The Relationship between Performance on a Visual Search Task and Autism Symptomology

by

Kimberly Armstrong
B.A., Simon Fraser University, 2007

Thesis submitted in partial fulfilment of
the requirements for the degree of

Master of Arts

in the

Department of Psychology

Faculty of Arts and Social Sciences

SIMON FRASER UNIVERSITY

Fall 2011

APPROVAL

Name: Kimberly Armstrong

Degree: Master of Arts

Title of Thesis: The Relationship between Performance on a Visual Search Task and Autism Symptomology

Examining Committee:

Chair: Shannon Zaitsoff
Assistant Professor, Department of Psychology

Dr. Grace Iarocci
Senior Supervisor
Associate Professor, Department of Psychology

Dr. John McDonald
Supervisor
Associate Professor, Department of Psychology

Dr. Shannon Johnson
External Examiner
Associate Professor, Department of Psychology
Dalhousie University

Date Defended/Approved: November 23, 2011

Declaration of Partial Copyright Licence

SFU SIMON FRASER UNIVERSITY
THINKING OF THE WORLD

STATEMENT OF ETHICS APPROVAL

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

(a) Human research ethics approval from the Simon Fraser University Office of Research Ethics,

or

(b) Advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University;

or has conducted the research

(c) as a co-investigator, collaborator or research assistant in a research project approved in advance,

or

(d) as a member of a course approved in advance for minimal risk human research, by the Office of Research Ethics.

A copy of the approval letter has been filed at the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Simon Fraser University
Burnaby, BC, Canada

ABSTRACT

This study aimed to investigate whether certain symptoms of autism were associated with enhanced performance on a conjunctive visual search task. Thirty individuals with autism completed the AQ and a conjunctive-search task. Results indicated that autism symptoms were differentially related to performance outcome measures on the conjunctive-search task. Attention to detail was found to be significantly related to the slope in the target-present condition, suggesting that better attention to detail was related to less distraction with increasing set size. Parent ratings of social skills were found to be significantly related to performance measured by the intercept of the target-absent condition, suggesting that poorer social skills were related to faster performance. The results have implications for understanding the relations between the two core symptoms of social/communication deficits and restricted/repetitive behaviours and interests (DSM-V 2013) in the revised diagnosis of autism.

Keywords: Autism Spectrum Disorder; Perception; Attention; Visual Search; Social

This work is dedicated to my parents, Barb and Frank Peabody.

ACKNOWLEDGEMENTS

There have been many people who have contributed to the completion of this work, both directly and indirectly. First and foremost I would like to thank my senior supervisor Grace Iarocci for all her support and guidance throughout this process. I am truly grateful for what you have taught me in the past two years. John McDonald, I so appreciate your help and insight particularly in the design stage of this project. Your suggestions and feedback were extremely helpful. I would like to extend my thanks as well to Stephen Hart and Rochelle Fouladi for their help during the formulation phase of this project. Thanks is also due to Simon Baron-Cohen and Michelle O'Riordan from the University of Cambridge, from whose research this work was inspired, and whose support and encouragement of me from 'across the pond' has made all the difference. Finally, I would like to thank Teresa Tavassoli and Bonnie Auyeung for helpful discussions in the formulation stage.

I also want to thank my lab mates for all their help with the study and constant encouragement the past few years- you are all amazing! Thanks to Rana Emami, Bernardus Larryant, Elina Birmingham, Krista Johnston, David Butler, Hayley Lagroix, and Fern Fayer for their help on various aspects of this project. I am very grateful to my SFU clinical cohort who has been a haven of comfort, humour, and support in the past few years- I couldn't have done it without you all! Thanks to my family, Frank, Barb, Mike and Jacquie Peabody for all the love and support. To my loving and devoted husband Arthur, I thank you for loving and supporting me unconditionally through the past few years, as well as those to come. Most importantly, I thank the families of individuals with autism, and the individuals themselves who participated in this research. This work was supported by a Canadian Institutes for Health Research (CIHR) trainee fellowship.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Autism Spectrum Disorder (henceforth referred to as ‘autism’, which includes autism, PDD-NOS and Asperger’s Disorder) is a neurologically based developmental disorder characterized by impairments in social interaction and communication, and by repetitive and stereotyped patterns of interests and behaviour (American Psychiatric Association, 2000). The symptoms of autism have long puzzled researchers; it has proven difficult to determine how the triad of impairments in the areas of social skills, communication, and repetitive behaviours that define the disorder are related. It has been so difficult, in fact, that a few experts in the field have suggested that we give up on searching for a single explanation to understand autism symptoms (Happé, Ronald, & Plomin, 2006).

In part because of the difficulty determining how these symptoms represent distinct or overlapping entities, and to increase clarity, the diagnostic criteria will be changing in 2013 with the DSM V from three domains of symptoms to two. The previously separate domains of impairments in social interaction, and impairments in communication will be amalgamated into one domain of social/communication deficits. Furthermore, for the first time unusual sensory issues are introduced under the second domain of fixated interests and repetitive behaviour domain. Within this new definition of autism, research into the potential relations between symptom domains in autism may begin to clarify the heterogeneity within the broad category of autism as well as inform about how different domains of development are connected. For example, an understanding of a relationship between superior visual perceptual abilities and inferior social abilities could bring insights into the relations between perceptual and social development and how the domains of autism symptomology are related.

There is mounting evidence that certain aspects of perception and visual attention are atypical in autism. Specifically, people with autism seem to perform better than typically developing people on visual tasks that require attention to detail, such as embedded figures tasks (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) impossible figures tasks (Mottron, Belleville, & Ménard, 1999), block design tasks (Rumsey & Hamburger, 1988) and visual-search tasks (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; O'Riordan, 2004; Plaistad, O'Riordan, & Baron-Cohen, 1998). Investigating what is unique about people with autism that enhances their performance on these types of tasks will provide a better understanding of how they process sensory information and how this might be related to their development in other areas of interest, such as in the newly amalgamated social/communication deficit domain.

Visual Search Tasks

Visual search tasks involve perceptual discrimination and visual attention. Specifically, they require a person to scan the environment for a particular target which has a unique visual target, such as colour or form, and distinguish it from similar stimuli. Two common types of visual search tasks are the feature-search task and the conjunctive-search task. A feature search task consists of a target stimulus that shares a feature (such as colour) with one type kind of distracter, but is unique with regard to another feature (such as shape). For example, a red circle amongst other red squares. A conjunctive-search task consists of a target stimulus that shares one feature with one type of distracter and another feature with the other type of distracter. For example, a red circle amongst red triangles and blue circles.

These two types of tasks involve different challenges in processing. A feature-search task is sometimes known as a “pop-out” task because its distinct feature makes it “pop-out” from the rest of the display making it easier to find, and resulting in a parallel search (i.e. searching all distracters at once). Therefore, search times are fairly independent from the number of distracters (Treisman & Gelade, 2000). A conjunctive-search task, however, the target is unique only in the combination of features, and therefore, search times are usually linearly associated with the number of distracters as people tend to search for the target in a serial manner.

In the lab environment, these types of tasks are typically set up so that the participant is sitting in front of a computer screen on which an array of stimuli is displayed. The aim of these basic feature and conjunctive-search tasks is to identify as quickly as possible whether the target stimulus is present within the array. This is indicated by pressing a designated key if it is present and another key if it is absent. Reaction time (RT) is measured by the computer in milliseconds from stimulus onset to when the answer key is pressed, and errors are examined by looking at the ratio of correct to incorrect responses in order to exclude responders who are pressing haphazardly.

Visual search tasks are typically analyzed in one of two ways. The first is by conducting a repeated-measures ANOVA. In this case the within-subject factors might include set size (how many elements are in the display) and task (what type of search task), and the between-subject factors are group (whether they have autism or not) and target presence or absence (Beck, Lohrenz, & Trafton, 2010). Sometimes researchers are interested in obtaining an outcome measure for each individual, however. Visual search tasks usually include varying display sizes (e.g. 6, 18, or 24 items per display) and it is possible to calculate the slope of an individual’s RTs as RT typically increases with the number of distracters in conjunctive tasks (Chun & Wolfe, 1996). For this study it was important to look at individual outcomes because it was necessary to look at their relation to individual autism symptomology scores. See figure 1 for a generalized graph of typical outcome results from a standard conjunctive visual search task.

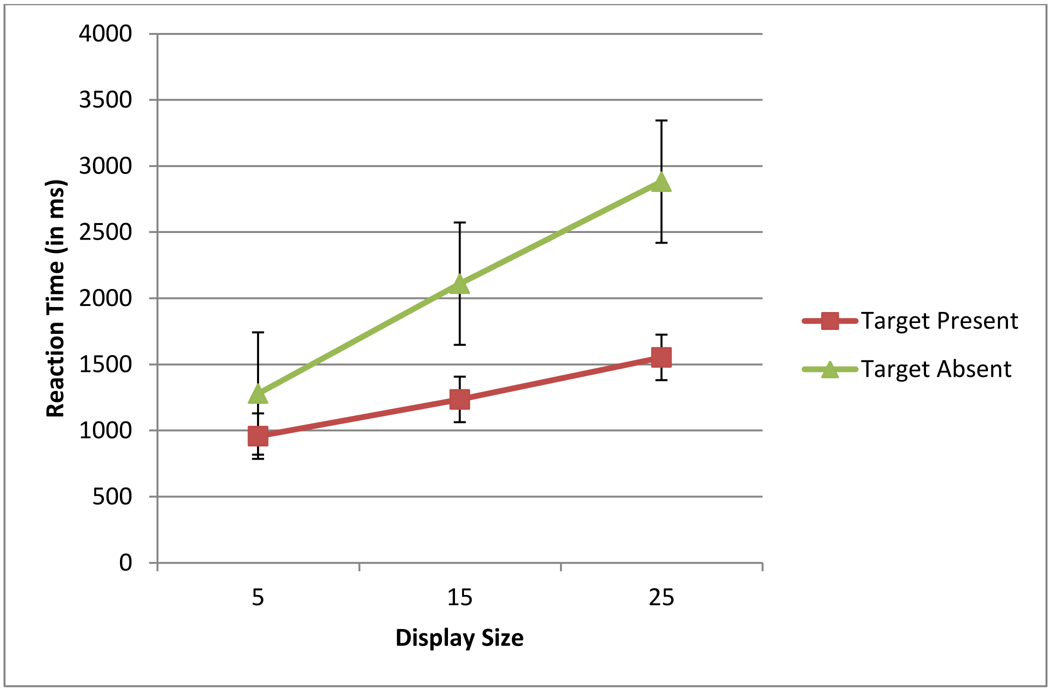

Figure 1. **Example of outcome measures on a typical conjunctive visual search task**

The slope represents search efficiency, and as the visual search task becomes more difficult, either by increasing the number of distracters or the similarity among distracters, searching generally becomes less efficient (Duncan & Humphreys, 1989). Perceptual discrimination plays a role in determining slope as the easier it is for an individual to discriminate between the target and the distracter the less time they need to spend on each item, increasing search efficiency. Slope is calculated by taking into account only the RT x set size function, thus an individual who responds with a median RT of 1100 ms could obtain the same outcome measure as a person responding with a much slower median RT of 2500ms. Another outcome measure that is sometimes used is the y-intercept of a person's RT x set size function (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Keehn, Brenner, Palmer, Lincoln, & Müller, 2008). This gives more information on how quickly they are responding, and is more related to information processing speed.

For example, in figure 1, the slope and intercept can be calculated for target-present (red line) and target-absent (green line) trials using the formula of y=mx+b, with 'm' representing the slope and 'b' representing the y intercept. The target-present slope in this example would be 29 and the target-absent slope would be 80. Using the same formula, the target-present intercept would be 809 ms, and the target-absent intercept would be 880 ms.

Visual Search in Autism

The feature-search task and the conjunctive-search task are the most common types of visual search tasks used to investigate visual search in people with autism. Better visual search performance among people with autism was first described by Plaisted and colleagues who found that a group of children with autism was more accurate at distinguishing highly similar stimuli when compared with a control group on a conjunctive-search task, but not on the feature-search task. This was hypothesized to be due to ceiling effects on the feature-search task (Plaistad et al., 1998). These results were corroborated with a subsequent replication of the first (O'Riordan et al., 2001).

The second experiment used vertical and tilted lines as the stimuli. In the typical population searching for a tilted line among vertical lines has been found to be processed in a parallel way, and searching for a vertical line among tilted lines has been found to be processed in a serial way (Treisman & Gormican, 1988). They found that the children with autism were faster at this task as well, especially in the more difficult, serial condition. This finding of faster feature detection in autism was also found to extend across the lifespan (O'Riordan, 2004), indicating that superior visual search ability is likely a developmentally stable characteristic of the disorder. Subsequent studies have determined that superior visual search ability in autism is not due to a better search strategy (Kemner, van Ewijk, van Engeland, & Hooge, 2008) or memory for previously searched distracters (Joseph et al., 2009) but rather greater discrimination ability (O'Riordan et al., 2001; O'Riordan, 2004), evidenced by shorter fixation times when searching an array (Joseph et al., 2009; Kemner et al., 2008).

Despite many years of research into this phenomenon, it is not clear what it is about people with autism that contributes to their enhanced performance on conjunctive-search tasks. It is possible that it is a particular symptom of autism that is related to this performance, or that it is the unique combination of autism symptomology that enhances performance on detailed visual processing tasks. The primary aim of this study was to better understand which symptoms or combination of symptoms contribute to performance on this task.

Theories of Perception in Autism

There are at least two theoretical accounts of the enhanced visual processing in autism. The weak central coherence theory posits the idea that people with autism have trouble integrating information from many different sources into a cohesive whole (Frith & Happé, 1994). This results in strengths in perceiving detailed and low-level information, but difficulty with higher-level cognitive processes and perception.

The enhanced perceptual functioning model (Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006), suggests that *superiority* of perceptual information (when compared to higher-order cognitive operations) leads to an atypical relationship between high and low order cognitive processes in autism. This makes perceptual processes more difficult to control, and also more disruptive to the development of other behaviours and abilities, such as social and communicative skills. This model also proposes the idea of the primacy of local orientation in autism; versus the global orientation people without autism generally adhere to first. In contrast to the weak central coherence theory, this model does not claim that there are necessarily deficits in higher order processes in autism, but rather that people with autism seem to have a tendency to attend to perceptual details more than is typical.

Symptom Clusters of Autism

Thus far, studies on visual search in autism have focused on differences between people with autism and the typical population, rather than on differences within the autism group itself. This is an important area to consider, as autism is a spectrum disorder and the lack of homogeneity in this group is a large obstacle in research. Moreover, although all individuals with an autism spectrum diagnosis by definition have impairments in all three areas of communication, social development, and increased restrictive and repetitive behaviours, some individuals have more marked symptoms in one or two of the areas. This makes it possible to measure the severity of the symptom domains in each individual with autism.

Joseph and colleagues (2009) investigated the relationship between autistic symptoms as measured by the Autism Diagnostic Observation Schedule (Lord et al., 2000) and performance on a visual search task. They found that faster reaction time scores as measured by the intercept were significantly associated with the social symptom scores as measured by the ADOS, meaning the more social impairments the children with autism showed, the faster they were at detecting a black ‘L’ amongst an array of black ‘T’s with stimuli in a variety of rotations on the visual search task. There was no significant association between target-detection speed (intercept) and the communication or the repetitive behaviour domains on the ADOS, and no relationship between slope and any of the domains.

Hypotheses

This study investigated whether performance on visual search for targets with conjunctive features is specifically associated with particular symptoms or clusters of symptoms that occur in autism. Greenaway and Plaisted (2005) outlined the consequences of people with autism having selective attention to certain types of stimuli. They posited that because social stimuli are made up of a high number of stimuli amalgamated in a complex way, over-selection of certain stimuli could result in people with autism focusing on one aspect (e.g. voice pitch or eyebrow positioning) while missing other subtle stimuli more important to social skills. This is consistent with the enhanced perceptual functioning model. This model predicts that people with autism should process detailed, visually presented stimuli better than typically developing people due to the superiority of detailed perceptual stimuli that they attend to first before seeing things at the global level. The previous studies on visual search in autism have supported this prediction. Joseph and colleagues (2009) found preliminary evidence to suggest that children with autism who show better performance on a feature visual search task as measured by intercept were more impaired on the social interaction domain of the ADOS.

In the current study it was hypothesized that higher scores on the social skills domain (reflecting poorer social skills) as measured by the AQ would be associated with better performance on the visual search task. In addition, it was predicted that the attention to detail domain of the AQ (one of the subdomains on that instrument) would be significantly associated with performance on the visual search task.

METHOD

Participants

Participants consisted of thirty individuals with autism between the ages of 8 and 19 years old. Participants were recruited from an Autism and Developmental Disorder Lab database of individuals with an autism diagnosis in the Lower Mainland who had consented to be contacted for future studies. There were 26 males and 4 females who participated, which reflects the relative prevalence rates of autism in males and females (American Psychiatric Association, 2000).

This study was conducted in accordance with the standards of the Department of Research Ethics at Simon Fraser University (SFU). Participants came to the Autism and Developmental Disorders Lab (ADDL) at the university. They completed the visual search task on a computer in a separate testing room. After completing this task, the Wechsler Abbreviated Scale of Intelligence (WASI) was administered to obtain an IQ score for the participants. The WASI is an IQ test that assesses cognitive functioning on verbal and nonverbal tasks. Full-scale IQ was calculated for each participant, and participants were excluded if they had a FSIQ of <75. The average IQ of this group was 104, which falls in the average range. A $20 gift card was given to each participant as compensation for their participation.

Participants were not excluded if they had other comorbid disorders (such as ADHD). This is because the high rate of comorbidity with autism and other disorders (American Psychiatric Association, 2000) would reduce the sample to only a very narrow group of people with autism when the research goal was to look at as broad a sample of people with autism as possible (including Autism, Asperser's Syndrome, and PDD-NOS). Out of the thirty participants in this study, eleven had a comorbidity of ADHD, three had an anxiety disorder, two had Tourette's syndrome, one had a nonverbal learning disability, and another had depression. Twelve were on psychostimulant medication (e.g. Concerta, Strattera, Biphentin), and three were on antidepressants.

For the purposes of this study, the participants must have been previously diagnosed by a clinician using the DSM IV-TR criteria for autism (American Psychiatric Association, 2000). The Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) was administered to all participants either by a trained researcher in the lab, or by a clinician in BC if they had had a recent diagnostic assessment. Clinical diagnoses of autism in the province of BC must be conducted by clinicians who were trained on the use of the ADI-R and the ADOS. The clinicians must use both these tools in their diagnostic assessment of a child suspected of having autism in order for the family to qualify for treatment funding in BC. The ADI-R is a standardized, semi-structured interview done with a parent or caregiver, and used to diagnose autism. It was used in this study to verify the autism diagnosis of participants made by independent clinicians. It has 93 items that ask about early development of the child. Questions fall into domains such as restricted interests, communication, and reciprocal social interaction. Scores are entered into the diagnostic algorithm for the measure to determine whether the child meets the cut-off for a diagnosis of autism. None of the prospective participants failed to meet the retrospective cut-off for an autism diagnosis as recommended by manual publishers. See table 1 for more detailed participant information.

Table 1. Participant Characteristics

Sex	IQ	Diagnosis	AQ Score
Male= 26	Mean= 104	Autism= 16	Mean= 34
Female= 4	SD=17	Asperger's=8	SD=6
		PDD-NOS= 6	

Measurement of Autism Symptoms

To measure autistic traits the Autism Quotient was administered. The AQ- Child version (Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008) was used for participants who were 8-11 years old, the AQ- Adolescent (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006) was used for 12-16 year olds, and the AQ- Adult was used for the 17-19 year olds (Baron-Cohen et al., 2001). All versions of the AQ are comparable in content and make-up of questions, the difference being the wording to make it appropriate for the given age group.

The AQ is a parent-report (child and adolescent versions) or self-report (adult version) questionnaire which measures traits in five domains found to be indicative of a diagnosis of autism: communication, social skills, attention switching, attention to detail and imagination. Each item has a Likert scale, and responses range from definitely agree to definitely disagree. The responses are worded in both directions to control for response bias, and half the questions are reverse-scored. The five specific domains on the AQ are made up of ten items each. For example, a question on the social domain is, "S/he prefers to do things with others rather than on her/his own", and a question on the attention to detail domain is, "S/he usually notices house numbers or other strings of information" (Auyeung et al., 2008).

Test-retest reliability on the AQ-Child (r=.85), AQ-Adolescent (r=.92) and AQ-Adult (r=.70) are all high, and the internal consistency as measured by Cronbach's alpha coefficient are moderate to high in all domains on all versions. The experimenter ensured that the parent of each participant had answered all questions on the questionnaire. All participants had computable AQ scores as per the administration instructions.

Visual Search Task

Apparatus

Stimuli were generated by a 16” CRT colour computer monitor on which the multi-element displays were shown. Participants were presented with a conjunctive-search in which the participant was to find a red ‘X’ amongst distracter red ‘T’s’ and green ‘X’s’.

Stimuli

Consistent with the type of tasks used in previous research in this area (Plaisted et al., 1998) the stimuli consisted of 5, 15 or 25 coloured letters presented on a black screen centred around a white cross. The letters were arranged on an imaginary grid of 16.8 cm x 16.8 cm, with each letter measuring half a centimetre in height and width. Letter stimuli varied on the dimensions of colour (either red or green) and form (either X or T). The target letter was always a red X, consistent with that in previous studies (O'Riordan et al., 2001).

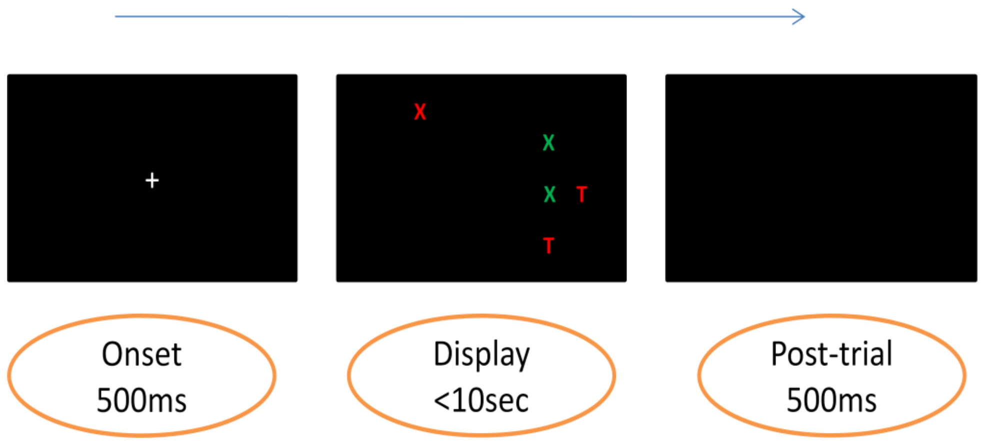

Figure 2. **Illustration of events occurring on a target-present trial with a 5 element display size**

Design and Procedure

The task lasted approximately 15 minutes, with a 1-minute break at the halfway mark. There were a total of 120 test trials (two blocks of 60 trials each), which contained two factors: display size (5, 15, or 25 letters) and whether the target was absent or present. The order of trials was randomized across display sizes and target-present/target-absent. Participants were instructed to search for the red letter X (which was placed amongst green X's and red T's) and to ignore any other letters that appeared on the screen.

The participants responded by pressing one of two buttons with their index fingers, which were labelled with a sticker with a red X on it (the "," key, which they pressed if they could find the target) and a sticker with a blank on it (the "z" key, which they pressed if they couldn't find the target). None of the other keys were marked, and three of the keys were removed (the escape key and the two window keys) in order to ensure that they were not pressed by accident. Participants were instructed to work as fast as they could, but to make as few mistakes as possible.

After being given the instructions participants were given 12 practice trials. As in the test trials, there were an equal number of practice trials for each display size, and half the trials had the target-present and half had the target-absent. The target-absent trials were included as “catch trials” to ensure that the participants weren’t responding haphazardly without locating the target. Before every practice and test trial, a central fixation point (in this case a white cross) appeared 500 ms before the stimuli, and the stimuli remained on the screen until the participant responded, or 10000 ms, whichever was shorter. A black screen appeared for 500 ms after each trial.

Reaction-Time and Accuracy Measurements

Medians were used for all analyses as a way of reducing the influence of outliers. Reaction time (RT) was measured in milliseconds and error data was collected for each trial. If a participant was distracted for a trial or there was a computer malfunction it was manually recorded and that trial was subsequently omitted and median was calculated using the remainder of the trials. This procedure was necessary for only two participants. Analyses were conducted on correct response trials only.

RESULTS

Alpha was set at .05 for all analyses. Outcome measures of performance on the visual search task were calculated by determining the slope and intercept for the target-absent and target-present trials separately using RTs from correct trials only. Consistent with previous research, target-present trials were responded to significantly faster overall than target-absent trials ($t(29)= 21.37$, $p=.00$), and slopes were significantly shallower on target-present trials than target-absent trials ($t(29)= 7.29$, $p=.00$). Because of the wide age range, all analyses were conducted after statistically controlling for age by entering it in the regression analyses.

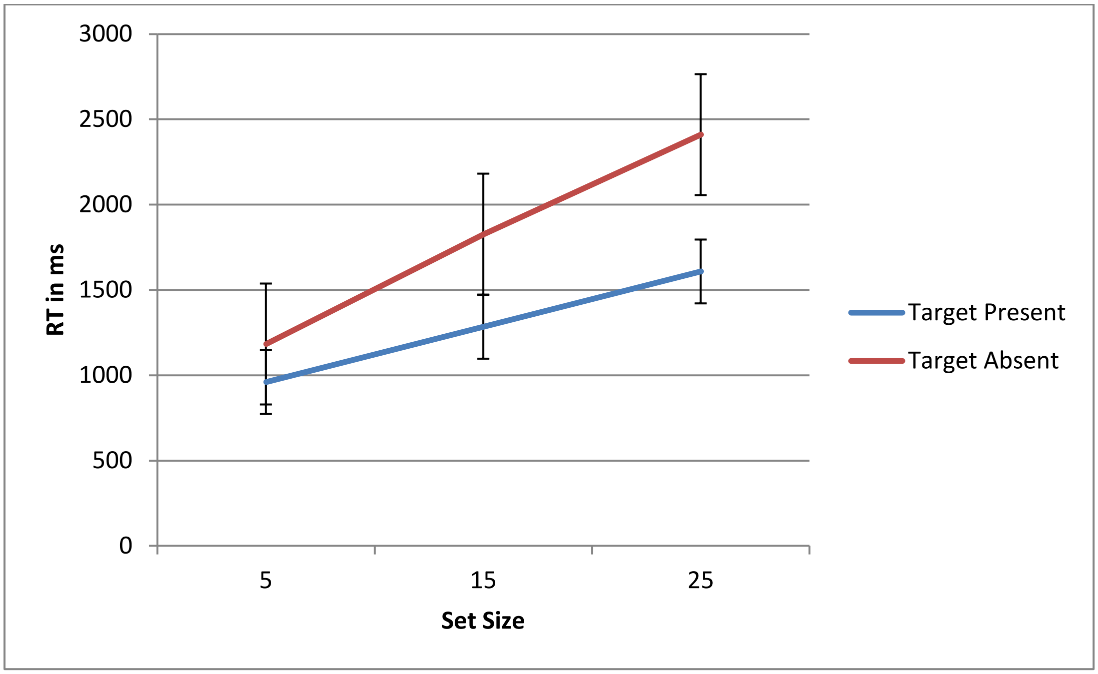

Figure 3. Results of the conjunctive-search task with standard error bars.

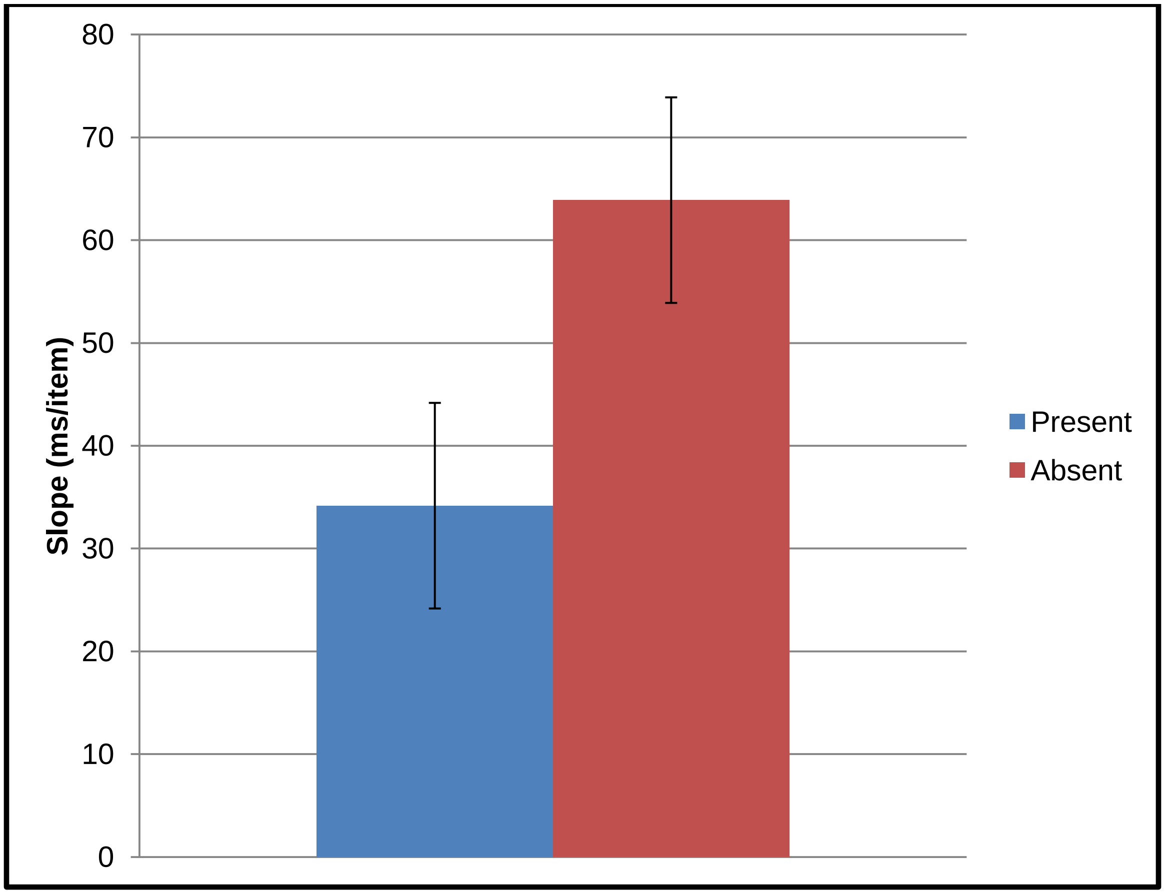

Figure 4. **Median slope of the RT x set size function**

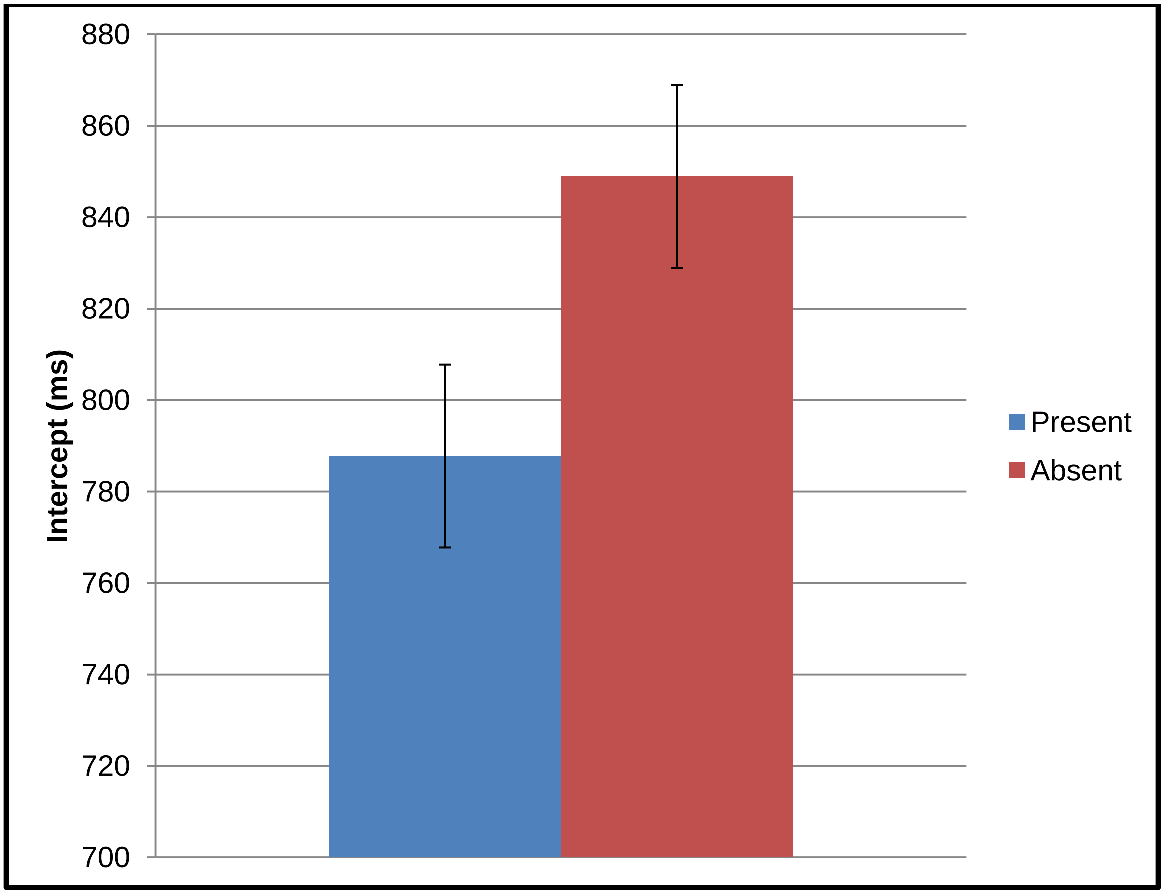

Figure 5. Median intercept of the RT x set size function

Speed-Accuracy Trade-Off

A correlation analysis was used (p=.05) to investigate whether there was evidence of a speed-accuracy trade-off. Speed was calculated by using the median RT for each individual's total responses. The average error rate for the group was 7%, which is comparable to previous research. No speed-accuracy trade-off was found (r= .25, p=.19).

Multiple Regression Analysis of Symptom Domains and Task Performance

Table 2. Results of Regression Analysis

	Slope Present		Slope Absent		Intercept Present		Intercept Absent	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Social	-.693	.495	.742	.466	-1.490	.150	-3.191**	.004
Attention Switching	.851	.404	.132	.896	1.128	.271	1.447	.161
Attention to Detail	-2.084*	.048	-.641	.528	.969	.342	-.405	.689
Communication	.634	.532	.029	.977	1.098	.284	.806	.428
Imagination	.355	.726	-.480	.636	-.999	.328	-.593	.559

Note. *p<.01, **p<.05

Target-Present Slope Analysis

An ordinary least squares regression analysis was conducted to find the partial regression coefficients of the five AQ domains. An F-test was conducted to determine whether the squared multiple regression coefficient was significant at $\alpha=.05$ when the five AQ domains were included in the model as predictors. The adjusted R^2 was used as an indicator because of the smaller sample size. It was found that R^2 was not significant ($F(6,23) = 1.062$, $p > .05$) and that adjusted $R^2 = .013$. This result implies that the predictors in the model do not account for a significant amount of the variance.

T tests were used to look at each of the five predictor variables separately to determine whether any of the corresponding standardized partial regression coefficients were significantly different from zero, which would indicate that they account for a significant proportion of the variance in RT above and beyond the others. In the regression equation of looking at whether any of the five domains of the AQ account for a significant amount of the variance in RT, the standardized partial regression coefficient for the attention to detail domain ($\beta = -.42$, $t(23) = -2.084$, $p = .048$) showed statistical significance at $\alpha = .05$ implying that this domain accounts for a significant amount of the variance in slope. This means that the higher the score in this domain, reflecting better attention to detail, the shallower the slope in the target-present condition. A shallower slope demonstrates that the responder is less influenced by the increasing number of distracters.

It is important to note that the reason why the correlation was not significant between overall AQ and RT, and the regression including all five AQ domains found the attention to detail domain to be significant is because in bivariate correlation all the domains are given equal weight, whereas in the regression equation, ordinary least squares determines the optimal weighting of the different domains (and in this case more weight would be given to the attention to detail scale). No other AQ domains accounted for a significant amount of the variance in this regression.

Target-Absent Slope Analysis

The same analysis was conducted for the slope in the target-absent condition. It was found that R^2 was not significant ($F(6,23) = .596$, $p > .05$) and that adjusted $R^2 = -.09$, which implies that the predictors in the model do not account for a significant amount of the variance. In the regression equation of looking at whether any of the five domains of the AQ account for a significant amount of the variance in RT, no AQ domains accounted for a significant amount of variance above and beyond the others in this regression.

Target-Present Intercept Analysis

The same analysis was conducted for the intercept of the target-present condition. It was found that R^2 was not significant ($F(6,23) = 1.279$, $p > .05$) and that adjusted $R^2 = .055$, which implies that the predictors in the model do not account for a significant amount of the variance. In the regression equation that examined whether any of the five domains of the AQ account for a significant amount of the variance in RT, no AQ domains were found to account for a significant amount of variance above and beyond the others in this regression.

Target-Absent Intercept Analysis

The same analysis was conducted for the intercept in the target-absent condition. It was found that R^2 was significant ($F(6,23) = 2.976$, $p < .05$) and that adjusted $R^2 = .290$, which implies that the predictors in the model account for a significant amount of the variance. In the regression equation with the five domains of the AQ, the standardized partial regression coefficient for social domain ($\beta = -.81$, $t(23) = -3.191$, $p = .004$) showed statistical significance at $\alpha = .05$ implying that this domain accounts for a significant amount of the variance in RT slope independently, above and beyond the other AQ domains. This indicates that the higher the score in this domain, reflecting poorer social skills, the faster the response in the target-absent condition.

Participant Subgroup Analysis

Because it was thought that having a comorbid diagnosis of ADHD or being on psychostimulant medication might affect performance on the conjunctive-search task, independent samples t-tests were performed to see if the groups differed on any of the outcome measures (slope-present, slope-absent, intercept-present, intercept-absent). There were ten participants who had a comorbid diagnosis of ADHD and twenty who did not, and the t tests showed no significant differences between the groups on any of the outcome measures at $p=.05$. There were eleven participants who were currently taking a psychostimulant medication and nineteen who were not. This group consisted of most, but not all, of the same grouping of participants as the previous analysis. The t tests of this analysis also showed no significant differences between the groups on any of the outcome measures at $p=.05$. This indicates that having a comorbid diagnosis of ADHD or taking a psychostimulant medication did not affect performance on the conjunctive-search task in this sample.

DISCUSSION

Numerous studies have found that performance on visual search tasks is enhanced in people with autism. The aim of this study was to examine whether certain symptoms of autism were related to the enhanced performance previously found in this group on visual search tasks. It was predicted that the social skill domain, and the attention to detail domain would be related to visual search performance. This hypothesis was supported, and these domains were found to account for a significant amount of the variance in performance above and beyond the other domains, but in different aspects of performance on the task.

Specifically, it was found that different symptoms of autism underlie different aspects of performance of conjunctive visual search tasks in this population. In particular, this study found that people who have better attention to detail are less distracted by distracters when the target is *present*, and people who have more social difficulties perform faster when the target is *absent* in an array. This latter finding provides more evidence for a possible link between enhanced perceptual processing, and diminished social processing. Until now, these two lines of research have been fairly separate in the autism field. However, this study suggests it would be worthwhile to investigate the relationship between these two symptom domains in more detail. This could be a key factor in helping researchers develop a unified explanation for the diverse symptom domains of autism, which has so far been elusive.

The current findings are consistent with Joseph et al.'s (2009) results indicating that impairments in social interactions are related to faster performance on a visual search task. Joseph et al.'s results differed somewhat in that they found social skills deficits to be related to the target-present condition rather than the target-absent condition. There are three methodological reasons why the outcomes of these two studies may differ.

First, the studies used different types of search tasks with different stimuli. Joseph et al.'s study was a feature visual search task while this study was a conjunctive visual search task. The studies used stimuli of different colours and shapes that may have been processed in different ways by participants (Bertone, Mottron, Jelenic, & Faubert, 2005). Secondly, the studies differed on the index they used to measure social skills. Joseph and colleagues used the social domain score from the ADOS which is a diagnostic measure and not designed to measure severity of autism symptomology, while this study used the AQ-Social domain score, which is a self-report measure. Therefore it is quite possible that the two scales were not measuring exactly the same aspects of social skills and behaviour. Finally, the studies used different types of statistical methods- Joseph and colleagues used correlation analysis while this study used regression analysis.

The overall finding that social processing and detailed perceptual processing are inversely related in autism, that is, poorer social processing is related to better perceptual processing was consistent across the studies. The methodological differences between these studies, and their different outcomes, further highlights the need to more thoroughly investigate the different aspects of visual search processing in autism. Researchers need to pay attention to the indices being used to measure particular processes, and to evaluate whether the tools and paradigms being used are actually measuring what we intend them to measure.

The finding from this study that different symptoms of autism were related to different aspects of search performance has significant implications for both the methodology of future studies, and for our understanding of previous research using visual search paradigms with people in this population. Past studies have assumed that a variety of visual search tasks have been measuring the same underlying processes in autism (O'Riordan et al., 2001; O'Riordan, 2004; Joseph et al., 2009). This is in part because results were consistent in demonstrating that people with autism appeared to have enhanced perceptual processing and discrimination based on the outcome measures used.

This study, however, found that different symptoms were related to different aspects of visual search in autism. The findings imply that target-present and absent conditions may involve different processes. For example, as the target-present condition includes the target element in an array of similar distracters, success in this condition may be more related to attention to detail. One's ability to attend to the small details would reduce the impact of increasing the set size, which is what was found in this study: the attention to detail domain was related to performance on the target-present, but not the target-absent condition. The target-absent condition, on the other hand, may be related to characteristics that are entirely different. As there is no target in this condition, performance on this task may instead be related to the decision of when one decides the element is absent (Chun & Wolfe, 1996). One could either scan every element in the display before deciding to respond, or they could scan enough elements that they are relatively confident that the target is absent. This study also suggests that the dependent measure one chooses may reflect different aspects of performance as the symptoms of autism found to be underlying performance varied depending on the outcome measure (slope or intercept thought to represent discrimination ability and speed of perceptual processing, respectively) chosen to represent performance on the visual search task.

The results of this study suggest that research on visual perception in autism needs to be re-focused on understanding more about the particular processes contributing to enhanced feature detection and search. This study also highlights the need to investigate further the link between enhanced visual perception and diminished social perception in autism. This research goal is timely and relevant since the new diagnostic criteria for autism is scheduled to be implemented in the DSM V in 2013.

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders- text revision* (4th ed.). Arlington, VA: APA.

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: Children's version (AQ-child). *Journal of Autism and Developmental Disorders, 38*(7), 1230-1240. doi:10.1007/s10803-007-0504-z

Baron-Cohen, S., Hoekstra, R. A., Knickmeyer, R., & Wheelwright, S. (2006). The autism-spectrum quotient (AQ)--adolescent version. *Journal of Autism and Developmental Disorders, 36*(3), 343-350. doi:10.1007/s10803-006-0073-6

Baron-Cohen, S. Wheelwright, S., Skinner, R., Martin, J. & Clubley, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High Functioning Autism, Males and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders, 3,* 5-17.

Beck, M. R., Lohrenz, M. C., & Trafton, J. G. (2010). Measuring search efficiency in complex visual search tasks: Global and local clutter. *Journal of Experimental Psychology: Applied, 16*(3), 238-250. doi:10.1037/a0019633; 10.1037/a0019633.supp (Supplemental)

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain: A Journal of Neurology, 128*(10), 2430-2441. doi:10.1093/brain/awh561

Chiang, H., & Carter, M. (2008). Spontaneity of communication in individuals with autism. *Journal of Autism and Developmental Disorders, 38*(4), 693-705. doi:10.1007/s10803-007-0436-7

Chun, M. M., & Wolfe, J. M. (1996). Just say no: How are visual searches terminated when there is no target present? *Cognitive Psychology, 30*(1), 39-78. doi:10.1006/cogp.1996.0002

Cohen, D., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple Regression/Correlation analysis for the behavioural sciences* (3rd ed.). Mahwah, N.J.: Lawrence Erlbaum.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*(3), 433-458. doi:10.1037/0033-295X.96.3.433

Frith, U., & Happé, F. (1994). Autism: Beyond 'theory of mind.'. *Cognition, 50*(1-3), 115-132. doi:10.1016/0010-0277(94)90024-8

Greenway, R. & Plaisted, K. (2005). Top-down attentional modulation in autistic spectrum disorders in stimulus-specific. *Psychological Science, 16*, 987-994.

Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature Neuroscience, 9*(10), 1218-1220. doi:10.1038/nn1770

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and asperger syndrome faster than normal on the embedded figures test? *Journal of Child Psychology and Psychiatry, 38*(5), 527-534. doi:10.1111/j.1469-7610.1997.tb01539.x

Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science, 12*(6), 1083-1096. doi:10.1111/j.1467-7687.2009.00855.x

Keehn, B., Brenner, L., Palmer, E., Lincoln, A. J., & Müller, R. (2008). Functional brain organization for visual search in AUTISM. *Journal of the International Neuropsychological Society, 14*(6), 990-1003. doi:10.1017/S1355617708081356

Kemner, C., van Ewijk, L., van Engeland, H., & Hooge, I. (2008). Brief report: Eye movements during visual search tasks indicate enhanced stimulus discriminability in subjects with PDD. *Journal of Autism and Developmental Disorders, 38*(3), 553-557. doi:10.1007/s10803-007-0406-0

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr., Leventhal, B. L., DiLavore, P. C., . . . Rutter, M. (2000). The autism diagnostic observation Schedule—Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3), 205-223. doi:10.1023/A:1005592401947

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic Interview—Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*(5), 659-685. doi:10.1007/BF02172145

Mottron, L., Belleville, S., & Ménard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry, 40*(5), 743-755. doi:10.1111/1469-7610.00490

Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In P. R. Zelazo (Ed.), *The development of autism: Perspectives from theory and research.* (pp. 131-148). Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*(1), 27-43. doi:10.1007/s10803-005-0040-7

O'Riordan, M. A. (2004). Superior visual search in adults with autism. *Autism, 8*(3), 229-248. doi:10.1177/1362361304045219

O'Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance, 27*(3), 719-730. doi:10.1037/0096-1523.27.3.719

Plaistad, K. C., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism: A research note. *Journal of Child Psychology and Psychiatry, 39*(5), 777-783. doi:10.1017/S0021963098002613

Rumsey, J. M., & Hamburger, S. D. (1988). Neuropsychological findings in high-functioning men with infantile autism, residual state. *Journal of Clinical and Experimental Neuropsychology, 10*(2), 201-221. doi:10.1080/01688638808408236

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24*(4), 613-620. doi:10.1111/j.1469-7610.1983.tb00137.x

Treisman, A. M., & Gelade, G. (2000). A feature-integration theory of attention. In S. Yantis (Ed.), *Visual perception: Essential readings.* (pp. 347-358). New York, NY US: Psychology Press.

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95*(1), 15-48. doi:10.1037/0033-295X.95.1.15