Age-Related Changes in Conjunctive Visual Search in Children with and without ASD

Grace Iarocci and Kimberly Armstrong

Visual-spatial strengths observed among people with autism spectrum disorder (ASD) may be associated with increased efficiency of selective attention mechanisms such as visual search. In a series of studies, researchers examined the visual search of targets that share features with distractors in a visual array and concluded that people with ASD showed enhanced performance on visual search tasks. However, methodological limitations, the small sample sizes, and the lack of developmental analysis have tempered the interpretations of these results. In this study, we specifically addressed age-related changes in visual search. We examined conjunctive visual search in groups of children with ($n = 34$) and without ASD ($n = 35$) at 7–9 years of age when visual search performance is beginning to improve, and later, at 10–12 years, when performance has improved. The results were consistent with previous developmental findings; 10- to 12-year-old children were significantly faster visual searchers than their 7- to 9-year-old counterparts. However, we found no evidence of enhanced search performance among the children with ASD at either the younger or older ages. More research is needed to understand the development of visual search in both children with and without ASD. ***Autism Res** 2014, 7: 229–236.* © 2014 International Society for Autism Research, Wiley Periodicals, Inc.

Keywords: attention; visual search; development; perception

Introduction

Alongside the deficits in communication, social adaptation, and imagination among persons with autism spectrum disorders (ASD), researchers have noted strengths in visual-spatial and perceptual skills [Mottron, Belleville, & Ménard, 1999; O'Riordan, 2004; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaistaid, O'Riordan, & Baron-Cohen, 1998]. For example, people with ASD perform better than typically developing (TD) people on visual tasks that require attention to detail, such as embedded figures [Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983], impossible figures [Mottron et al., 1999], and block design tasks [Rumsey & Hamburger, 1988]. It is not known, however, to what extent these advantages in visual-spatial tasks among persons with ASD are related to an increased ability to discriminate information (perceptual account), or to increased attentional efficiency to search the visual field for specific targets (attentional account), or to a combination of perceptual and attentional factors. The preliminary evidence suggests that low-level visual perception (e.g. orientation discrimination, contrast sensitivity) may be atypical in individuals with ASD [e.g. Bertone, Mottron, Jelenic, & Faubert, 2005] and may advantage performance in some contexts but not in others (e.g. face processing). The perceptual account may be further complicated as it seems that the type of low-level perceptual atypicality may vary across individuals with ASD [Shafai, Armstrong, Iarocci, & Oruc, 2013].

With regard to the attentional account, a series of visual search studies were conducted and showed that the search performance of persons with ASD was enhanced when compared with their TD peers. However, methodological differences across studies (e.g. types and number of stimuli, number of trials), the small sample sizes, and the lack of developmental analysis (i.e. assessing search performance at only one developmental time period) have tempered the interpretations of these results. Significant deviations from the norm, whether with regard to deficient or enhanced attention, are best evaluated within a developmental framework. The components of selective attention such as visual search develop at different rates, and much like delays, advances in attentional development have important consequences on the developing visual system. Thus, without a developmental analysis of visual search among children with ASD, we suspect that conclusions about enhanced visual search in ASD may have been premature.

From the Department of Psychology, Simon Fraser University, Burnaby, British Columbia, Canada (G.I.,K.A.)
Received August 12, 2013; accepted for publication January 12, 2014
Address for correspondence and reprints: Grace Iarocci, Department of Psychology, Simon Fraser University, 8888 University Dr., Burnaby, British Columbia V5A 1S6, Canada. E-mail: giarocci@sfu.ca
This research was supported by:Grant Sponsor: Social Sciences and Humanities Research Council of Canada (SSHRC); Grant Number: 767–2011-2317 to G.I.; Grant Sponsor: Michael Smith Foundation for Health Research (MSFHR); Scholar Award to G. I. Grant Sponsor: Autism Research Training (ART) program funded by the Canadian Institutes of Health Research (CIHR); Grant Number: STN 63728 to K.A.
Published online 20 February 2014 in Wiley Online Library (wileyonlinelibrary.com)
DOI: 10.1002/aur.1359

Visual Search and Development

Visual search is a form of selective attention that involves scanning the visual field for a target that has unique features among an array of similar distractor stimuli. The feature-search and conjunctive-search paradigms provide the ideal framework in which to study spatial attention. In a feature-search task, the target is distinguished from distractors based on one feature, such as color (e.g. a red "X" among green "X's). Within this context, the target's distinct feature "pops-out" within the array, and search performance is largely unaffected by the number of distracters in the visual field [Treisman & Gelade, 2000]. However, in a conjunctive-search task, the target is detected only when the features (e.g. color and form) are integrated across dimensions (e.g. a red "X" among red "T"s and green "X"s). Here, search is thought to be more effortful as there is an increase in reaction time (RT) and/or errors as a function of display size.

Visual search tasks usually include varying display sizes (e.g. 6, 18, or 24 items per display), and performance can be measured in two ways. RTs can be calculated as a measure of overall speed. Slope, however, is calculated by taking into account only the RT × set size function, as RT typically increases with the number of distracters in conjunctive tasks [Chun & Wolfe, 1996]. 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].

The few studies on differences between simple feature search and feature conjunction search in children suggest that school-age children perform as well as adults on simple feature search tasks involving brightness, color, or orientation. However, children's performance on conjunction search tasks show better performance with age in both search rate (i.e. measured by a decrease with age in RT slopes over display size) and overall RT [e.g. Lobaugh, Cole, & Rovet, 1998; Merrill & Conners, 2013; Merrill & Lookadoo, 2004]. To determine which of several aspects of the conjunction search task was critical for obtaining these age-related differences, Trick and Enns [1998] compared a standard conjunction search task (multiple items in a spatial array) with the same task in which only one item was presented at the center of the screen (known location), in another they were presented at any one of the many possible locations in the standard task. Age differences were observed only in the standard task—when multiple items were spatially arrayed across the visual field. Thus, feature conjunction processing was not difficult for young children; rather, the age-related changes were associated with the moving of attention from one item to another. Several other processes may also show age-related changes and warrant further study (e.g. the strategy used for inspecting items, tagging items that have already been inspected, disengaging attention from a nontarget item, moving to the next candidate item).

Visual Search and ASD

Both feature and conjunctive-search tasks have been used to investigate feature detection and integration in people with ASD. The initial study on conjunctive visual search in ASD found that children with ASD ($n = 8$) were more accurate at distinguishing highly similar stimuli than their typically developing (TD) mental age-matched peers ($n = 8$), but not on a feature-search task [Plaistad et al., 1998]. Thus, only the conjunctive-search involving feature integration showed differences in performance across the groups. A second study included different stimuli (i.e. vertical and tilted lines in a feature-search paradigm), to extend the findings to a different search context [O'Riordan et al., 2001]. In this study, children with ASD ($n = 12$) were faster than the TD group ($n = 12$) at finding the vertical line among tilted lines but not on the easier task of finding a tilted line among vertical lines. This study used different matching procedures by matching the groups on performance IQ instead of verbal IQ, which was used in the first study. Again, the difference in search performance across the groups was evident in the more difficult search task. Subsequent studies were conducted in an attempt to determine which of several aspects of the conjunction search task was critical for obtaining these results. The researchers concluded that enhanced visual search ability in ASD was not due to better search strategy ($n = 8$) [Kemner, van Ewijk, van Engeland, & Hooge, 2008] or memory for previously searched distracters but rather, the shorter fixation times when searching a visual array ($n = 21$) [Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009], supporting the idea that people with ASD may have greater feature discrimination ability [O'Riordan, 2004; O'Riordan et al., 2001]. Enhanced visual search performance was also found among adults ($n = 10$) [O'Riordan, 2004] and toddlers with ASD ($n = 17$) [Kaldy, Kraper, Carter, & Blaser, 2011].

Current Study

In the current study, we extend previous research by evaluating conjunctive visual-search performance within a cross-sectional developmental design. We compare visual search performance in children with and without ASD in order to examine age-related changes in conjunctive visual-search, including whether differences in search performance are evident early and/or consistently across ages and groups. We examine conjunctive visual search in groups of children with and without ASD at 7–9 years

Table 1. Participant Characteristics

	ASD		TD	
Group	7–9 Years	10–12 Years	7–9 Years	10–12 Years
n	13	21	14	21
Age	8.1 (0.8)	10.9 (0.8)	8.3 (0.6)	11.2 (0.8)
IQ (WASI)	111 (17.3)	106 (16.6)	106 (13.6)	108 (13.6)
AQ	33 (8.3)	32 (6.3)	18 (8.0)	16 (5.8)

WASI, Wechsler Abbreviated Scale of Intelligence.

of age when visual search efficiency is beginning to improve, and later, at 10–12 years when efficiency has improved [Trick & Enns, 1998]. We expected to replicate previous developmental findings and thus predicted better search in the older TD group than the younger TD group. However, the enhanced search performance of younger and older individuals with ASD found in previous studies [Kaldy et al., 2011; O'Riordan, 2004] led us to hypothesize that they might be faster, more efficient, and/or more accurate as compared to the TD group at both ages.

Methods

Participants

Sixty-nine individuals between the ages of 7 and 12 years participated in the experiment. The children were recruited through community advertisements and from our lab's database. All participants were tested individually with a researcher administering the task. There were 34 participants (five female) with high-functioning ASD; the group of 7- to 9-year-olds had a mean age of 8.1 years ($n = 13$), and the group of 10- to12-year-olds had a mean age of 10.9 years ($n = 21$). There were 35 TD participants (9 female); the group of 7- to 9-year-olds had a mean age of 8.3 years ($n = 14$), and the group of 10- to12-year-olds had a mean age of 11.2 years ($n = 21$). The participants with ASD were matched on IQ with the TD group using the Wechsler Abbreviated Scale of Intelligence (WASI). The full-scale IQ was calculated for each child, and participants were excluded if they had a FSIQ of <80. The average FSIQ of the ASD and TD groups were equivalent and within the average range (see Table 1 for more detailed participant information). Parents of participants were asked whether their children were color blind or had any other visual impairment. Two participants originally contacted about the experiment were excluded for this reason. None of the participants included in the study reported any visual impairment. This study was conducted in accordance with the standards of the Department of Research Ethics at the university where it was conducted.

Measures

Confirmation of diagnosis in this study required a British Columbia (BC) clinical diagnostic report and the Ministry of Child and Family Development ASD funding eligibility report. The province of BC, in which this study was conducted, is unique in Canada in that obtaining a diagnosis of ASD is tied directly to substantial government funding, and therefore, there are standardized diagnostic practices in place. All individuals are required to be diagnosed by an ADOS and ADI-R trained clinician who uses these tools as well as clinical judgment to determine the diagnosis. Even individuals who have been diagnosed in a different province or country are required to be re-diagnosed upon their arrival in BC in order to access funding. The participants in this study received a standardized diagnosis for ASD in BC.

The AQ was administered to parents of the participants at the time of testing as an estimate of current level of ASD symptoms. The AQ-Child is a parent-report questionnaire which measures traits in five domains found to be indicative of a diagnosis of ASD: 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 items are reverse-scored [Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008]. Test–retest reliability ($r = 0.85$) is high, and the internal consistency as measured by Cronbach's alpha coefficient are moderate to high in all domains. All participants had computable AQ scores as per the administration instructions, and the mean of the group was above the cutoff for ASD.

See Table 1 for more detailed participant information.

Conjunctive Visual-Search Task

Stimuli. Stimuli for the conjunctive visual search task were generated by a CRT color computer monitor on which the multielement displays were shown. Participants were presented with a conjunctive-search task in which the participant was asked to find a red "X" among distracter red "T"s and green "X"s. Consistent with the type of tasks used in previous research in this area [O'Riordan et al., 2001], the stimuli consisted of 5, 15, or 25 colored letters presented on a black screen centered around a white cross fixation point. The letters were arranged on an imaginary grid of 16.8 cm × 16.8 cm, with each letter measuring half a centimeter in height and width. The minimum distance between elements was 0.7 cm. Letter stimuli varied on the dimensions of color (either red or green) and form (either X or T). The target letter was always a red "X". See Figure 1 for an example of a target-present trial.

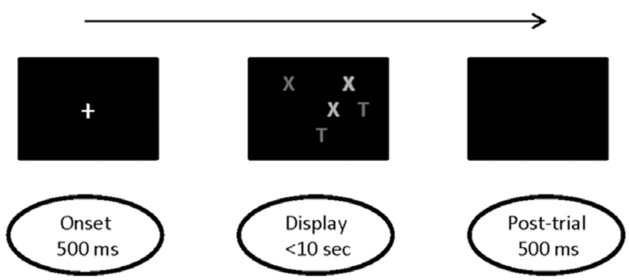

Figure 1. Illustration of events occurring on a target-present trial with a five-element display size.

Design and procedure. Participants were tested individually by a researcher. The task was approximately 15 min in length, with a break at the halfway mark. There were a total of 120 test trials (two blocks of 60 trials each) including manipulations of display size (5, 15, or 25 letters) and target presence or absence. The order of trials was randomized across display sizes and target presence. Participants sat 30 cm away from the computer screen. The participants were asked to identify as quickly as possible, without making mistakes, whether the target stimulus was present within an array. Participants were instructed to search for the red letter X (which appeared among 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, each labeled with a red X sticker (the "," key to indicate that the target was present) or a blank sticker (the "z" key to indicate that the target was absent). 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 accidently.

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 of the trials were target-present and half were 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 (a white cross) appeared 500 ms before the onset of stimuli. Following the central fixation point, the stimulus remained on the screen until the participant responded; if the participant did not respond within 10,000 ms, the stimulus automatically disappeared from the screen. A black screen appeared for 500 ms after each trial.

RT and accuracy measurements. Medians were used for all analyses as a way of reducing the influence of outliers. RT was measured in milliseconds, and error data were collected for each trial.

Results

Alpha was set at 0.05 for all analyses. Performance on the conjunctive visual-search task was calculated by using median RTs from correct trials only. Slopes of the target-present and target-absent trials were calculated for each participant for use in the efficiency analysis.

Matching of Participants

A one-way ANOVA was performed, and there were no significant differences between the ASD and TD groups on age ($F(1, 67) = 0.361$, $P > 0.05$) or FSIQ ($F(1, 67) = 0.09$, $P > 0.05$). Within the 7- to 9-year-old age group, there were no significant difference between diagnostic groups on age ($F(1, 25) = 0.62$, $P > 0.05$) or FSIQ ($F(1, 25) = 0.96$, $P > 0.05$). Within the 10- to 12-year-old age group, there were no significant differences between diagnostic groups on age ($F(1, 40) = 1.82$, $P > 0.05$) or FSIQ ($F(1, 40) = 0.70$, $P > 0.05$).

Error

A repeated-measures ANOVA was conducted with between-subjects factors of age group (younger or older) and diagnostic group (ASD or TD), and within-subject factors of target presence (present or absent) and set size (5, 15, or 25 elements). As expected, within-subjects factors of target presence ($F(1, 65) = 98.84$, $P < 0.001$) and set size ($F(2, 65) = 41.67$, $P < 0.001$) were significant. There was also a significant age group difference in accuracy ($F(1, 65) = 11.87$, $P < 0.01$). Visual inspection of error rates indicated that the ASD group had lower accuracy than the TD group on the target present condition. There was no diagnostic group by age group interaction ($F(1, 65) = 0.26$ $P > 0.05$), meaning that age-related differences in accuracy were similar across the groups of children with and without ASD. There were no significant interactions between age and target presence ($F(1, 65) = 3.69$, $P > 0.05$) or set size ($F(1, 65) = 2.11$, $P > 0.05$), or between group and target presence ($F(1, 65) = 2.35$, $P > 0.05$) or set size ($F(1, 65) = 1.74$, $P > 0.05$). There was a significant difference in accuracy between diagnostic groups ($F(1, 65) = 6.50$, $P < 0.05$). An analysis of the error rates indicated that the TD group was more accurate overall than the ASD group. See Table 2 for more information.

Age and Group Search Analyses

A repeated-measures ANOVA was conducted with between-subjects factors of age group (younger or older) and diagnostic group (ASD or TD), and within-subject factors of target presence (present or absent) and set size (5, 15, or 25 elements). As expected, within-subjects

Table 2. Accuracy on the Visual Search Task

		ASD		TD	
Set Size	Target presence	7–9 Years	10–12 Years	7–9 Years	10–12 Years
5	Present	0.89 (.09)	0.94 (.09)	0.91 (.08)	0.95 (.05)
	Absent	0.93 (.07)	0.96 (.05)	0.96 (.03)	0.99 (.04)
15	Present	0.80 (.14)	0.86 (.11)	0.85 (.14)	0.90 (.10)
	Absent	0.95 (.06)	0.98 (.03)	0.96 (.04)	0.98 (.03)
25	Present	0.69 (.13)	0.80 (.13)	0.78 (.15)	0.88 (.10)
	Absent	0.94 (.10)	0.98 (.03)	0.97 (.03)	0.97 (.03)

factors of target presence ($F(1, 65) = 222.64$, $P < 0.001$) and set size ($F(2, 65) = 333.73$, $P < 0.001$) were significant. Consistent with previous studies [e.g. Trick & Enns, 1998], there was also a significant age group difference in search performance ($F(1, 65) = 18.74$, $P < 0.001$). There was no diagnostic group by age group interaction, meaning that age-related differences performance were similar across the groups of children with and without ASD ($F(1, 65) = 0.018$, $P > 0.05$). Visual inspection of RTs indicated that older children had better performance than younger children in both groups. There were no significant interactions between age and target presence ($F(1, 65) = 0.015$, $P > 0.05$) or set size ($F(1, 65) = 1.641$, $P > 0.05$), or between group and target presence ($F(1, 65) = 0.249$, $P > 0.05$) or set size ($F(1, 65) = 0.021$, $P > 0.05$). There was no significant difference in performance between diagnostic groups on RT ($F(1, 65) = 2.05$, $P > 0.05$), meaning that the ASD and TD groups exhibited the same pattern of performance; they were faster with increasing age. Efficiency was examined by conducting a repeated-measures ANOVA with a between-subjects factor of age group (younger or older) and diagnostic group (ASD or TD), and within-subject factors of slope in the target present and absent conditions. As expected, the within-subjects factor of target presence was significant ($F(1, 65) = 167.57$, $P < 0.001$). There were no significant interactions between target presence and diagnostic group ($F(1, 65) = 0.20$, $P > 0.05$) or age group ($F(1, 65) = 0.57$, $P > 0.05$). There were no significant differences on efficiency between the age groups ($F(1, 65) = 2.09$, $P > 0.05$) or diagnostic groups ($F(1, 65) = 0.01$, $P > 0.05$). See Figures 2 and 3 for results of the conjunctive search analysis for the ASD and TD groups at younger and older ages.

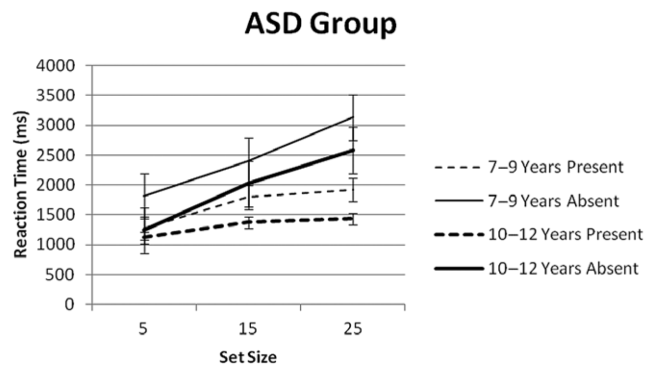

Figure 2. Results of the conjunctive-search task with standard error bars for the ASD group.

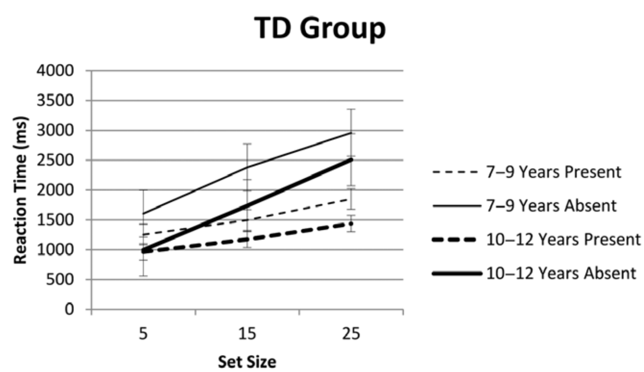

Figure 3. Results of the conjunctive-search task with standard error bars for the TD group.

Testing for Ceiling Effects

To rule out the possibility that the lack of diagnostic group differences was due to ceiling effects (i.e. that both groups of participants earned a maximum score due to the ease of the task), the same analyses were conducted with only the participants who were 7–10 years old. This was the age of participants in the previous conjunctive visual search studies which found enhanced performance among ASD participants [e.g. O'Riordan et al., 2001]. In the current study, there were 21 participants in the ASD group and 18 in the TD group in this age range. No significant difference between the groups was found on RT ($F(1, 37) = 0.276$, $P > 0.05$) or efficiency ($F(1, 37) = 0.016$. There was still a significant difference between the groups on accuracy ($F(1, 37) = 4.87$, $P < 0.05$), with the ASD group being less accurate than the TD group.

Testing for Number of Trials

We considered whether possible fatigue might play a role (this study included 120 trials vs. 60 trials in previous studies). Thus, we re-analyzed only the first 60 trials (first block in our study) on the 7- to 10-year olds which consisted of an equivalent number of trial types as previous studies [O'Riordan et al., 2001]. We did not find significant differences between the groups on RT ($F(1, 37) = 0.276$, $P > 0.05$) or efficiency ($F(1, 37) = 0.003$, $P > 0.05$). In this analysis, accuracy between the groups was *not* significant ($F(1, 37) = 3.07$, $P > 0.05$), indicating that the ASD and TD groups had the same level of accuracy in the first 60 trials.

Power

Since our hypothesis was not supported and instead we found no differences across groups on search performance, we conducted an estimate of power to quell concerns that the lack of difference was due to Type II error. When using $\alpha = 0.05$, with *n's* of 34 in the ASD group, and 35 in the TD group, our power was 0.98 [Howell, 2009]. When looking at the different age groups separately, it was found that in the 7- to 9-year-old group, with *n's* of 13 in the ASD group and 14 in the TD group, our power was 0.74. In the 10- to 12-year-old group, with an *n* of 21 in each group, our power was 0.89. Overall, we had sufficient power to detect a difference between the groups, especially when combining all participants and looking between the diagnostic groups across age ranges.

Discussion

The aim of this study was to examine conjunctive visual search performance among younger (7–9 years) and older (10–12 years) children with and without ASD. We found that 10- to 12-year-old children with and without ASD matched on IQ showed faster RTs when detecting targets with two features (i.e, color and shape) among similar distractors than the 7- to 9-year-old children with and without ASD. With regard to the TD children, the finding is consistent with previous developmental research showing age-related improvements on conjunctive visual search performance in children at approximately 10 years of age [Plude, Enns, & Brodeur, 1994; Trick & Enns, 1998]. However, unlike Trick and Enns [1998], we did not find search efficiency improvements with age in either group. This may be due to the type of conjunctive search employed; in the current study, color was a feature which may have elicited preattentive "pop out" for a subset of the items [Wolfe, Cave, & Franzel, 1989] as red is easier to segregate from green [Duncan & Humphreys, 1989] than shades of gray in the Trick and Enns study. Thus, in the current study set size may not have had as much of an effect on search performance because there may have been some guidance from preattentive processing of likely targets due to color "pop out." However, when young children engage in a fully deliberate serial search item by item to find the target item that is unique with regard to at least two features (shade of gray and form in the Trick and Enns study), it is effortful. They must move their attention strategically from one item to another until they have found their target. When no target is present, children must decide to abandon their search for the target item, and this too takes effort. According to Enns and colleagues, it is not the process of feature conjunction that is taxing for younger children, but rather, the movement of attention from one item to another that shows the most improvements with age. However, they cautioned that further work would be needed to investigate which aspect(s) of the search movement is implicated in the age effects (e.g. having a systematic plan for inspecting the array of items, tagging items that have already been inspected, disengaging attention from an irrelevant nontarget item, and moving to the next item) before definitive conclusions can be drawn. It would also be important to employ longitudinal designs to observe changes in visual search during critical developmental periods. This would permit the tracking of visual search trajectories as they mature over time.

Changes that occur over a shorter time span of the visual search task are also informative with regard to the factors that impact visual search performance. For example, in adults it was found that the cognitive strategy one used had a significant impact on visual search efficiency. A passive strategy that involved "the target item just popping into the mind" was much more efficient than actively directing attention to the search target [Smilek, Enns, Eastwood, & Merikle, 2006], The authors concluded that the improved search performance was due to reducing the reliance on executive control processes while permitting more rapid automatic processes for directing attention to drive the search. Based on their findings, the authors reasoned that further research on type of search instructions and cognitive strategy employed during search might be especially pertinent to understanding the visual search performance of children and particularly those with ASD, who have limited or impaired executive control functions. Would these children be able to search more efficiently under *some* conditions than those with fully developed executive control functioning and might the search efficiency of these children increase if they used a passive strategy that relied on their implicit processes rather than their immature executive processes? Clearly, significant strides need to be made to more fully understand how instructions and task demands influence the search performance of children.

Contrary to our hypothesis, we found no evidence of enhanced conjunctive search performance in the children with ASD at either the younger or older ages. Rather, we found decreased accuracy for the ASD group overall. Although the conjunctive search task was the same as the one used in previous visual search studies that found enhanced performance in people with ASD, we reasoned that perhaps potential differences in methodology might have influenced search performance in this study. To investigate this hypothesis further, we re-analysed the data using the same participant ages and the number of trials as in the original study [O'Riordan et al., 2001] wherein enhanced search performance among individuals with ASD was found. Even with these new parameters, no performance differences emerged across the groups, and the significant difference in accuracy disappeared when investigating performance on the first 60 trials only. This suggests that whereas the TD and ASD groups had comparable accuracy during the first block, the ASD group fatigued faster during the second block, resulting in lower accuracy overall.

We speculate on possible reasons why previous studies found enhanced search among individuals with ASD and we did not. One possibility is age-related differences in performance. We found that older children were significantly faster searchers than the younger children, yet in previous studies age differences were not considered.

Another possibility is that the finding of enhanced search in ASD is less robust than can be gleaned from the research literature. Studies with null findings in this area may exist but are rarely published in peer-reviewed journals. Thus, the possibility remains that the research literature reflects a performance difference bias [Sterling, Rosenbaum, & Weinkam, 1995],

Finally, methodological differences may, in part, explain the mixed findings across studies. A wide range of stimuli, procedures, and conditions have been used in previous studies on visual search, and the impact on task performance in people with ASD is poorly understood. For example, there is preliminary evidence that low-level visual perception (e.g. orientation discrimination, contrast sensitivity) in ASD is atypical [e.g. Bertone et al., 2005] and may advantage performance in some contexts but not others. Furthermore, the type of low-level perceptual atypicality may vary across individuals with ASD [Shafai et al., 2013]. Perceptual factors are implicated in visual search [Duncan & Humphreys, 1989]; thus, it may be helpful, as a starting point, to examine subgroups of children with ASD separately based on their perceptual performance. This differentiation may allow more refined hypotheses about visual search performance in children with ASD.

Attentional factors also need to be explored more thoroughly and from a developmental perspective. Future research could investigate the development of visual search beginning early in development and extending into adulthood to permit a more comprehensive understanding of age-related changes. Longitudinal research would be especially valuable in specifying whether developmental changes in visual search performance are similar across groups and whether there are similar developmental trajectories within the group of children with ASD. This type of methodology would more convincingly reveal which, if any, individuals with ASD show enhanced visual search abilities.

Author Note

Grace Iarocci, Department of Psychology, Simon Fraser University, 8888 University Dr. Burnaby, BC V5A 1S6, Canada

Kimberly Armstrong, Department of Psychology, Simon Fraser University, 8888 University Dr. Burnaby, BC V5A 1S6, Canada

The authors are grateful to the children and parents who participated in this study. Also deserving thanks are Elina Birmingham, Krista Johnston, Rana Emami, Bernardus Larryant, Hayley Lagroix, Fern Fayer, David Butler, Barb Peabody, and Andrea Hamel for helpful contributions at various stages of this research.

The authors declare that they have no conflict of interest.

References

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, 1230–1240. doi:10.1007/s10803-007-0504-z

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, 2430–2441. doi:10.1093/brain/awh561

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

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

Howell, D.C. (2009). Statistical Methods for Psychology (7th ed.). Belmont, CA: Wadsworth.

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, and Allied Disciplines, 38, 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, 1083–1096. doi:10.1111/j.1467–7687.2009.00855.x

Kaldy, Z., Kraper, C., Carter, A.S., & Blaser, E. (2011). Toddlers with autism spectrum disorder are more successful at visual search than typically developing toddlers. Developmental Science, 14, 980–988. doi:10.1111/j.1467–7687.2011.01053.x

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, 553–557. doi:10.1007/s10803-007-0406-0

Lobaugh, N.J., Cole, S., & Rovet, J.F. (1998). Visual search for features and conjunctions in development. Canadian Journal of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale, 52, 201–212. doi:10.1037/h0087293

Merrill, E.C., & Conners, F.A. (2013). Age-related interference from irrelevant distracters in visual feature search among heterogeneous distracters. Journal of Experimental Child Psychology, 115, 640–654.

Merrill, E.C., & Lookadoo, R. (2004). Selective search for conjunctively defined targets by children and young adults. Journal of Experimental Child Psychology, 89, 72–90.

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, and Allied Disciplines, 40, 743–755. doi:10.1111/1469–7610.00490

O'Riordan, M.A. (2004). Superior visual search in adults with autism. Autism: The International Journal of Research and Practice, 8, 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, 719–730. doi:10.1037/0096–1523.27.3.719

Plaistaid, 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, and Allied Disciplines, 39, 777–783. doi:10.1017/S0021963098002613

Plude, D.J., Enns, J.T., & Brodeur, D. (1994). The development of selective attention: a life-span overview. Acta Psychologica, 86, 227–272.

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, 201–221. doi:10.1080/01688638808408236

Shafai, F., Armstrong, K., Iarocci, G., & Oruc, I. (2013). Low- and high-level vision in individuals with autism spectrum disorder. Journal of Vision, 13, 841.

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

Smilek, D., Enns, J.T., Eastwood, J.D., & Merikle, P.M. (2006). Relax! Cognitive strategy influences visual search. Visual Cognition, 14, 543–564. doi:10.1080/13506280500193487

Sterling, T.D., Rosenbaum, W.L., & Weinkam, J.J. (1995). "Publication decisions revisited: The effect of the outcome of statistical tests on the decision to publish and vice versa," The American Statistician, 49, 108–112.

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: Psychology Press.

Trick, L.M., & Enns, J.T. (1998). Life-span changes in attention: the visual search task. Cognitive Development, 13, 369–386.

Wolfe, J.M., Cave, K.R., & Franzel, S.L. (1989). Guided search: an alternative to the feature integration model for visual search. Journal of Experimental Psychology. Human Perception and Performance, 15, 419–433.