 2013).

Neuroimaging research shows that atypical functional connectivity plays a part in limiting the ability of the individuals with ASD to process and remember complex information in VisWM. One study looked at the neural correlates of cognitive load on the visual perceptual processing of children with ASD (Vogan et al., 2014). As cognitive load increased, typically developing (TD) children recruited more frontal and posterior parietal regions. On the other hand, children with ASD showed increased recruitment of only the posterior visual regions. This increased activation of only the posterior visual regions suggests that individuals with ASD rely more on visually-based processing. They may emphasise more on visual features and details of objects to remember complex information, as compared to a more effective use of VisWM (Ring et al., 1999). Increase activation of the posterior visual regions may be adequate for visuo-spatial processing. However, it is likely inefficient for more complex cognitive operations such as VisWM. Such a processing style would have implications when the information to be remembered and monitored exceeds the

VisWM's capacity, thus resulting in the social and executive deficits typically observed in ASD (Vogan et al., 2014).

Figure 1-1: Example of reduced network synchronisation in ASD during set-shifting (black lines represent connections among regions which indicated reduced task-dependent theta-synchronisation during set-shifting in children with ASD). The size of the regions in this network, indicated by the size of the red dots, represents increasing magnitude of group differences in connectivity strength for these regions.

(Doesburg, Vidal, & Taylor, 2013)

Impairments in working memory of individuals with ASD affect the way information is processed, which in turn impact on the behaviours that rely on how such information is

processed. A review of the working memory in high-functioning adolescents with autism (Barandse et. al, 2013) found impairments in the visuospatial WM of these individuals. Most of these studies used validated tasks such as the WRAML Finger Windows and CANTAB spatial span and spatial WM. Another study which used a size sequencing task also showed that adolescents with ASD made more errors and had a higher reaction time than healthy controls (McGonigle-Chalmers, 2008). The individuals with ASD had difficulties updating context-relevant information and modifying their thinking and behaviours. Such updating processes also play important roles in the adjustment of behaviour to social situations. Understanding of social situations requires the integration of a greater number of elements than does understanding of the physical world. Social stimuli (e.g. a facial expression, a gesture, or a spoken sentence) are also transient and more difficult to predict.

Interventions aimed at increasing VisWM's ability to process complex stimuli in ASD may address an important building block for learning how to interact. Understanding how VisWM can be optimised or enhanced in populations with ASD could enable these individuals to adapt to their social world in a more effective and appropriate manner. To explore how to optimise VisWM of individuals with ASD, we must first understand the basic processes underlying VisWM.

Baddeley's Model of Working Memory

Working memory involves both the ability to maintain information 'on-line' over a brief period of time and to manipulate ideas internally to plan complex responses (Baddeley, 2000). Baddeley introduced a multi-component store model to explain WM processes, depicted in Figure. 1-2. The central executive acts as an attention resource by channelling information to the other three components: the phonological loop, the visuospatial sketchpad and the episodic buffer. The phonological loop stores auditory information which can be

silently rehearsed in a continuous way. The visuospatial sketchpad stores visual and spatial information. The component of episodic buffer was later incorporated into the model (Baddeley, 2000) as a store where integrated representations could be maintained. This study focused on the VisWM by looking at how visual information is bound and maintained in the episodic buffer.

Figure 1-2. Baddeley's multi-component model of working memory (2000).

Visual Working Memory Network

Studies from neurophysiological, neuropsychological and neuroimaging studies of VisWM showed that processes involve a distributed network of frontal and posterior cortical areas (Hannula & Ranganath, 2008). VisWM storage is mediated by a frontoparietal network that encodes task objectives and abstract representation, and a posterior sensory 'feature storage' network for the storage of detailed visual representations (Sreenivasan et al., 2014; D'Esposito & Postle, 2015). These cortical regions are regulated by the PFC (Ranganath, 2006).

In individuals with ASD, however, a less distributed network is seen. Neuroimaging studies showed an enhanced local connectivity in posterior brain regions (occipitoparietal/ventral and occipitotemporal/dorsal pathways) but reduced connectivity between task-related brain regions (Sahyoun, Belliveau, Soulieres, Schwartz, & Mody, 2010). For example, individuals with ASD had activations within the posterior brain regions that were similar to TD individuals (Koshino et al., 2008a) but showed underconnectivity of the fusiform and frontal areas.

In addition to a less distributed VisWM network, individuals with ASD also consistently showed atypical frontal lobe abnormalities, particularly in the PFC (Luna et al., 2002). This is consistent with behavioural studies which show intact working memory performance on simple memory tasks, but impaired performance on more complex tasks, compared to TD individuals (Williams et al, 2005; Minshew & Goldstein, 2001). So how do we then help them to optimise VisWM to remember complex information such as scenes? To understand how we can look at strategies to optimise the way more complex visual information can be encoded and stored in VisWM, we first need to understand the capacity of VisWM, and how features and images are stored.

Capacity Limitation of VisWM

Despite the complex demands placed on VisWM when remembering, monitoring, and storing manifold scenes in our daily environments, it is well-established that the TD individual's VisWM capacity for simple, highly discriminable items is about three to four objects. The precision in which the object is encoded decreases when the complexity of the object increases (Awh et al., 2007). How then does VisWM encode and store the amount of visual information that it encounters daily?

Two main groups of theories have been proposed to explain VisWM capacity: a discrete slots class and a continuous resource class (Luck & Vogel, 2013). Slot-based theories assume that only a limited number of items can be stored in VisWM. Once the limit is reached, no information about the other items can be stored in VisWM. On the other hand, resource-based theories assume that VisWM capacity can be flexibly divided and spread among all the items presented. However, as the number of items increases, there will be fewer resources available for each item. Therefore, the precision of each item reduces as the set size increases (Luck & Vogel, 2013).

Although research is still inconclusive as to the nature of resource allocation among the items to be stored, there is general agreement that VisWM is a flexibly allocated resource of limited capacity (Brady et al., 2011). Neural network modelling and electrophysiological recordings suggest that the multi-dimensional objects can be easily remembered as single-dimensional objects (Luck & Vogel, 1997). Using neural network modelling, it has been shown that neurons that represent a given item are linked together in synchronous firing. These cell groups are formed dynamically and will combine whatever sets of neurons are necessary to represent a given object. Therefore, although there is limited slot-based capacity, the resource can be flexibly allocated depending on how the cell groups are formed (Wei, Wang, & Wang, 2012).

Extensive research has gone into looking at how images are stored in VisWM. If resource allocation can be flexibly allocated to take in more information through the combination of single-dimensional to form multi-dimensional objects, then could multiple objects be bound or organised into a more integrated representation that can be encoded and stored more efficiently in VisWM? Emerging research shows that items can be structured into representations that transcend individual object features. There are two main ways to structure items into more organised representations. Individual items can be bound and

organised according to their spatial context, where items are related to each other by their spatial positions in a layout. Multiple items can also be bound according to their featural context, where items are grouped according to the similarities and differences in their features (Brady, Konkle, & Alvarez, 2011). Whether such multiple items are stored in spatial and/or featural context during the encoding process is influenced by visual perceptual processes. The visual perceptual processes would affect the nature of stored representations in VisWM and the corresponding memory processes.

Since visual perceptual processes affect the nature of stored presentations in VisWM and corresponding memory processes, how does the atypical visual processing of ASD affect VisWM processes? Impairments that have been associated with ASD, especially in visuo-spatial working memory, suggest that items are encoded and stored using more of the posterior regions, even when cognitive load is increased (Ring et al., 1999). This could mean that individuals with ASD may fail to integrate and structure the multiple items according to spatial or featural context. Hence the weak coherence processing characterising ASD may impact on the individual's ability to encode and store more complex information such as natural scenes in VisWM.

Phases in the Visual Working Memory: Encoding, maintenance and retrieval

VisWM is a complex process that can be differentiated into three phases: encoding, maintenance and retrieval. Differences in areas and levels of activation in brain regions have been found in these three phases of VisWM. A recent functional MRI study by Kochan, Valenzuela, Slavin, McCraw, Sachdev & et al., (2011) on TD individuals investigated the impact of load-related neural process on binding of picture and position. The study found that different brain areas were recruited depending on the memory phase. This is consistent with previous neuroimaging studies on working memory. During the encoding phase, content-

specific visual posterior regions were activated. However, during the maintenance phase, there was a shift to frontal and parietal regions where there is no apparent specialisation. Specifically, the study also showed that activation in these frontal and parietal regions was increased when load was increased. This converges with behavioural data which suggests that a switch from passive (parallel) to active binding may occur with increasing task demands (Allen, Baddeley, & Hitch, 2006). During the retrieval phase, Kochan et al. (2011) found that areas related to the Default Mode Network (DMN) had greater deactivation compared to the encoding and maintenance phases. The DMN is hypothesised to play a role in general monitoring of the internal mental and external environment (Gusnard & Raichle, 2001). Kochan et al.'s (2011) findings are in line with previous research which showed the DMN to be relatively deactivated during performance of challenging cognitive tasks (Binder et al., 1999).

Recent event-related potential (ERP) studies have found different neural activations for phases of encoding, maintenance and retrieval during VisWM process. Malecki and his associates (2009) used an ERP paradigm and showed that the neural generators of sustained activity differed for encoding and maintenance. The topography and polarity of slow wave shifts over parieto-occipital electrodes sites were different during encoding and maintenance of scene representations. This suggests that there was sustained firing of visual brain regions during encoding but when the maintenance phase started, the visual stimulation ceased. The sustained activation in the posterior visual regions was shifted to the parietal or frontal region.

Although differences in working memory processes for individuals with ASD and TD individuals have been found using neuroimaging and behavioural studies, there is a lack of information on the timecourse of how such differences in neural activations may happen. ERPs reflect synchronous activation of electrical fields associated with the activity of large groups of neurons. They represent changes in the brain's electrical activity in response to a

discrete stimulus or event. ERPs that reflect visual perceptual and memory processes are important in exploring how these cognitive processes may differ between typical and atypical populations, including ASD (Nelson & McCleery, 2008). ERPs have high temporal resolution and are best suited to index changes in the different timecourse of a given cognitive process, even when behavioural responses could sometimes be similar but have a different neural and perceptual operation. ERPs provide insight on the nature and timing of the underlying neural atypicality, as well as their developmental course.

To the best of our knowledge, no electroencephalogram (EEG) study has been conducted in the ASD population to investigate the electrophysiological indices of encoding and maintenance in VisWM. Being able to differentiate the activations and processes involved in the encoding and maintenance phases would clarify the differences in VisWM for complex information in the ASD population. Such information would help us to examine how differences in perceptual processing can impact the way in which complex information are encoded and maintained in VisWM. This in turn would help us to develop strategies that would enable individuals with ASD optimise their VisWM when processing complex visual information.

In the next few sections, we will discuss how perceptual processes influence the organisation and integration of objects into a spatial context for a typical individual. When an image is perceived as a coherent whole, this in turn affects how the image is processed and stored in the VisWM. The perceptual processing of individuals with ASD would then be examined to help understand how these processes are atypical and how they would influence the way images are processed and stored in the VisWM in individuals with ASD.

Perceptual Processes and its influence on Visual Working Memory

Studies have shown that items are encoded along with spatial and featural context information (Olson & Marshuetz, 2005; Vidal, Gauchou, Tallon-Baudry & O'Regab, 2005; and Hollingworth, 2006). Because of such perceptual binding, items are not stored in memory completely independent of each other. A study by Jiang et al. (2000) showed that recall of individual items is dependent on the spatial context present during encoding. They found that the accuracy of change detection of location was decreased when the initial spatial context of items was changed. Understanding of the influence of spatial context will help to understand how such object-to-location binding might work for real-world objects in scenes. Knowing how the image is presented, and how the individual items relate holistically to each other at a group as well as contextual level, will help us to better understand where and how the impairment in VisWM occurs for the individual with ASD.

To understand the relationship between visual perception and VisWM, an interactive model of VisWM has been proposed where visual perception and VisWM are parallel (Gao, Gao, Li, Sun, & Shen, 2011). At different stages of the visual perception, corresponding perceptual representations are formed and gradually assembled until the final coherent representation is constructed. Hence the storage of the coherent representation is affected by how the image is visually perceived and processed. Studies looking at the dynamic relationship between visual perception and VisWM showed that storage of visual image in VisWM could be enhanced depending on how those visual stimuli were perceived initially (Woodman & Vogel, 2008). Neuroimaging studies also showed support for the interactive nature of visual perception and VisWM. VisWM tasks have been found to activate brain regions for more high-level cognitive processes, as well as brain regions for sensory and perceptual coding of visual stimuli (Awh & Jonides, 2001; Silvanto & Cattaneo, 2010). This supports the notion that VisWM is not just a higher-level process that happens after

perception, but rather it relies on active interaction with visual perception (Gao et al., 2011). Therefore, if individuals with ASD present with different perceptual processes, it may be possible that the representations in VisWM may be different from that of TD individuals. This may in turn impact on their ability to remember more complex information in VisWM.

Perceptual Binding and its relationship to holistic processing

Perceptual binding is an adaptive process where multiple elements are combined into a unified higher order image to form the new integrated ‘units’ of representation. In this way, the limited capacity of VisWM can be increased to hold more complex representations (Ranganath, 2006). These levels of representation are not independent of individual item representations. Thus perceptual grouping or binding models assume that the limits on VisWM capacity are dependent on how many groups are encoded through perceptual binding (Cowan, 2001).

Dimensions can be integrated through perceptual binding in various ways. The dimensions that are bound together can be from the same domain (e.g. binding of colour and shape into an integrated visual representation) or across domains (e.g. binding of face and name which involves the cross-modal binding of a visual and verbal dimension). Such integrated representations are present in our everyday lives. One such example, which is the paradigm employed in the current study, is the binding of an object and its position in natural scenes. These integrated representations are postulated to be maintained in the episodic buffer proposed in Baddeley’s model of working memory (Baddeley, 2000).

Neuroimaging findings are still inconclusive on whether binding of features in VisWM engages specific cognitive processes not otherwise involved in memory for individual features (Fougnie & Alvarez, 2011). Recent functional MRI studies on perceptual binding found that object areas in the left ventrolateral prefrontal cortex (VLPFC), and spatial areas in

the dorsal and right PFC and parietal cortex were all activated during the picture-position binding task (Munk et al., 2002). However, the activation was smaller than what was seen when only the object or the spatial tasks were performed separately. This activation pattern was also found in another study, suggesting that smaller activations for different specialised areas may indicate that the individual features have been bound into an integrated representation involving other neural areas, for example, the PFC (Sala & Courtney, 2007).

Neuroimaging studies using positron emission tomography (PET) to measure changes in regional cerebral blood flow during object identity and spatial location matching-to-sample tasks show that visuospatial processing tends to involve the dorsal stream – occipitoparietal pathway, whereas object processing tends to involve ventral, occipitotemporal pathway (Haxby et al., 1991; Ungerleider & Haxby, 1994). These studies also show a similar distinction found in the PFC, where the dorsolateral region is involved in spatial working memory while ventrolateral region is involved in nonspatial working memory. Thus there is converging evidence that most working memory tasks involve a network consisting of dorsolateral PFC, parietal, and occipital areas (Jonides et al., 1993). Functional MRI findings also suggest that the PFC and parietal cortex are differentially active during the maintenance of abstract information compared with object-specific information (Ackerman & Courtney, 2012). The study contrasted encoding and maintenance of spatial relations compared to item locations in visual scenes. Findings showed greater activations in the anterior regions of both the PFC and the intraparietal sulcus (IPS) during the maintenance of spatial relational information (i.e. ‘top of’ or ‘bottom of’) in VisWM compared with information specific to the item (i.e. locations of specific objects in the spatial layout).

Electrophysiological Studies on Perceptual Binding

Currently, studies have largely used behavioural paradigms that looked at accuracy and reaction time of how object and locations in spatial scenes are processed. Although differences in electrophysiological correlates and timecourse have been found for processing of object identification and location in spatial scenes (van Hoogmoed, van den Brink, & Janzen, 2012), there is still limited electrophysiological studies looking specifically at the neural correlates of object-to-position binding in more naturalistic scenes.

EEG studies show that perceptual binding is associated with synchronous oscillatory neural responses (Singer, 1999). There are two types of oscillatory activity related to stimulus that can be used to investigate the timecourse of stimulus- or task-related oscillations (Tallon-Baudry & Bertrand, 1999). Evoked oscillations are phase-locked to the onset of a stimulus while induced oscillations reflect temporal coordination of neuronal responses that are not phase-locked to external events (Tallon-Baudry & Bertrand, 1999). Such synchrony of oscillatory neuronal activity may underlie the coordination of neural activity between and within functionally specific brain regions (Singer, 1999). It is also related to feature binding in working memory (Tallon-Baudry et al., 1998). EEG findings on binding of verbal and spatial information during WM tasks suggest that bound and unbound information are processed at different stages (Wu et al., 2007). Images may be processed and maintained differently depending on the degree of coherence. Studies also show increased alpha power in the sensors over the brain regions that were task irrelevant (e.g. regions along the dorsal pathway during the object identification task) when oscillatory power during maintenance of spatial information was contrasted with object identification. Increase in alpha power in the posterior regions has been found to be associated with maintenance of information in VisWM. This increase in alpha power may reflect suppression of interference that incoming sensory input may bring to the currently maintained information. Hence alpha power modulation can

be used as a marker of the involvement of a sensory region in WM storage and maintenance (Ikkai, Blacker, Lakshmanan, Ewen, & Courtney, 2014). In a more recent study, abstract relational and concrete sensory information may be maintained differently in VisWM. During the maintenance of abstract relational information, posterior visual regions became task irrelevant and were suppressed (Ikkai et al., 2014). Hence the encoding and maintenance of abstract relational information appears to be related to more frontal regions, as compared to local features that are related to more posterior regions.

Perceptual Binding in the ASD Individuals.

Being able to perceive the meaningful patterns or coherence within an image requires us to integrate separate features into a more perceptual whole. The detection of coherence in separate local features enables us to compose it into a meaningful gestalt that can then be encoded and stored in VisWM. This perceptual process, referred to as “perceptual organisation’ (Wagemans et al., 2012), plays an important role in helping us to relate to our physical and social environments. A deficit in perceptual organisation not only affects how we perceive objects and scenes, but it also affects our social awareness and interactions, as precise visual perception is important when processing faces or social scenes. Perceptual organisation is achieved through perceptual binding of individual features into a more integrated or coherent whole.

Research on binding in VisWM of individuals with ASD has consistently found weaker performance on face-name and face-position binding (Minshew & Keller, 2010). However, these studies may not be generalisable to the understanding of fundamental differences in VisWM involving non-social images. Difficulties found in the binding of features that are social in nature may be confounded with both fundamental difficulties in VisWM and social difficulties. While faces and names are familiar stimuli for typical individuals, this is not the

case for individuals with ASD as they have been found to have significant difficulties with social stimuli. Hence use of such social stimuli may not be appropriate to investigate fundamental visual processes in the ASD. Differences in ASD for binding faces with name or position may result from neural differences inherent in processing social stimuli and not those involved in processing complex stimuli which may or may not be social in nature.

Research has shown that individuals with ASD are characterised by atypical perceptual processing. Specifically, their ability to process contextual information has been shown to be impaired. One of the most researched perceptual processes of individuals with ASD has been their ability to perform gestalt as compared to local processing. How then does atypical perceptual processing styles impair the ability to process natural scenes, and hence encode and store the scenes in VisWM? We can first examine how the coherence of a scene affects the way it is processed, encoded and stored in VisWM.

Coherence and its effect on scene perception

Coherence within an image can affect how it is processed and maintained in the VisWM (Linden, 2007). It refers to the logical relationship between different elements forming an image. Pictures with higher degrees of coherence are likely to be processed more globally or relationally while pictures with lower degrees or no coherence are likely to be processed more locally or at an item-specific level (Linden, 2007).

Differences in perceptual organisation and global/local processing have been found between TD individuals and individuals with ASD. TD individuals are shown to prefer global processing when there is an inherent structure or relationship in the image. However, individuals with ASD prefer to engage in more local features processing than global processing (Minshew and Keller, 2010), even when the visual material is cohesive. This preference is attributed to a lack of spontaneous use of structure or context inherent in

information (Frith, 2001). This emphasis on local processing is thought to be a characteristic deficit in ASD.

Currently, two main theories have been proposed to understand the atypicality in global and local processing seen in ASD. The first is the theory of Weak Central Coherence (WCC). This theory postulates that individuals with ASD seem to have difficulties integrating information into a meaningful whole, although their attention to and processing of local-level information appears enhanced or at least preserved (Happe & Frith, 2006). The second theory, the Enhanced Perceptual Functioning (EPF) hypothesis, in contrast to the WCC theory, emphasises enhanced local processing in people with ASD and does not indicate a qualitative or quantitative deficiency in their global processing (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). According to the EPF hypothesis, global processing is not automatic or even involuntary like that seen in typical populations. Rather, it is more optional and if explicitly required, ASD individuals can extract gist information from the visual information (Mottron et al., 2006). To date, there is still inconsistent and often contradictory results for both theories (Behrmann, Thomas, & Humphreys, 2006).

More recently, a meta-analysis study was conducted looking at local and global visual processing in ASD (Van der Hallen, Evers, Brewaeys, Van den Noortgate, & Wagemans, 2015). The findings did not show an enhanced local processing or an impairment in global processing. Rather, results show atypicality in the timecourse of the local-global processing during perception, that is, individuals with ASD are slower in processing the global features of a representation (Van der Hallen et al., 2015). On the other hand, TD individuals are quicker to perceive the global features of a representation. Thus, atypical perception in ASD may be related to when local and global processing takes place, rather than the inability to perform global processing in general (Van der Hallen et al., 2015).

Global and Local Processing in ASD

Much of research on perceptual processing in ASD has focused on local-global visual processing. Local and global aspects of a representation must be perceived and balanced to be able to meaningfully organise it into a coherent whole (Kimchi, 1992). During local processing, smaller regions of the visual representation are processed. Such processing of local or specific details do not require interaction between different aspects of the image, including spatial or featural context. However, global processing involves processing larger portions of the image. It enables us to concentrate more on the overall features in order to understand the full picture or the entire visual scene, while also having a general idea of the details present. The various elements of the visual images need to be processed together, as processing different attributes of the visual image independently does not provide a whole or a global gist. There also needs to be a filling in of information, a process called ‘perceptual’ or ‘visual’ closure, to help in completing the details into a gestalt whole (Kimchi, 1992).

Caution must be taken when making inferences about gestalt processing from the global/local paradigm. Many studies on gestalt processing tended to use tasks that test the global rather than gestalt processing (e.g. traditional local-global stimuli such as Navon letters). Kimchi (1992) has argued that ‘global’ and ‘gestalt’ processing are different. In global processing, place relationships depict the arrangements in which the global representation can be identified by how the local elements are placed, without reference to what the local elements are. The Navon letter is a good example. The letters (which are considered the local elements) can be interchanged without affecting the global form. However, nature relationships depict arrangements where the global form is defined by the nature of the local elements. Faces are an example of a global stimuli with such nature relationships. The different local elements of a face (e.g. eye, nose) cannot be interchanged without affecting the global form. Such relational processing underlies gestalt processing,

where the ‘whole is more than the sum of the parts’ (Brosnan, Scott, Fox, & Pye, 2004).

Research has shown that individuals with ASD have an impairment in holistic face processing. They show a deficit in their ability to recognise faces when there are changes in orientation and featural information (Joseph & Tanaka, 2003). In particular, individuals with ASD appeared to have difficulty processing information from the eye region but attended more to the mouth area (Wolf et al., 2008). It was hypothesised that individuals with ASD actively avoid looking at the eyes as the emotionally charged nature of the eye region caused discomfort and threat to the individuals with ASD (Tanaka & Sung, 2016). In this study, holistic, gestalt and global processing will be used interchangeably to refer to the processing of local features in relation to each other to form a coherent whole.

Electrophysiological Studies of effects of Coherence on Visual Processing in ASD.

Neuroimaging, EEG and ERP studies have shown evidence of reduced gestalt processing in individuals with ASD. Much of the research has focused on the use of faces as stimuli. Several studies have shown that individuals with ASD do not show a ‘face inversion effect’ in the N170 component (McPartland, Dawson, Webb, Panagiotides, & Carver, 2004), suggesting a reduced use of holistic processing when processing faces. Unlike TD individuals, individuals with ASD did not show a difference in EEG power in the gamma band during upright versus inverted face processing (Grice et al., 2001), suggesting reduced neural or perceptual binding when processing upright faces. However, it is still unclear if these studies on face processing could be generalised to non-social stimuli such as natural scenes. A more fundamental question of how gestalt processing may be affected by coherence in a non-social configuration such as object processing studies has not been adequately addressed using electrophysiological studies. Although comparisons made using traditional local-global stimuli such as Navon letters have found inconsistent difficulties with

tasks requiring global processing (Caron, Mottron, Berthiaume, & Dawson, 2006), these tasks again tended to test global rather than gestalt processing.

To better understand how gestalt processing may be affected in individuals with ASD and hence their performance on VisWM tasks, we also need to understand if there are any differences in the processes of perceptual closure in individuals with ASD.

Perceptual Closure in ASD

Perceptual closure is one of the fundamental principles underlying gestalt processing as such processing require the completion of elements into forming a gestalt figure (Kimchi, 1992). The filling-in of missing information that enables eventual object recognition under partial viewing conditions is referred to as ‘perceptual closure’ (Foley, Foley, Durso, & Smith, 1997).

There are limited neuroimaging studies on perceptual closure. However, neuroimaging studies of object recognition, which is closely related to perceptual closure, has shown that these processes occur in the lateral-occipital complex (LOC) (Malach et al., 1995).

Electrophysiological studies have looked at the process of perceptual closure and found an ERP component that indexed perceptual closure (Doniger et al., 2000). This is called *closure negativity* (N_{CL}). The amplitude of N_{CL} increases gradually as stimuli is presented in progressively more completed forms. At the point of identification, N_{CL} amplitude increases significantly, thus indexing the perceptual closure process (Doniger, Foxe, et al., 2001). The scalp distribution of N_{CL} is consistent with neural generators within the LOC.

Neuroimaging and EEG studies on fragmented coherent and scrambled images found an extended network of dorsal and frontal regions to be involved in perceptual closure processes. Besides N_{CL}, a relative negativity manifested over bilateral occipito-temporal scalp occurring in the 230-400 ms timeframe (Doniger et al., 2000), studies have also shown the

existence of generators outside of the lateral occipital complex (LOC) such as the frontal regions that are involved in perceptual closure (Sehatpour, Molholm, Javitt, & Foxe, 2006). The timing of these frontal processes obtained from EEG recordings suggests that closure processes are present relatively late in visual processing and likely reflect repeated processing within these structures (Sehatpour et al., 2006).

Impairment in perceptual closure has been shown in patients with schizophrenia (Doniger, Silipo, Rabinowicz, Snodgrass, & Javitt, 2001). Schizophrenia patients are impaired in their ability to recognise fragmented images (Doniger, Silipo, et al., 2001). When N_{CL} was used to index their perceptual closure process, behavioural findings showed impaired performance where the image was almost complete or complete before it was recognised (Doniger, Silipo, et al., 2001). N_{CL} generation was also impaired, where the patients with schizophrenia showed significantly reduced N_{CL} amplitudes.

Electrophysiological Studies of Perceptual Closure in ASD.

Despite electrophysiological studies showing evidence of differences in object detection and recognition between individuals with ASD and TD individuals, there has been little research looking at the timecourse of perceptual closure processes in ASD.

Electrophysiological studies have found less specialisation within neural networks recruited during visual perception in the group with ASD (Milne, Scope, Pascalis, Buckley, & Makeig, 2009). Studies have also shown atypical early peaks in impairments in object boundary detection (Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2008). Thus, understanding the topography of effects of perceptual closure processes, which occurs prior to object recognition, will help us to better identify the current differences shown in object detection between individuals with individuals with ASD and TD individuals.

Objectives of Study

The current study investigated how positions of objects were processed as part of a larger spatial representation or context such as an outdoor or indoor scene. Natural scenes were chosen as these are daily complex information that individuals with ASD are faced with. Also, in such scenes, the positions of these objects could be defined relative to a larger spatial representation that codes the relative locations of objects in context (Hollingworth, 2007). Such object-to-scene binding would require more holistic or gestalt processing, as compared to local processing, where the object-position is stored independently from the larger scene representation (Hollingworth, 2007).

Scenes are representations where objects are embedded in their spatial and featural context. Global features of a scene depict broad characteristics such as the division between the sky and the ground. On the other hand, local features include gradations in brightness across a small amount of space and give information about fine-grained details like the objects in the scene. This enables us to investigate the nature of object-position binding and how this perceptual binding is affected by the coherence of the scene or image. Both behavioural and psychophysiological research have shown support for a feedback model of scene processing where early global information affects finer featural processing (Bullier, 2001). This feedback model proposed that a scene is initially analysed to extract early global information. This global information is then projected to other brain regions which affect further local processing based on task relevance or valence of the scene (Bar, 2004). This is similar to the ‘scene coherence effect’ which proposed that objects are more accurately recognised when they are observed within coherent rather than scrambled scenes (Biederman, 1972), showing that an object’s meaningful context affects perceptual recognition and memory. Therefore, is such a scene coherence effect also present in individuals with ASD, who may not process coherence and global gist that easily?

The objectives of the current investigations were to understand the effects of perceptual processing on the VisWM in individuals with ASD. Specifically, this thesis investigated the differences between perceptual closure between TD individuals and individuals with ASD. It also looked at the effect of coherence on gestalt/local processing on the encoding and maintenance of complex visual information in the VisWM of individuals with ASD. To the best of our knowledge, no ERP study evaluating the topography of effects of perceptual closure processes in individuals with ASD has been published. There is also limited neuroimaging and electrophysiological studies examining the effects of coherence on perceptual binding of object-to-position, and in particular, object-to-scene binding in ASD.

There has been a variety of autism interventions over the years, ranging from pharmacological therapies, occupational therapy, speech and language therapy, and behavioural and developmental approaches. Current interventions have focussed predominantly on behavioural and developmental approaches as it has been shown to be effective in developing social, adaptive and behavioural functioning of children with ASD (Ospina et. al, 2008). Other approaches have attempted to take an integrated developmental and behavioural approach, for example, the Early Start Denver Model which integrates a developmental model that is relationship-focused, with well validated behavioural approaches such as Pivotal Response Treatment (Dawson et. al, 2010). However, to date, there is still limited research on whether the interventions targeted at the perceptual processes of individuals with ASD can help to remediate or compensate for the perceptual atypicality characterising these individuals.

Specifically, the aims of this study were a) to investigate the differences in perceptual closure between individuals with ASD and TD individuals and how training could improve perceptual closure performance in individuals with ASD; and b) to investigate the difference in perceptual binding in VisWM between individuals with ASD and TD individuals for

coherent and non-coherent stimuli; and if perceptual closure training can impact on how coherence within a scene is processed; and how this in turn affects VisWM in individuals with ASD. Differences in these two perceptual processes were investigated using ERPs and behavioural data. First, an ERP paradigm was used to elucidate neural differences of perceptual closure (Study 1), and the effects of scene-based coherence on perceptual binding (object-to-position binding) in the VisWM (Study 2); between individuals with ASD and TD individuals. As perceptual closure involves an interplay of both local and global processing, the ERP paradigm would provide insights into how these processing may differ between adolescents with ASD and typical adolescents. How these differences then affect VisWM were investigated in Study 2, where the differences in how the adolescents with ASD and typical adolescents recalled objects embedded in scenes were examined. The study also examined the effect of training on visual closure and the recall of object-position binding in the VisWM (Study 3). Given that differences in perceptual closure could impact on VisWM of individuals with ASD, the objective of this study was to examine, whether training to improve the perceptual closure could impact on VisWM of these individuals. If the training does improve the perceptual closure and VisWM of these individuals, we can further consider how to further explore its impact on higher order processing, such as of emotion recognition for example, to improve it as well. Interventions that could overcome or otherwise compensate for the perceptual differences in individuals with ASD should be explored. To the best of our knowledge, there is still limited research on how more basic visual processes can impact on the social difficulties characterising individuals with ASD. The research design is depicted schematically in Figure 1-3.

Figure 1-3. Research framework

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CHAPTER II: STUDY 1

Perceptual Closure in Individuals with ASD

An ERP Study

Introduction

Individuals with ASD have atypical perceptual processes, especially when interplay of global and local processing are involved. Perceptual closure is one fundamental principle underlying global processing. Difference in perceptual closure can affect how an image is processed as a coherent whole, which can in turn affect how it is encoded into the VisWM of an individual. Study 1 aimed to investigate if individuals with ASD show difference in perceptual closure. As far as we know, there has been no electrophysiological study looking at perceptual closure in individuals with ASD.

Perceptual closure is a neural process whereby the individual fills in missing parts of a stimulus to complete the image and produce a recognisable object. It is important in everyday life as it produces a perceptual processing benefit that allows people to recognise objects at a much less completed level than they otherwise could (Snodgrass & Feenan, 1990). Such a processing benefit could be critical when quick identification of what is in the surrounding is important, for example, during an impending car accident. This processing benefit would also be important in real-life situations as environments are in a constant state of change, especially when the situations are social in nature. Thus, it is important to understand the process of perceptual closure in a clinical population like ASD, where impairments are found in social communication and social interaction.

This study seeks to understand if the perceptual closure process differs for the individuals with ASD, as differences in object recognition and related processes have been found in this population (Simmons et al., 2009). Perceptual closure and object recognition are related processes. Object recognition can be viewed as the final arrangement of several simplified geometric components into a meaningful whole through the process of perceptual closure (Foley, Foley, Durso, & Smith, 1997). While neuroimaging and electrophysiological research has looked at the object identification processes, there has been limited knowledge

on the timecourse and neural correlates of the related process of perceptual closure which precede object recognition. To understand perceptual closure, we first need to understand how object recognition takes place.

Object Recognition and Perceptual Closure

Past literature on object recognition have showed support for both bottom-up as well as top-down approaches to object recognition. The Recognition-by-components (RBC) theory is one of the best-known bottom-up models (Biederman, 1987; Biederman & Gerhardstein, 1993; Hummel & Biederman, 1992). The RBC theory states that object recognition is dependent on how the parts of an object are broken down by the observer, and how these parts are then represented in relation to each other. This approach presupposes a hierarchical processing model, where the visual features in the image needs to be fully extracted first in the lower-level visual cortical areas, before they are projected to higher-level regions (i.e. inferior temporal cortex), where a visual representation of the image is formed (Snodgrass & Kinjo, 1998). Thus, this bottom-up model emphasised forward connections. RBC proposes that the bottom-up processing occurs for all levels of fragmented stimuli, including the final complete image. Any parallel or feedback connections are not considered to be significant.

However, there are problems with such a bottom-up only approach. Studies show that the model can explain recognition of geometric objects, where the parts typically join in easily identifiable ways because they interpenetrate (e.g. how a chair is joined to its leg). However, it does not adequately explain natural objects where the parts are formed by spontaneous growth and evolution (Kurbat, 1994). Kurbat (1994) from his meta-analysis, concluded that a combination of both bottom-up and top-down approaches are needed to understand object recognition. Most top-down approaches propose that object recognition is achieved through a template matching or model selection process. Such templates are

postulated to contain 2D views of an object or an exemplar of the object. Some approaches also propose that the top-down process activates categories against which the image is matched using categorical or semantic analysis. While research is still ongoing with regards to the process that is actually occurring, it is an established fact that the PFC is involved in this top-down process (Snodgrass & Kinjo, 1998).

One of the most widely researched model for top-down facilitation process in object recognition is the 3-part mechanism proposed by Bar (2003). The model proposed that 1) low spatial frequencies (LSFs) in the image are first projected quickly by anatomical pathways from early visual areas directly to the PFC; 2) the LSFs then activate expectations about possible interpretations of the input in the PFC; 3) in the final step, these ‘guesses’ are then projected back to the inferior temporal cortex, where they activate the corresponding object representations to be integrated with the bottom-up process (Bar, 2003).

Several neuroimaging studies have been conducted to investigate the model proposed by Bar (2003). Bar and his associates (2006) used a combination of magnetoencephalography (MEG) and functional fMRI and found, in support of this model, that object recognition activated activity in the left OFC 50 ms earlier than it did in recognition-related areas in the temporal cortex. The LSFs in the image were found to directly modulate this early orbitofrontal activity. Figure 2-1 illustrates the 3 steps of the top-down facilitation model. Another study also showed the involvement of the magnocellular pathway in triggering the top-down facilitation during object recognition (Kveraga, Boshyan, & Bar, 2007). Line drawings of objects were either of low-luminance contrast and achromatic (which is magnocellular-biased) or chromatically defined and isoluminant (red-green; which is parvocellular-biased). These drawings were used to identify which of the 2 main pathways was used to trigger top-down facilitation in object recognition. Findings indicated that the magnocellular-biased stimuli significantly activated pathways from occipital visual cortex to

the OFC and from OFC to the fusiform gyrus. Thus, neuroimaging studies provided support for the interplay of global and local processing during object recognition.

Figure 2-1. Model for top-down facilitation for object recognition.

A partially processed, LSF image of the visual image is rapidly projected to the orbito-frontal cortex (OFC) from the early visual regions. At the same time, the ventral visual stream performs a detailed slower analysis of the visual image. The ‘gist’ image projected to the OFC activates predictions about possible objects similar to the image in their LSF appearance. These are then fed back to the ventral object recognition regions to facilitate bottom-up processing (Bar et al., 2006)

Interplay of Global and Local Processing during Perceptual Closure

Although research has shown that individuals with ASD present with atypical perceptual processing, there is still limited research on how closure processes occur in ASD. Nonetheless, many studies looking at atypical perceptual processing in ASD have focused on global and local processing (Van der Hallen, Evers, Brewaeys, Van den Noortgate, &

Wagemans, 2015). Eye tracking studies have also shown that individuals with ASD showed reduced visual exploration and a greater tendency to explore areas close to the current fixation when viewing visually complex scenes such as photographic scenes (Heaton & Freeth, 2016). To date, findings are still contradictory due to several reasons. These reasons include, but are not restricted to, the heterogeneity of sample as well as the stimuli used. Most of the research consist of behavioural studies, which lack the precision needed to understand how the perceptual processes may differ in ASD.

To make sense of the behavioural research, Van der Hallen et al. (2015) conducted a meta-analysis of global and local processing studies in individuals with ASD. He included studies that used visual stimuli that were based more on geometric figures (e.g. Embedded figures test, block design, visual illusions). Van der Hallen et al. (2015) found that there was no deficit in global processing or enhanced local processing, based on the accuracy rate of identification. However, he noted that the reaction time of the individuals with ASD was slower when global processing was needed, especially when there were irrelevant or contradictory local elements involved. He concluded that instead of the global-to-local interference that was postulated for TD individuals, the difference between individuals with ASD and TD individuals was due to a local-to-global interference in individuals with ASD. However, there are some limitations in this meta-analysis and thus, conclusions drawn from this analysis may be limited. The meta-analysis included only stimuli that were geometric in nature. As Kurbat (1994) has postulated, the recognition of such objects may be different from biological objects. While geometric objects can rely on posterior and temporal regions for recognition, more complex or irregular objects such as biological objects may rely on template matching in the PFC. Hence Van der Hallen and associatess' (2015) meta-analysis may not be relevant for more complex information processing that occurs in the real-world setting. In addition, as only behavioural studies were included, there is a need for EEG

research to examine the timecourse of global/local processing and perceptual closure during object recognition in individuals with ASD.

Electrophysiological Findings on Perceptual Closure

To date, there is no ERP study on perceptual closure in ASD. Neuroimaging studies looking at the interplay of global and local processing during the process of object recognition in individuals with ASD are also limited. A study by Milne and his associates (2009) showed that spatial frequencies of simple visual images resulted in less increase in the induced alpha- and gamma-band power for the group with ASD. As gamma-band power reflects the neural correlates of perceptual binding (Engel & Singer, 2001), reduced involvement in neural networks activated during visual perception in individuals with ASD may suggest an impairment in perceptual binding (Milne, Scope, Pascalis, Buckley, & Makeig, 2009). Research findings also suggest reduced efficiency of neuro-integrative mechanisms that underlie neural integration at the visual perceptual level in ASD (Milne et al., 2009). This reduced efficiency could contribute to the deficit in perceptual binding in the population with ASD (Brock, Brown, Boucher, & Rippon, 2002). In addition, differences in object boundary detection have been found in individuals with ASD (Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2008). Findings showed that individuals with ASD have a slight delay in object boundary detection, followed by a subsequent increase in activity at the lateral occipital sites. It is plausible that an inherent difference in signal timecourse may explain the differences in global and local processing seen between individuals with ASD and TD individuals.

Electrophysiological studies on perceptual closure often use a closure negativity called the N_{CL} to index the perceptual closure process (Figure 2-2). The N_{CL} is a bilateral ERP component associated with perceptual closure and is manifested as a negativity bilaterally at

the occipito-temporal electrode sites (Doniger et al., 2000). It tracks activation processes even prior to actual identification. N_{CL} occurs within the timeframe of 230-400ms and is maximum at about 290-300ms. Its peak latency is consistent with MEG studies of object recognition. In a study which used MEG to track object recognition (Vanni, Revonsuo, Saarinen, & Hari, 1996), the N_{CL} amplitude was found to build up over a number of pre-identification steps, rather than as an all-or-non occurrence at the point of closure. In Doniger et al.'s study (2000), they found an incremental increase in N_{CL} over the occipito-temporal electrodes as participants reached the identification stage of fragmented objects. Although N_{CL} largely reflects neural activity from the LOC and nearby structures, further studies also showed the existence of other neural generators outside of the LOC. Using both EEG and functional MRI, Sehatpour and his associates (2006) examined the spatiotemporal dynamics of the closure process and found a corresponding negativity at the fronto-temporal scalp regions which onsets at about 50ms before the point of closure. This additional processing may be related to involvement of semantic processing areas and frontal executive areas, pointing to a closure process which involves both LOC and frontal cortical regions (Sehatpour, Molholm, Javitt, & Foxe, 2006). It is suggested that the pre-recognition increase in N_{CL} amplitude represents the extraction of successively more local components until closure or recognition occurs. Although it is still unclear whether earlier or later visual areas are included in the closure processes, these areas are likely to be involved in constructing boundaries from partial information as well as segregating the foreground from the background to facilitate the perception of complete objects.

Figure 2-2. NCL Closure Negativity ERP component. Group-average waveforms for controls (left plot) and patients with schizophrenia (right plot) at a right-hemisphere parieto-occipital electrode at the level of object identification (ID) and at 3 prior levels. (Doniger et al., 2002)

A recent study utilised spatial frequencies to look at the timecourse of object recognition in ASD. Caplette and his associates (2016) conducted a spatial frequency study on how HSFs (which are analogous to local elements) and LSFs (which are analogous to global elements) were extracted by individuals with ASD and TD individuals during object recognition. Participants were shown a short video consisting of an object image with random spatial frequencies. Participants were asked if the object matched the label given with the image. Findings showed that there was no difference in reaction times or in the average information needed to identify the object. When the spatial frequency sampling was analysed, it was found that the TD individuals used LSFs through the identification process and HSFs only when the time for recognition increased. This indicated that the TD individuals used a coarse-to-fine sampling when identifying the object. Such sampling would indicate a process similar to global-to-local processing. On the other hand, the individuals with ASD used the HSFs right from the beginning. Both LSFs and HSFs were simultaneously sampled by the individuals with ASD. Thus, it was argued that individuals with ASD did not need to use the

LSFs for object identification as the HSFs enabled them to identify the objects (Caplette, Wicker, & Gosselin, 2016). However, the findings did not show conclusively if such a sampling was a result of abnormal top-down processing. It was also not clear if the process can be applied to a situation where the label of the objects needed to be recalled, rather than matched. In this study, the object and a label were presented simultaneously. The participant had to say whether the label correctly identified the image shown. Thus, the LSFs sampling that occurred together with the HSFs could have resulted from this process of matching the label with the image given. The use of different spatial frequencies may also not mimic the usual perceptual closure process in the real-environment where objects often look fragmented, rather than graded or blurred.

There is limited research on the topography of effects of perceptual closure of objects in ASD because functional and effective connectivity research looking at global/local processing have generally focused on more complex information processing. Studies that examined global and local processing have mostly used geometric images where global and local elements interfered with each other, thus forcing one type of processing over another. In this current study, fragmented line-drawn images were used. This allows for an interplay of both local and global elements of the image. It would provide insight into how coherence or global processing in individuals with ASD spontaneously occurs. A study looking at the topography of effects would also provide insight if the delay in global processing found in Van der Hallen et al.'s (2015) meta-analysis was due to an actual delay in global processing with a similar pattern of scalp activations, or a delay due to a different pattern of scalp activations. This would shed light on whether the atypical perceptual processing in ASD is also found in lower level visual processing and if atypical scalp activations underlie the closure process of fragmented images.

Research Hypotheses

Given the above background information, the following hypotheses were proposed:

1. It was hypothesised that ASD would recognise the object at a higher level of completeness; compared to TD.
2. It was hypothesised that:

TD: N_{CL} would be manifested over the bilateral occipito-temporal scalp electrodes;

Relative negativity (i.e. a decrease in amplitude) over frontal scalp region during closure would be found.

ASD: N_{CL} would be manifested differently (in terms of peak latency and amplitude) over the bilateral occipito-temporal scalp electrodes when compared to TD;

When compared to TD, activation over frontal scalp regions during closure would be different.

Method

Participants and Screening Procedure

Nineteen ASD and 17 TD males from 13 to 16 years old with normal or corrected-to-normal vision participated in the study. The participants were recruited via advertisements posted on the lab website, recruitment flyers sent out to parents, and through word-of-mouth. The group with ASD had a mean age of 176.00 ± 15.19 months while the TD group had a mean age of 168.13 ± 12.99 months (see Table 2-2). Participants had a nonverbal reasoning of at least 80 (average and above) as assessed by the Ravens Standard Progressive Matrices (RSPM)(Raven, 2000). The RSPM was selected as verbal reasoning was not a skill that was

investigated in the study. The population with ASD was thus selected using the RSPM which is a visual reasoning task, as visual perceptual skills were the effects of interest. Exclusionary criteria included a reported history of known neurological (e.g. epilepsy) or major psychiatric disorders. Individuals undergoing drug treatment were also excluded. In the TD group, 11 were right-handed while 3 were left-handed. The handedness of 3 TDs were not known. In the group with ASD, 16 were right-handed while 3 were left-handed.

The group with ASD consisted of adolescents currently studying in Singapore mainstream or special schools. Eight were studying in mainstream schools while 11 were studying in special schools. The 19 participants in the group with ASD were diagnosed by both medical practitioners and psychologists. Eighteen of the 19 participants in the group with ASD had been diagnosed with ASD or Autistic Disorder. The remaining participant was diagnosed with Asperger Syndrome. Standardised tests such as the Autism Diagnostic Observation Schedule (ADOS)(Lord, Rutter, Goode, et al., 1989), Childhood Autism Rating Scale (CARS)(Schopler, Reichler, DeVellis, & Daly, 1980) or Gilliam Autism Rating Scale – Second Edition (GARS-2)(Gillam, 2006), clinical observations, and structured interviews were used in the diagnostic protocol. The group with ASD and TD groups were matched on nonverbal reasoning and chronological age. Two individuals with ASD were excluded as their nonverbal reasoning scores were lower than 80. Another individual with ASD was excluded as he was on medication. For the TD group, one TD individual did not complete the task. Three individuals with ASD and 1 TD individual was further excluded as they had fewer than 20 artifact-free ERP trials in the conditions that were being analysed. The final analyses were conducted on 13 participants with ASD and 15 TD participants. A study using split-half segmentations on a pool of 26 respondents showed that about 30-40 participants are needed to achieve 99% power for EEG studies for a stringent threshold of $p < .01$ (Sands, 2009). Based on the analysis of power (using calculated Φ values) of selected studies looking

at visual processing differences between individuals with individuals with ASD and TD individuals (see Appendix I for details), it is estimated that a sample size of at least 12 per group would be needed to detect statistically significant differences at $\alpha = 0.05$ and 80% power. The current study had a sample size of 13 adolescents with ASD and 15 TD adolescents. The statistical power of this study was thus deemed sufficient. The experiment was approved by the Institutional Review Board at Nanyang Technological University in Singapore. Informed consent and assent were obtained from the parents and participants respectively prior to the experiment. The data collection was carried out over a period of 3 and a half years.

Procedure

There was a total of 2 sessions. The first session was a pre-testing session where informed assent and consent were obtained from the participant and his parents. Once the participant and his parents have provided consent to participate, the RSPM and selected subtests from the Test of Visual Perceptual Skills – Third Edition (TVPS-3)(Martin, 2009) and NEPSY-II (Korkman, Kirk, & Kemp, 1989; Korkman, Kirk, & Kemp, 2007a; Korkman, Kirk, & Kemp, 2007b) were administered. The second session consisted of the EEG session where they were asked to do the perceptual closure task. The protocol flow of Study 1 is presented in Table 2-1.

Standardised Assessments with Baseline Behavioural Measures

Both ASD and TD participants were administered four standardised measures to obtain a baseline of their visual perceptual, visuospatial memory, and affect recognition abilities. The parents of both groups of participants were also administered questionnaires about social communication and ASD symptoms.

Table 2-1

Protocol Flow of Study 1

Groups	Sessions	
	First Session: Pre-Testing Session	Second Session: EEG Session
ASD (13)	<u>Inclusion Criteria Measures</u> Nonverbal reasoning <ul style="list-style-type: none"> • Ravens Standard Progressive Matrices 	Study 1 Perceptual Closure
TD (15)	<u>Baseline Measures with Behavioural Measures</u> Visual Perceptual Abilities <ul style="list-style-type: none"> • TVPS-3 Figure-Ground subtest • TVPS-3 Visual Closure subtest Visuospatial Memory (for Study 2) <ul style="list-style-type: none"> • NEPSY-II Memory for Designs subtest Social Communication and Social Functioning <ul style="list-style-type: none"> • NEPSY-II Affect Recognition subtest • ASD Spectrum Quotient (AQ) • Social Communication Questionnaire (SCQ) 	Study 2 VisWM

Visual Perceptual Abilities. The Test of Visual-Perceptual Skills, Third Edition (TVPS-3) (Martin, 2009) is an individually-administered standardised test used to determine a child's visual perceptual strengths and weaknesses. The participants were administered the Figure Ground and Visual Closure subtests to obtain a behavioural baseline of their visual local and global processing for this study. The Figure Ground subtest assesses an individual's

ability to distinguish a visual form from irrelevant background information. Individuals who perform well on Figure Ground tasks are better able to observe details in picture (Anselmo, 1985) which requires more local processing. Therefore, higher accuracy scores on the Figure Ground subtest would indicate better local processing ability. The Visual Closure subtest is based on the gestalt principle of closure. It assesses an individual's ability to complete a fragmented image. Higher accuracy scores on this subtest would indicate better gestalt processing.

Visuospatial Memory. To obtain a baseline of their visuospatial memory ability for Study 2, the individuals were administered the Memory for Designs subtest from the NEPSY-II, a neuropsychological assessment test kit (NEPSY-II) (Korkman, Kirk, & Kemp, 1989; Korkman, Kirk, & Kemp, 2007a; Korkman, Kirk, & Kemp, 2007b). The Memory for Designs subtest requires an individual to remember visual designs and their locations on a grid. Higher accuracy scores on this subtest would indicate better visuospatial memory of abstract patterns in their locations.

Current Social Communication and Social Functioning. To obtain a measure of current functioning in social communication and social functioning skills in adolescents with ASD, they were administered the Affect Recognition (AR) subtest from the NEPSY-II (Korkman, Kirk, & Kemp, 1989; Korkman, Kirk, & Kemp, 2007a; Korkman, Kirk, & Kemp, 2007b). The AR subtest measures an individual's ability to recognise affect (disgust, sad, fear, disgust and neutral) from photographs of children's faces. A higher score indicates a better ability to recognise affect. Parents of both TD participants and participants with ASD were also asked to complete the Social Communication Questionnaire Current Form (SCQ) (Rutter, Bailey and Lord, 2003) and the Autism Quotient (AQ) (Baron-Cohen et al., 2006). The SCQ is a 40-item questionnaire that evaluates communication skills and social functioning of children who may have ASD. It is used as a screening instrument for ASD. A higher score indicates more symptom severity. The SCQ manual recommends a cutoff score

of 15 or greater on the Lifetime form as an indication of a possible ASD. However, a significant minority of children with autism had scores near 15. The general population mean was 5.2 (Berument et al., 1999). The current study's mean scores for ASD (12.13+5.41) did not meet the recommended cutoff score. This could be due to the change in behaviours following interventions the children have undergone since diagnosis. However, it is significantly above the general population mean of 5.2. The AQ is a 50-item questionnaire that looks at the autistic traits in an individual. It can be used as a screening instrument for high-functioning ASD. A score of 32+ has been proposed to be a useful cutoff for distinguishing individuals who have clinically significant levels of autistic traits (Baron-Cohen et. al, 2001). The group with ASD just missed the recommended cutoff (31.54+8.40). Table 2-2 shows the means and SDs for the baseline behaviour measures for the two groups. A correlation test was conducted for the demographic and baseline behaviour measures. The Autism Spectrum Quotient and Social Communication Questionnaire scaled scores were found to be significant correlated ($p < .05$). This was within expectations as social communication difficulty is a core impairment in individuals with ASD. Significant correlations ($p < .05$) were also found for nonverbal reasoning, visual closure and figure ground. This was within expectation as visual perceptual skills are fundamental skills underlying nonverbal reasoning ability. However, as the TD and ASD groups did not differ significantly in their nonverbal reasoning skills, visual closure and figure ground perceptual skills, the correlation found between these measures were not of concern (Table 2-3 shows the correlations for the demographic and baseline measures).

Table 2-2

Demographics and Standard Measures of TD participants and participants with ASD

Demographics and Standard Measures	TD (<i>n</i> =15)	ASD (<i>n</i> =13)	Significance
Age (in months)	176.00±15.19	168.13±12.99	<i>t</i> (30)=1.58, <i>p</i> =0.126
Nonverbal Reasoning	115.03±12.81	110.59±16.52	<i>t</i> (30)=0.85, <i>p</i> =0.403
Affect Recognition (NEPSY-II)*	8.94±1.53	6.00±3.22	<i>t</i> (30)=3.30, <i>p</i> =0.003
Autism Spectrum Quotient*	13.27±7.26	31.54±8.40	<i>t</i> (26)=-6.18, <i>p</i> =0.000
Social Communication Quotient*	6.07±3.62	12.13±5.41	<i>t</i> (28)=-3.61, <i>p</i> =0.001
Visual Closure (Test of Visual Perceptual Skills-3)	2.94±3.28	10.94±4.75	<i>t</i> (30)=1.39, <i>p</i> =0.176
Figure Ground (Test of Visual Perceptual Skills-3)*	13.63±3.52	12.19±5.21	<i>t</i> (30)=0.92, <i>p</i> =0.037

Note. * *p* < .05

Standard measures are presented using scaled scores.

Affect Recognition, Visual Closure and Figure Ground: Range 1-19

Autism Spectrum Quotient: Range 0-50

Social Communication Questionnaire: Scores above the cutoff of 15 suggest the individual is likely to have ASD

Table 2-3

Correlations of Standard Measures

Demographics and Standard Measures		Age	ASQ	SCQ	Nonverbal Reasoning	Figure Ground	Visual Closure	Affect Recognition
Age (in months)	Pearson Correlation	1	-.27	.27	-.25	-.19	-.10	-.07
	Sig. (2-tailed)		.193	.180	.197	.340	.631	.734
Autism Spectrum Quotient (ASQ)	Pearson Correlation	-.27	1	.74*	.15	-.04	-.07	-.34
	Sig. (2-tailed)	.193		.000	.463	.852	.757	.095
Social Communication Quotient (SCQ)	Pearson Correlation	.27	.74*	1	-.16	-.16	-.15	-.33
	Sig. (2-tailed)	.180	.000		.413	.413	.457	.088
Nonverbal Reasoning	Pearson Correlation	-.25	.15	-.16	1	.53*	.57*	.18
	Sig. (2-tailed)	.197	.463	.413		.003	.001	.353
Figure Ground (Test of Visual Perceptual Skills-3)	Pearson Correlation	-.19	-.04	-.16	.53*	1	.64*	.24
	Sig. (2-tailed)	.340	.852	.413	.003		.000	.212
Visual Closure (Test of Visual Perceptual Skills-3)	Pearson Correlation	-.10	-.07	-.15	.57*	.64*	1	.02
	Sig. (2-tailed)	.631	.757	.46	.001	.000		.914
Affect Recognition (NEPSY-II)	Pearson Correlation	-.07	-.34	-.33	.18	.24	.02	1
	Sig. (2-tailed)	.734	.095	.088	.353	.212	.914	

Note. *Correlation is significant at the 0.05 level (2-tailed).

Perceptual Closure Task Stimuli and Experimental Design

The visual closure study used an object recognition task with increasing levels of closure as the independent variable. Target stimuli consisted of 100 line drawings (black on a white background) of animate and inanimate objects. These drawings were selected from the Snodgrass and Vanderwart (1980) normed set. This study followed previous research on perceptual closure of fragmented images, where an ascending method of limits (AML) procedure was used. The AML procedure involves the incremental increase in the amount of visual information that is available with each subsequent image presented until ‘closure’ is achieved (Snodgrass & Feenan, 1990). Images were stored as 256 x 256 pixel bitmaps and divided into 16 x 16 segments. Segments containing black pixels were randomly and increasingly removed in order to create 7 incrementally fragmented version of each picture (Snodgrass & Corwin, 1988). Level 1 referred to the complete picture and Level 7 the most fragmented image, where the proportion of deleted segments for any level equals $[1 - .7^{(\text{level}-1)}]$. Fragmented stimuli were presented starting with Level 7, as TD individuals were found to identify objects at a mean level of 3 (Doniger et al., 2000). Stimuli was presented on a computer using eprime software. Using this technique, brain activity during both object recognition and the completion processes can be collected. It can inform on whether these processes change in an all-or-none manner or in a more gradual way, as indexed by the latency and amplitude changes (Doniger et al., 2000).

Figure 2-3 shows the perceptual closure paradigm sequence that was used, Images were presented from the least complete level (Level 7) to the most complete level (Level 1). After the presentation of each fragmented image, a “Press any key to answer” cue appeared, prompting the participant to press any key if he wanted to answer. If no key was pressed, the fragmented image would continue to be presented with the next most complete image of the same picture. The picture sequence continued until a key was pressed by the participant or

when the complete image was presented. The participant then verbally named the picture. Once the verbal response was recorded by the experimenter, the participant would be asked to press a button to initiate the next sequence of fragmented images. The experiment consisted of 5 blocks. Each block contained 20 picture sequences. Participants were not given any break during the 5 blocks, except for natural breaks when the next block was being prepared.

At the start of the experimental task, a 'Press any key to begin' prompt appeared at the centre of the computer screen until the participant pressed any key to start. Then, the stimulus would be presented on the computer screen for 750 ms, followed by a screen with a 'Press any key to answer' prompt for 2000ms. The visual closure task lasted for about 30 minutes, excluding natural breaks and response time.

Figure 2-3. Perceptual closure paradigm sequence, stimuli and timing in a single trial (7 levels of increasing closure)

EEG Recording. The EEG/ERP data was recorded using a 64-channel sponge-based HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc.). The 64 EEG electrodes cover a wide area of scalp ranging from nasion to inion, and from the right ear to the left ear arranged uniformly and symmetrically. The impedance of the electrodes was kept below 50 k Ω . ERPs were recorded continuously throughout each stimulus-presentation trial, as depicted by Figure 2-3. Recordings were made with a Nets Amp 300 amplifier with a 250 Hz sampling rate, 24 bit analog to digital converter. Recordings were referenced to the vertex electrode, and data was then re-referenced offline to the left and right mastoids.

This study used high-density ERP recordings to examine the scalp activity during the perceptual closure processes and to elucidate the topography of effects of this activity for individuals with ASD. ERPs are scalp-recorded changes in the brain's electrical activity (also known as EEG). This electrical activity is evoked by the onset of a stimulus event. ERPs represent the average of the neural activity elicited by the stimulus event belonging to each trial. ERPs have a temporal resolution up to a precision of a few tens of milliseconds. Hence it can be used to examine the topography of effects of cognitive processes.

For the EEG session, the participant was first fitted with the sensor net and then provided instructions for the tasks. Prior to administering the experimental task, a short practice session using images different from the actual experimental task was provided to ensure the participant understood the task instructions. Participants proceeded to the actual experiment once a minimum of 80% accuracy on the practice was attained. Participants were instructed to name the objects as quickly as possible and with as few mistakes as possible. The level of fragmentation at which a response was made and responses for each image were recorded.

ERP Data analysis

Only trials with correct responses were included in the analysis to remove correct guesses that were not due to recognition. Trials with eye blinks and large eye movements were rejected offline on the basis of vertical and horizontal electro-oculograms (HEOG and VEOG) prior to averaging. In addition, each trial was also checked visually, and obvious blink artefacts were additionally excluded from analysis. After filtering and artifact-removal, the EEG data was segmented into -100 to 550ms epochs. The epoched data for the level at which identification occurs (level ID) and for the three preceding levels (1-prior, 2-prior, and 3-prior) were examined for P1, N1, N_{CL} and frontal activity based on Doniger and colleagues' study (2000). Nine topographical regions of interest (ROIs) were chosen. The ROIs were differentiated according to LAT (laterality: left, midline and right) and AP (anterior-posterior location: frontal, centro, parieto-occipital) factors as shown in Figure 2-4. Each ROI consisted of 4 electrodes: left frontal (AF3, F3, F5, F7), midline frontal (FP1, FP2, AFz, Fz), right frontal (AF4, F4, F6, F8), left centro (FC5, FT7, C3, C5), midline centro (FC1, FC2, CP1, CP2), right centro (FC6, FT8, C4, C6), left parieto-occipital (TP7, P3, P7, T5-P7), midline parieto-occipital (PO3, PO4, O1, O2) and right parieto-occipital (TP8, P4, P6, T6-P8).

Both the conventional surface voltage and Current Source Density (CSD) mapping were used to inspect the closure process. The traditional mapping represents interpolated potential distributions derived from the 64-scalp measurements using a linked-mastoids reference.

Figure 2-4. Nine regions of interests (ROIs)

Conventional Surface Voltage Measurements. Brain potentials were analysed by computing the mean amplitudes for the relevant time intervals using both original waves (ID, 1-prior, 2-prior, and 3-prior) and difference waves (ID/1-prior vs. ID/2-prior vs. ID/3-prior). The analyses were based on previous research using a similar paradigm of perceptual closure (Doniger et al., 2000; Doniger et al., 2002; Sehatpour et al., 2006). Mean amplitudes for each wave was taken from a 40ms window centred at peak latency of 108ms for P1, and a 40ms window centred at peak latency of 144ms for N1. As N_{CL} is a broader component, a 100ms window centred at peak latency of 254ms (204-304ms) was used. The time window used was larger than previous research on the N_{CL} , where a time window of 20ms centred at peak latency was used for P1 and N1, and a time window of 20-40ms centred at peak latency was

used for N_{CL} (Doniger et al., 2000; Doniger et al., 2002; Sehatpour et al., 2006). This larger time window was identified based on visual inspection of the group average waveforms of both TD and ASD groups. Mean amplitude and the peak latency of the N_{CL} were determined at the two electrode sites of maximal amplitude, T5-P7 and T6-P8, from group average waveforms collapsed across levels ID, 1-prior, 2-prior, and 3-prior. The two electrodes were chosen as previous findings from Doniger et al. (2000) found maximal N_{CL} activity at the bilateral occipito-temporal electrodes, T5 and T6. As the sensor net used in this study did not have electrodes T5 and T6, T5-P7 and T6-P8 were selected as they were closest in location to T5 and T6. Closure-related frontal activity was defined as the mean area within a 304 to 504 ms time window. Frontal-related perceptual closure effects were measured at bilateral frontal electrode pairs (FP1/FP2, F5/F6, FC5/FC6 and FT7/FT8). These electrodes, as shown in Table 2-4, were selected based on previous research on perceptual closure (Doniger et al., 2000, Doniger et al., 2002, Sehatpour et al., 2006).

Table 2-4

ERP Components and Corresponding Electrodes

ERP Components	P1 Component	N1 Component	N _{CL} Component	Frontal	
Time window	88-128ms	124-164ms	204-304ms	304-404ms	404-504ms
Brain regions/ Electrodes	Left occipito-temporal electrodes : T5-P7		Left Frontal electrodes: FP1		
	Right occipito-temporal electrodes: T6-P8		Right frontal electrodes: FP2		

Current Source Density (CSD) mapping. CSD is a true reference-free technique, in that any ERP recording reference scheme will give identical CSD estimates. The issue of choosing a reference arbitrarily is thus avoided. CSD topographies also have more precise localised peaks than corresponding ERP topographies as volume-conducted contributions from distant regions are removed. Such peaks more closely represent the direction, location, and intensity of current generators that underlie an ERP topography (Mitzdorf, 1985; Nicholson, 1973). Hence, the temporal peaks of CSD waveforms are more focused than the corresponding ERP waveforms (Kayser & Tenke, 2006b) and provides a more precise time course of any given ERP/CSD component. (Urbano, Babiloni, Onorati, & Babiloni, 1996). The CSD toolbox developed by Kayser (2009) was used. Only results after CSD transformation were reported, following the convention of previous research.

Three sets of ERP analyses were performed for the N_{CL} ERP component:

- 1) A set of global analyses using data from a grid of 36 electrodes distributed into 9 ROIs across the scalp was conducted using a mixed ANOVA with factors Group (2 levels: ASD vs. TD), Levels (3 levels: ID minus 1-prior vs. ID minus 2-prior vs. ID minus 3-prior), LAT (3 levels: left vs. midline vs. right), and AP (3 levels: frontal vs. centro vs. parieto-occipital) to examine for group differences in amplitudes of N_{CL}. For example, the amplitude increase between ID level and 1-prior would be denoted as ID minus 1-prior. Group differences in amplitude and peak latency of P1 and N1 were examined for the ID level.

Significant main effect or interaction involving the factor group would be further analysed by separate analyses on the TD group and group with ASD. The dependent variables were the mean amplitudes within the ROIs restricted to predefined time epochs. The Greenhouse-Geisser correction was applied to correct for violations of the sphericity assumption (Greenhouse and Geisser, 1959)

when necessary. The Bonferroni correction for multiple t-test comparisons was applied where relevant.

- 2) A second set of ERP analyses to test for significant NcL amplitude differences between successive levels at T5-P7 and T6-P8 was conducted by comparing levels ID minus 1-prior with ID minus 2-prior and ID minus 3-prior for each group. This was based on previous research on perceptual closure which reported perceptual closure to be maximal at the bilateral occipito-temporal sites (namely T5 and T6).
- 3) A third set of ERP analyses to test for frontal-related perceptual closure effects at bilateral frontal electrode pairs (FP1/FP2, F5/F6, FC5/FC6 and FT7/FT8) (Doniger et al., 2000, Doniger et al., 2002, Sehatpour et al., 2006) was conducted.

Results

Behavioural

TD participants correctly identified 85.9% (85.9 ± 6.25 /min-max range 74-98) of pictures, with a modal ID level of 3.6 (3.6 ± 0.83 /min-max range 2-5). This was similar to previous findings, where the modal ID level was 3 (Doniger et. al, 2000). Participants with ASD correctly identified 82.4% (82.4 ± 7.10 /min-max range 60-92) of pictures, with a modal ID level of 2.92 (2.92 ± 0.95 /min-max range 1-5). The results are presented in Table 2-5. Both Correct% and MeanID scores were found to follow normal distribution using Shapiro-Wilk test (Correct%: $W=0.982, p=0.903$; MeanID: $W=0.963, p=0.401$). The identification rate for TD and ASD was similar ($t(26)=1.36, p=0.093$). However, TD and ASD showed a significant difference in Mean ID level ($t(26)=1.72, p=0.049$). Both the Modal and Mean ID levels had similar distribution curves. The distribution curves for Modal and Mean ID levels for both groups areas shown in Figure 2-5.

Table 2-5

Behavioural Performance

Behavioural Measures	TD (<i>n</i> =15)	ASD (<i>n</i> =13)	Significance
Correct (%)	85.87 $\pm$ 6.47	82.38 $\pm$ 7.10	$t(24)=1.33, p=0.093$
Modal ID Level	3.60 $\pm$ 0.83	2.92 $\pm$ 0.95	-
Mean ID Level	3.50 $\pm$ 0.57	3.09 $\pm$ 0.68	$t(26)=1.72, p=0.049^*$

Note. * $p < .05$

TD **ASD**

Figure 2-5. Comparison of the distribution curves for the modal ID and mean ID levels for

TD and ASD.

ERP Results

The ERP data was checked for normality using Shapiro Wilk test. The results are presented in Table 2-6. The Independent Samples Mann-Whitney U test, a nonparametric test, was used for the P1, N1 and N_{CL} peak latency measures as they did not follow a normal distribution.

Table 2-6.

Test of Normality for Mean Amplitude and Peak Latency

ERP	No. of electrodes met normality assumption*			
	ID/1-prior	ID/2-prior	ID/3-prior	ID level
	Amp	Amp	Amp	Latency
P1	33/36	34/36	30/36	4/36
N1	28/36	32/36	30/36	7/36
N _{CL}	33/36	35/36	34/36	19/36
Frontal				
340-440	32/36	28/36	29/36	
440-540	30/36	30/36	32/36	

* Shapiro Wilk W $p < .05$

Closure negativity: N_{CL}. Mean amplitudes and peak latencies for N_{CL} are reported in Table 2-7.

The overall mixed ANOVA (Groups x LAT x AP) did not show any significant main or interaction effects for N_{CL} amplitude at ID level. No significant group differences were also found in the peak latency at ID level. There was also no significant main or interaction effects for the overall ANOVA (Group x Level x LAT x AP) analysis for difference in amplitude increase between ID minus 1-prior, ID minus 2-prior, and ID minus 3-prior.

The analysis done by conducting a mixed ANOVA (Group x Level x Electrode Pair) on the bilateral occipito-temporal electrode pairs (T5-P7 and T6-P8) showed a significant Level x Electrode interaction ($F(2,52)=4.18$; $p=0.021$, $\eta^2_p=0.14$). A one-way ANOVA was conducted separately on left (T5-P7) and right (T6-P8) occipito-temporal electrodes. The difference in amplitude increase between ID minus 1-prior, ID minus 2-prior, and ID minus 3-prior was found to be significant for the right occipito-temporal electrode (T6-P8) ($F(2,54)=4.15$, $p<0.05$, $\eta^2_p=0.13$). Further t-tests showed that the difference in amplitude increase was significant between ID minus 1-prior and ID minus 3-prior ($t(27)=-2.31$, $p=0.029$, $\eta^2_p=0.17$). The difference in amplitude increase between ID minus 1-prior and ID minus 2-prior approached significance ($t(27)=-2.03$, $p=0.052$, $\eta^2_p=0.13$). Following Bonferroni correction for multiple t-test comparisons, the difference in amplitude increase between ID minus 1-prior and ID minus 2-prior did not reach significance level ($p=0.017$). The CSD scalpmaps and waveforms are presented in Figure 2-6.

Figure 2-6. CSD scalp maps and ERP waveforms maps at 204-304ms. Top: The CSD scalp plots show scalp recordings of group mean topographies between ID and 3-prior at 204-304ms. CSD maps of ASD showing the observed negativity over the posterior regions only for the 3-prior level. TD also showed an observed negativity over the right posterior regions and prefrontal regions for the 3-prior level. Bottom: The waveforms of scalp recordings from the two representative occipito-temporal electrodes (T5-P7 and T6-P8). The N_{CL} at ID level produced larger negativity when compared to the 3-prior.

Table 2-7.

Mean Amplitude and Peak Latency at ID level

Electrode	P1 Component		N1 Component		N _{CL} Component		Frontal	
	88-128ms		124-164ms		204-304ms		304-404ms	404-504ms
	Mean Amp	Peak Latency	Mean Amp	Peak Latency	Mean Amp	Peak Latency	Mean Amp	Mean Amp
T5-P7								
TD	0.106	146.13	0.083	180.00	0.119	298.40		
	(0.073)	(13.169)	(0.070)	(11.514)	(0.115)	(21.636)		
ASD	0.133	147.69	0.092	186.46	0.130	307.69		
	(0.116)	(9.586)	(0.083)	(11.949)	(0.087)	(28.212)		
T6-P8								
TD	0.069	143.73	0.047	178.93	0.132	297.87		
	(0.086)	(10.082)	(0.084)	(12.418)	(0.121)	(23.898)		
ASD	0.122	141.23	0.082	180.31	0.103	297.23		
	(0.116)	(15.265)	(0.115)	(12.906)	(0.110)	(28.816)		
FP1								
TD								
ASD								
FP2								
TD								
ASD								

Note: mean and standard deviation (in parentheses) are reported.

Early Processing: P1 and N1 ERP Components. Mean amplitudes and peak latencies for P1 and N1 are reported in Table 2-7.

The mixed ANOVA (Groups x LAT x AP) did not show any significant main or interaction effects for P1 and N1 amplitudes at ID level. No significant group differences were also found in the peak latency at ID level. The waveforms of the scalp recording for P1 and N1 are shown in Figure 2-7.

TD

ASD

Figure 2-7. The waveforms of scalp recordings from the two representative occipito-temporal electrodes (T5-P7 and T6-P8) for P1 and N1. No significant differences are found.

Frontal Activity. Mean amplitudes for frontal activity are reported in Table 2-7. The mixed ANOVA (Group x Level x LAT x AP) for between-group differences in mean amplitude from 3-prior to 2-prior to 1-prior to ID did not show any significant main or

interaction effects with Group factor for both early and late frontal activity. Interactions involving other remaining factors were also not significant.

The mixed ANOVA (Groups x LAT x AP) did not show any significant main or interaction effects for amplitude at ID level for early and late frontal activity. There was also no significant main or interaction effects for the mixed ANOVA (Group x Level x LAT x AP) analysis for difference in amplitude increase from 3-prior to 2-prior to 1-prior to ID level.

An analysis was done by conducting a mixed ANOVA (Group x Level x Electrode Pair) on the bilateral frontal electrode pairs (FP1/FP2, F5/F6, FC5/FC6 and FT7/FT8) for ID minus 1-prior, ID minus 2-prior, and ID minus 3-prior. For early frontal activity, a significant Group x Electrode Pair interaction was found ($F(3,78)=2.77, p=0.047, \eta^2_p=0.10$). For late frontal activity, a significant Group x Electrode Pair effect approached significance ($F(3,78)=3.21, p=0.078, \eta^2_p=0.11$). Separate analyses were conducted for the TD and ASD. The group difference in increase in mean amplitude for ID minus 1-prior, ID minus 2-prior, and ID minus 3-prior was significant for the TD group for prefrontal electrode pair FP1/FP2 only ($F(2,28)=5.089, p<.028$). Further analyses showed that the increase in mean amplitude in the TD group was significant only for ID minus 1-prior and ID minus 3-prior ($F(1,14)=6.276, p=0.025$). After Bonferroni correction for multiple t-test comparisons was applied, the effect did not reach significance ($p=0.017$). Figure 2-8 shows the CSD scalpmaps and waveforms for the frontal activity.

Figure 2-8. CSD Scalp maps and ERP waveforms maps at 304-504ms. Top: The CSD scalp plots show scalp recordings of group mean topographies between ID and 3-prior at 304-504ms. The TD group had relative negativity over the prefrontal scalp regions at 404-504ms. This was not seen in the group with ASD. Bottom: The waveforms of scalp

recordings from the two prefrontal electrodes (FP1 and FP2). The ID level showed relative negativity as compared to the 3-prior level for the TD group.

Discussion

This study found that adolescents with ASD could recognise objects at similar accuracy rate as TD adolescents. However, they needed a slightly higher level of completeness than TD adolescents. The TD adolescents recognised most of the fragmented images at a lower level of completeness, while the adolescents with ASD recognised most of the fragmented images at a higher level of completeness. The results were consistent with the hypotheses. The behavioural results found in this study are also consistent with van der Hallen's (2015) meta-analysis of global and local processing in individuals with ASD, where he found that individuals with ASD took a longer time when global processing was involved. In the individuals with ASD, the need for higher level of completeness suggest that the recognition of an object may take a longer duration as they would need to process more details of the image before recognition can occur. This is also consistent with eye tracking studies where individuals with ASD showed reduced visual exploration and a greater tendency to explore areas close to the current fixation when viewing visually complex scenes such as photographic scenes (Heaton & Freeth, 2016). The current findings also extend the conclusion of Van der Hallen et al.'s (2015) meta-analytic findings, as the meta-analysis only included studies on geometric figures. Not only do individuals with ASD take a longer time when global processing is involved in recognising geometric figures, they also take a longer time when global processing is involved in object recognition.

In this study, the topography of effects of perceptual closure provided an understanding of how adolescents with adolescents with ASD and TD adolescents differed in their processing of fragmented images in terms of the interplay of local and global processing.

Early visual processing was found to be similar for TD individuals and individuals with ASD. Measurements of the P1 and N1 amplitudes and peak latencies during the point of closure did not yield significance. Contrary to the hypotheses that differences would be found for N_{CL} amplitude and peak latency at the occipito-temporal sites, the TD individuals and individuals with ASD did not show any significant difference. Instead, both TD adolescents and adolescents with ASD showed an increase in N_{CL} amplitude between the different levels prior to closure at the right occipito-temporal site. The left occipito-temporal site also approached significance. This suggests that the individuals with ASD and TD individuals undergo similar topography of effects and have similar scalp activations in early visual processing. Early visual processing and the perceptual closure process at the occipito-temporal sites are similar in individuals with ASD and TD individuals.

Differences in closure-related frontal activity were shown between the adolescents with ASD and TD adolescents. Consistent with the study's hypotheses, differences in mean amplitudes in the frontal scalp regions were found. The TD group showed reduced negativity in prefrontal scalp activations soon after the N_{CL}. When the differences in amplitude increase in the prefrontal scalp negativity were examined for the ID minus 1-prior and ID minus 3-prior levels, it was found that at ID level, the frontal negativity reduced in amplitude, as compared to ID minus 3-prior level. The topographic scalp plots also showed activations throughout, including the prefrontal, parietal and occipital regions. However, the group with ASD did not show a reduced negativity in the prefrontal scalp regions. Rather, the group with ASD showed higher activation in the posterior, parietal and temporal regions. Thus, while the TD group showed activations in both frontal and posterior regions, the group with ASD showed more localised activations within the posterior, parietal and temporal regions. This means that for the TD group, the process of perceptual closure and eventual object recognition in the occipital and temporal region was mediated by top-down facilitation by

prefrontal brain areas. Such a top-down facilitation is not present in the group with ASD. The behavioural findings showed that the group with ASD recognised the fragmented figures with similar accuracy rate but at a slightly higher level of completeness compared to TD.

Combined with the EEG findings, this provides evidence that differences in perceptual closure between the TD group and group with ASD may be explained by a qualitatively different neural process, and not just a delay or later access to gestalt/global processing.

The pattern of activation decrease in the PFC electrodes suggests that a model or template selection may occur in the PFC, as postulated by Bar (2006) and supported by various neuroimaging and EEG studies (see Figure 2-9). For the group with ASD, it appears that the eventual identification may not be due to a gestalt processing mediated by PFC, but rather an actual match in the inferior temporal regions. This is consistent with the atypical connectivity found in individuals with ASD during visual processing, where there is more enhanced local connectivity between nearby brain region and reduced long-range connectivity. This study also sheds light on whether the early perceptual processing is affected at the point of input or higher up in the brain circuits associated with frontal lobes. The amplitudes and peak latencies of the early visual processing components and the NCL were similar for the TD group and the group with ASD. This was consistent with studies which showed that high-functioning individuals with ASD had early visual areas that were organised similar to typical controls (Hadjikhani et al., 2004). Therefore, visual processing atypicality are likely to be due to higher-level visual areas and possible top-down influences. As postulated by various theorists, the process of object recognition and coherent images involves an interplay of global and local processing (Mottron & Dawson, 2013). This could explain why individuals with ASD may find it difficult when images become more complex and they can no longer use local processing to arrive at a gestalt representation.

This study showed that adolescents with ASD did not use both global and local processing when identifying the fragmented image. Instead, local processing was used to identify the fragmented image. Frontal ERP responses seen in TD adolescents were not found in the adolescents with ASD. The use of local processing by the individuals with ASD was unlike that found in a timecourse study on object recognition by Caplette and his associates' (2016). Using spatial frequencies, the study found that both LSFs and HSFs were sampled by the group with ASD at the same time. However, as mentioned previously, the sampling of the LSFs could be due to two labels that were provided together with the picture with graded SFs. The labels could have activated the LSFs sampling when the individuals with ASD tried to match the image with LSFs to the two labels. Thus, in the current study, where no gestalt image was presented to initiate gestalt processing, individuals with ASD relied on local processing to identify the fragmented object.

Figure 2-9. Object recognition in the group with ASD. In the group with ASD, the image is processed through detailed slower analysis of the visual input along the ventral visual stream. The processing of LSF image of the visual input is not performed simultaneously or at a later stage. Identification or recognition of the image is performed by ventral object recognition regions using bottom-up processing (modified from Bar et al., 2006).

The current findings can be better explained by the WCC theory (Happe & Frith, 2006) as compared to the EPF theory (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). The EPF theory states that individuals with ASD have a heightened response to sensory stimulation. This leads to an excessive refinement of low-level processes at the expense of high-level processes. Individuals with ASD therefore would show superior local processing which is mandatory in nature. Although the group with ASD did recognise the fragmented images, the electrophysiological findings suggested that this was achieved through local processing of the fragmented details, as compared to gestalt or global processing. The group with ASD did not show a delay in global processing, but rather showed a lack of global processing. Thus, it supports the proposition of WCC theory of a deficit in ability to integrate information into a more coherent whole, when the information gets to a stage of complexity where local processing alone does not work.

Limitations and Future Research

The limitations of the study include its small sample size, limited age range as well as the inclusion of only males. This study found a significant N_{CL} effect for right occipito-temporal electrode. However, it did not reach significance after Bonferroni correction. This may be due to the small sample size. Based on the observed effect size ($\eta^2_p=0.17$), it is estimated that a sample size of 40 would be needed to obtain significance at $p=.05$.

Previous research has shown that the N_{CL} effect is manifested bilaterally at the occipito-temporal electrodes. However, the N_{CL} effect was not seen in the left occipito-temporal electrodes for both adolescents with ASD and TD adolescents. This could be due to the age of the participants in this study. Previous studies have used adult participants. Research has shown that children improve in their global processing in categorisation and visual search tasks between 5 and 23 years. The findings suggest that grouping ability have a longer

developmental trajectory than individuation abilities (Kimchi, Hadad, Behrmann, & Palmer, 2005). Future studies would need to include more participants across the different ages to investigate what the developmental trends for perceptual closure are for both participants with ASD and TD participants. Including female participants would also help to better understand if there is a gender difference in perceptual closure for the population with ASD.

It would be more informative for future studies to conduct simultaneous EEG and fMRI to locate the brain areas involved in the timecourse of perceptual closure and object identification. Functional and dynamic connectivity studies will be able to provide more insight into the feedforward and feedback mechanisms involved. Possible differences in dorsal and ventral stream processing can also be explored.

Such differences in frontal effects in perceptual closure of objects can affect more complex information processing e.g. scene processing. Research can be conducted on how such complex information processing is affected by these differences in perceptual closure, and how the interplay of global and local processing occurs. Such differences would also impact on the VisWM, where the encoding, maintenance and retrieval of images are dependent on how the images are perceived at the point of encoding. This is investigated in the following study 2 on how individuals with ASD and TD individuals process the global and local elements in a scene.

Training programs targeted at using metacognitive strategies that involve template or model matching can be conducted. EEG can be used to examine the differences in timecourse and activations pre-and post-training. A behaviour study investigating the effects of such perceptual closure training on perceptual closure and VisWM of individuals with ASD was conducted as part of Study 3.

Linkages to and Motivations for Study 2 and 3

The current study showed that only local processing was used in the recognition of the fragmented images. While this appears to support the WCC theory, there is a need to further investigate how the individuals with ASD would process more complex images. Study 2 investigated how individuals with ASD and TD individuals would differ when asked to remember locations of objects placed in intact or scrambled scenes. Scenes are complex visual representations that require both local and gestalt processing. Neural processing involved in scene processing is similar to that involved in object recognition, where the scene is first categorised through global processing of the gist information (or LSFs) and then processed in detail through local processing (or HSFs) (Kauffmann, 2014). Investigating how individuals with ASD process and remember intact and scrambled scenes would help to understand how the differences in perceptual closure found in Study 1 impact on more naturalistic visual information that individuals with ASD encounter daily. If such basic visual processes also impact on how individuals with ASD perceive and remember scenes, then training programs on holistic processing should target at a more basic level of perceptual closure to address fundamental differences, before generalising and moving on to higher order processing such as scene and face processing. Study 3 will look at how training on perceptual closure using metacognitive strategies would impact directly on perceptual closure of individuals with ASD, as well as indirectly on VisWM of individuals with ASD.

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CHAPTER III: STUDY 2

Effects of coherence on object-to-scene binding in visual working memory of individuals with ASD

An ERP Study

Introduction

Differences in perceptual closure during object recognition were found in individuals with ASD in Study 1. The individuals with ASD used more local processing when recognising fragmented images. The impact of such differences in more basic perceptual processes on the VisWM is further investigated in Study 2. Research has shown that the VisWM of individuals with ASD is impaired, especially when the tasks are more complex or place higher demands on the VisWM (Steele, Minshew, Luna, & Sweeney, 2007). This study investigated if the differences in the interplay of local and global processing during perceptual closure and object recognition found in Study 1 also impacts how complex information are encoded and maintained in the VisWM of individuals with ASD. Since visual perception has been shown to affect VisWM processes (Gao, Gao, Li, Sun, & Shen, 2011), how does the difference in the interplay of local and global processing during perceptual closure affect VisWM processes of individuals with ASD?

Study 2 examined the effects of coherence on object-to-scene binding in VisWM of individuals with ASD. Scenes were used as they would be more relevant to how the individuals would use context-relevant information in their day-to-day functioning.

Using slow wave shifts, it investigated if coherence would facilitate object-to-scene binding, and hence VisWM performance, in individuals with ASD. Slow waves, which occurs during the maintenance phase, is a sustained ERP component that has been shown to reflect working memory processes (Ruchkin, Canoune, Johnson, & Ritter, 1995). Slow wave shifts recorded during a working memory task can provide insight into the relationship between brain structure and cognitive processes. Specifically, the study examined differences between individuals with ASD and TD individuals with respect to the neural generators of sustained activity for coherent and scrambled scenes during the stimulus-encoding and delay-

maintenance phases of VisWM. Slow negative ERP shifts were used to examine these differences as they reflect sustained neural firing (Birbaumer, Elbert, Canavan, & Rockstroh, 1990). Differences in capacity of VisWM and accuracy have also been reflected in amplitude differences in slow wave shifts (Drew, McCollough, & Vogel, 2006). More successful maintenance is also associated with changes in slow-shift amplitude during visual input and delay period. Hence slow wave shifts could be used to examine possible differences in VisWM between individuals with ASD and TD individuals, for coherent and scrambled images.

Although visual perception and VisWM have been shown to interact with each other, research on the mechanisms underlying this interaction has been mixed. Research on TD individuals showed a limit of about three to four objects per scene (Luck & Vogel, 1997, 2013). Studies looking at how VisWM for natural scenes are processed and can be improved have shown a scene coherence effect (Biederman, 1972). Recognition memory has been shown to be consistently better for objects seen within coherent versus scrambled scenes (Biederman, 1972; Velisavljevic & Elder, 2008). Questions were then raised as to whether the global context presented by a coherent scene acts to make the representation of independent objects at the encoding stage more precise or that the objects and context are encoded and maintained together in memory to form a more reliable representation than objects encoded and stored without a coherent global context. Subsequent research showed that the memory encoding of objects and scene context are not independent but are bound together in VisWM. In another study, participants were asked to view a natural scene and remember objects in the scene (Hollingworth, 2006). They had to respond to a forced choice task with two options. In each trial, one 4-second interval contained the target object and another 4-second interval contained a distractor object. The distractor object was either the same object rotated 90 degrees in depth or a similar object which was a different item of the

same object category. In addition, target and distractor objects were presented either within the original scene background (with arrows pointing at them) or in isolation. It was found that individuals could discriminate better when both target and distractor objects were presented within the original scene background than when they were presented in isolation. Hence the findings suggest that object and scene representation are not independent but are bound together in VisWM.

Coherence effects on Object Processing

Having established the robustness of the scene coherence effect on memory of objects in natural scenes, we need to explore how this scene context facilitates the processing of objects and the subsequent memory of these objects in the VisWM. Three main models have proposed explanations for the effects of scene context on object processing. These three models are: the perceptual schema model, the priming model and the functional isolation model (Henderson & Hollingworth, 1999). A common concept underpins these three models. Scene perception is generally assumed to activate a corresponding scene scheme. This scene schema is postulated to contain generalised ideas about the objects that are likely to be in the scene and where its position may be. Thus, it can change and facilitate the processing of objects present in the scene. However, the models differ in their explanations of how and when object processing is influenced by the schema. Both the perceptual schema and priming models propose that context effects are due to an early top-down facilitation. The perceptual schema model postulates that the activation of the scene schema facilitates the initial stages when schema-consistent objects are perceived and analysed. This means there is continuous interaction between perceptual analysis and scene schema. The priming model proposes that the effect of context occurs at a later stage whereby the activation of the scene scheme primes the stored representations of objects that are congruent with the schema. Hence this matching happens after the details of the object have been perceived. Such top-

down facilitation, as proposed by the two models, would result in a reduction of perceptual information and resources needed to identify a primed object. On the other hand, the functional isolation model states that context does not facilitate object identification. Rather, it influences the later post-perceptual semantic phase (e.g. decision-making, attention). Thus, object identification results only from a bottom-up visual analysis. Recent neuroimaging research have shown support for a top-down facilitation of scene effects on object recognition, thereby providing evidence for the perceptual schema and priming model, and not the functional isolation model. This is similar to the top-down facilitation proposed by Bar (2004) in his model of object recognition. However, given that different mechanisms can lead to context effects on object processing, it is unclear if these context effects are present for individuals with ASD.

As mentioned in Chapter 1, two main theories have been proposed to understand the atypicality in global and local processing seen in ASD: the Weak Central Coherence (WCC) theory which postulates that individuals with ASD seem to have difficulties with integration of individual units into a meaningful and gestalt whole, although their processing of local features seems superior or at least intact (Happé & Frith, 2006); and the Enhanced Perceptual Functioning (EPF) hypothesis which emphasises enhanced local processing in individuals with ASD and does not claim a qualitative or quantitative deficiency in their global processing (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). According to the EPF hypothesis, global processing is not automatic or even involuntary like that seen in typical populations. Understanding the interplay between global and local processing during scene processing and its impact on VisWM performance will help to shed light on the hypotheses of these two models.

Neuroimaging research have also shed light on the underlying neural processes in scene processing. Scene processing in TD individuals has been found to follow a process

similar to object recognition and perceptual closure. As with object recognition, scene processing follows a coarse-to-fine processing, where the gist (or LSF) of the scene is first processed, followed by the details (or HSF). The gist (or LSF) information is sent to the higher-order areas rapidly, enabling a coarse initial processing of the visual scene. This is then sent back through feedback connections into the lower-level visual areas to guide a finer analysis based on the details (or HSF) (Kveraga, Boshyan, & Bar, 2007; Peyrin et al., 2010). Research also shows that in scene perception, gestalt or global processing seems to be preferentially performed in the right hemisphere, while the details are preferentially performed in the left hemisphere (Kauffmann, Ramanoel, & Peyrin, 2014). Although atypical perceptual processing has been found in individuals with ASD, how such differences in the interplay of global and local processing happen when processing complex information such as visual scenes have not been investigated.

Scene Context effects on VisWM in individuals with ASD.

Research on the effects of scene coherence in individuals with ASD have produced contradictory results. Behavioural studies on context effects in individuals with ASD have generally found context effects for both TD individuals and individuals with ASD. However, these studies have not controlled for possible local inter-object effects and the influence of post-perceptual processes, which would indicate the use of more local processing as compared to global processing. For example, if the probe consisted of all the objects embedded within the original scene, then the participants with ASD could use the local inter-object relationships to guide their recognition. To address such concerns, Van Eylen and associates (2013) examined the use of scene context in object recognition of individuals with ASD by using an eye-movement paradigm to look directly at how scene context can affect object processing. The study found that both context effects and congruent contextual information facilitated object recognition. This was based on the assumption that shorter

fixation would indicate easier recognition. Thus, objects shown in a congruent context would be fixated shorter, later and less frequently than the same objects shown in an incongruent context. This was found for both TD individuals and individuals with ASD. However, there are some limitations to this study. Firstly, individuals with high functioning ASD have often been seen to show similar behavioural results but have different underlying neurological processes (Pijnacker, Geurts, van Lambalgen, Buitelaar, & Hagoort, 2010). Research has also shown that the format of VisWM assessment can affect the detection of deficits in individuals with ASD. Specifically, the complexity of task (e.g. dual tasks, and tasks that require higher cognitive load and flexibility) is a key factor. The task used in Van Eylen and associates' (2013) study may not have been complex enough to detect the deficit. Line drawings were also used in the study. This is different from a natural scene with its complex combination of colours and contours. In addition, for VisWM, deficits have been shown in high functioning ASD when spatial WM is tapped on without the use of verbal responses and coding (i.e. the use of phonological loop)(Williams, Goldstein, Carpenter, & Minshew, 2005).

To understand scene coherence and its effect on VisWM, we need to look at how the interplay of global and local processing underlies scene processing in individuals with ASD. Research on the effects of gestalt or global processing on the VisWM of individuals with ASD is limited. In individuals with ASD, research on VisWM has not specifically evaluated how coherence or context affects the process of object-to-scene binding. Specifically, how coherent and scrambled images may affect the encoding and maintenance of object-to-scene binding in TD individuals and individuals with ASD have not been systematically examined.

The current research investigated the processing of complex visual information in the VisWM of individuals with ASD. It explored the effect of coherence on object-to-scene binding using natural scenes. Coherence was operationalised as either an intact or scrambled

image. This study used natural scenes, which are non-social stimuli, in an intact or scrambled form. Binding was operationalised by the integration of object with its position in the scene.

To better understand if different neural mechanisms underlie similar behavioural results, an EEG or neuroimaging study is needed. To understand when and how the binding occurs and may differ for individuals with ASD, sustained neural activity was examined using slow wave shifts in the two sequential phases of working memory: encoding and maintenance. Malecki and associates' (2009) ERP study, together with functional MRI studies on visual scene processing (Aguirre, Zarahn, & D'Esposito, 1998a, 1998b) suggests that positive slow wave shifts were recorded by surface occipito-temporal electrodes during encoding phase and likely generated in the occipital and inferior temporal cortex. However, negative slow wave shifts were mostly recorded by surface parieto-occipital electrodes with the onset of the maintenance phase. These slow wave shifts were thought to be likely generated by parieto-occipital regions. Activations in the PFC during maintenance period have also identified PFC as the neural substrate for the storage buffers proposed in Baddeley's (2000) model. In addition to indexing topographic and polarity differences during the encoding and maintenance of scenes, slow wave differences are also found under different demands or capacity (Malecki, Stallforth, Heipertz, Lavie, & Duzel, 2009). The sensitivity of slow wave shifts in detecting sustained activity when different conditions are presented to VisWM enables examination of how the encoding and maintenance process may differ between individuals with ASD and TD individuals.

Research Hypotheses

Given the above background information, the following hypotheses were proposed:

1. It was hypothesised that TD individuals would show differences in amplitude of slow waves during encoding and delay period between Intact and Scrambled

condition. Individuals with ASD would show similar amplitudes of slow waves during encoding and delay period between Intact and Scrambled condition.

This was based on the idea that TD individuals would process the intact and scrambled scenes differently, by making use of the coherence within the intact scenes. Individuals with ASD would process the Intact and Scrambled scenes in a more similar manner.

2. It was hypothesised that the individuals with ASD would have similar reaction times and error rates in the Intact and Scrambled condition of the VisWM task.

However, TD individuals would have shorter reaction times and fewer errors in the Intact scene condition than the Scrambled scene condition.

This is based on studies which show that individuals with ASD have poorer gestalt perception than TD individuals. Hence, TD individuals would use coherence of the scene in the intact condition to aid in their recall. Individuals with ASD would not use coherence of the scene in the intact condition to aid in their recall, possibly resulting in no difference in performance for both conditions.

Method

Participants and Screening Procedure

Participants in Study 2 (19 ASD and 17 TD males) were the same as those recruited for Study 1. They were tested during the same session. The same inclusion criteria of nonverbal reasoning score of at least 80 and no use of medication was applied. In addition, for this study, one TD individual did not complete the task and another was removed as an outlier based on a boxplot of behavioural reaction time on the experimental task for TD group. Four adolescents with ASD and 3 TD adolescents were further excluded as they had fewer than 20 artifact-free ERPs in the conditions that were being analysed. The final analyses were

conducted on 12 participants with ASD and 13 TD participants. The statistical power of this study was thus deemed sufficient based on the same power analysis conducted for Study 1.

Standardised Assessments and Baseline Behavioural Measures

Both participants with ASD and TD participants were administered a series of standardised measures to obtain a baseline of their visual perceptual and memory abilities, as well as their current functioning in social communication and social functioning skills. The group with ASD and TD group were matched in age and nonverbal reasoning. As expected, they also differed in their social communication and social functioning. The visual perceptual skills of the group with ASD and TD group were not significantly different. However, the group with ASD had relatively lower scores on the visual spatial working memory task, as compared to the TD group. Table 3-1 shows the means and SDs for the pre-assessment behaviour measures for the two groups.

VisWM Task Stimuli and Experimental Design

The VisWM study was a delayed-match-to-sample VisWM task with scene-based coherence as the independent variable. Target stimuli consisted of 6 objects embedded in natural scenes, either in an intact or scrambled condition. An example of the events and timings of a single trial is shown in Figure 3-1. There was a total of 4 blocks of 32 trials each. The participant had to decide whether the object in the probe presented was in the same position as the target stimulus shown previously by pressing either 'Yes' or 'No' on a SR box.

The presentation sequence of the intact and the scrambled scenes within each block were randomised. Each block consisted of 32 trials and lasted for 7.5 minutes each.

Table 3-1

Demographics and Standard Measures of TD participants and participants with ASD

Demographics and Standard Measures	TD (<i>n</i> =13)	ASD (<i>n</i> =12)	Significance
Age (in months)	176.31±13.57	170.33±14.19	<i>t</i> (23)=-1.08 <i>p</i> =0.294
Nonverbal Reasoning	117.50±10.77	113.21±14.75	<i>t</i> (23)=-0.84 <i>p</i> =0.412
Affect Recognition (NEPSY-II) ^a	9.08±1.61	6.00±3.38	<i>t</i> (23)=2.87 ^a <i>p</i> =0.012
ASD Spectrum Quotient ^b	12.75±5.46	34.30±4.72	<i>t</i> (20)=-9.79 ^b <i>p</i> =0.000
Social Communication Questionnaire ^b	6.42±3.75	13.75±4.52	<i>t</i> (22)=-4.33 ^b <i>p</i> =0.000
Figure Ground (Test of Visual Perceptual Skills-3 rd Edition)	14.31±3.47	12.50±4.66	<i>t</i> (23)=-1.11 <i>p</i> =0.280
Visual Closure (Test of Visual Perceptual Skills-3 rd Edition)	13.85±2.82	12.42±2.78	<i>t</i> (23)=1.27 <i>p</i> =0.215
Memory for Designs (NEPSY-II) ^a	12.54±1.51	9.42±4.03	<i>t</i> (23)=2.52 ^a <i>p</i> =0.025

Note. ^a *p* <.05; ^b *p*<.005

Standard measures are presented using scaled scores.

Affect Recognition, Memory for Designs, Visual Closure and Figure Ground:
Range 1-19

ASD Spectrum Quotient: Range 0-50

Social Communication Questionnaire: Scores above the cutoff of 15 suggest the individual is likely to have ASD

EEG Recording.

The EEG/ERP data was recorded using a 64-channel sponge-based HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc.). The 64 EEG electrodes cover a wide area of scalp ranging from nasion to inion, and from the right ear to the left ear arranged uniformly and symmetrically. The impedance of the electrodes was kept below 50 k Ω . ERP was recorded continuously throughout each stimulus-presentation trial. Recordings were made with a Nets Amp 300 amplifier with a 250 Hz sampling rate, 24 bit analog to digital converter. Recordings were referenced to the vertex electrode, and data was then re-referenced offline to the left and right mastoids.

The VisWM task consisted of 4 blocks, each lasting 7.5 minutes. There was a total of about 35 minutes of the VisWM task. Natural breaks lasting about 1 minute were provided in between blocks.

Procedure

The VisWM task followed the visual closure task presented in Study 1. A natural break of 5 minutes was provided as the experiment was being set up. The experimenter then administered the practice task with standardised instructions. This was a short practice session using stimuli different from the actual experimental task to ensure the participant understood the task instructions. Participants proceeded onto the actual experiment task when they attained at least 75% accuracy on the practice task.

Data analysis

Behavioural data.

An overall ANOVA with factors Group (ASD vs. TD) and Condition (intact vs. scrambled) was conducted using correct responses (Acc) and reaction time (RT) as dependent variables. Simple effects analyses were further conducted for each group if a

significant interaction effect of the experimental factors was found. Correction for multiple comparisons was made using the Bonferroni adjustment.

Figure 3-1. VisWM paradigm sequence, stimuli and timing in a single trial

EEG Data Preprocessing.

Only trials with correct responses were analysed. Trials with eye blinks and large eye movements were rejected offline on the basis of vertical and horizontal electro-oculograms (HEOG and VEOG) prior to averaging. In addition, each trial was also checked visually, and obvious blink artefacts were additionally excluded from analysis. After filtering and artifact-removal, the EEG data was segmented into -100 to 4800 ms epochs. Analysis of slow wave shift potentials was limited to the first 4800ms of the trial. Slow wave shift ERPs were time-locked to the onset of the sample stimulus and spanned a recording period comprising of the sample presentation of 3000ms and the first 1800ms of the delay interval. This gave rise to an epoch's length of 4900ms including a 100-ms baseline prior to stimulus onset.

Figure 3-2. Twelve regions of interests (ROIs).

Brain potentials during stimulus presentation and maintenance were analysed by computing the mean amplitudes for the following time intervals: encoding (0-400ms, 400-800ms, 800-1800ms, and 1800-2800ms) and maintenance (3200-4000ms and 4000-4800ms). The ROIs were differentiated by LAT (laterality: left, midline and right) and AP (anterior-posterior location: frontal, fronto-central, centro-parietal and parieto-occipital) factors as shown in Figure. 3-2. Each ROI consisted of 3 electrodes: left frontal (F3, F5, F7), midline frontal (FP1, Fz, FP2), right frontal (F4, F6, F8), left fronto-central (FC5, FT7, FC3), midline fronto-central (FC1, FCz, FC2), right fronto-central (FC6, FT8, FC4), left centro-parietal (TP7, C5, CP5), midline centro-parietal (CP1, Pz, CP2) and right centro-parietal (CP6, C6, TP8), left parieto-occipital (P5, P3, T5-P7), midline parieto-occipital (PO3, POz, PO4) and

right parieto-occipital (P4, P6, T6-P8). Brain potentials were analysed by computing the mean amplitudes for the predefined time intervals.

A mixed ANOVA with factors Group (ASD vs. TD), Condition (intact vs. scrambled), LAT (left vs. midline vs. right), and AP (frontal vs. fronto-central vs. centro-parietal vs. parieto-occipital) was conducted for each predefined time epochs. Post-hoc tests for each group were conducted if any significant interaction for Group factor was found. The dependent variables were the mean amplitudes within ROIs restricted to predefined time epochs. The Greenhouse-Geisser correction was applied to adjust p -values when the assumption of sphericity was violated. The Bonferroni correction for multiple t-test comparisons was applied where relevant.

To test whether the differences in scalp topography during maintenance were reliable, mean amplitudes for the time epochs were normalised using the Min-Max Normalisation method (Wilding, 2006). The Min-Max Normalisation method for EEG data processing rescales the data to fit the range 0 to 1.

Results

Behavioural data

The behavioural measures of Accuracy and RTs were tested for normality. The results are presented in Table 3-2. Table 3-3 and Figure 3-3 show the main findings for both groups. Both groups had significantly more correct responses for the intact than the scrambled scenes (TD: $t(12)=3.89$, $p=0.001$; ASD $t(11)=2.69$, $p=0.021$). The TD group also had significantly more correct responses than the group with ASD, for both intact ($t(23)=-2.64$, $p=0.015$) and scrambled ($t(23)=-2.48$, $p=0.021$) scenes. As the RT for scrambled scenes was not normally distributed, a Wilcoxon Signed-Ranks Test was conducted to look at differences in RTs between intact and scrambled scenes for the groups. The TD group had also significantly

shorter reaction times for the intact than the scrambled scenes ($Z=-2.166$, $p=.030$). The group with ASD had similar reaction times for the intact and scrambled scenes ($Z=-.314$, $p=.754$).

Table 3-2.

Test of normality for the behavioural measures of the experimental task

Measure	Condition	Shapiro-Wilk		
		Statistic	df	Sig.
Accuracy	Intact	0.953	26	.265
	Scrambled	0.974	26	.736
RT	Intact	0.952	26	.257
	Scrambled	0.667	26	.000

Table 3-3.

Means and standard deviations of the behavioural measures of the experimental task

Group	Condition	Accuracy [Mean (SD)]	RTs [Mean (SD)]
ASD	Intact	46.42 (8.36)	1361.64 (210.31)
	Scrambled	42.42 (5.76)	1360.24 (247.39)
TD	Intact	53.54 (4.82)	1317.28 (190.55)
	Scrambled	47.46(4.35)	1387.81(254.81)

Figure 3-3. Graphs showing the percentage of accurate responses and reaction times for both Intact and Scrambled Conditions.

EEG data

Effects of interest

Figure 3-4 shows the grand average waveforms for encoding and maintenance period of the TD group and group with ASD.

Encoding Period. The mixed ANOVA revealed a significant Group x Condition interaction for the time intervals: 0-400ms ($F(1,23)=4.97$, $p=0.036$, $\eta^2_p=0.18$), 400-800ms ($F(1,23)=6.29$, $p=0.020$, $\eta^2_p=0.22$), 800-1800ms ($F(1,23)=14.89$, $p=0.001$, $\eta^2_p=0.39$), and

1800-2800ms ($F(1,23)=10.39, p=0.004, \eta^2_p=0.31$). Further analysis was conducted separating the group with ASD and TD group. For the group with ASD, significant Condition x LAT interactions were found for 0-400ms ($F(2,22)=7.72, p=0.003, \eta^2_p=0.41$), 400-800ms ($F(2,22)=5.33, p=0.013, \eta^2_p=0.33$), 800-1800ms ($F(2,22)=8.42, p=0.002, \eta^2_p=0.43$), and 1800-2800ms ($F(2,22)=8.58, p=0.002, \eta^2_p=0.44$). The group with ASD showed a significant Condition effect for left ROIs for 0-400ms ($F(1,11)=6.85, p=0.024, \eta^2_p=0.38$), 800-1800ms ($F(1,11)=17.03, p=0.002, \eta^2_p=0.61$), and 1800-2800ms ($F(1,11)=11.17, p=0.007, \eta^2_p=0.50$). The Condition effect for left ROIs for 400-800ms approached significance ($F(1,11)=3.50, p=0.088, \eta^2_p=0.24$). For the TD group, a significant Condition x AP was found for 800-1800ms ($F(3,36)=3.83, p=0.047, \eta^2_p=0.24$) and 1800-2800ms ($F(3,36)=5.84, p=0.002, \eta^2_p=0.33$). The TD group showed a significant Condition effect for 800-1800ms for frontal ($F(1,12)=14.00, p=0.003, \eta^2_p=0.54$), fronto-central ($F(1,12)=13.54, p=0.003, \eta^2_p=0.53$), centro-parietal ($F(1,12)=10.64, p=0.007, \eta^2_p=0.47$), and parieto-occipital ($F(1,12)=5.89, p=0.032, \eta^2_p=0.33$) ROIs.

Maintenance Period. The mixed ANOVA revealed a significant Group x Condition interaction for both time intervals: 3200-4000ms ($F(1,23)=17.15, p=0.000, \eta^2_p=0.43$) and 4000-4800ms ($F(1,23)=14.10, p=0.001, \eta^2_p=0.38$). Further analysis was conducted separating the ASD and TD groups. For the group with ASD, significant Condition x LAT interactions were found for 3200-4000ms ($F(2,22)=4.67, p=0.020, \eta^2_p=0.30$) and 4000-4800ms ($F(2,22)=3.90, p=0.036, \eta^2_p=0.26$). For 3200-4000ms, a significant Condition effect was found for left ($F(1,12)=17.75, p=0.001, \eta^2_p=0.60$) and midline ($F(1,12)=8.26, p=0.014, \eta^2_p=0.41$) ROIs. For 4000-4800ms, a significant Condition effect was found for left ($F(1,11)=14.78, p=0.003, \eta^2_p=0.57$) and midline ($F(1,11)=6.59, p=0.026, \eta^2_p=0.38$) ROIs. For the TD group, significant Condition x AP interactions were found for 3200-4000ms

($F(3,36)=4.05$, $p=0.014$, $\eta^2_p=0.25$) and 4000-4800ms, ($F(3,36)=4.76$, $p=0.023$, $\eta^2_p=0.28$).

For 3200-4000ms, a significant Condition effect was found for frontal ($F(1,12)=20.32$, $p=0.001$, $\eta^2_p=0.63$), fronto-central ($F(1,12)=17.75$, $p=0.001$, $\eta^2_p=0.60$), centro-parietal ($F(1,12)=8.26$, $p=0.014$, $\eta^2_p=0.41$) ROIs. For 4000-4800ms, a significant Condition effect was found for frontal ($F(1,12)=17.66$, $p=0.001$, $\eta^2_p=0.60$), fronto-central ($F(1,12)=10.89$, $p=0.006$, $\eta^2_p=0.48$) ROIs.

ASD**Left ROIs***Frontal* *Fronto-central* *Centro-parietal* *Parieto-occipital*

Figure 3-4a. Grand average waveforms during encoding and maintenance period for intact and scrambled conditions for ASD group. During the encoding, early and late maintenance, the slow-wave potential was more positive over the left ROIs for the scrambled condition. One representative electrode (circled in red) from each electrode cluster is presented.

Figure 3-4b. Grand average waveforms during maintenance period for intact and scrambled conditions for TD group. During late encoding, early and late maintenance, the slow-wave potential was more positive over the frontal, fronto-parietal, and centro-parietal ROIs for the intact condition. One representative electrode (circled in red) from each electrode cluster is presented.

Topographic analyses.

Figure 3-5 shows the scalpmaps at the encoding and maintenance phases of the TD group and group with ASD.

Encoding Period. For the group with ASD, a significant interaction was found between LAT x Condition for 0-400ms ($F(2,22)=7.34, p=0.004, \eta^2_p=0.40$), 400-800ms ($F(2,22)=5.16, p=0.015, \eta^2_p=0.32$), 800-1800ms ($F(2,22)=8.42, p=0.002, \eta^2_p=0.43$), and 1800-2800ms ($F(2,22)=8.58, p=0.002, \eta^2_p=0.44$). Distinct scalp distributions were found for the left ROIs during 0-400ms ($F(1,11)=6.08, p=0.031, \eta^2_p=0.36$), 400-800ms ($F(1,11)=32.87, p=0.000, \eta^2_p=0.75$), 800-1800ms ($F(1,11)=17.03, p=0.002, \eta^2_p=0.61$). Post-hoc comparisons between the group with ASD and TD group showed significant Group x Condition effect for 400-800ms ($F(1,23)=42.64, p=0.000, \eta^2_p=0.65$), and 800-1800ms ($F(1,23)=33.12, p=0.000, \eta^2_p=0.59$) for the left ROIs. For the TD group, a significant Condition x AP interaction was found for 800-1800ms ($F(3,36)=3.83, p=0.047, \eta^2_p=0.24$), and 1800-2800ms ($F(3,36)=4.27, p=0.011, \eta^2_p=0.26$). Distinct scalp distributions were found during 800-1800ms for the frontal ROIs ($F(1,12)=14.00, p=0.003, \eta^2_p=0.54$), fronto-central ($F(1,12)=13.54, p=0.003, \eta^2_p=0.53$), centro-parietal ($F(1,12)=10.64, p=0.007, \eta^2_p=0.47$), and parieto-occipital ($F(1,12)=5.89, p=0.032, \eta^2_p=0.32$) ROIs. For 1800-2800ms, a significant Condition effect was found for frontal ($F(1,12)=5.39, p=0.039, \eta^2_p=0.31$) ROIs. Post-hoc comparisons between the TD group and group with ASD showed significant Group x Condition effect for 800-1800ms for frontal ($F(1,23)=12.79, p=0.002, \eta^2_p=0.36$), fronto-central ($F(1,23)=8.82, p=0.007, \eta^2_p=0.277$), centro-parietal ($F(1,23)=12.43, p=0.002, \eta^2_p=0.35$), and parieto-occipital ($F(1,23)=9.81, p=0.005, \eta^2_p=0.30$) ROIs.

Maintenance Period. To test whether the differences in scalp topography during delay were reliable, mean amplitudes for the two time epochs were normalised using the Min-Max

method. For the ASD group, a significant interaction was found between Condition x LAT for 3200-4000ms ($F(2,22)=3.79, p=0.039, \eta^2_p=0.26$) and approached significance for 4000-4800ms ($F(2,22)=3.30, p=.056, \eta^2_p=0.23$), similar to the non-rescaled data. Distinct scalp distributions were found for the left ($F(1,11)=9.25, p=0.011, \eta^2_p=0.46$) ROIs during 3200-4000ms, and for the left ($F(1,11)=13.23, p=0.004, \eta^2_p=0.55$) and midline ($F(1,11)=7.32, p=0.020, \eta^2_p=0.40$) ROIs during 4000-4800ms. Post-hoc comparisons between the group with ASD and TD group also showed significant Group x Condition effect for 3200-4000ms for left ($F(1,23)=23.66, p=0.000, \eta^2_p=0.51$) ROIs only. For the TD group, a significant interaction was found between Condition x AP for 3200-4000ms ($F(3,36)=3.98, p=0.015, \eta^2_p=0.25$), similar to the non-rescaled data. Distinct scalp distributions were found during 3200-4000ms for the frontal ($F(1,12)=18.87, p=0.001, \eta^2_p=0.61$), fronto-central ($F(1,12)=18.02, p=0.001, \eta^2_p=0.60$), and centro-parietal ($F(1,12)=7.67, p=0.017, \eta^2_p=0.39$) ROIs, but not for 4000-4800ms. Post-hoc comparisons between the TD group and group with ASD also showed significant Group x Condition effect for 3200-4000ms for frontal ($F(1,23)=16.77, p=0.000, \eta^2_p=0.42$), fronto-central ($F(1,23)=14.25, p=0.001, \eta^2_p=0.383$), and centro-parietal ($F(1,23)=8.47, p=0.008, \eta^2_p=0.27$).

Figure 3-5. CSD Scalp maps at encoding (0-2800ms) and maintenance (3200-4800ms) phases. The scalp plots show differences in group mean topographies between intact and scrambled scenes (Intact>Scrambled) for TD and ASD groups.

Discussion

Overall, the TD adolescents performed significantly better for both the intact and scrambled scenes, as compared to the adolescents with ASD. As expected, the TD adolescents had significantly more correct responses on the intact as compared to the scrambled scenes. They were able to identify more accurately if the object shown during the probe was in the same or different position from the stimulus. The adolescents with ASD, contrary to expectations, showed significantly more correct responses on the intact as compared to the scrambled scenes, albeit to a lesser degree. The TD adolescents also responded faster on the intact as compared to the scrambled scenes. The adolescents with ASD did not show any significant difference on the reaction times. The adolescents with ASD, in general, had lower accuracy scores for both intact and scrambled scenes than the TD

adolescents. Thus, TD adolescents performed better than the adolescents with ASD, despite being matched in nonverbal ability and age, as measured using standardised measures.

Although the TD group and group with ASD showed similar pattern of responses (intact better than scrambled), the underlying neurological processes need to be examined. Research has shown that individuals with high functioning ASD may show similar behavioural results while employing different neurological processes (Pijnacker et al., 2010). In this experiment, the task may not have been complex or difficult enough to detect differences in the behavioural measures, as the group with ASD achieved at least 65% accuracy. The task difficulty was intentionally not set high so as to obtain sufficient trials for EEG processing. Hence the underlying neural correlates need to be examined to better understand how context effects affect the adolescents with ASD and TD adolescents in their processing and maintenance of scenes.

Although the behavioural measures for TD group and group with ASD showed similar patterns where there was better accuracy for intact than for scrambled scenes, the underlying neural correlates during encoding and maintenance phases were different. As expected, for the TD group, slow wave shifts during the encoding and maintenance phases had a different topography for intact and scrambled scenes. The frontal-central-parietal ERPs when processing the intact scenes had larger positive amplitudes than the scrambled scenes during the encoding and maintenance phases. The group with ASD also showed a different topography when processing the intact and scrambled scenes during the encoding and maintenance phases. The left and midline ERPs when processing and maintaining the scrambled scenes had larger positive amplitudes than the intact scenes.

The findings suggest that both groups used local processing on both the intact and scrambled scenes. The group with ASD did not recruit the frontal-central-parietal ROIs when

processing intact images. On the other hand, the TD group appeared to recruit higher order cognitive processes to help in the processing of the intact images. The greater activation in the frontal-central-parietal regions could indicate higher order attentional or cognitive processes involved in processing of intact images. Compared to the group with ASD, there was also greater activation in the right ROIs, where gestalt processing occurs. This finding is consistent with previous studies showing right hemisphere involvement during gestalt processing by TD individuals. The recruitment of higher order cognitive processes could explain the better accuracy and faster response shown by the TD group.

The differences in the pattern of activation for the intact as compared to the scrambled scenes for the TD adolescents appear to be better explained by the priming model. The perceptual schema and priming models both postulate that scene context is involved in the perceptual stage. The increased activation in the PFC starts during the encoding stage and is sustained through the maintenance phase for the intact condition when compared with the scrambled condition. This would suggest more support for the priming model as the perceptual schema model should also see difference in the parietal, temporal and occipital areas if there was an ongoing interaction between perception and the activated schema. However, only difference in activation of the PFC is found. Hence it suggests that only after object details are perceived, then the object(s) are compared with scene schemas generated and then matched in the PFC. This final representation is maintained in the PFC even after the visual image has been removed. The findings are also not explained by functional isolation model as existing literature has shown that there is an interplay between gist and local details of the scene. In addition, the scene knowledge and object perception are assumed to be separate. If that is the case, then any difference seen in activations for intact and scrambled images should not be sustained in the maintenance phase.

On the other hand, the differences in the pattern of activation for intact compared to the scrambled scenes for the adolescents with ASD are not adequately explained by the perceptual scheme or priming models, as no scalp differences were seen in the prefrontal and frontal scalp areas. Rather, the differences in activation were found mainly in the left scalp regions. There was an increase in the activation of the left scalp regions when the scrambled scenes were compared with the intact scenes. Left hemispheric regions have been shown to be involved in local or detailed processing. The group with ASD appeared to use local processing for both scrambled and intact scenes. Higher activation in the left hemisphere were found for scrambled scenes, as would be expected. Such differences were also found early in the encoding stage. Hence the functional isolation model also does not adequately explain how the group with ASD processes the intact scenes. The neural correlates underlying both the intact and scrambled scenes were found in the left scalp regions. It is likely that the group with ASD used local-to-local relation processing for both the scrambled and intact conditions. Therefore, despite similar behavioural results showing higher accuracy for intact scenes, this did not result from a gestalt or global processing of the intact scene. The difference in perceptual processing also likely did not result from a difference in attention for the group with ASD as the differences in activation between intact and scrambled scenes was restricted to the left scalp regions, and not PFC.

The results provide evidence that the VisWM network in ASD and TD differs depending on the coherence of the scene. For the TD individuals, additional higher order and gestalt processing may occur when coherent images are processed and maintained by the TD individuals. These processes occurred even during the early maintenance phase for the TD individuals. On the other hand, individuals with ASD may not process intact images in a gestalt manner but rather involve the left hemispheric regions for both intact and scrambled images. The left hemisphere regions have been shown to be involved in local processing. The

better performance accuracy shown by the TD individuals suggests that the additional cognitive processes involved in the working memory process enabled the TD individuals to better optimise their VisWM and to facilitate recall. An alternative explanation may be the group with ASD's visual exploration and ability to attend to all parts of the scene may have also limited their overall performance.

The current findings provide support for the interactive nature of visual perception and VisWM. Differences in the encoding phase due to differences in visual processing was sustained in the maintenance phase of the VisWM and resulted in a difference in overall performance level of the TD group and group with ASD. The differences in visual processing are due to differences in the interplay of local and global/gestalt processing that affect earlier and lower level visual processing (such as perceptual closure and object recognition), as well as more complex and higher level visual processing (such as scene processing), as shown in Study 1 and Study 2. The TD individuals used gestalt processing when presented with scenes. Hence, the context present in the scene images are processed and maintained as integrated images in VisWM. On the other hand, individuals with ASD used local processing when presented with scenes. Hence, the scenes were not processed and maintained as integrated images in VisWM. These in turn would impact on how these representations are retained in the maintenance phase of the VisWM, thus affecting how these images or representations are recalled or recognised. This is represented schematically in Figure 3-6.

Figure 3-6. Theoretical model linking visual perception to VisWM

Limitations and Future Research

Similar to Study 1, the limitations of study 2 include the limited age range as well as the inclusion of only males. Future studies would need to include more participants with ASD across the different ages to understand if there are any differences in developmental trajectory between ASD and TD. Differences, if any, in developmental trajectory can further insight into the relationship between aspects of cognitive functioning and brain structure underlying VisWM in ASD. A comparison of males and females individuals with ASD would also inform us if there is a gender difference.

Another limitation to the research study was that an eye tracker was not available to track the visual exploration of the intact and scrambled scenes by the TD group and group with ASD. Knowing how the groups differ in their visual exploration by examining different

aspects of eye-movement behaviour (including spread of fixations, scan-path length progression, fixation rate, visual persistence, and reversion to areas previously viewed) (Heaton & Freeth, 2016) would provide additional information on how differences in intact and scrambled scenes are processed. Heaton and Freeth (2016) found in their study that individuals with ASD had reduced visual exploration when viewing photographic scenes. Analyses of visual exploration paths suggested a greater tendency to explore areas close to the current fixation (i.e. visual persistence) in the group with ASD. The differences were not accounted for by fixation rate. They suggested that the observed viewing patterns may explain relative superior local processing in individuals with ASD.

Although it is a limitation in the current study, the intra-individual comparison design would minimise the effects of visual exploration on the interplay between the local and global processing of the group with ASD with regards to how they process more complex visual information like scenes.

Future research could employ simultaneous EEG-functional MRI to examine the functional and dynamic connectivity of the brain areas involved in the interplay of global and local processing of scenes during visual working memory process. A comparison of how coherence impacts on scene processing and memory of object-position, object and position could also help to identify the processes involved in encoding, maintenance and even retrieval.

Motivations and Linkages to Study 3

The current findings show similar atypicality in the interplay of global and local processing in both perceptual closure and scene processing. Individuals with ASD are less likely to use the global features in the image to help in their recall. Therefore teaching coherence as a metacognitive strategy for individuals with ASD may help to improve their VisWM. Study 3

investigated how perceptual closure and VisWM could be improved using a perceptual training program that involves priming a categorical representation of the object to develop the use of global processing on perceptual closure process.

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CHAPTER IV: STUDY 3

**Effects of perceptual closure training on perceptual closure and object-to-scene
binding in visual working memory of individuals with ASD**

Introduction

Consistent with research on atypical visual perceptual processing in the individuals with ASD, Study 1 and Study 2 have shown that the interplay of global and local processing when processing images is different. Individuals with ASD are less likely to use the global features in the image to help in their recall. This study investigated if perceptual closure processes could be trained and its impact on the use of coherence in scenes to improve the VisWM of individuals with ASD.

As mentioned, two theories have been proposed to explain superior local processing in ASD: the Weak Central Coherence (WCC) theory (Frith, 1989) and the Enhanced Perceptual Functioning (EPF) theory (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). The WCC theory (Frith, 1989) proposes that ASD presents with a fundamental difficulty with integrating individual pieces of information, both perceptually and conceptually. As a result, they rely on piecemeal, local processing. According to this theory, individuals with ASD have a fundamental deficit in their ability to use context and process globally. There are, however, limitations to this model. The model is unable to explain the absence of deficits in certain tasks that requires global processing. For example, individuals with ASD show an intact ability to construct global representations and in object recognition (Mottron et al., 2006).

On the other hand, the EPF theory (Mottron et al., 2006) proposes that superior local processing is a result of overdeveloped low-level perception and atypical relationships between low and high level processing. They argued that the default mode of individuals with ASD is more locally oriented, but that there is no deficit in global processing. Thus higher-order global processing is optional in ASD but mandatory in TD. They further proposed that the enhanced functioning of primary perceptual brain regions is atypically activated during both social and nonsocial tasks. It has been proposed that the local precedence in individuals with ASD arises from increased autonomy of lower order from higher order processes. This is

unlike the TD individuals where higher order processing is mandatory (Liu, Cherkassky, Minshew, & Just, 2011). The findings of Study 1 and 2 provide more support for the WCC model, as only local processing was used in both the processing of fragmented images as well as the intact scenes. Hence, the local processing in individuals with ASD may not just be an enhancement of local processing with no deficit in global processing. Research on training paradigms has shown that visual perceptual processing can be modified. A study conducted on TD individuals to modify visual processing showed that when extensive training was given to teach TD individuals to process the local elements in a Navon-type stimulus, the precedence of global processing was decreased (Dulaney & Marks, 2007). Another study examined how TD individuals could be trained to recognise novel figures in the form of ‘Greebles’ and compared performance between experts and novices (Gauthier, Williams, Tarr, & Tanaka, 1998). Greebles refer to an invented category of novel objects which are used as stimuli in object and face recognition studies. The use of Greebles allow standardised exposure and training, with expertise being achieved after 9 hours of training. The study found ‘experts’ to use a more configural processing to aid in their accuracy and speed of recognition of the Greebles. The researchers also proposed that the neural networks used by novice and experts could be different.

Changes in ERP signal have been associated with expert training in Greebles. A negative ERP called the N170 has consistently been found to be delayed and enhanced for inverted faces but not for inverted objects (Eimer, 1998; Rossion, Rossion et al., 2002). Individuals who received training in recognising Greebles at the expert level showed a similar delay and enhancement for inverted Greebles in the left hemispheres, while none was found in non-experts (Rossion et al., 2002). This finding also showed that the mechanisms underlying the N170 effect for face-inversion extended to visually homogenous nonface object categories, only when recognition for such object categories were intensively trained.

In Gauthier and Tarr's work on expertise training of nonface objects, including Greebles and objects (Gauthier et al., 1998), they delineated three types of holistic processing: 1) holistic-configural; 2) holistic-inclusive; and 3) holistic-contextual. Holistic-configural refers to the effects that result from individual object parts placed in the context of the other individual parts from the same object. Holistic-inclusive effects occur when better recognition of individual object parts take place in the context of other individual parts from the same object. Holistic-contextual effects occur when individual object parts are better recognised in context of other parts than in isolation. According to these researchers, face recognition and processing are achieved because of such holistic processing. However, such holistic processing is not specific to faces. If the same level of expertise attached to face processing can be achieved for nonface stimuli, such holistic processing where an object is better recognised in context of its other parts would also be activated (Gauthier et al., 1998).

Individuation training is a critical element that is necessary for developing expertise in holistic processing (Gauthier et al., 1998; Rossion et al., 2002). Here, individuals are trained to recognise and label individual objects, and not just broad categories. Training on classifying stimuli at multiple semantic levels facilitates the acquisition of knowledge about the stimulus being learned. Such individuation training is said to reduce basic level processing and increase configural or holistic processing. A study which specifically explored the mechanism underlying individuation training showed that different kinds of perceptual expertise could be trained using different paradigms (Rossion et al., 2002). While individuation training develops configural processing and speeds up the naming of individual objects, categorisation training develops basic level processing. Hence expertise training can develop holistic face-like processing of objects in typical individuals.

In individuals with ASD, where holistic processing is shown to be weaker, expertise training might be needed to develop better object recognition processing by improving their

ability to process holistically. Thus far, there has been limited training in visual processes underlying object recognition in individuals with ASD. Research on training has largely investigated developing the ability of individuals with ASD to recognise faces and emotional expressions. One recent research examined how individuals with ASD could be trained to process faces in a more configural or holistic manner (Faja, Aylward, Bernier, & Dawson, 2008a). They adapted the training protocol by Gauthier et al. (1998) by adding tasks to facilitate the visual attention of the individuals with ASD. The individuals with ASD were then trained with explicit rule-based guidelines for viewing faces as this approach was found to be more effective in changing the learning behaviour of the individuals with ASD in their previous study (Faja et al., 2008). The experimental group was trained using faces while the control group was trained using houses. Individuals with ASD were trained for 5-8 sessions (each lasting 30 mins to an hour) to become experts within their trained stimuli domain. Hence both social stimuli (i.e. face-like) and non-social objects (i.e. houses) were better recognised after training. The experimental group also showed an increased face inversion effect in behavioural and electrophysiological measures.

Face recognition and processing is something that typical individuals do almost automatically and very well by employing holistic processing to recognise at a subordinate level. However, this is not something that individuals with ASD have expertise in. Although typical individuals need to undergo expertise training in recognising Greebles or nonface stimuli, the converse may not be true for individuals with ASD who are not face experts. Instead, it could be that individuals with ASD need to be trained to perform holistic processing for objects. This may then help them to generalise such holistic processing to faces. If the holistic processing operating when faces are processed in typical individuals can be also applied to objects after expertise training, then it may be possible that the holistic

processing that is trained in individuals with ASD can be further trained to be applied to face recognition and processing.

To date, there has been no published literature examining how perceptual closure processing can be developed or enhanced in individuals with ASD. This study investigated the effects of perceptual closure training on perceptual closure and VisWM task performances in adolescents with ASD. The training protocol developed by Gauthier et al. (1998) and modified by Faja et. al (2008) was employed for the intervention in this study.

The following specific hypotheses were evaluated:

Before training:

It was hypothesised that the individuals with ASD in both training and control groups would recognise the object at a similar level of closure.

It was also hypothesised that the individuals with ASD in both training and control groups would have similar accuracy and reaction times for both intact and scrambled scenes.

After training:

It was hypothesised that the ASD training group would recognise the object at a less complete representation, compared to pre-training. ASD control group would not show a difference.

It was hypothesised that the ASD training group would have higher accuracy for intact scenes and faster reaction times for intact scenes than scrambled scenes, when compared to their pre-test performance. The ASD control group would not show any difference in their accuracy and reaction times for both pre-training and post-training performance on the intact compared to scrambled images.

Method

Participants and Screening Procedure

Twenty-one male adolescents with ASD from 13 to 16 years old were recruited to participate in the study. Nineteen of the participants with ASD were the same participants recruited for Study 1 and 2. Two more individuals with ASD were recruited for the training study. The same exclusionary criteria, which included a reported history of known neurological (e.g. epilepsy) or major psychiatric disorders, was applied. Individuals undergoing drug treatment were also be excluded. All recruited participants had normal or corrected-to-normal vision. Participants consisted of adolescents currently studying in Singapore mainstream or special schools, and had been clinically diagnosed with ASD, Autistic Disorder, or Asperger Syndrome based on their medical and school records. Three were excluded as their nonverbal reasoning was below 80. Another was excluded as he was on medication. The final sample consisted of one training group of 9 individuals with ASD and one control group of 8 individuals with ASD. Based on the analysis of selected studies evaluating intervention on visual processing in individuals with ASD (please see Appendix A for details), a sample size of at least 10 per group would be sufficient to obtain at least a medium effect size. This study was most similar to Faja and associates' (2008) study where individuals with ASD were trained to process faces using a local-holistic approach. Faja and associates' (2008) study had a sample size of 5 and an average effect size of $d=0.55$. Our sample consisted eventually of 9 participants for training group and 8 for the control group. The statistical power was deemed sufficient as this study had significantly more trials.

Standardised Assessments and Baseline Behavioural Measures

Both the training and control groups were administered a series of standardised measures to obtain a baseline of their visual perceptual and memory abilities, as well as their

current functioning in social communication and social functioning skills. The group with ASD and TD group were matched in age and nonverbal reasoning. They were also matched in their communication and social functioning. Their performance on the standardised tests measuring visual perceptual skills and visual spatial working memory task was also comparable. Table 4-1 shows the means and SDs for the pre-training behaviour measures for the two groups.

Table 4-1

Demographics and Standard Measures for Training and Control groups

Demographics and Standard Measures	Training (<i>n</i> =10)	Control (<i>n</i> =8)	Significance
Age (in months)	168.33±12.81	172.25±14.96	<i>t</i> (15)=-.58 <i>p</i> =0.569
Nonverbal Reasoning	110.56±16.25	109.75±15.85	<i>t</i> (15)=0.103 <i>p</i> =0.919
Affect Recognition (NEPSY-II)	5.89±3.18	6.43±3.21	<i>t</i> (14)=-.336 <i>p</i> =0.742
Autism Spectrum Quotient	32.13±3.56	30.57±11.28	<i>t</i> (13)=.349 <i>p</i> =0.737
Social Communication Questionnaire	11.22±3.03	13.88±6.96	<i>t</i> (15)=-1.041 <i>p</i> =0.314
Figure Ground (Test of Visual Perceptual Skills-3)	11.89±4.83	13.88±4.91	<i>t</i> (15)=-.84 <i>p</i> =0.414
Visual Closure (Test of Visual Perceptual Skills-3)	11.22±4.09	12.38±5.01	<i>t</i> (15)=-.52 <i>p</i> =0.609
Memory for Designs (NEPSY-II)	8.67±3.67	8.50±4.93	<i>t</i> (13)=-.08 <i>p</i> =0.941
Pre_Corr%	77.46±9.54	86.38±3.16	<i>t</i> (15)=-2.52 <i>p</i> =0.024*

Pre_MdID	2.89±1.05	3.25±1.28	$t(15)=-.64$ $p=0.533$
Pre_MeanID	3.20±0.75	3.24±0.76	$t(15)=-.13$ $p=0.898$
Pre_Intact_Acc%	66.84±11.15	73.24±12.62	$t(15)=-1.11$ $p=0.284$
Pre_Scrambled_Acc%	65.10±10.63	68.36±6.35	$t(15)=-.75$ $p=0.463$
Pre_Intact_RT	1394.41±234.83	1416.57±221.87	$t(15)=-.20$ $p=0.845$
Pre_Scrambled_RT	1443.53±257.10	1375.76±228.79	$t(15)=.57$ $p=0.577$

Note. * $p < .05$

Standard measures are presented using scaled scores.

Affect Recognition, Visual Closure and Figure Ground: Range 1-19

Autism Spectrum Quotient: Range 0-50

Social Communication Questionnaire: Scores above the cutoff of 15 suggest the individual is likely to have ASD

Procedure

The training paradigm was modified from Faja et al.'s (2008) face expert computerised training. Training stimuli consisted of line drawings with varying degrees of completeness. These images were fragmented in the same manner as the stimuli used in Study 1. All 8 participants in the training group were provided with 125 training trials presented across 5 sessions lasting 30-45 mins. Training sessions were conducted individually with one trainer to one participant. It was scheduled at the convenience of the participant with a maximum of two sessions on any given day. All 5 sessions had to be completed within one-and-a-half weeks. In a previous study on TDs, expertise on identifying

Greebles was achieved in 7-10 hours using a set of 10-30 novel stimuli (Gauthier, Williams, Tarr, & Tanaka, 1998). Faja et al.'s (2008) study on individuals with ASD found that expertise in face recognition was achieved over a period of 4-8 hours using a computerised face-specific training that was based on a modified version of Gauthier and Tarr's expertise protocol. Based on these previous research, this study used a training program with a total duration lasting about 3 to 4 hrs. Although duration was shorter in this study, the number of trials presented was significantly greater. Hence, the duration was deemed to be sufficient. The tasks were also presented using both paper-and-pencil format and via a computer. Participants could take a short break between blocks of practice when needed. The ASD control group were provided with 5 sessions of verbal tasks which were not related to perceptual closure, for a similar duration.

Each training session included several minutes of *explicit rule-based instruction* where participants were instructed on how to move their eye while viewing the fragmented images, in order to attend to the entire image. They were also taught to imagine drawing lines or filling-in of lines to attempt to complete the picture. This was then followed by a sequence of learning comprising *inspection*, *matching-category* and *matching-image*. Each stimulus was first presented for *inspection* in conjunction with the appropriate categorical label, at the level of fragmentation that was one level less fragmented (i.e. level 2) than the mean level of fragmentation (i.e. level 3) found in Study 1. This was to ensure that the participants started at a level that was less difficult than what most of the participants were initially able to do. The pairing of categorical and subcategorical classifications for each image was aimed at facilitating the 'filling-in' of the fragmented image. *Matching-category* blocks would follow, during which the participant first viewed the fragmented image and then indicated which category it belonged to. *Matching-image blocks* then followed, during which participant first

viewed the fragmented image and then indicated, from a choice of 3, which image it corresponded to.

The pre-training session was either the first EEG session on perceptual closure and VisWM tasks (for the participants involved in Study 1 and 2), or a behavioural session without EEG session on the same tasks. The post-training behavioural session was administered within 2 months from the last day of training. Stimuli used for pre-training, post-training and familiarisation were not used for training.

Data Analysis

Perceptual Closure.

Focused analyses to test for training effects were conducted separately on the training and control groups using repeated measures analysis of variance (ANOVA). The dependent variables were the percentage of accurate responses and mean ID level of recognition.

VisWM.

Focused analyses to test for training effects were conducted separately on the training and control groups using repeated measures ANOVA. As the pre-training measures for accuracy and reaction times were not significantly different for both groups, change scores for accuracy and reaction times for intact and scrambled conditions for each participant (i.e. Intact minus Scrambled) were used for the analysis. Hence, the dependent variables were the change scores for the percentage of accurate responses and reaction time.

Results

Perceptual Closure

The behavioural measures of Accuracy and RTs were tested for normality. The results are presented in Table 4-2. The training group participants correctly identified 77.46%

(77.46 $\pm$ 9.54/min-max range 60-88) of the pictures before training. Recognition was obtained with a modal ID level of 2.89 (min-max range 1-4) and a mean ID level of 3.20 (3.20 $\pm$ 0.75/min-max range 2.19-4.22). After perceptual closure training, they correctly identified 76.67% (76.67 $\pm$ 11.58/min-max range 58-91) of the pictures. Recognition was obtained with a modal ID level of 4.11 (min-max range 3-6) and a mean ID level of 4.00 (4.00 $\pm$ 0.85/min-max range 2.92-5.31). The control group participants correctly identified 86.38% (86.38 $\pm$ 3.16/min-max range 82.00-92.00) of the pictures before training. Recognition was obtained with a modal ID level of 3.25 (min-max range 1-5) and a mean ID level of 3.24 (3.24 $\pm$ 0.67/min-max range 2.42-4.42). After training, they correctly identified 87.00% (87.00 $\pm$ 6.78/min-max range 77-95) of the pictures. Recognition was obtained with a modal ID level of 4.13 (min-max range 2-5) with a mean ID level of 3.85 (3.85 $\pm$ 0.81/min-max range 2.60-4.79). The behavioural measures of both groups are presented in Table 4-3. Both the Modal and Mean ID levels had similar distribution curves, as presented in Figure 4-1.

Table 4-2.

Test of normality for the behavioural measures

Measure		Shapiro-Wilk		
		Statistic	df	Sig.
Correct_diff		0.926	17	.184
MeanID_diff		0.918	17	.135
Accuracy	Intact-Scrambled pre	0.951	17	.480
	Intact-Scrambled post	0.859	17	.015
RT	Intact-Scrambled pre	0.958	17	.591
	Intact-Scrambled post	0.947	17	.414

Table 4.3

Behavioural Measures of Training and Control Groups

Measures	Pre	Post	Significance
Perceptual Closure			
Correct (%)			
Training	77.46±9.54	76.67±11.58	$F(1,8)=0.04; p=0.852, \eta^2_p=0.01$
Control	86.38±3.16	87.00±6.78	$F(1,7)=0.10; p=0.765, \eta^2_p=0.01$
Mean ID Level			
Training	3.20±0.75	4.00±0.85	$F(1,8)=21.37; p=0.002, \eta^2_p=0.73^*$
Control	3.24±0.67	3.85±0.81	$F(1,7)=16.71; p=0.005, \eta^2_p=0.71^*$
VisWM			
Accuracy			
Training			
Intact	66.84±11.15	71.53±11.18	$Z=-1.423, p=.155, r=-.450$
Scrambled	65.10±10.62	64.24±12.92	
Control			
Intact	73.24±12.62	76.76±12.90	$Z=-.339, p=.735, r=-.085$
Scrambled	68.36±6.34	71.29±13.10	
Reaction Time			
Training			
Intact	1394.41±234.83	1391.58±217.16	$F(1,8)=0.80; p=0.396, \eta^2_p=0.091$
Scrambled	1443.53±257.10	1386.25±234.58	
Control			
Intact	1416.57±221.87	1381.32±268.65	$F(1,7)=2.39; p=0.166, \eta^2_p=0.254$
Scrambled	1375.76±228.79	1406.69±250.69	

* $p < .05$

Training

Control

Figure 4-1. Comparison of the distribution curves for the modal ID and mean ID levels for Training and Control groups.

Prior to training, the control group showed significantly higher accuracy than the training group ($t(15)=-2.52, p=0.024$). There was no group difference in mean ID level ($t(15)=-.13, p=0.898$). As the post training measure for accuracy was not normally distributed, a Wilcoxon Signed-Ranks Test was conducted to look at differences in

accuracy between intact and scrambled pre and post training. After training, accuracy between intact and scrambled condition was not statistically difference for both Training Group ($Z=-1.423$, $p=.155$, $r=-.450$) and Control Group ($Z=-.339$, $p=.735$, $r=-.085$). However, the mean ID level was significantly different pre- and post-training for both training ($F(1,8)=21.37$; $p=0.002$, $\eta^2_p=0.73$) and control groups ($F(1,7)=16.71$; $p=0.005$, $\eta^2_p=0.705$). The pre- and post-training measure for both training and control groups are presented in Figure 4-2.

Perceptual Closure Task

Figure 4-2. Graphs showing the pre- and post-training measures for both Training and Control Groups.

VisWM

The training group participants' accuracy on the VisWM task was 66.84% (66.84 ± 11.15 /min-max range 48.44-79.69) for Intact and 65.10% (65.10 ± 10.63 /min-max range 48.44-79.69) for Scrambled before training. Reaction time was 1394.41 (1394.41 ± 234.83 /min-max range 1088.76-1674.52) for Intact and 1443.53 (1443.53 ± 257.10 /min-max range 1108.55-1865.71) for Scrambled before perceptual

closure training. After perceptual closure training, they correctly identified 71.53% (71.53 $\pm$ 11.18/min-max range 48.44-84.38) for Intact and 64.24%(64.24 $\pm$ 12.92/min-max range 42.19-78.13) for Scrambled. Reaction time was 1391.58(1391.58 $\pm$ 217.16/min-max range 1190.71-1875.57) for Intact and 1386.25(1386.25 $\pm$ 234.58/min-max range 1035.58-1667.96) for Scrambled. For the control group, they correctly identified 73.24% (73.24 $\pm$ 12.62/min-max range 62.50-95.31) for Intact and 68.36%(68.36 $\pm$ 6.35/min-max range 60.94-81.25) for Scrambled. Reaction time was 1416.57(1416.57 $\pm$ 221.87/min-max range 1027.80-1655.41) for Intact and 1375.76(1375.76 $\pm$ 228.79/min-max range 1017.02-1645.59) for Scrambled. After training, they correctly identified 76.76% (76.76 $\pm$ 12.90/min-max range 62.50-96.88) for Intact and 71.29(71.29 $\pm$ 13.10/min-max range 57.81-92.19) for Scrambled. Reaction time was 1381.32(1381.32 $\pm$ 268.65/min-max range 1412.70-1749.48) for Intact and 1406.69(1406.69 $\pm$ 250.69/min-max range 1010.20-1746.959) for Scrambled. The results are presented in Figure 4-3.

The two groups did not show any difference on the accuracy or reaction times for intact or scrambled images prior to training. After training, repeated measures ANOVA on the change scores for accuracy were not significant for both training ($F(1,8)=2.50$; $p=0.153$, $\eta^2_p=0.238$) and control groups ($F(1,7)=0.04$; $p=0.846$, $\eta^2_p=0.006$). The change scores for reaction times were also not significant for both training ($F(1,8)=0.80$; $p=0.396$, $\eta^2_p=0.091$) and control groups ($F(1,7)=2.39$; $p=0.166$, $\eta^2_p=0.254$). The pre- and post-training measures for both groups are presented in Figure 4.3.

Visual Working Memory Task

Figure 4-3. Graphs showing the pre- and post-training measures for both Training and Control Groups under Intact and Scrambled Conditions.

Discussion

After training, both training and control groups were able to improve in their ability to recognise fragmented images at a lower level of completeness. However, the number of items recognised did not increase for both groups. It is hypothesised that the improvement in behavioural measures for the mean ID level could be due to practice effects with the tasks.

This was especially so as the period between the pre- and post- tasks was short. It was also possible that the participants were more motivated and attended better to the tasks after getting to know the research staff better during training. Such an effect was also found in a face expertise training on individuals with ASD by Faja et. al (2012). Individuals with ASD were provided with either face or house training. After training, both groups showed better performance on immediate and delayed recall of faces. However, only the face training group showed an increased face inversion effect both behaviourally and in the electrophysiological changes to faces in the P1 component. In Study 3, as electrophysiological signals were not measured, thus possible neurological changes were not evaluated.

The ability to generalise perceptual abilities to scenes which were required for gestalt processing were evaluated. After training, the change scores of both the accuracy and reaction times for both training and control groups were not significant. However, the effect size for accuracy change was large ($r=-0.450$) for the training group as compared to the control group ($r=-0.085$). Based on the observed effect size ($\eta^2_p=0.238$), it is estimated that a sample size of 13 per group would be needed to obtain significance at $p=.05$.

Previous research on individuals with ASD focused largely on training recognition of faces or objects. In the recent study by Faja et al. (2012), individuals with ASD increased in their immediate memory for faces after training. Electrophysiological measures suggested that these improvements are due to an increase in configural processing. However, there appears to be a lack of research in the ASD literature investigating the processes that precede the eventual identification of the object. In this study, an attempt was also made to reduce this reliance on local processing by training metacognitive strategies to improve the gestalt processing of the adolescents with ASD. By also targeting the recognition processes operating before actual recognition where identification happens, individuals with ASD

would need to use the gestalt of the fragmented image to identify the object using a template match, instead of relying on local processing of individual parts.

Nevertheless, the initial findings from this training study suggest that while the accuracy of object identification did not improve, the identification of the object occurred at a lower level of completeness. Perceptual closure training can improve perceptual closure of individuals with ASD for object recognition. Perceptual closure, which refers to the process in which individuals could identify fragmented images, could be improved by training. This means that individuals would be able to identify objects at an earlier stage of processing. Such training effects could also generalise to other stimuli that require gestalt processing.

Limitations and Future Research

Similar to Study 1 and 2, one of the major limitations is the limited sample size. This study showed a large effect size for the VisWM task, although it did not reach significance due to its small sample size. Better control in matching the participants for the two groups can also be achieved with a larger sample size from which to choose from. However, the sample size could not be increased as the time and resources needed are beyond that of a doctoral study. It will also be important to do the training on younger children to determine whether such training is more effective as younger children tend to have greater plasticity and whether earlier development of expertise in perceptual closure will improve their ability to perform gestalt or global processing.

Another limitation is the relatively short duration and intensity of training. Both the training and control groups showed improvement in perceptual closure. This could be due to practice effects on the experimental tasks. To minimise these practice effects and evaluate the training effects better, future research could increase the duration, intensity and the number of training trials for the training program. For future research, the duration of training could be

lengthened and intensified. The number of trials used during the training program can also be increased. Multiple data points at various intervals using both behavioural and EEG measures could be collected to better understand how the training is changing the neural processes. Neural processing differences during processing may not translate to observable behavioural changes.

The effect of the training was not seen in the performance on the VisWM task. There may be a need to incorporate training to explicitly teach how strategies taught in the perceptual closure training can be used to look at the coherence within a scene to effect an improvement in performance on the VisWM task. Research has shown that individuals with ASD have difficulty with generalising to untrained tasks after training without explicit generalisation practice. Recent reviews have found that one of the most significant barriers to positive treatment outcomes was the generalising of a skill learned in intervention to daily use (Karkhaneh et al., 2010; Vismara & Rogers, 2010; Wass & Porayska-Pomsta, 2014).

Another direction for future research would be to examine if such perceptual closure training for objects translates to dynamic stimuli. While initial training in perceptual closure for objects may be critical for individuals with ASD to focus their attention on the object and apply the rule-based strategies for better closure processing, more complex and naturalistic stimuli need to be introduced during both training and assessment. This will help to better understand the progress made during training and the challenges faced to generalise such skills.

Further investigating of how training more basic visual perceptual processing such as perceptual closure is needed to find interventions that can begin at a more fundamental level of processing. Such fundamental level of processing can also be started at a younger age. Appropriate intervention at an early age can lead to good developmental achievements.

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CHAPTER V: GENERAL DISCUSSION

Social situations are dynamic and complex. Hence quick processing of what is perceived in such social environments is important. This requires the ability to efficiently process, retain, accumulate and integrate the perceived visual information into VisWM (Hollingworth, 2006). This thesis focused on how atypical visual perceptual processes in individuals with ASD may impact on how such complex information are processed in VisWM. Characterised by reduced functional connectivity between frontal and posterior cortical areas (Just, Cherkassky, Keller, Kana, & Minshew, 2007; Just, Keller, Malave, Kana, & Varma, 2012) and atypical frontal abnormalities in PFC (Sahyoun, Belliveau, Soulieres, Schwartz, & Mody, 2010), neuroimaging research shows that atypical functional connectivity plays a part in limiting the ability of the individuals with ASD to process and remember complex information in VisWM. Understanding how VisWM can be optimised or enhanced in populations with ASD can enable these individuals to adapt to their social world in a more effective and appropriate manner.

Research has shown that individuals with ASD are characterised by atypical perceptual processing, particularly in the interplay of local and global processing when processing contextual information. Local and global aspects of a representation must be perceived and balanced to meaningfully organise them into a coherent whole. Thus, atypical perceptual processing in the population with ASD can affect how representations such as scenes are stored in VisWM and the corresponding memory processes. Impairments that have been associated with ASD, especially in visuo-spatial working memory, suggests that items are encoded and stored using more of the posterior regions, even when cognitive load is increased (Ring et al., 1999). This could mean that individuals with ASD may fail to integrate and structure the multiple items according to spatial or featural context. VisWM is not just a higher-level process that happens after perception, but rather it relies on active interaction with visual perception (Gao et al., 2011). Therefore, if individuals with ASD present with

different perceptual processes, it is plausible that the representations in VisWM may be different from that of the TD individuals. This may in turn impact on their ability to remember more complex information in VisWM.

Perceptual closure is one of the fundamental principles underlying gestalt processing as such processing requires the completion of elements into forming a gestalt figure (Kimchi, 1992). A filling in of information, a process called ‘perceptual’ or ‘visual’ closure, is necessary to help in completing the details into a gestalt whole (Kimchi, 1992). Neuroimaging and EEG studies on fragmented coherent and scrambled images found an extended network of dorsal and frontal regions involved in perceptual closure processes. This is in addition to the NCL which is a relative negativity manifested over bilateral occipito-temporal scalp and occurs in the 230-400 ms timeframe just prior to recognition (Doniger et al., 2000). Despite electrophysiological studies showing evidence of differences in object detection and recognition between individuals with ASD and TD individuals, there has been little research looking at the timecourse of perceptual closure processes in ASD. Similarly, no ERP study has been conducted in individuals with ASD individuals to investigate the electrophysiological indices of encoding and maintenance in VisWM.

The current thesis aimed to fill this research gap to understand the effects of perceptual processing on the VisWM in individuals with ASD. Specifically, this thesis investigated the differences between perceptual closure between TD individuals and individuals with ASD. It also examined the effect of coherence on gestalt/local processing on the encoding and maintenance of complex visual information (scenes) in the VisWM of individuals with ASD. To the best of our knowledge, no ERP study evaluating the topography of effects of perceptual closure processes in individuals with ASD has been published. There is also limited neuroimaging and electrophysiological studies examining the effects of coherence on perceptual binding of object-to-position, and in particular, object-to-scene binding in ASD.

Study 1 investigated the difference in perceptual closure between individuals with ASD and TD individuals by using an ERP paradigm to elucidate neural differences of perceptual closure. Study 2 further explored the difference in perceptual binding in VisWM between individuals with ASD and TD individuals for coherent and non-coherent stimuli by using an ERP paradigm. Individuals with ASD were asked to recall the position of objects in either an intact or scrambled scene. Study 3 was an intervention study which attempted to explore if perceptual closure training could improve perceptual closure in individuals with ASD and if such training could also impact on how coherence within a scene is processed and aid in the recall of object-position binding in the VisWM.

Summary of the Findings in Each Study

The interplay of local and global processing on perceptual closure in individuals with ASD was first explored using electrophysiology to examine the closure process underlying object recognition in study 1. This study found that adolescents with ASD could recognise objects at a similar accuracy rate as TD adolescents. However, adolescents with ASD needed a slightly higher level of completeness than the TD adolescents. Differences were also found in the topography of effects of perceptual closure. While early visual processing and perceptual closure process were found to be similar for both the adolescents with ASD and TD adolescents, differences in closure-related frontal activity were observed. The TD group showed activations in the prefrontal regions at the point of closure which was not found in the group with ASD. Instead, topographic scalp plots showed that the activations were generated mainly in the occipital, parietal and temporal scalp regions. This suggests that for the TD group, the process of perceptual closure and eventual object recognition in the occipital and temporal region was mediated by top-down facilitation in the prefrontal brain areas while the group with ASD did not show such frontal-posterior distribution.

Study 2 further explored how the differences in local and global processing would affect the effects of coherence on scene processing. As expected, the TD group could recall intact better than scrambled scenes. However, the group with ASD also had better recall for intact scenes. While the TD group responded significantly faster on the intact scenes, the group with ASD did not show any significant difference in their reaction times for both intact and scrambled scenes. Overall performance on accuracy and reaction times was also better for the TD group when compared to the group with ASD. However, while the pattern of accurate responses for intact and scrambled scenes were similar, the underlying scalp activation differed. The TD group showed larger positive amplitudes in frontal-central-parietal scalp regions when processing the intact scenes during the encoding and maintenance phases. The group with ASD, however, showed larger positive amplitudes for the scrambled scenes. Thus, while both groups used local processing on both intact and scrambled scenes, the group with ASD did not recruit the frontal-central-parietal brain regions when processing the intact images. The TD group appeared to recruit higher order cognitive processes when processing the intact images, which could also explain the better accuracy and faster response shown by the TD group.

Study 3 attempted to use metacognitive strategies aimed at eliciting gestalt processing to see if perceptual closure and VisWM of object-positions in scene could be improved. Results were not conclusive as the sample size was small. Although the number of object recognised did not differ, the individuals with ASD in both training and control groups were able to recognise the fragmented images at a lower level of completeness after training. As no electrophysiological measures were taken, conclusions could not be drawn if the better performance was due to different neurological underpinnings. Similarly, the transfer of the effects of perceptual closure training also did not reach significance for the VisWM task. However, the effect size of the training as compared to the control group was larger. It is

likely that with a larger sample size, the effect of the training would reach significance for the training group.

Effects of atypical perceptual processing on Visual Working Memory in Autism Spectrum Disorder

Study 1's distribution of scalp activations provided support for differences in closure-related neural processing. Both adolescents with ASD and TD adolescents showed similar topography of effects and scalp activation at the point of closure. However, differences were found in closure-related frontal activity. The TD adolescents recruited prefrontal scalp regions suggesting that the process of perceptual closure and eventual object recognition in the occipital and temporal regions were mediated by top-down facilitation by prefrontal brain areas. This is consistent with the top-down model of object recognition proposed by Bar et al. (2006), where the interplay between gestalt/global and local processing aids in the eventual object recognition. The pattern of activation decrease in the PFC scalp regions suggests that a model or template selection may be occurring in the PFC, as postulated by the model (Bar et al., 2006). On the other hand, the adolescents with ASD did not show such a prefrontal scalp activation. The closure processes were largely confined within the occipital, parietal and temporal regions. This is consistent with what the disrupted connectivity theory proposed (Belmonte, Allen, et al., 2004; Belmonte, Cook, et al., 2004), where there is underconnectivity between frontal-posterior regions but overconnectivity within the local regions. Hence, this shows that there is a lack of interplay between global and local processing, and the adolescents with ASD were using mainly local processing for object recognition.

This lack of interplay between the global and local processing, which is a hallmark of the atypical perceptual processing in individuals with ASD, was also extended to scene

processing. This was investigated in Study 2 using a VisWM experimental design. Although global processing is also investigated in this study, findings in this study further extends our understanding of the atypical perceptual processing by looking at a higher order contextual processing of objects embedded in scenes, and how differences in processing the stimuli would also impact on the eventual storage and retrieval of the stimuli. The findings from this study further support the notion of a lack of global processing when individuals with ASD are presented with intact and scrambled scenes. Although both TD group and group with ASD used local processing on intact and scrambled scenes, the group with ASD did not recruit frontal-central-parietal brain regions when processing the intact scenes. This is unlike the TD group, who recruited these brain regions. These brain regions are usually associated with higher order attentional or cognitive processes. This could also explain the better overall performance seen in the TD group, despite being matched on nonverbal reasoning. The findings can be better explained by the proposition of WCC theory of a deficit in ability to integrate information into a more coherent whole, when the information gets to a stage of complexity where local processing alone does not work. Findings in Study 1 and 2 provide support for the theoretical model proposed to link visual perception to VisWM. The theoretical model linking visual perception to VisWM is presented in Figure. 5-1.

Figure 5-1. Theoretical model linking perception to VisWM

Study 3 aimed to look at whether global processing could be developed and used to facilitate perceptual closure skills in the group with ASD and whether this would also extend to processing of the holistic aspect of scenes to facilitate retention of the positions of objects embedded in the scenes. Although results are preliminary due to the small sample size, findings seemed to point to the trainability of global processing using metacognitive strategies. This in turn also affects the processing of scenes by tapping on its inherent coherence. This provides converging support that how a stimulus is perceived would impact on its storage in the VisWM. The effect size for the pre- and post-training accuracy measures was large, suggesting that the training also impacted on how the participants with ASD perceived the intact scenes that facilitated the recall of the object's position.

Limitation and Future Directions

Some limitations specific to each study have been stated in the previous three corresponding chapters. The discussion here would focus on the issues that this entire thesis has yet to address and thus require further investigations.

First, the thesis employed a static representation of object recognition and scene processing. Further investigations on how the interplay of local and global processing affects the perceptual process and VisWM on dynamic stimuli would be important. Research has found that the neural networks recruited by children with ASD when perceiving visual changes are less sensitive to the salience of the stimuli as compared to TD children (Clery, Bonnet-Brilhault, et al., 2013). This was also found in adults with ASD (Clery, Roux, et al., 2013). Dynamic stimuli would also have greater ecological validity to better reflect the processing needed in daily encounters and social interactions.

Second, this thesis used object stimuli for Study 1 and scenes for Study 2. It may be worthwhile to also look at how a scrambled version of the fragmented stimuli is perceived by individuals with ASD. ERP studies show that magnocellular-driven top-down information flow through the PFC provides critical information to the ventral stream closure process (Sehatpour, Molholm, Javitt, & Foxe, 2006). Parvocellular/ventral stream activation is seen for simple objects that can be identified without top-down input such as illusory contour detection. However, the closure process is slower for more complex processes such as closure of fragmented images, as a result of convergent bottom-up and top-down processes (Murray, Foxe, Javitt, & Foxe, 2004). The inclusion of fragmented images in both intact and scrambled form would provide a platform to understand how the perceptual closure processes for fragmented stimuli can be extended to understanding how perceptual closure impacts on intact and scrambled scenes.

Third, a developmental study to look at the differences in perceptual closure and scene processing in the VisWM would also be helpful to identify the earliest time that intervention can take place and have an effect. Current research on the development of configural processing in faces and objects for TD individuals have been inconclusive (Macchi Cassia, Turati, & Schwarzer, 2011; Picozzi, Cassia, Turati, & Vescovo, 2009; Robbins, Shergill, Maurer, & Lewis, 2011). Overall, the findings showed that children even as young as 3 to 4 years old can perceive faces holistically, but not non-face objects. Research conducted on 6 to 16-year-old children also suggests that sensitivity to spacing information steadily improves with age (de Heering & Schiltz, 2013). So far, a direct comparison of face and nonface configural processing development has not been conducted for population with ASD. Perceptual closure of objects is a relatively simple task that even younger children with ASD can engage in. Providing intervention at an early age and for more basic perceptual processes may help to change the trajectory of atypical perceptual processing for later and more complex processing, such as those for faces and social situations.

Lastly, the Ravens Standard Progressive Matrices (RSPM)(Ravens, 2000) was used as a measure of the participants' nonverbal reasoning skills, as verbal reasoning was not a skill that was investigated in the study. Future studies could include a more comprehensive measure of the participants' reasoning skills to explore if there are systematic differences in cognitive skills due to atypical perceptual processing of individuals with ASD.

These limitations listed above may not be exhaustive, but they provide worthy points to consider for future investigations.

Conclusions

The findings from the current thesis extend the understanding of the atypical neural connectivity that characterises ASD. Focusing on the perceptual processing seen in ASD, this

thesis found that processing coherence and gestalt is atypical in this group. This difference can also be observed in low-level perceptual processes such as the perceptual closure. When such basic perceptual processing is affected, it would in turn affect higher order processing such as VisWM. This is because basic visual perceptual processes and higher order VisWM are interactive in nature. While research has shown that such atypical connectivity underlies the processing of complex information, the current findings provide initial evidence that such atypical processing is also seen in perceptual closure, a low-level visual perceptual process. However, the effects may not be observable in the population with ASD in their daily functioning.

ASD is a neurodevelopmental disorder which brings with it significant impairments beyond that of social communication and social interaction. Although research on the neural underpinnings of ASD has been building up over the last decade, there is still a lack of understanding on how the difficulties of these individuals can be ameliorated or remediated. Through the research presented in the thesis, a model for atypical perceptual processing has been formulated. Baddeley's model of VisWM provides the understanding of the encoding, maintenance and retrieval of information (Baddeley, 2000). However, by looking at how the initial perceptual processing affects and interacts with the encoding and maintenance of complex information in the VisWM, we can start to understand the relationship between impaired VisWM seen in clinical populations who have atypical perceptual processing. This model lays the pathway for future research to systematically refine our understanding of the VisWM difficulties faced by individuals with ASD by delineating the atypical perceptual processing seen in these individuals and suggesting possible strategies to address such difficulties.

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Appendix I.

Power Calculations

Reference	Sample	EEG/ERP	Design	Significance	Power
Visual Processing					
McPartland et al. (2011)	ASD (36) TD (18)	256-Channel Geodesic Sensor Net	Independent Variable(s): Stimuli (Face vs. House) x Condition (TD vs. ASD)	N170 Amplitude: $F(1,47)=49.77$, $P<0.01$; Latency: $F(1,47)=63.92$, $p<0.01$	N170 Φ (Amplitude) = 8.295; Power>0.99 Φ (Latency) = 10.65; Power>0.99
Batty et al. (2011)	ASD (15) TD (15)	30-Channel Easycap Electrode cap	Independent Variable(s): Emotion (7 levels) x Group (TD vs. ASD)	P1 Amplitude: $F(1,27)=6.79$, $p<.02$ Latency: $F(1,27)=4.88$, $p<.04$ N170 Amplitude: <i>ns</i> (F-value not available) Latency: $F(1,27)=6.67$, $p<.02$	P1 Φ (Amplitude) = 26.298; Power>.099 Φ (Latency) = 18.9; Power>0.99 N170 Φ (Amplitude)= NA Φ (Latency) = 25.833; Power>0.99
Wong et al. 2008	ASD (12) TD (12)	128-Channel Geodesic Sensor Net	Independent Variable(s): Task (Implicit vs. Explicit) x Emotion (4 levels), Hemisphere (2 levels), Electrodes (5) and Group (ASD vs. Control)	P1 Amplitude: $F(1,20)=5.35$, $p<.05$ Latency: $F(3,13,62.29)=3.37$, $p=.023$ N170 Amplitude: $F(1,20)=28.12$, $p<.001$ Latency: $F(1,20)=4.79$, $p<.001$	P1 Φ (Amplitude) = 18.533; Power>.099 Φ (Latency) = 11.67; Power>0.99 N170 Φ (Amplitude) = 97.411; Power>.99 Φ (Latency) = 16.593 Power>0.99
Vandenbroucke et al. 2008	ASD (13) TD (31)	Biosemi 48- channel Active Two EEG system	Independent Variable(s): Boundary (3 levels) x Group (ASD vs. Control)	Negativity specific to boundary detection Amplitude: $F(42,1)>9$, $p<.005$	Negativity specific to boundary detection Φ (Amplitude) >32.44; Power>.99
Visual Working Memory					
Dawson et al, (2002)	ASD (33) DD (17) TD (21)	64-channel Geodesic sensor net	Independent Variable(s): Condition (Familiar vs, unfamiliar) x Hemisphere (2) x Group (ASD, DD, TD)	P400 Amplitude: $F(1,52)=11.54$, $p<.001$	P400 Φ (Amplitude)=66.292; Power>.99

Appendix II. The NTU Institutional Review Board Approval letter

Research Support Office

Reg. No. 200604393R

IRB 12/06/17

13 July 2012

A/Prof Annabel Chen
School of Humanities and Social Science

NTU INSTITUTIONAL REVIEW BOARD APPROVAL

Project Title: investigating the neural correlates of visual working memory in Autism: A Study of the Effects of Visual Closure on feature blinding

(Amount Approved: SGD\$5,000; to be funded by NTU HASS Incentive Grant)

I refer to your application for ethics approval with respect to the above project.

The Board has deliberated on your application and noted from your application that your research involves conducting training session to subjects. The result of the training session will be reflected using pre and post tests.

You have also confirmed that informed consent will be obtained from the participants and you have guaranteed the confidentiality of your participants' biodata obtained from them.

The Board is therefore satisfied with the bioethical considerations for the project and approves the ethics application under Full Board review.

A handwritten signature in black ink, appearing to read "Lee Sing Kong".

Prof Lee Sing Kong,
Chair, NTU Institutional Review Board
encl.

cc Chair, School of Humanities and Social Science
Members, NTU Institutional Review Board

Appendix III. ASD Consent and Assent Forms

PARENT CONSENT FORM

I have been asked to participate in a research study conducted by Dr SH Annabel Chen from NTU. My child has been asked to participate in this study. His participation in this study is entirely voluntary. It is recommended that I read the information below and ask questions about anything I do not understand before deciding whether or not to participate.

PURPOSE OF THE STUDY

I understand that this project is looking at how children with ASD can improve on their ability to process and remember complex visual information. I understand that the entire process will involve one session of standardized and cognitive assessment of up to 60 minutes, and two electroencephalography (EEG) recording sessions of up to 90 mins each, which will include memory and visual perceptual tasks. There will also be 5 training sessions of up to 30 minutes each, which will take place over one week during the school holidays or term time.

PROCEDURES

If I volunteer to participate in this study, I will be asked to have my child undergo 60 minutes of paper/pencil, and two 90 minutes session of visual memory and visual perceptual tasks with 64-channel topographic EEG acquisition. During this time, he will be asked to relax and complete the memory and visual perceptual tasks. There will be regular breaks between the tasks. He will also undergo 5 training sessions of up to 30 minutes each.

If I agree to my child's participation, my child will be randomly picked to be in either the training group, or the comparison group. I will not be informed which group your child is in. Both groups will go through the same procedures. The children in the comparison group will be provided with activities that are not related to the study. After the study has been completed, children who were in the comparison group will be offered the same training.

POTENTIAL RISKS AND DISCOMFORTS

I understand that EEG acquisition requires the placement of electrodes on the scalp for the purpose of recording an EEG. No risks have been associated with this procedure. Techniques used to attach electrodes have been used at numerous research institutions for many years with no significantly negative side effects reported.

I understand that my child can remove the electrodes at any time if he so desires and there is no risk of electroshock from this procedure. We do not expect any psychological, legal, or financial risks for participating in the research, but as always, there may be possible unforeseeable risks that have not been identified.

No information about my child or provided by me during the research project will be disclosed to anyone outside the project's team members without written permission. All hard copy data will be stored in locked filing cabinets in NTU and all computerised data will be stored on password protected computers and back-up drives.

PAYMENT or BENEFITS

I will be provided with an incentive of \$60 for my child's and my time on this study. The screens conducted may also provide a better understanding of my child's cognitive profile for learning. I will receive a written feedback letter that provides a summary of my child's cognitive profile obtained during the screens. These would include standardized evaluation of his nonverbal cognitive skill, his visual perceptual skills and social perception based on his performance on the screens.

RIGHTS OF RESEARCH SUBJECTS

My child's participation is voluntary. I may withdraw my consent at any time and discontinue my child's participation without penalty. My child's relations with the school will not be affected if I withdraw my child's participation in the study. Payment for time spent will be pro-rated based on sessions completed, at a rate of \$8 per hour.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I have read and understand the information provided above. I have been given an opportunity to ask questions and all of my questions have been answered to my satisfaction.

BY SIGNING THIS FORM, I WILLINGLY AGREE TO ALLOW MY CHILD TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.

Name of Participant: _____

Name of Participant's Parent or Guardian:

Signature of Subject's Parent or Guardian

Date

SIGNATURE OF INVESTIGATOR

I have explained the research to the subject of his/her legal representative, and answered all of his/her questions I believe that he/she understands the information described in this document and freely consents to participate.

Name of Investigator or person obtaining consent:

Signature of Investigator or person obtaining consent

Date

For clarification regarding ethical issues, please contact the NTU Institutional Review Board (IRB).

Contact Person: Ms Germaine Foo, Secretariat of NTU-IRB

Email address: irb@ntu.edu.sg; Telephone: 65-65922495

Address: Block N2.1 B4-07, 76 Nanyang Drive, Singapore 637331

For clarification regarding the research, please contact the co-investigator, Ms Chan Yee Pei, at 92278191.

PARTICIPANT ASSENT FORM

{To be read to the child by the researcher}

Hello! We are conducting a study to find out how children with ASD can improve on their ability to remember information. We also want to know what the human brain does when these children try to remember information. Your parents have allowed us to meet with you today so that you can help us in this study. There are four main parts to this study.

1. In the first part, you will be asked to do some activities so that we can have a better idea of how you think and remember information. This takes about 60 minutes.
2. The second part will be 90 minutes. During this session, we will record the brain's activity while we ask you to look at and remember some pictures. Just like a plug you stick into an outlet carries electricity, small paths in your brain carry electrical signals from one place to another. A method called electroencephalography (EEG) measures the effects that this electrical activity has on or near the surface of your head. This should not be painful to you. If you feel any discomfort, you will be able to tell someone at any time and you should feel free to do so. You won't make anyone mad if you want to stop. For the EEG, we will need to place small, smooth pieces of metal (called electrodes) on your head. They are not painful.
3. The third part will consist of 5 sessions where you will learn some visual skills using both paper and computer-based tasks. Each session will last for about 30 minutes. You will attend these sessions within one week.
4. The fourth part will be 90 minutes and will be similar to the second part where we will record the brain's activity while we ask you to look at and remember some pictures.

At any point in the study, you can tell us that you do not want to participate in the study. No one will be angry if you decide you do not want to do it. Do you have any questions?

If you are happy to do the tasks and take part in the study, please tick (✓) on the 'YES' box. If you don't want to do the tasks, please check on the 'NO' Box.

YES

NO

Name of Pupil : _____

School : _____

Class : _____

Date : _____

Appendix IV. TD Consent and Assent Forms

PARENT CONSENT FORM

I have been asked to participate in a research study conducted by Dr Annabel Chen Shen-Hsing from NTU. My child has been asked to participate in this study as a control subject. His participation in this study is entirely voluntary. It is recommended that I read the information below and ask questions about anything I do not understand before deciding whether or not to participate.

PURPOSE OF THE STUDY

I understand that this project is looking at how children with ASD can improve on their ability to process and remember complex visual information. I understand that the entire process will involve one session of standardized and cognitive assessment of up to 60 minutes, and two electroencephalography (EEG) recording sessions of up to 90 minutes each, which will include memory and visual perceptual tasks.

PROCEDURES

If I volunteer to participate in this study, I will be asked to have my child undergo 60 minutes of paper/pencil, and two 90 minutes session of visual memory and visual perceptual tasks with 64-channel topographic EEG acquisition. During this time, he will be asked to relax and complete the memory and visual perceptual tasks.

POTENTIAL RISKS AND DISCOMFORTS

I understand that EEG acquisition requires the placement of electrodes on the scalp for the purpose of recording an EEG. No risks have been associated with this procedure. Techniques used to attach electrodes have been used at numerous research institutions for many years with no significantly negative side effects reported.

I understand that I and my child can remove the electrodes at any time if I or he so desires and there is no risk of electroshock from this procedure. We do not expect any psychological, legal, or financial risks for participating in the research, but as always, there may be possible unforeseeable risks that have not been identified.

No information about my child or provided by me during the research project will be disclosed to anyone outside the project's team members without written permission. All hard copy data will be stored in locked filing cabinets in NTU and all computerised data will be stored on password protected computers and back-up drives.

PAYMENT or BENEFITS

I will be paid \$50 for my child's time on this study. The screens conducted may also provide a better understanding of my child's cognitive profile for learning.

RIGHTS OF RESEARCH SUBJECTS

My child's participation is voluntary. I may withdraw my consent at any time and discontinue my child's participation without penalty. My child's relations with the school will not be affected if I withdraw my child's participation in the study. Payment for time spent will be pro-rated based on sessions completed, at a rate of \$8 per hour.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I have read and understand the information provided above. I have been given an opportunity to ask questions and all of my questions have been answered to my satisfaction.

BY SIGNING THIS FORM, I WILLINGLY AGREE TO ALLOW MY CHILD TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.

Name of Participant: _____

Name of Participant's Parent or Guardian: _____

Signature of Subject's Parent or Guardian

Date

SIGNATURE OF INVESTIGATOR

I have explained the research to the subject of his/her legal representative, and answered all of his/her questions I believe that he/she understands the information described in this document and freely consents to participate.

Name of Investigator or person obtaining the consent:

Signature of Investigator or person obtaining consent

Date

For clarification regarding ethical issues, please contact the NTU Institutional Review Board (IRB).

Contact Person: Ms Germaine Foo, Secretariat of NTU-IRB

Email address: irb@ntu.edu.sg

Telephone: 65-65922495

Address: Block N2.1 B4-07, 76 Nanyang Drive, Singapore 637331

For clarification regarding the research, please contact the co-investigator, Ms Chan Yee Pei, at 92278191

PARTICIPANT ASSENT FORM

{To be read to the child by the researcher}

Hello! We are conducting a study to find out how children with ASD can improve on their ability to remember information. We also want to know what the human brain does when these children try to remember information. To understand how these children differ in how they remember information, we need to find out how typical children like you remember information. Your parents have allowed us to meet with you today so that you can help us in this study. There are three main parts to this study.

1. In the first part, you will be asked to do some activities so that we can have a better idea of how you think and remember information. This takes about 60 minutes.
2. The second part will be about 90 minutes. During this session, we will record the brain's activity while we ask you to remember some pictures. Just like a plug you stick into an outlet carries electricity, small paths in your brain carry electrical signals from one place to another. A method called electroencephalography (EEG) measures the effects that this electrical activity has on or near the surface of your head. This should not be painful to you. If you feel any discomfort, you will be able to tell someone at any time and you should feel free to do so. You won't make anyone mad if you want to stop. For the EEG, we will need to place small, smooth pieces of metal (called electrodes) on your head. They are not painful.
3. The third part will be about 90 minutes. This session is similar to the second session but will be conducted after two weeks.

At any point in the study, you can tell us that you do not want to in the study. No one will be angry if you decide you do not want to do it. Do you have any questions?

If you are happy to do the tasks and take part in the study, please tick (✓) on the 'YES' box. If you don't want to do the tasks, please check on the 'NO' Box.

YES

NO

Name of Pupil : _____

School : _____

Class : _____

Date : _____

Appendix V. The Curriculum Vitae of CHAN Yee Pei

Phone: 65-92278191

Email: ypchan1@e.ntu.edu.sg

HIGHEST EDUCATIONAL QUALIFICATIONS ATTAINED

<u>Degree</u>	<u>Institution</u>	<u>Year</u>
PhD in Psychology (<i>Neurocognitive Science and Neuropsychology</i>)	Nanyang Technological University	Candidate
Master of Educational Psychology	University of Queensland	1999
Graduate Diploma of Personnel Management	Singapore Institute of Management	1995
Bachelor of Soc Sci (Psych) (2 nd Upper)	National University of Singapore	1992
Bachelor of Arts	National University of Singapore	1991

PUBLICATIONS

- Chan, Y.P., Yee, Y.Y. & Chen, A. (2016). Effects of coherence on visual working memory of individuals with ASD: An event-related potential study. (Poster presentation at Organisation for Human Brain Mapping Conference 2016, Geneva, Switzerland).
- Chan, Y.P., Yee, Y.Y. & Chen, A. (2016). Contextual effects on visual working memory encoding in autism spectrum disorder: an event-related potential study. (Poster presentation at International Symposium on Cognition and Neuroscience 2016, Nanyang Technological University).
- Chan, Y.P., Khoo, S.W. & Chen, A. (2015). Relationship between Gestalt Processing and Affect Recognition on Autism spectrum disorder. ASD (manuscript in preparation).
- AMS-MOH Clinical Practice Guidelines (2010). ASDs in Pre-School Children. Ministry of Health. Singapore (as a Member of Workgroup)
- Chan, Y.P. (2002). Developing Play in Pre-schoolers. http://www.autism_spectrum_disorder-we-can.com/HTML/Articles/playskills_novnews2002.pdf.
- Chan, Y.P. (1999). *A survey of pica among people with intellectual disability*. (Unpublished master's thesis). University of Queensland, Brisbane, Australia.
- Chan, Y.P. (1996). Military Psychology: Military Leadership and Unit Cohesion. *Pointer Journal*, 1, 22-28. SAFTI MI Library.
- Chan, Y.P. (1991). *The self-serving bias in the private and public attributions: a cross-cultural study*. (Unpublished honour's thesis). National University of Singapore, Singapore.

PROFESSIONAL/POSTER PRESENTATIONS

Ser Wee Khoo, Yee Pei Chan & Shen-Hsing Annabel Chen (2015). Relationship between Gestalt Processing and Affect Recognition: Comparing Youths with and without Autism spectrum disorder. (Poster presentation at Asia-Pacific Conference on Vision (APCV) 2015 Nanyang Technological University).

Public Forum on ASD 2008. Organised by DIRC and KK Women's and Children's Hospital.

Co-Presenter with Dr Lam Chee Meng at 2002 WeCan Third Annual ASD Best Practice Conference (Singapore) November 2002. Title of presentation 'Assessment for Children for School Readiness in Singapore Mainstream Education'.

PROFESSIONAL TRAINING/ACCREDITATION

Registered Supervisor (Educational Psychology) (Singapore)
 Registered Psychologist (Singapore)
 Certified ASD Diagnostic Observation Schedule (ADOS) – Clinician and Researcher
 Certified ASD Diagnostic Interview – Revised (ADI- R) – Clinician and Researcher
 Accredited Myers-Briggs Type Indicator (MBTI) Trainer

EMPLOYMENT HISTORY**Full-time**

Jan 1994 – Dec 1996	Ministry of Defence, Applied Behavioural Sciences Dept (Psychologist) <ul style="list-style-type: none"> Assisted in designing and implementing selection systems, organisation climate surveys and leadership development programs for the Airforce
Jan 1999 – Dec 1999	Dept of Family, Youth and Community Care (Disability Operations Government Service, Queensland Australia)(Locum Psychologist) <ul style="list-style-type: none"> Provided behavioural intervention/support to individuals with intellectual disability who were being serviced by Disability Operations, Department of Youth and Family Affairs, Queensland
Jan 1998 - Dec 1999 Behavioural	Centre for ASDand Autism spectrum disorder-related Disorders/Applied Analysis Queensland (Senior Therapist) <ul style="list-style-type: none"> Assessment, intervention and training for children, families, teachers and schools. Implementation of one-on-one home-based early intervention program for children with autism spectrum disorder, with a goal towards full inclusion in mainstream schools. Educational support in school for children with ASD
Mar 2000-May 2001	Star EdPsy (S) Pte Ltd (Educational Psychologist) <ul style="list-style-type: none"> Diagnostic and Psycho-Educational assessment for children with special/learning needs Therapy and educational support for children with special needs Trainer for related workshops and certificate courses
Jun 2001-Aug 2003	ASDResource Centre (Educational Psychologist) <ul style="list-style-type: none"> Diagnostic and Psycho-Educational assessment for children with ASDand related disabilities Therapy and educational support for children with autism spectrum disorder Lecturer for related courses and workshops
Aug 2003 -Feb 2004	Educational Psychologist (Freelance, Singapore) <ul style="list-style-type: none"> Diagnostic and Psycho-Educational assessment for children with special/learning needs Functional Assessment and Behavioural/Learning Support for children with special/learning needs Therapy for children with special/learning/behavioural needs Trainer for related workshops and certificate courses
Mar 2004 –Nov 2006	Educational Psychologist (Freelance, Beijing China) <ul style="list-style-type: none"> Diagnostic and Psycho-Educational assessment for children with special/learning needs Functional Assessment and Behavioural/Learning Support for children with special/learning needs Therapy for children with special/learning/behavioural needs School support

Part-time

Jan 1998 – Dec 1998	St Ita's School (Brisbane Queensland, Australia)(Educational Psychologist) <ul style="list-style-type: none"> • Psychological support for children with learning and socio-emotional issues
Jan 2008 - Apr 2011	KK Women's and Children's Hospital (Senior Educational Psychologist) <ul style="list-style-type: none"> • Clinical supervision of team of therapists (Occupational Therapist, Speech/Language Therapist, Psychologist, Learning Support Facilitators and Learning Support Educators) for a pilot project on community-based therapy for children in selected PCF preschools. • Clinical supervision of junior psychologists • Clinic-based assessment • Clinic-based intervention
Feb 2007 – now	Chrysalis Psychological Consultancy Ltd (Educational Psychologist) <ul style="list-style-type: none"> • Diagnostic and Psycho-Educational assessment for children with special/learning needs • Functional Assessment and Behavioural/Learning Support for children with special/learning needs • Therapy for children with special/learning/behavioural needs • School support • Training and workshops for parents and teachers
Nov 2007 – Jun 2008	Civil Service College (Consultant Psychologist)
Nov 2016 – now	KK Women's and Children's Hospital (Principal Psychologist) <ul style="list-style-type: none"> • Clinical supervision of team of therapists (Occupational Therapist, Speech/Language Therapist, Psychologist, Learning Support Facilitators and Learning Support Educators) for a nation-wide community-based therapy program for children. • Program and process evaluation • Provide consultation on research projects and analysis for development and evaluation of program • Development of framework and implementation of project to look at stepping down of children from EIPIC centres to mainstream preschools

TRAINING/SUPERVISION EXPERIENCE

2000	Star EdPsy (S) Pte Ltd (Educational Psychologist) <ul style="list-style-type: none"> • Keming Primary School (MBTI Workshop for Teachers) • Rainbow Centre (MBTI Workshop for Teachers)
Mar 2000 –Dec 2003 Degree	Singapore Institute of Management – Open University Psychology Program (Tutor/Lecturer)
Mar 2000 – Dec 2003	University of Sheffield Masters of Education (Tutor)
Jul 2000 – Dec 2000	Diploma for Early Childhood Studies (Lecturer)
Jun 2001 – Aug 2003	Autism Resource Centre (Trainer for teacher and parent workshops and lectures)

Aug 2012 – May 2015	<p>Nanyang Technological University (NTU) School of Humanities and Social Sciences (Teaching Assistant)</p> <ul style="list-style-type: none"> • HP3702/HP317 Child Psychopathology (AY2012/13 SEM 1) • HP207/HP2700 Abnormal Psychology (AY2012/13 SEM 2) • HP327/HP3704 Clinical Neuropsychology (AY2013/14 SEM 1) • HP2700/HP207 Abnormal Psychology (AY2013/14 SEM 2) • HP3702/HP317 Child Psychopathology (AY2014/2015 SEM 1) • HP2700/HP207 Abnormal Psychology (AY2014/2015 SEM 2)
October 2012	<p>Nanyang Technological University (NTU) School of Humanities and Social Sciences (Guest Lecturer)</p> <ul style="list-style-type: none"> • HP411 Clinical Psychology (Topic: Development Disorders in Children)
July 2012 – now	<p>Autism Resource Centre (Associate Trainer and Supervisor)</p> <ul style="list-style-type: none"> • Teaching Practice Supervisor for Diploma in Special Education (Autism Studies) for Allied Educators (Learning & Behavioural Support) • Associate Trainer for Diploma in Special Education (Autism Studies) for Allied Educators (Learning & Behavioural Support)
2014	<p>Chrysalis Psychological Consultancy Ltd (Educational Psychologist)</p> <ul style="list-style-type: none"> • May : Lumiere Montessori House (MBTI workshop for Teachers) • Sept : Parent Workshop on Understanding Children
Aug 2017 – now	<p>Eden School (Clinical Supervision)</p> <ul style="list-style-type: none"> • Provide clinical supervision for the Autism Therapists

RESEARCH EXPERIENCE

1998 - 1999	<p>University of Queensland, Brisbane, Schonell School of Education, Australia (Research Assistant)</p> <ul style="list-style-type: none"> • 1998 : Associate Professor Christa van Kraayenoord • 1998-1999 : Professor Carmen Luke • 1998-1999 : Emeritus Professor John Elkins
June 2016 – Dec 2016	<p>Nanyang Technological University (NTU) School of Humanities and Social Sciences</p> <ul style="list-style-type: none"> • Brain Literacy Project (looking at developing understanding of brain processes in learning using a RTI model in 2 mainstream primary schools)

LANGUAGE PROFICIENCY

Spoken

English (first)
Mandarin
Cantonese

Written

English (first)
Mandarin