Seeing the trees from the forest or vice versa: An examination of the local bias hypothesis in autism spectrum disorder

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Submitted: May 6th, 2010

A thesis submitted to McGill University in partial fulfillment of the requirement of the degree of M. Sc. in the Department of Psychology

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Abstract

Two prominent theories of perceptual functioning in autism were tested. WCC theory maintains that individuals with autism spectrum disorder (ASD) preferentially attend to local elements. EPF model, on the other hand, maintains that persons with ASD can attend to either the local or the global elements and that they are sensitive to small changes in environmental contingencies. Individuals with ASD and typically developing individuals (TD) performed both the selective attention task, which employed instructions about which level of the hierarchical figure to attend, and the divided attention task, which employed implicit contingencies to bias to which level of the stimulus to attend. A global advantage and global interference were found for both groups. Furthermore, ASD persons demonstrated sensitivity to the contingencies relative to TD persons. This supports the EPF model indicating that individuals with ASD perform as TD individuals for global forms but can more flexibly modify their default level of selection according to changes in environmental contingencies.

Résumé

Deux théories perceptuels ont été testé. WCC clâme que les personnes qui présentent un trouble envahissant du développement (TED) montrent une inclination aux traitement locaux. EPF dit que les personnes avec TED peuvent traiter les niveau global ou local, et qu'ils sont sensibles aux petites différences dans les éventualités de l'environnement. Les personnes avec TED et le groupe de développement typique (DT) ont exécuté la tâche d'attention sélective, qui a employé des instructions duquel le niveau être présent, et la tâche d'attention divisée, qui a employé des éventualités implicites. Un avantage global et une interférence globale ont été trouvés pour les deux groupes. De plus, seulement les personnes avec TED ont démontré la sensibilité aux éventualités. Ces résultats soutiennent le compte d'EPF, et indiquent que les individus avec TED peuvent performer d'une manière caractéristique la tâche des formes globales, et peuvent modifier leur niveau implicite selon les changements subtils dans l'environnement.

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Introduction

In this thesis, I examine the nature of visual processing in individuals with autism spectrum disorders (ASD), in the context of two prominent perceptual theories of ASD functioning; weak central coherence and enhanced perceptual functioning. Autism spectrum disorders include autistic disorder, Asperger's syndrome (AS), and pervasive developmental disorder (not otherwise specified; PDD-NOS) and are marked by difficulties in social functioning, significant delays in language development, and interests that are narrow in focus (DSM --IV--TR, American Psychological Association, 2000). Two experimental manipulations were carried out. The first condition examined the extent to which visual processing in ASD is dominated by either the local or global features of the visual environment. The second condition assessed whether individuals with an ASD relative to TD individuals are more sensitive to subtle changes in environmental contingencies and as a result can modify their default level of visual selection.

Theoretical Background

Visual selection in ASD. Visual processing plays a key role in social problems experienced by persons with ASD, as the ability to process information from the visual environment is essential for understanding the visual cues that convey socially relevant information and ultimately furnish understanding of intents and expectations of other individuals (Huurre & Aro, 1998, Van Hasselt, Kazdin, Hersen, Simon, & Mastantuono, 1985). Researchers studying the social skills of blind individuals have found deficits in a variety of verbal and nonverbal behaviours (Van Hasselt et al., 1985), and report greater difficulty in making friends, poorer social skills and greater feelings of loneliness (Huurre & Aro, 1998; although see Sharkey & Stafford [1990] for some evidence of certain intact social skills during turn-taking conversations).

Although a diagnosis of autism is not given until an age of two (and often later), many studies have been conducted using home videos of a child's first birthday party to retroactively track any behaviours that may be indicative of autism development (Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002). Using this method, unlike typically developing (TD) newborns, who prefer to look at stimuli resembling faces and preferentially look at the eye region of a face (Farroni, Csibra, Simion, & Johnson, 2002), individuals with an ASD show overall diminished interest in faces (McArthur & Adamson, 1996; Osterling & Dawson, 1994; Osterling et al., 2002) and do not demonstrate a preference for face-like stimuli. This pattern of behaviour appears to be unique to people with autism, as individuals with other developmental disorders including Williams syndrome (Mobbs, Garrett, Menon, Rose, Bellugi, & Reiss, 2004;

Riby & Hancock, 2008) and Down syndrome (Berger & Cunningham, 1981) do not demonstrate similar social dysfunctions.

One account of atypical face processing in ASD maintains that this deficit occurs as a result of an altered basic perceptual functioning in ASD (Behrmann, Thomas, & Humphreys, 2006). More specifically, this hypothesis maintains that individuals with autism, unlike TD individuals, display a so-called local processing bias and as a result fail to extract the gestalt or the whole (Behrmann et al., 2006; Happé, 1999). Because faces are perceptually similar, a feature-by-feature analysis of the face parts is not sufficient for identification; one needs to derive the spatial relations between the different parts to be successful (Behrmann et al., 2006). Thus, understanding the nature of visual processing in ASD provides an important basis for understanding the nature of the core social deficits in autism.

The theoretical accounts of the local processing bias in ASD. Two main theories have been forwarded to explain the apparent local bias in ASD – a Weak Central Coherence (WCC; Frith, 1989; Frith & Happé, 1994, Happé, 1999; Happé & Frith, 2006) theory and an Enhanced Perceptual Functioning (EPF; Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006) model. According to the original version of WCC (Frith, 1989), persons with ASD have difficulties integrating the local elements into a cohesive whole, or forming an overall gist, due to an inherent failure to attend to the global or meaningful whole

(Frith, 1989). This core deficit in central processing was believed to both cause and explain deficits in social cognition (e.g., Behrmann et al., 2006; Frith, 1989). The WCC theory can explain both the superior performance of persons with ASD on the block design task (BDT) and the inferior performance of persons with ASD on tasks that require integration of local elements into a coherent whole, as in determining the gist of a story (Plaisted, 2001). However, findings of no global deficits and no local superiorities of the ASD group by Ozonoff, Strayer, McMahon, & Filloux (1994) challenged the validity of the WCC model.

In contrast, according to the EPF model, global and local visual processing proceed independently of one another, with individuals with ASD showing an enhanced ability to process information at a low-level and a typical ability to process information at the global level. According to the EPF model, the ‘default’ setting for persons with autism is to process local information, however, as the two processes occur concurrently, persons diagnosed with an ASD can choose when to attend and process global information (Mottron et al., 2006). The EPF account can also explain the superior performance of persons with ASD on the BDT and the ‘typical’ performance of persons with ASD on some global tasks such as in judging whether one global melody is the same or different from another global melody (Mottron, Peretz, & Ménard, 2000). Both theories do account for the areas of superior performance by persons with ASD, however.

Peak performance in ASD. Although persons diagnosed with an ASD show deficits in social functioning relative to typically developing peers, they often demonstrate superior performance in other domains, including visuospatial tasks (Caron, Mottron, Berthiaume, & Dawson, 2006; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) and low-level perceptual tasks (Bertone, Mottron, Jelenic, & Faubert, 2005; Bonnel, Mottron, Peretz, Trudel, Gallun, & Bonnel, 2003). The observation that individuals diagnosed with an ASD outperform comparison individuals in certain domains has been referred to as peak performance (Caron et al., 2006). Overall the findings from the studies of superior performance of persons diagnosed with an ASD indicate that, unlike TD persons, they display a bias toward attending to the local (or most basic) elements present within a global form. This general result dovetails with the local processing bias proposed as a mechanism that underlies atypical faces processing in ASD.

Peak performance in ASD: Visuospatial tasks. Visuospatial tasks require the perception of spatial relationships between the objects. Individuals with autism appear to outperform typically developing participants on two of the most common tasks, block design task (BDT) and embedded figures task (EFT).

In the BDT, participants are asked to reproduce a number of geometric designs of varying levels of difficulty (see Figure 1). In general, only a small percentage of TD persons are especially good at the BDT (i.e., show a high level of performance in the BDT as compared to other subtests of the Wechsler Intelligence Scales) in comparison to about 22 - 38% of persons diagnosed with an ASD demonstrating this peak in performance (Siegel, Minshew, & Goldstein, 1996).

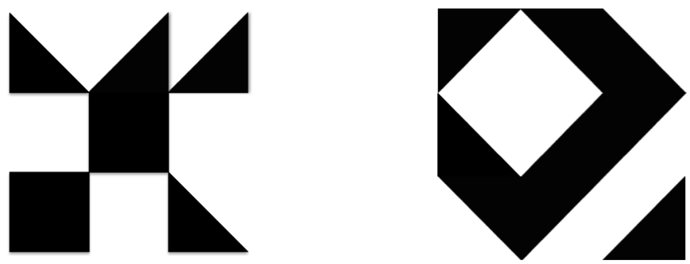

Figure 1. Two examples of a black and white version of a block design. This design on the left has low PC, whereas the design on the right has high PC.

Caron el al. (2006) studied the performance of four groups. Two groups were diagnosed with an ASD, with only one group demonstrating a peak in BDT performance. Two comparison groups were also included; one of typical intelligence without a diagnosis of autism, and the other a non-autistic gifted group on the BDT. Caron et al. (2006) manipulated the perceptual cohesiveness of the overall pattern made by the blocks (see Figure 1), (i.e., the amount of mental segmenting required for solving a pattern of the BDT). The results indicated that the HFA-peak individuals outperformed both comparison groups when the geometric designs displayed high perceptual cohesiveness. However, this difference between the HFA-peak and non-autistic gifted group disappeared when participants were presented with designs displaying low perceptual cohesiveness.

Similarly, individuals with ASD outperform TD individuals in the EFT, which consists of a complex figure that contains an embedded simple shape (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). In this task, participants are asked to identify the embedded simple shape (Figure 2).

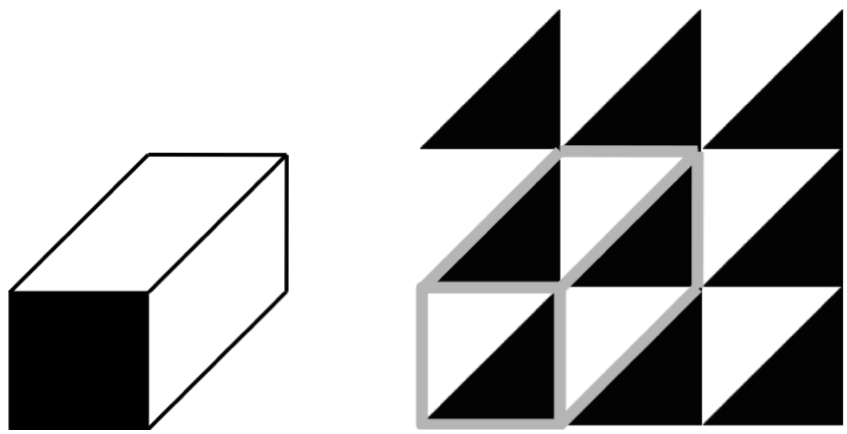

Figure 2: An example of the EFT. Participants must determine where in the large figure on the right one can find the shape on the left. Outlined in grey is the location of the simple shape on the left.

Shah and Frith (1983) found that young adolescents with autism performed significantly better than both comparison individuals matched for verbal mental age and young adolescents diagnosed as “mildly mentally retarded non-autistic” (p. 615). Similarly, Jolliffe and Baron-Cohen (1997) found that two groups diagnosed with an ASD (one group with HFA and the other with AS) were significantly faster at locating the embedded form within the global figure, whereas the TD comparison group of adults, although not significantly different in accuracy, was significantly slower to identify the location of the embedded figures.

Peak performance in ASD: Low level perceptual tasks. In addition to visuospatial tasks, individuals diagnosed with an ASD demonstrate a superior ability to detect the orientation of low-level visual gratings relative to their peer group of typically developing individuals. For example, Bertone et al. (2005) reported that high functioning adults with autism were better able to detect the orientation of a grating with similar contrast than their TD peers. This peak performance is also observed in the auditory domain as well, as Bonnel et al. (2003) reported a heightened ability for pitch detection and sound categorization in adolescents diagnosed with an ASD relative to the comparison group.

Thus, the findings from the studies of peak performance in individuals with an ASD suggest that individuals diagnosed with an ASD are better able to segment the whole (global) form into smaller pieces than TD persons. In addition, individuals with an ASD may also have a general bias toward the processing of local or basic elements that comprise the whole (Happé, 1999). This stands in contrast to the general bias toward processing the whole rather than the parts that is commonly found among TD persons (Deruelle, Rondan, Gepner, & Tardif, 2004; Joseph & Tanaka, 2003; Milne, Swettenham, Hansen, Campbell, Jeffries, & Plaisted, 2002).

Evaluation of the theoretical accounts of the local processing bias. Both WCC and EPF make clear predictions about expected performance of individuals with ASD in a number of domains, including perceptual and visuospatial coherence. However, the available evidence does not provide clear-cut support for either account.

A hierarchical global-local task originally designed by Navon (1977, see Figure 3) has been used to examine processing strategies of persons with ASD and comparison groups. The data from this procedure generally indicate that persons with ASD perform differently than comparison groups (Mottron, Burack, Stauder, & Robaey, 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000). Whereas typically developing persons commonly show a global precedence, as the global letter (the H) interferes with the speed and accuracy in naming the local letters (the “K”s) (Navon, 1977), the findings of performance by persons with ASD are not so clear-cut (i.e., Mottron et al., 1999; Plaisted, Swettenham & Rees, 1999). Global precedence is comprised of two processes: (1) global advantage, and (2) global interference. Global advantage is the finding that participants are faster and more accurate in identifying the global form, while global interference is the finding that participants are slower to detect a target stimulus at the local level, when the local and global forms are incongruent (Navon, 1977; Plaisted et al., 1999).

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K K             K K
K K             K K
K K             K K
K K             K K
K K             K K
K K K K K K K K K K
K K K K K K K K K K
K K             K K
K K             K K
K K             K K
K K             K K
K K             K K
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Figure 3: An example of a Navon (hierarchical) stimulus. The global “H” is made up of a number of local “K”s.

To examine the proposed local bias in ASD, Plaisted et al. (1999) tested a group of school-aged children diagnosed with HFA, and a group of age-matched TD children in a divided attention task and a selective attention task using the Navon hierarchical stimuli. In the divided attention task, the participants were asked to pay attention to both the local letters and the global letter, and press a button when the target (e.g., a letter “X”) appeared at either level. Plaisted et al. (1999) found that the TD children showed both the common global advantage (i.e., less errors identifying the target when it was located at the global level) and global interference (i.e., more errors when the target appeared at the local level), whereas the children with HFA displayed both a local advantage (i.e., less errors identifying the target when it was located at the local level) and a local interference (i.e., more errors when the target appeared at the global level).

This result provides support for both the WCC theory and the EPF model, as both accounts predict a bias toward local processing among individuals with ASD.

In Plaisted et al's (1999) selective attention task, on the other hand, the participants were told to attend to either the local level or the global level in order to find the target letter. The TD children and the children with HFA both responded quicker to the global targets than the local targets. This finding provides supports for the EPF account, which, unlike the WCC theory, does not predict a deficit in global processing.

Other research groups have found mixed evidence that individuals with ASD demonstrate a local processing bias, as Ozonoff et al., (1994) found global advantage and interference for both the ASD and comparison groups, yet Rinehart et al. (2000) found greater local interference for HFA but not AS individuals. In a comprehensive study designed to reconcile the discrepancies in the literature regarding global-local processing in autism, Wang, Mottron, Peng, Berthiaume, and Dawson (2007) manipulated a number of factors, including task instruction, visual angle, and exposure duration. The task instructions were varied between a free-choice task and a forced-choice task. In the free-choice condition, the participants were asked to report both the global number and the local number in whichever order they chose. In the forced-choice condition, the participants were asked to report just the local number in one condition, and just the global number in another condition. The visual angle varied from the largest stimuli (global number was 5.41 x 7.95 degrees and local numbers were 1.10 x 1.51 degrees) to the smallest stimuli (global number was 2.24 x 3.29 degrees and local numbers were 0.34 x 0.55 degrees), and the exposure duration was varied between 80ms, 200ms, and 500ms. Wang et al. (2007) found that the participants diagnosed with autism were equally likely to choose global and local targets across all visual angles and exposure times during the free-choice tasks, whereas the comparison group of TD students showed a global advantage for short durations and the small visual angle. This replicated Plaisted et al. (1999) finding of global interference among the TD children on the divided attention task.

In Wang et al's (2007) forced-choice condition, the participants with autism demonstrated local interference, while the comparison group showed bidirectional interference and an overall global advantage. Thus, the performance of persons diagnosed with an ASD did not replicate the findings reported by Plaisted et al. (1999), whose HFA participants showed a global advantage, but Wang et al. (2007) did replicate Plaisted et al's (1999) results for the TD group.

In response to the research results of global advantage and global interference (e.g., Mottron et al., 1999; Ozonoff et al., 1994; Plaisted et al., 1999; Rinehart et al., 2000) observed with persons with ASD with the Navon hierarchical stimuli, Frith and Happé (2006) introduced two revisions to the original WCC theory. First, the idea of a core deficit in global processing was revised to that of a more secondary outcome, with more emphasis placed on superiority in local or detail-focused processing. Second, the deficit in central coherence was reworded as a processing bias or cognitive style, which could be overcome in tasks with explicit demands for global processing (i.e., in the selective attention task when participants are explicitly instructed to attend to the global form).

Environmental contingency processing in ASD. According to the EPF model, persons with ASD have enhanced low-level discriminations, indicating that they are better able to detect small differences *between* stimuli, which may lend to a modification of their processing strategies. For example, when Iarocci, Burack, Shore, Mottron, and Enns (2006) biased the probability that the target shape would appear at the global level or the local level in a visual search task, they found that the TD children were affected by the contingency manipulations toward the global level, but that the children diagnosed with an ASD successfully modified their search strategies in response to both the global and the local contingencies. This finding is convergent with evidence from a spatial cueing task (Posner, 1980; Friesen & Kingstone, 1998), in which Ristic, Mottron, Friesen, Iarocci, Burack and Kingstone (2005) found that adolescents and young adults with ASD were more sensitive to spatial contingencies than comparison individuals matched on age and IQ.

The Present Study

Thus, it appears that several key questions regarding the proposed local bias in autism are still open for investigation. For example, does a local processing bias operate at the expense of global perceptual processes, as implied by the original WCC theory, or is it flexible and task dependent as according to EPF? Alternatively, is there an intermediary level, as suggested by the revised WCC theory, where global processing biases function only with explicit instructions? The focus of the present study was to examine these questions and address the relative merits of the WCC theory and EPF model with respect to visual processing and task contingency in ASD.

Two tasks were administered in this study. The first task, the selective attention task, was designed to address the inconsistencies in the literature on local versus global processing by giving participants explicit instructions about which level of a modified hierarchical figure to select and attend to. The main goal of this manipulation was to replicate the findings of previous studies using hierarchical shape stimuli. The second task, the divided attention task, was designed to address the findings of enhanced sensitivity of persons with ASD to contingency manipulations, by manipulating implicit contingencies as a guide as to which level (global or local) the target would appear. The proportion of time that a target stimulus would be located at a global level or a local level was manipulated (e.g., 0%, 20%, 40%, 50%, 60%, 80% or 100%).

The goal of this manipulation was to assess whether individuals diagnosed with an ASD are better able to discriminate between different levels of contingency and to modify their performance accordingly. Thus, this overall design allowed for a direct comparison of the role of task instruction on performance for both the persons with ASD and the comparison group of typically developing individuals.

Both the updated WCC theory and EPF models make clear predictions about the expected patterns of performance for both the selective attention and divided attention tasks. For the selective attention task, both the updated WCC theory and the EPF model predict no difference in performance between the two groups; the former due to the explicit instructions given as to which level to attend, and the latter due to parallel processing of global and local forms. Both theories predict comparable if not superior performance of individuals with an ASD on the local elements. More specifically, the WCC account predicts a pattern of local interference in persons diagnosed with an ASD in incongruent stimulus trials (i.e., the trials in which the global and local forms are different). Conversely, EPF predicts no interference due to the parallel processing of the global and local targets.

In the divided attention task, both WCC and EPF predict overall better performance with increase in local contingency (i.e., target appearing at the local level) from 20% to 100%. However, the two theories differ in terms of their predictions regarding global processing. The WCC theory predicts deficits for the global contingencies due to the implicit nature of the bias, whereas EPF predicts no deficits for the global contingencies. Finally, the EPF model additionally predicts that persons diagnosed with an ASD will modify their performance strategies according to the different contingencies, thereby showing sensitivity to the small variations between contingencies (40%, 50%, and 60%). It is important to note that both the ASD and TD group will show faster RTs for the larger contingencies, unrelated to the global-local information, as there will be less switches between the global and local levels, therefore less trials associated with a switching cost (i.e., Wilkinson, Halligan, Marshall, Büchel, & Dolan, 2001). This leads to faster average reaction times. Therefore it is the difference in performance between the ASD and TD groups at each level of contingency that is of interest here.

Method

Participants

The participants ranged in age from 12 to 29 (SD = 4) years, and in IQ from 80 to 120 (SD = 13)[1]. With these criteria, the participants included

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[1] Although the age span is 17 years, researchers have found that many aspects of attending to these hierarchical stimuli reach adult-like levels by 12 years, leading the author to believe that this particular age span is not encompassing an important developmental period (i.e., Kimchi, Hadad, Behrmann, & Palmer, 2005).The IQ span is similarly explained, as all participant were within 1.5 standard deviations of the mean, and the two groups were matched according to age, gender, and full-scale IQ (as measured by the Wechsler Intelligence Scale for Children or the Wechsler Adult Intelligence Scale). It is also important to note that statistical

15 TD adolescents and adults, 15 adolescents and adults diagnosed with autism and 1 adolescent diagnosed with AS. The participants with autism and Asperger syndrome were recruited from the database of the Specialized Clinic for Diagnosis and Evaluation of Pervasive Developmental Disorders at Rivière-des-Prairies Hospital (Montreal, Quebec, Canada). The typically developing participants were recruited from the community, and were screened for a past or current history of psychiatric, neurological, or other medical disorders. All the TD participants had a typical educational background, reported normal or corrected-to-normal vision, and one participant diagnosed with ASD was taking Risperdal (an atypical antipsychotic used to aid with irritability in some persons diagnosed with an ASD) at the time of testing. Detailed demographic information is presented in Table 1.

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analyses were run, comparing the oldest and youngest participants, but there were very few significant results, and none that added to this report. As well, by collapsing the data across a somewhat large IQ span, one is most likely to find a more general picture of performance as opposed to one that is specific to a small range of intelligence.

Table 1: A summary table of average age (SD and age range) and average IQ (SD and IQ range) of both the comparison group and the persons diagnosed with an ASD. Autism was diagnosed using the algorithm of the Autism Diagnostic Interview – Revised (ADI-R) (Lord, Rutter, & Le Couteur, 1994) combined with the Autistic Diagnostic Observation Schedule - General (ADOS-G), both of which were conducted by a trained researcher (LM) who obtained reliability on these instruments. In terms of diagnostic cut-offs, all 15 participants with autism and the one participant with AS scored above the ADI cut-off in the three relevant areas for diagnosis (social, communication, restricted interest and repetitive behaviours). In addition, 11 participants with autism were administered the ADOS as well, and all scored above the cut-off. The other 4 people diagnosed with autism who were not administered an ADOS were administered an expert clinical DSM--IV diagnosis of autism following a direct observation based on the ADOS procedure. The groups did not differ significantly on age or FSIQ, both *p*s > 0.85.

Group	Average Age (years) ± SD	Age Range (years)	Average IQ ± SD	IQ Range
TD	19.07 ± 3.990	13 – 29	102.27 ± 13.134	82 – 120
ASD	18.81 ± 3.885	12 – 27	102.5 ± 12.128	80 – 120

Apparatus and Stimuli

The tasks were run on a Power Macintosh computer, running VScope software (Rensick & Enns, 1992) with a 14 inch Apple Colour Plus screen, set to black and white. The stimuli were presented on a computer monitor placed in a dark room and viewed from a distance of approximately 57 cm. The participants responded using a two button response box.

The stimuli were black and white drawings shown on a white background. They included a global shape (diamond or square, measuring 3.12° high by 3.12° wide) that was made up of 8 local elements (diamond or square, measuring 0.62° high by 0.62° wide). The combination of global and local elements resulted in three types of stimuli that were manipulated in this study. They are illustrated in Figure 4. The congruent stimuli (Figure 4A) consisted of the same shape at both the global and local levels (e.g., a global diamond made up of local diamonds). The incongruent stimuli (Figure 4B) consisted of different shapes at each level (e.g., a global square made up of local diamonds).

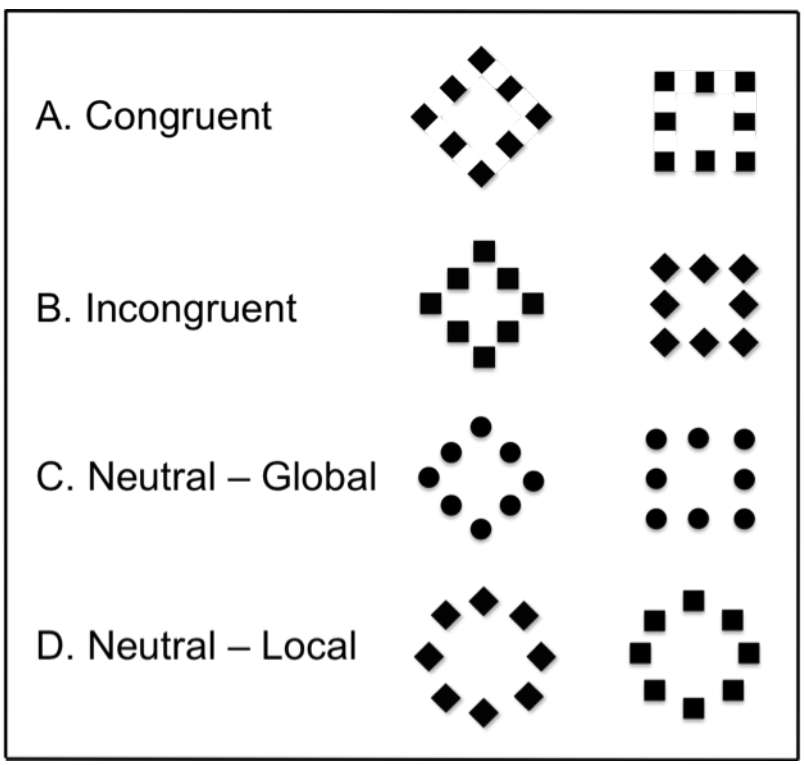


Figure 4: Illustration (not to scale) of the stimuli used. All 8 stimuli were used for the selective attention task, and the bottom 4 stimuli were used for the divided attention task.

The neutral stimuli consist of one neutral shape (a circle) and one target shape (a diamond or square) presented at either the global (Figure 4C) or local (Figure 4D) level.

Design and Procedure

Each trial started with a presentation of a feedback sign from a previous trial for a duration of 1000 ms, followed by a blank screen for a duration of 500 ms. Then, one of the eight stimuli was displayed at the centre of the screen until a response was made or until 3000 ms had elapsed, whichever came first. Feedback was give in the form of a “+” for a correct response, “-“ for an incorrect response, and “0” for no response. All of the participants completed both the selective attention and the divided attention conditions, with task order counterbalanced across participants.

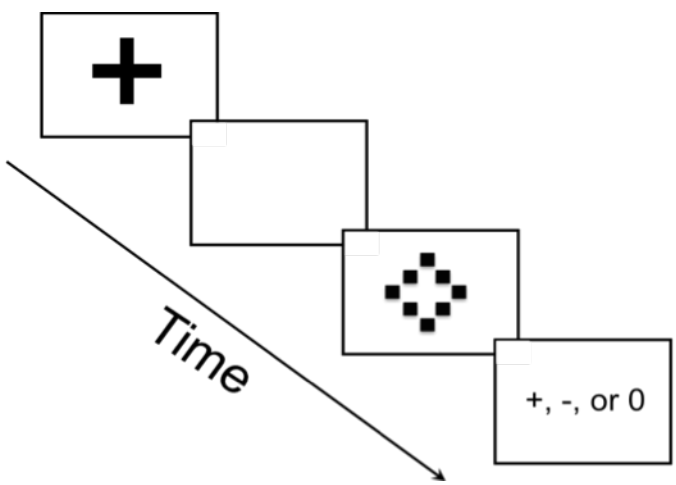


Figure 5: A schematic representation of the sequence of events in one single trial (not to scale). The start of the first trial was signaled by the presentation of a fixation cross (1 second); subsequently the feedback symbol served as the fixation for the next trial. The screen went blank for 1 second, followed by a target presented in the middle of the screen. The stimulus remained on the screen until a response was made, or if 3 seconds had elapsed, whichever came first. Subjects were then given feedback, which remained on the screen for 1 second.

The selective attention task. The selective attention task consisted of two parts. First the participants were presented with one block of 120 “attend-to-global” trials, at which time they were explicitly instructed to attend the global shape and ignore the local shape. This was followed by a block of 120 “attend-to-local” trials, where the participants were explicitly instructed to attend to the local shape and ignore the global shape. The task order was counterbalanced across participants. All permutations of congruent, incongruent, or neutral stimuli were presented equally often in random order.

The divided attention task. Only the neutral stimuli were employed in the divided attention task, therefore a target shape (i.e., a diamond or a square) was only present at one level for each trial. The participants were instructed to attend to both the local and global levels and to respond to either the diamond or the square (i.e., the target shapes) at either level. The percentage of time that the target stimulus appeared at the global or the local level was manipulated. The target was located at the global level 0%, 20%, 40%, 50%, 60%, 80%, or 100% of the time. The contingency of the target was blocked, with blocks presented in random order. Each level of contingency consisted of 100 experimental trials. As the main interest was in determining whether individuals with an ASD are sensitive to changes in contingency, the participants were not informed about the contingency manipulation.

Participants' response times and response accuracy were recorded. The participants were instructed to respond as quickly and as accurately as possible. Several practice trials were run at the beginning of each condition.

Results

Response time (RT) and accuracy were analyzed. Incorrect button presses and response time outs (RT > 3000 ms) were classified as errors and removed from the RT data. The correct raw RTs were then subjected to an adaptive outlier removal procedure (Van Selst & Jolicoeur, 1994), which resulted in 1.85% trial attrition rate. All the data were used in accuracy computation, calculated as (1 – error rates) x 100%.

To examine any potential effect of task order presentation, an omnibus between-within analysis of variance (ANOVA) was run on both mean RT and accuracy. For selective attention, Group, Task Order, Processing Level and Congruency were included as factors. For divided attention, Group, Task Order, Processing Level and Contingency were included as factors. Both analyses indicated that there were no significant main effects or interactions involving task order (all F values < 2, all p's > 0.05). Table 2 (found in the Appendix) present all mean interparticipant RTs, standard deviations and accuracy scores for the selective attention and divided attention tasks as a function of group and processing level.

Selective Attention Task

Response time. A between-within ANOVA was performed on inter-participant mean RT data, with Group (TD, ASD) as the between-subjects factor, and Congruency (congruent, incongruent, neutral) and Processing Level (global, local) as within-subjects factors. There were no main effects or interactions between the Groups, indicating that overall performance by the TD group and the persons with ASD was equated. There were main effects of both Congruency [$F(2,58) = 21.566$, $p < 0.0001$] and Processing Level [$F(1,29) = 45.203$, $p < 0.0001$]. The RTs for both the TD group and the persons with ASD were faster on the trials with congruent stimuli than on the trials with incongruent stimuli, and both groups displayed faster RTs when instructed to attend to the global processing level as opposed to the local processing level.

A two way interaction between Processing Level and Congruency [$F(2,58) = 8.183$, $p = 0.001$] was found. Follow-up two tailed t-tests, which were used to compare congruency types at each processing level, revealed that this interaction was driven by the result that all three Congruency types were significantly different from each other at the Local Level [all t's > 3.033, all p's < 0.005, two tailed), but not at the Global level [Congruent vs Neutral, $t(30) = 1.368$, $p > 0.05$; Congruent vs Incongruent, $t(30) = 3.745$, $p < 0.001$; Neutral vs Incongruent, $t(30) = 2.258$, $p < 0.05$]. Figure 6 illustrates mean RTs as a function of Congruency and Processing Level.

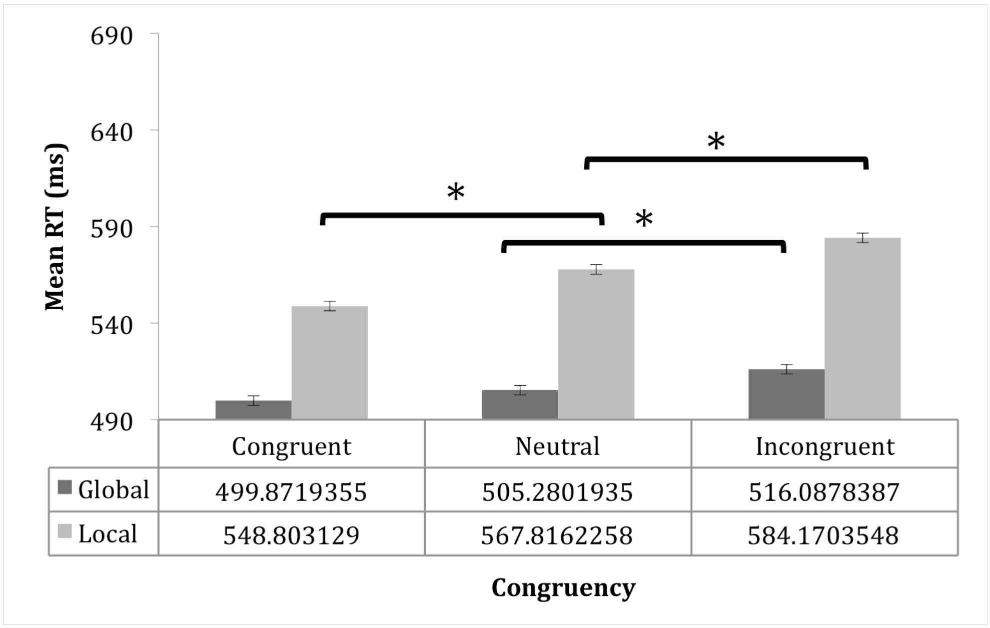


Figure 6: Processing Level by Congruency interaction. An asterisk (*) indicates significance at $p < 0.05$. Error bars are depicting standard error of the mean.

Accuracy. A between-within ANOVA was performed on the accuracy data, with Group (TD, ASD) as the between-subjects factor, and Congruency (congruent, incongruent, neutral) and Processing Level (global, local) as within-subjects factors. This analysis returned one significant main effect of Congruency [$F(2,58) = 17.995$, $p < 0.0001$], indicating that response accuracy was lowest for incongruent stimuli. No other effects were reliable (all Fs < 1). Figure 7 illustrates mean accuracy scores as a function of Congruency.

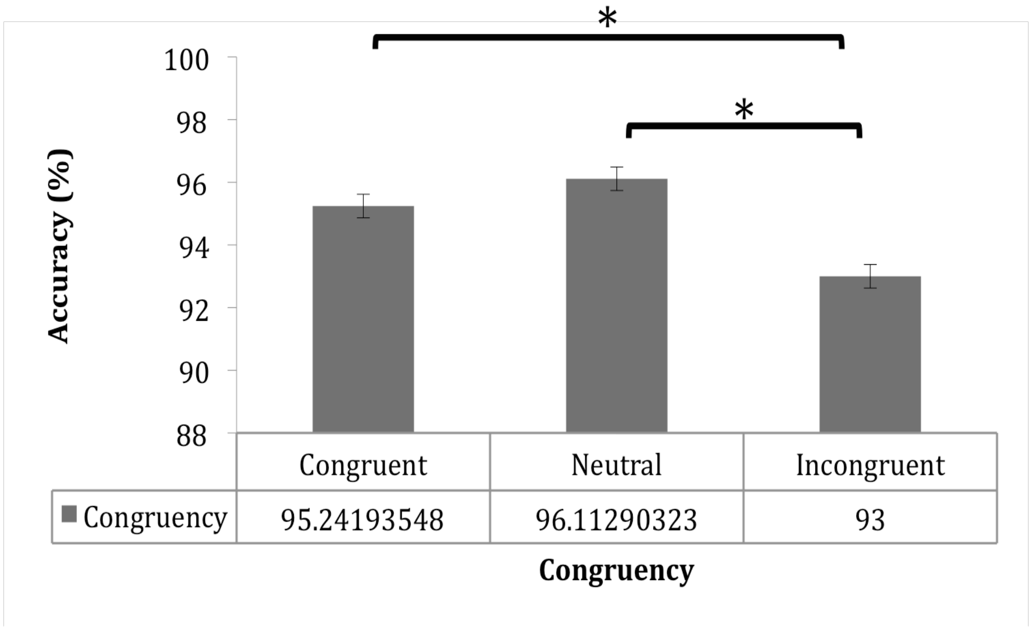
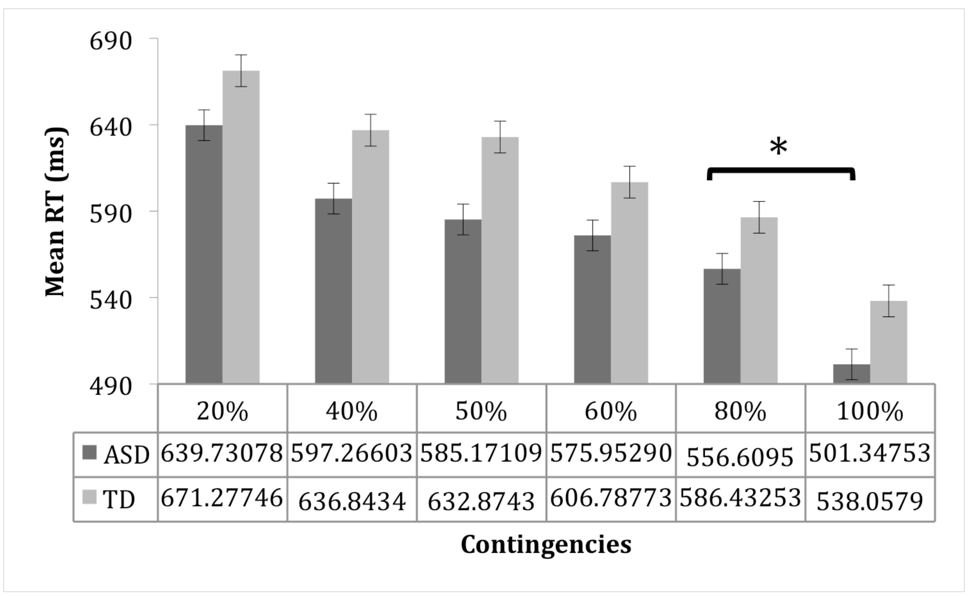


Figure 7: Main effect of Congruency. An asterisk (*) indicates significance at $p < 0.05$. Error bars are depicting standard error of the mean.

Divided Attention Task

Response time. A between-within ANOVA was performed on interparticipant mean RT data, with Group (TD, ASD) as the between-subjects factor, and Contingency (0%, 20%, 40%, 50%, 60%, 80%, 100%) and Processing Level (global, local) as within-subjects factors. There were no main effects or interactions involving Group. Main effects of both Contingency [$F(5,145) = 51.652$, $p < 0.0001$] and Processing Level [$F(1,29) = 43.474$, $p < 0.0001$] were significant, indicating that overall RT decreased with increased contingency level and that participants responded faster in response to targets at the global relative to the local level.

As one of the main hypotheses of this study was to investigate the role of contingency, an additional analysis was carried out to explore the main effect of Contingency. Two-tailed paired t-tests were used to compare RTs for each contingency level across Group and Processing Level. Significant differences emerged only between the 80% and 100% contingency for both levels. However this difference was only reliable for the persons with ASD and not for the TD persons [ASD: Global, $t(15) = 2.2320$, $p < 0.05$; Local, $t(15) = 2.3017$, $p < 0.05$; TD: Global, $t(14) = 1.7655$, $p > 0.05$; Local, $t(14) = 2.0462$, $p > 0.05$]. Figure 8 illustrates mean RTs as a function of Group and Contingency.



	20%	40%	50%	60%	80%	100%
ASD	639.73078	597.26603	585.17109	575.95290	556.6095	501.34753
TD	671.27746	636.8434	632.8743	606.78773	586.43253	538.0579

Figure 8: Processing Level by Contingency analysis. An asterisk (*) indicates significance at $p < 0.05$. Error bars are standard error of the mean.

Accuracy. A between-within ANOVA was performed on interparticipant mean accuracy, with Group (TD, ASD) as the between-subjects factor, and Contingency (0%, 20%, 40%, 50%, 60%, 80%, 100%) and Processing Level (global, local) as within-subjects factors. Two main effects and one interaction were significant. Main effects of Contingency [$F(5,145) = 8.439$, $p < 0.0001$] and Processing Level [$F(1,29) = 11.755$, $p < 0.05$] were found. They indicated that both groups were more accurate on the trials where the target shape was located at the global level than at the local level.

A Processing Level x Group interaction [$F(1,29) = 4.560$, $p < 0.05$] further indicated that the persons with ASD, but not the TD individuals, were more accurate on those trials where the target was located at the global level as compared to the trials when the target was located at the local level. This observation was confirmed by two-tailed post-hoc t-tests [ASD, $t(95) = -1.819$, $p < 0.05$]; TD, $t(89) = 0.5874$, $p > 0.5$]. The interaction between Processing Level and Group is illustrated in Figure 9.

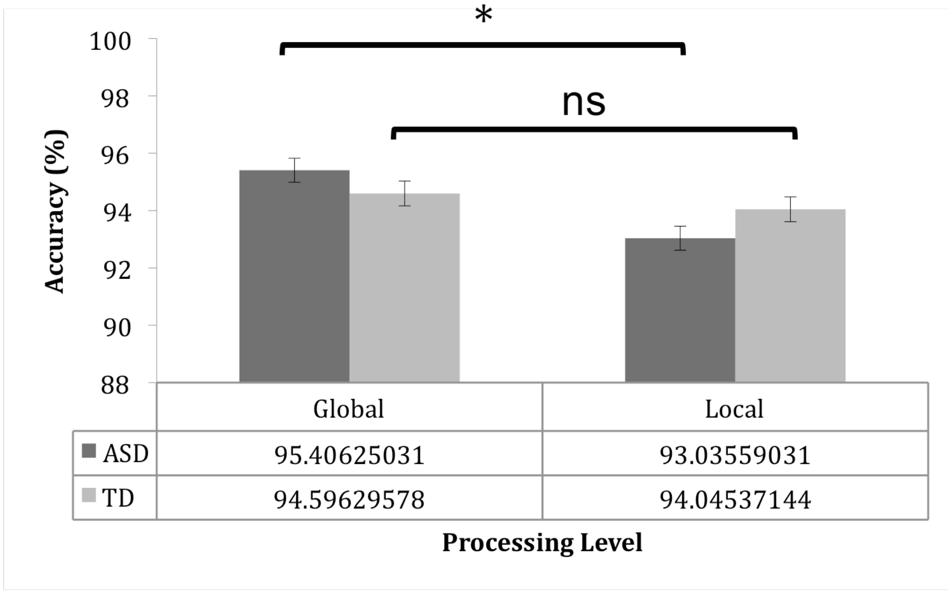
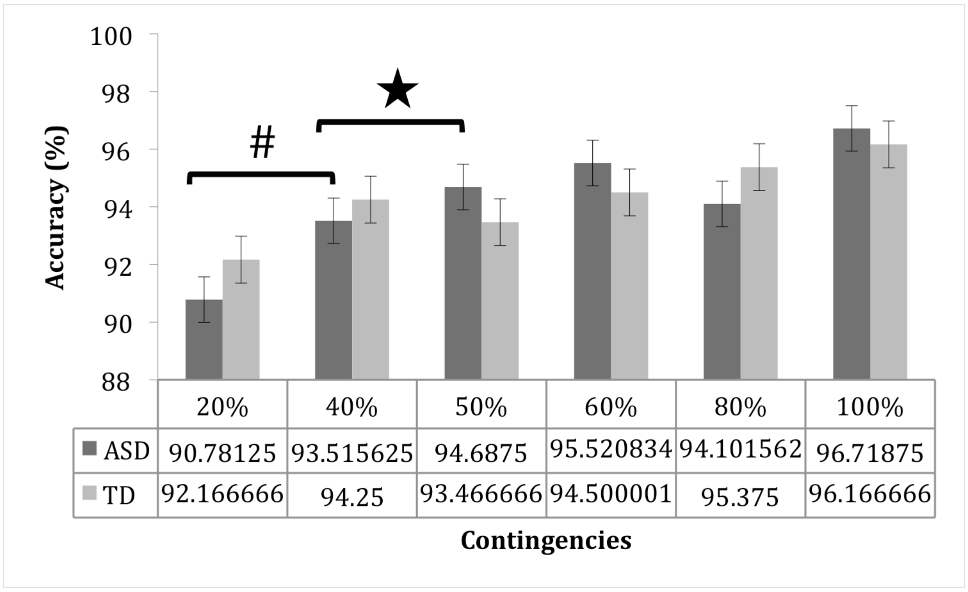


Figure 9: Processing Level by Group interaction. An asterisk (*) indicates significance at p < 0.05. Error bars are depicting standard error of the mean.

As in the analysis of RT, and as per an *a priori* hypothesis, I conducted two-tailed, paired t-tests comparing accuracy for each contingency level across Group and the Processing Level. A significant difference emerged between the 20% and 40% contingencies for the global level [$t(30) = 2.178$, $p < 0.05$]. When comparisons were performed with each group, a significant difference between the 40% and 50% contingencies at the Local level for the ASD group only [$t(30) = 2.202$, $p < 0.05$]. Figure 10 illustrates mean accuracy as a function of Contingency and Group.



	20%	40%	50%	60%	80%	100%
ASD	90.78125	93.515625	94.6875	95.520834	94.101562	96.71875
TD	92.166666	94.25	93.466666	94.500001	95.375	96.166666

Figure 10: Contingency by Group analysis. The star (★) indicates significance for the ASD group at the local level at $p < 0.05$. The number sign (#) indicates significance collapsed across both groups at the global level at $p < 0.05$. Error bars are depicting standard error of the mean.

Discussion

The focus of this study was to examine the relative merits of the WCC theory and EPF model of ASD (Happé, 1999). The findings provide moderate support for the EPF account, as they support two of three predictions that were based on the EPF account.

In the selective attention task, no differences were found between the persons with ASD and the comparison group in mean response time or accuracy. A main effect of Congruency was found, indicating that both groups were fastest for congruent stimuli, and were least accurate on the incongruent stimuli. Both groups were also fastest to respond to the global targets rather than the local targets. Thus, the two groups demonstrated a similar pattern of performance with differences in performance seen at all three types of stimuli when the target was at the Local level, and yet there were no differences in RTs for identifying congruent and neutral stimuli at the global level.

In the divided attention task, no differences were found between the persons with ASD and the comparison group in RTs, however there was a significant group interaction with accuracy. Both groups were quicker and more accurate when responding to the 100% contingency and when the target shape was located at the global level. In addition, persons with ASD displayed sensitivities to the 80% versus 100% contingencies in RTs, and the 40% versus 50% contingencies in accuracy. Persons with ASD also showed significant improvements in accuracy on the trials when the target was located at the global level rather than at the local level, whereas the comparison group showed no differences in accuracy scores between the two levels.

Selective Attention

The selective attention task with hierarchical stimuli was used to examine the inconsistencies in the literature on performance of persons with ASD. By explicitly informing the participants about which level to attend to, any differences in performance could be due to either a bias towards one level (global or local), or interference from the global or local level. Both the WCC theory and EPF model predict intact global processing. A main effect of processing level was found, with both groups being faster at identifying the global form than the local form. This finding replicates Plaisted et al. (1999), and indicates a global advantage for both groups. This finding supports both WCC and EPF.

The second set of hypotheses addressed the performance of both groups for the incongruent stimuli. WCC predicted that the local shape would interfere with the ability of a person with ASD to identify the global shape for incongruent trials, whereas EPF predicted no interference due to the parallel processing of the global and local targets. Results indicated a main effect of Congruency in both RT and accuracy in both groups. Replicating Plaisted et al. (1999), TD participants and the persons with ASD performing significantly faster and more accurately on the congruent trials than the incongruent trials. An analysis of the interaction between congruency and processing level shows a greater effect of Congruency at the Local rather than the Global level, demonstrating global interference. This result lends tentative support to the EPF theory of parallel processing mechanisms for global and local targets as no differences were found between the persons with ASD and the TD group. In contrast, the revised WCC theory predicted local interference, which was not revealed by the data.

Divided Attention

The divided attention task employed hierarchical stimuli that consisted of a target shape (diamond or square) and a neutral shape (a circle). It was used to explore the possibility that persons with ASD are more sensitive to contingency manipulations, and as a result could modify their strategies to benefit from these contingencies. Predictive probabilities were used as the implicit manipulation that indicated to the participants which level they should attend to. Both WCC and EPF predicted an increase in accuracy and decrease in overall RT with increases in contingency from 20% local to 100% local. The results support this prediction, as a main effect of Contingency was found for both RT and accuracy.

The first set of hypotheses examined the performance for the global contingencies. The WCC theory predicts poor performance, as persons with ASD would be biased towards local processing without explicit instructions otherwise. The EPF model, on the other hand, predicts no deficits in either global or local processing. The results from the divided attention task also favour the EPF model over the WCC theory. A main effect of processing level indicated that both the persons with ASD and the TD group were more accurate at identifying the global targets as compared to the local targets. Additionally, an interaction between processing level and group indicated that persons with ASD, but not the TD individuals, were more accurate at identifying global rather than local targets.

The second set of hypotheses were specific to the EPF model and examined the effect of increased sensitivity to the contingencies in individuals with ASD, with specific predictions concerning the 40%, 50%, and 60% contingencies. Post hoc t-tests conducted on the accuracy data revealed that persons with ASD showed a modification strategy for the 40% versus 50% local contingency. This provides support for the notion that persons with ASD demonstrate heightened sensitivity to the implicit biases in a global-local paradigm, and lends further support to the EPF model.

General Discussion

Overall the results from the current study provide more support for the EPF model over the WCC theory. However, two unexpected results were observed. They are discussed in turn.

The first unexpected result was that persons with ASD overall performed better at the global relative to the local level. One of the predictions that was shared by both EPF and WCC was that persons with ASD would overall perform better at the local level, supporting the local bias hypothesis. Yet the opposite result was found in both the selective and divided attention tasks. Although a number of researchers have found a global advantage and interference in the selective attention task (i.e., Ozonoff et al., 1994; Plaisted et al., 1999), a finding of a global advantage in the divided attention task was not predicted, and counters the findings from the Plaisted et al. (1999) study.

There are at least three possible reasons as to why this result was observed. First, the participants in the Plaisted et al. (1999) study were an average of 10 years of age, and the participants in the current study were an average of 19 years of age. Developmental studies have found that the global bias is strongest in TD children and dissipates once they reach mid-adolescence (Mondloch, Geldart, Maurer, & de Schonen, 2003). The developmental trajectory for autism, however, is unclear. Plaisted et al's (1999) participants may have shown stronger biases, albeit local, due to their age, but clear conclusions cannot be drawn without further developmental studies of persons with ASD. Second, although the global size of the stimuli employed in this study was comparable to those used by Plaisted et al. (1999) (4.6˚ high by 3.0˚ wide versus 3.12˚ high by 3.12˚ wide), the local size of the stimuli employed in the current task was roughly twice as big as that of Plaisted et al. (1999; 0.3˚ high by 0.2˚ wide versus 0.62˚ high by 0.62˚ wide). Third, in the current study the global form was made up of only eight local elements whereas the global form was made up of 56 local elements in the Plaisted et al. (1999) study. This stimulus discrepancy raises a very real possibility that stimulus size may play a key role in the selection of either local or global elements in ASD (Mottron, Burack, Iarocci, Belleville & Enns, 2003). That is, the local stimuli were different in size, because increasing the number of local elements necessarily leads to a reduction in their size, which is another point of difference between the current study and the Plaisted et al. (1999) study. Further investigations that employ better stimulus control are needed to elucidate the exact nature of the discrepant results.

The second unexpected finding was that accuracy data did not completely mirror the data observed with RT. This may be due to a ceiling effect, as the average accuracy scores ranged from 89% to 96.75%. This may explain why some of the findings for RTs were not replicated in the accuracy data. To alleviate this concern, future studies could employ adaptive testing procedures, which would guard against ceiling effects and at the same time maintain the overall performance between the two groups. Alternatively, one could lower accuracy performance by making testing a lower-functioning group of ASD participants.

The final unexpected finding was the moderate support for the hypothesis that individuals with ASD are better able than TD individuals to adjust their selection level in response to implicit task contingencies. Together with the past data, [i.e., a social endogenous cueing task (Ristic et al., 2005), a visual search task (Iarocci et al., 2006)], the present finding supports the idea that persons with ASD are sensitive to implicit contingencies in the environment. However, the data from the current study provided only moderate support for this hypothesis, while the results from other research studies (i.e., Ristic et al., 2005; Iarocci et al., 2006) are quite robust. The underlying factor of this disparity is difficult to pinpoint. One could argue that the difference in results may be due to instruction type, as Ristic et al. (2005) explicitly informed their participants of the contingencies. However Iarocci et al. (2006) used an implicit manipulation, similar to the one used in the current study. Another possibility is that the disparate finding are due to the number of selected contingencies, as Ristic et al. (2005) and Iarocci et al. (2006) used only one predictive contingency pair and one non-predictive contingency pair, whereas the current study employed four different contingency pairs (three predictive and one non-predictive contingency pair). The number of contingencies in this study could have made it more difficult to identify which conditions were informative and which ones were not. One way of investigating this issue further would be to equate the three tasks (global-local, endogenous cueing and visual search) for difficulty and task instruction by perhaps introducing a secondary task (i.e., an n-back task) and running a between-subjects design, with half of the participants receiving explicit task instructions, and the other half receiving the implicit task instructions.

Taken together these data raise several intriguing questions about the nature of the visual processing in autism and offer a fruitful ground for future investigations. First, although it is generally accepted that performance on global-local tasks in typically developing individuals is adult-like by early teenage years (i.e., Kimchi et al., 2005), it is still possible that there may be subtle differences between the performance of young teenagers and young adults with ASD. One reason for why one might expect this developmental trajectory is the amount of general visual experience that adults may have in comparison to teenagers. This visual experience may be particularly expressed with over learned hierarchical stimuli, like faces for example. Addressing this question would necessitate a systematic cross sectional or a longitudinal experimental approach in which performance of ASD and TD individuals is studied. Another possibility is that Navon hierarchical stimuli may not be complex enough such that the performance observed with these figures may not generalize to the performance of individuals with ASD in more complex naturalistic settings. The visual environment that we experience in day-to-day interactions is complex and often ambiguous. Natural visual events often contain several levels of global and local elements (e.g., one could perceive a person globally, or perceive different parts of a person as being global in nature, like a torso or a face). Future studies may address this issue by presenting more complex hierarchical stimuli and examining the differences that may be perceived in performance between ASD and TD individuals. Dovetailing with this point, it is possible that the proposed local processing bias in individuals with ASD may be more in more complex visual environments. Furthermore, it is possible that the nature of the environmental contingencies that are typically used to comprehend the visual environment may differ between ASD and TD individuals. The results of the current study revealed that there were only moderate differences between the two groups in response to this variable. While on the one hand this result may indicate that there were no significant differences between the two groups, alternatively one might expect that larger differences would be observed when more complex and less contextually impoverished displays are used (Birmingham & Kingstone 2009).

Finally, these data carry implications for the understanding of flexibility and visual strengths shown by persons with ASD. Persons with ASD have been found to make better use of relevant cues in target detection tasks (i.e., Ristic et al., 2005; Iarocci et al., 2006), are more sensitive at detecting low level visual and auditory stimuli (i.e., Bertone et al., 2005; Bonnel et al., 2003), and show superiorities at a number of tasks such as the block design task (i.e., Caron et al., 2006) embedded figures task (i.e., Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), and are less susceptible to visual illusions (i.e., Ropar & Mitchell, 2002; Mitchell, Mottron, Soulières, & Ropar, 2010). Further research identifying the strengths of persons with ASD and determining how to tap into these strengths in real world situations is paramount to increased success of persons with ASD in social situations. In addition, as the issue of the exact nature of social cognitive deficits is still unknown, it is important for both perceptual and cognitive researchers to fuse their efforts in order to generate a more complete picture of the differences between autism and typically developing populations.

Conclusions

The revised WCC and EPF were put to the test using a selective attention and a divided attention task. Results offer moderate support for the EPF model and additional support for the notion of enhanced sensitivity to contingency manipulations in ASD.

Acknowledgements: The candidate would like to thank the following people for their contributions to this work; the research assistants (Anthony Hosein Poitras Loewen and Patricia Jelenic) at the Specialized Clinic for Diagnosis and Evaluation of Pervasive Developmental Disorders at Rivière-des-Prairies Hospital (Montreal, Quebec, Canada), David I. Shore and Jacob A. Burack for working through the preliminary design with me, Heungsun Hwang and Shahin Zangenehpour for offering statistical help if I needed it, and Caitlin Mouri, Jacob A. Burack, Shahin Zangenehpour and Jelena Ristic for proofreading this manuscript.

Finally, a large thanks to Avi Chaudhuri for starting me on this path, and to Jacob A. Burack for taking me under his wing.

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Appendix

Table 2. Mean interparticipant RTs, standard deviations and accuracy scores for the selective attention and divided attention tasks as a function of group and processing level.

Condition	Global						Local					
	TD			ASD			TD			ASD		
	RT	SD	ACC	RT	SD	ACC	RT	SD	ACC	RT	SD	ACC
Selective Attention												
Congruent	509	88	94.93	492	57	95.88	543	88	95.33	554	68	94.81
Neutral	513	93	96.07	498	66	96.63	565	85	95.33	570	70	96.38
Incongruent	526	83	93.33	507	63	93.31	584	78	93.07	584	81	92.31
Divided Attention												
20%	647	97	93	631	120	92.5	696	124	91.33	648	91	89.06
40%	617	102	94.5	582	81	95.94	656	77	94	613	85	91.09
50%	620	102	93.6	569	64	95.38	646	108	93.33	602	63	94
60%	593	107	95.44	560	77	95.94	620	76	93.55	592	81	95.10
80%	572	97	94.83	528	56	95.94	601	47	95.92	585	95	92.27
100%	520	69	96.2	484	62	96.75	556	74	96.13	519	73	96.69