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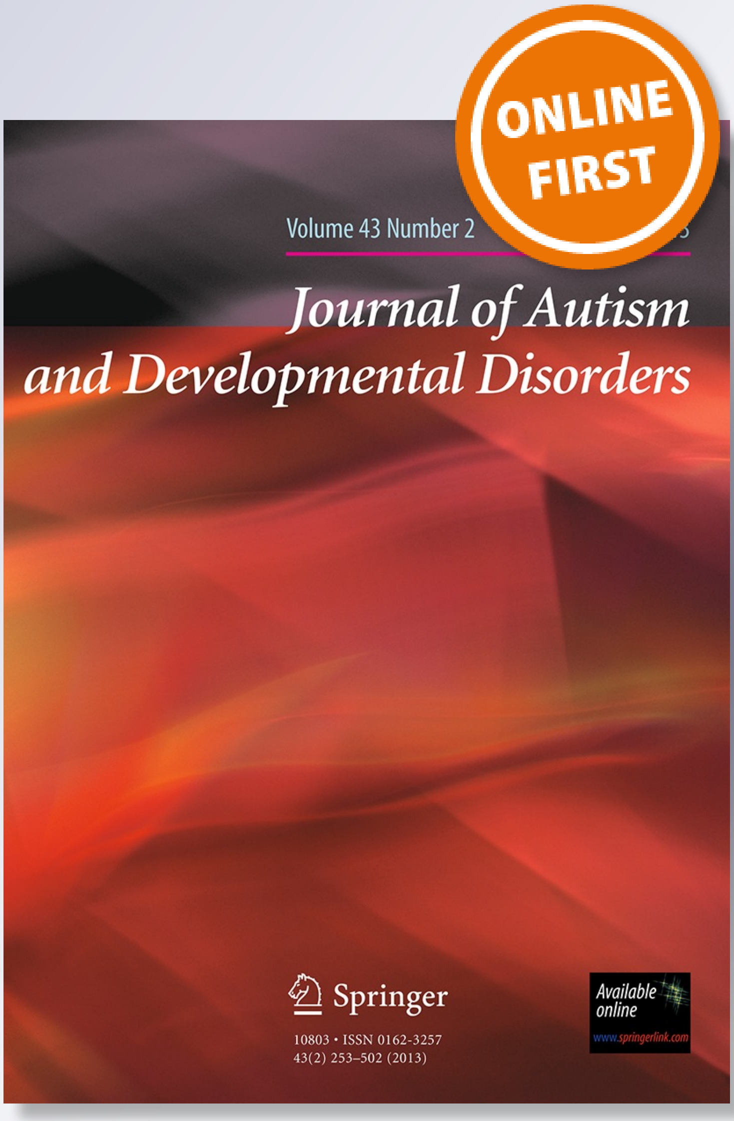

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ORIGINAL PAPER

Practice Makes Improvement: How Adults with Autism Out-Perform Others in a Naturalistic Visual Search Task

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Abstract People with autism spectrum disorder (ASD) often exhibit superior performance in visual search compared to others. However, most studies demonstrating this advantage have employed simple, uncluttered images with fully visible targets. We compare the performance of high-functioning adults with ASD and matched controls on a naturalistic luggage screening task. Although the two groups were equally accurate in detecting targets, the ASD adults improve in their correct elimination of target-absent bags faster than controls. This feature of their behavior is extremely important for many real-world monitoring tasks that require sustained attention for long time periods. Further analyses suggest that this improvement is attributable neither to the motor speed nor to the level of intelligence of the adults with ASD. These findings may have possible implications for employment opportunities of adult individuals with ASD.

Keywords Autism · Visual search · Luggage screening

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Introduction

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder diagnosed by behavioral atypicalities in social interactions and communication, as well as repetitive and stereotyped interests and behaviors. However, in contrast to these atypicalities that are often detrimental to functioning in daily life, extensive research indicates that ASD individuals also have unique perceptual and attentional characteristics as evidenced by superiority in visual processing and visual search compared to controls (for recent reviews, see Dakin and Frith 2005; Simmons et al. 2009). Although these demonstrations of enhanced visual skills have been highly informative, most of the studies to date have employed relatively simplistic tasks that lack the complexity of real-world visual scenes. The question to be addressed by this study is whether the superior visual skills reported in ASD transfer to enhanced performance in more realistic and naturalistic conditions.

Accurate performance on visual search tasks is a critical component of many workplace decisions, such as screening for dangerous objects at airport security, finding defects in products during a manufacturing process, and detecting abnormalities in mammograms. More mundane examples include locating one's keys on a cluttered desk and finding a desired box of cereal from the dense array of options on a supermarket shelf. If the visual search superiority of individuals with autism translates to complex visual scenes such as those above, not only would such a finding shed light on the visual skills of these individuals across a broader range of realistic scenarios, but these results would also have potential practical implications for the performance of ASD individuals in day-to-day job environments.

The goal of the current paper is to characterize the visual search ability of high-functioning adults with autism under

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one set of naturalistic conditions. We designed a Luggage Screening task, akin to that performed by airport luggage screeners, in which detection is required when a target is present and rejection is required when a target is absent. This is a realistic representation of a real-world visual search task that has been used in multiple studies with non-ASD adults (e.g., Gonzalez and Madhavan 2011). We compared the performance of a group of high-functioning ASD individuals to matched control participants in terms of correct detection of targets present (hit rate), correct rejection of targets absent (correct rejection rate), and response time. We also explored possible explanations for the differences in the performance profile between the ASD group and the control group.

In the following sections, we first summarize research demonstrating the superiority of ASD individuals on visual search tasks. Next, we describe research confirming that luggage screening is a complex and challenging visual search task for non-autistic adults. Based on this literature, we then outline predictions about how individuals with autism might fare under such complex visual search conditions.

Superiority of ASD Individuals on Visual Search

There is growing consensus that many individuals with ASD show superior performance across a host of visual tasks. Individuals with ASD (children and adults) outperform matched controls on the Embedded Figures task (Jolliffe and Baron-Cohen 1997; Shah and Frith 1983; although see White and Saldana 2011 for different results) and on Block Design tasks (Caron et al. 2006; Shah and Frith 1983) (also see Simmons et al. 2009 for more extensive review). Both types of task test participants' ability to discern particular patterns in the visual input and, in the latter case, reconstruct the pattern. Two prominent theories of autism, that of Weak Central Coherence (for example, see Happe and Frith 2006) and that of Enhanced Perceptual Function (Keita et al. 2011; Mottron et al. 2006) are consistent with the empirical findings cited above with the emphasis on the detail-focused cognitive style in the former theory and the emphasis on the superiority of sensory processing in the latter theory. These theories are also consistent with the observed performance of ASD individuals in compound, hierarchical tasks: their tendency toward processing leads to enhanced identification of individual letters even when presented in the context of incongruous global letters (for example, many small 's' letters organized into the shape of a larger 'H') (for example, Behrmann et al. 2006; Brosnan et al. 2004; Dakin and Frith 2005; Scherf et al. 2008). Even more relevant for the current study are the numerous reports in which children and adults with autism are better able than controls at discriminating target objects from distractor objects in conjunction visual search tasks in which, for example, the combination of two (or, in some cases, even three) stimulus dimensions, such as color and orientation, uniquely define the target in a conjunction task (O'Riordan 2004; O'Riordan and Plaisted 2001; Plaisted et al. 1998).

The superior visual discrimination ability of ASD individuals in visual search tasks has been mostly demonstrated via faster processing speed, while their accuracy has been roughly similar to that of matched controls (O'Riordan 2004; O'Riordan and Plaisted 2001; O'Riordan et al. 2001; Plaisted et al. 1998). For example, high-functioning adults with ASD were faster than controls at finding a target and made fewer fixations in both easy and difficult search tasks (Kemner et al. 2008; O'Riordan 2004). Furthermore, this enhanced ability has been observed across the age range of individuals with autism. Jarrold et al. (2005) found that adolescents with autism were close to one full second faster at detecting targets even in small (seven item) visual search displays than were matched controls. Joseph et al. (2009) showed that middle-school-aged children with autism exhibited overall faster response time in visual search than their typical counterparts; and, in a study using an eye tracker to measure looking behavior, toddlers with ASD were more successful than typical controls at finding the target in a visual search task and scrutinized roughly twice as many items as controls in the same amount of time (Kaldy et al. 2011).

Visual Search and Decision Making in the Real World: The Luggage Screening Example

In the real world, scanning for a target item of unknown location and presence amongst a number of noise items, and making a determination on the target item's presence or absence is a taxing—albeit common—task (Gonzalez and Madhavan 2011; Wolfe et al. 2005). For example, an airport security officer scans consecutive bags in search of possible threats in passenger luggage. Target prevalence is invariably low under such conditions, but misses (failure to detect a present target) have high cost. False alarms (deciding that the target is present when it is not) are also costly due to actions undertaken to resolve the uncertainty. In many visual search tasks, both correct detection of target-present instances and rejection of target-absent instances can usually be improved through more extensive and onerous search, but these strategies also incur added costs of time and effort. Ideally, performance would be fast, as well as accurate, on both correct identifications when the target is present and on correct rejections when the target is absent. Given practical constraints on the time and effort one can devote to such tasks, there is often a tradeoff in the ability to avoid the two types of errors. For example, in a visual search experiment using simulated X-ray images of luggage, Wolfe et al. (2007) computed signal detection performance based on participants' false alarm and miss errors, and found that a decrease in false alarms at low target prevalence was accompanied by a dramatic increase in miss errors.

Several cognitive and memory factors that influence visual search and detection have been identified in the case of luggage screening, including category and exemplar diversity (Brunstein and Gonzalez 2011), similarity between items during training and transfer (Gonzalez and Madhavan 2011), framing of incentives and context (Lacson et al. 2008), frequency of the presence of targets (Madhavan and Gonzalez 2010), and monitoring and control (McCarley et al. 2004). These studies indicate that visual search in this realistic task is a complex activity that depends on cognitive processing beyond the mere perception of visual stimuli. Luggage screening is a cognitively demanding task of high difficulty for non-autistic adults. Even in such complex search tasks, however, it is possible to improve performance through training and practice. As one example, Gonzalez and Madhavan (2011) demonstrated the beneficial effects of training with diverse categories of threats, rather than with one consistent category, in order to improve participants' detection of novel targets.

However, tasks such as luggage screening present another challenge to the improvement of performance through training and practice: they require sustained attention (vigilance) (Ballard 1996; Parasuraman 1986). Sustained attention requires alertness and receptivity to stimuli that are difficult to detect or which occur infrequently. Thus, a critical question addressed here is how individuals with ASD fare under such conditions, not only in visual search involving complex scenes but whether ASD individuals can evince sustained attention to demonstrate an improvement in performance through experience with the task.

To examine these questions, we designed a realistic Luggage Screening task, similar to that used in previous research with non-ASD adults (e.g., Gonzalez and Madhavan 2011), requiring both detection when a target is present and rejection when a target is absent. This is a faithful representation of complex visual search tasks where both hits and correct rejections are important. We also divided the task into two halves and compared performance across these halves to assess change in performance with practice.

Hypotheses

In light of the mounting evidence regarding the relative superiority in visual processing and visual search of individuals with ASD, we first predicted that they would show an advantage over matched controls in performance (response time, hit rate, and correct rejection rate) in the Luggage Screening task. We expected that the task would be challenging for ASD adults, as it is for control adults, but that the observed superiority of ASD individuals in simpler visual search tasks would translate to an advantage in this more challenging task. This advantage could potentially manifest in accuracy or reaction time and/or might emerge in target detection or rejection. To manipulate the degree of difficulty, we varied the amount of "clutter" (obstructing or distracting items) present in the bag that was being scanned for a target item. We chose bags that differed significantly in clutter to maximize the chances of observing a relative difference in the performance of participant with ASD.

We also explored whether performance in the Luggage Screening task was correlated with IQ (full scale intelligence quotient, FSIQ), with the expectation that it would not be correlated in the ASD group if visual enhancement is a fundamental characteristic of ASD rather than a reflection of other intellectual competencies.

Methods

Participants

Thirteen ASD and 13 matched control adults were recruited to participate in this study in exchange for \$10 compensation. Participants were male, Caucasian, right-handed, of similar age across the two groups (ASD $M = 27.6$, $SD = 8.59$, min = 18, max = 45; control $M = 28.5$, $SD = 6.29$, min = 20, max = 45), $F(1, 25) = .082$, $p = .77$, and of similar FSIQ (ASD $M = 109.8$, $SD = 14.5$, min = 83, max = 124; control $M = 109.6$, $SD = 4.89$, min = 101, max = 118), $F(1, 25) = .001$, $p = .97$, as determined by the Wechsler Abbreviated Scale of Intelligence (WASI). The diagnosis of ASD was established using the Autism Diagnostic Interview (ADI), Autism Diagnostic Observation Schedule (ADOS), and expert clinical opinion. All subjects met criteria for ASD on the ADI, 10 met criteria for autism on the ADOS, and 3 met criteria for spectrum. Across our sample, ASD individuals had an average ADOS social score of 8.4 (range 4–12), average ADOS communication score of 4.2 (range 2–8), and average ADOS stereotypical behaviors score of 2.8 (range 0–5). Potential ASD participants were excluded if they had an identifiable etiology for their ASD. Exclusion was based on neurological history and examination, chromosomal analysis, and/or metabolic testing. All participants were required to have a negative history of significant head injury and birth or neonatal difficulties. All participants had normal or corrected-to-normal vision and all provided informed consent to a protocol approved by the Institutional Review Boards of the University of Pittsburgh and of Carnegie Mellon University.

The Luggage Screening task

We created an experimental version of the visual search task of screening carry-on luggage. The Department of Homeland Security's Transportation Security Administration supplied jpeg X-ray images of empty bags and a wide array of isolated items such as laptops, pillboxes, toys, containers, and clothing. These images have been used in a number of previous studies to construct images resembling packed bags (e.g., Brunstein and Gonzalez 2011; Gonzalez and Madhavan 2011).

For the current study, we created artificial packed bags using a computer program. To create each bag, the program first randomly selected an image of an empty bag, and then added randomly selected X-ray images of items into the bag one-by-one to create realistic representations of bags filled with items. In some cases, a "target item"—selected from a pool of threatening items including knives, guns, and sharp objects—was also inserted into the bag. The location of the target item was randomly selected within the edges of the empty bag image, and the orientation of the target item was held constant across bags. We ensured that for any bag containing a target item, the target was never completely unobstructed or completely obstructed by surrounding items. In the instances where the computer-generated bags failed to meet these criteria, another bag was generated to replace it. The computer program used a parameter to set the visual clutter in the bags. "Clutter" was defined as the density of items in the bag, which was determined by both the total number of items and the bag's area. "Low-clutter" bags had fewer items and more empty space, allowing a potential target to be more clearly visible. "High-clutter" bags were those with a large number of items, less empty space, and potentially greater obstruction of a target. Because performance with low target prevalence engages other strategies (Wolfe et al. 2005), we avoided these additional complications and set a 50 % base rate such that targets were present and absent equally often. As such, 50 % of the bags were high-clutter and the other 50 % were low-clutter, and 50 % of each type of bag contained a target item. A sample target item and bags (for all four combinations of high-clutter or low-clutter, and target-present or target-absent) are shown in Fig. 1.

Procedure

Participants were seated in front of a computer screen in a private room, filled out a demographic questionnaire, and were informed that they were to play the role of an airport security screener. They were then introduced to the task and instructed that their job was to report whether or not they saw a particular target item in each X-ray image of luggage.

Participants first completed a training block consisting of 20 bags. They were given unlimited time to view the training target before beginning the experimental screening task. The training target was different from any of the targets used in subsequent test trials. For each bag, participants were instructed to click on a button labeled "Yes" if they thought the target was present or on another button labeled "No" if they thought the target was absent. Each bag was presented for 4 s or until the participant entered a response, whichever came first. If no response was entered within the 4 s, the bag disappeared and a decision was required to move on. After a present/absent decision was made for each training bag, participants received feedback about whether their responses were correct or incorrect. In the target-present trials, a red box also indicated the location of the target after they responded.

Participants then completed the experimental task consisting of 320 bags, divided into 8 blocks of 40 bags each. A different target item was introduced at the beginning of each block. The blocks appeared in the same order for all participants, and the same bags were used for all participants to control for difficulty, but the order of bags within each block of 40 bags was randomized for each individual. Within each block of 40 bags, there were 10 bags of each of the four types: low-clutter target-present, low-clutter target-absent, high-clutter target-present, and high-clutter target-absent. The 50 % base rate for target presence was unknown to participants.

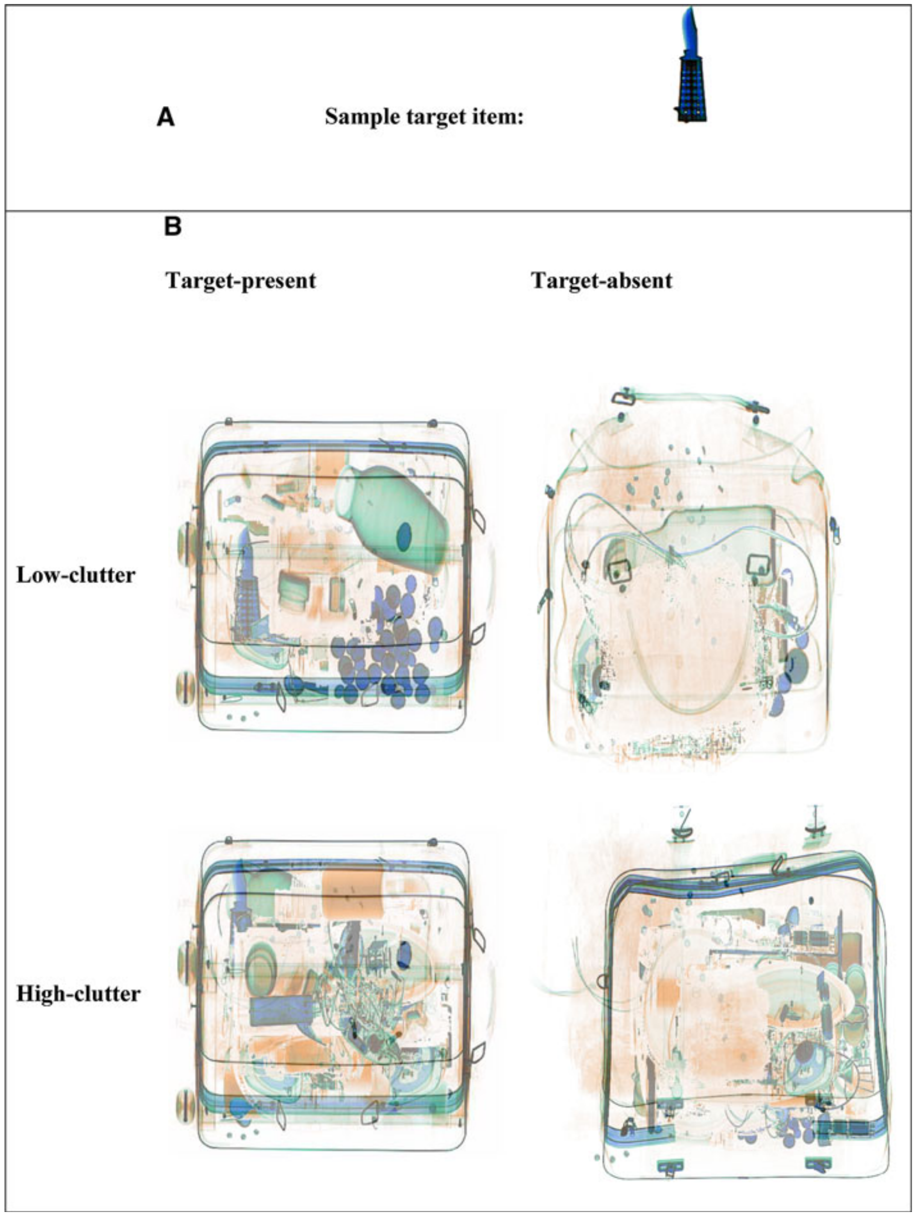
For each block, participants were given unlimited time to study the target item before moving onto the bag search, at which point the isolated image of the target item was no longer available. As in the training block, participants were instructed to click one of two buttons to indicate whether they thought the target was present or absent, and each bag was presented for a maximum of 4 s before a decision was required. A "Yes" answer was recorded as a hit on target-present trials and as a false alarm on target-absent trials; a "No" was recorded as a miss on target-present trials and as a correct rejection on target-absent trials. During the 320 experimental trials, participants received no feedback about the accuracy of their responses. The entire experimental portion of the task took approximately 30 min.

Results

Luggage Screening Task

The 320 test trials were divided into two halves (160 trials per half) to assess any changes in search performance with experience on the task. ANOVAs with clutter (low-clutter,

Fig. 1 Examples of a target item (a), and bags of low- and high-clutter, with and without the target present (b)



high-clutter) and half (first, second) as within-subjects variables and group (ASD, control) as a between-subjects variable were conducted on hit rate, correct rejection rate, d prime (d'), and response time for hits, correct rejections, false alarms, and misses.

Figure 2 presents the hit rate (panels a and b) and the correct rejection rate (panels c and d) for the ASD group (panels a and c) and the control group (panels b and d), as a function of the bag clutter (low-clutter or high-clutter) and practice (first or second half of experimental trials). As evident in panels a and b of Fig. 2, the ASD group ($M = .71$, $SE = .03$) was as accurate as the control group ($M = .76$, $SE = .03$) in the correct detection of targets for target-present bags, $F(1, 24) = 1.39$, $p = .25$. Both groups were more accurate in detecting targets in low-clutter bags ($M = .88$, $SE = .02$) than in high-clutter bags ($M = .59$, $SE = .02$), $F(1, 24) = 410.47$, $p < .001$, *Partial* $\eta^2 = .94$. Also, both groups were more accurate in detecting targets in the first half of bags ($M = .79$, $SE = .01$) than in the second half of bags ($M = .68$, $SE = .01$), $F(1, 24) = 57.73$, $p < .001$, *Partial* $\eta^2 = .71$.

As observed in panels c and d of Fig. 2, the ASD group ($M = .92$, $SE = .01$) was as accurate as the control group ($M = .90$, $SE = .01$) in the correct rejection of target-absent bags, $F(1, 24) = .530$, $p = .47$. However, the ASD and control groups differed in their performance with task practice (half × group), $F(1,24) = 6.87$, $p < .05$, *Partial* $\eta^2 = .22$. The ASD group showed a significant improvement in the correct rejection of target-absent bags, $F(1,12) = 6.51$, $p < .05$, *Partial* $\eta^2 = .35$, from the first

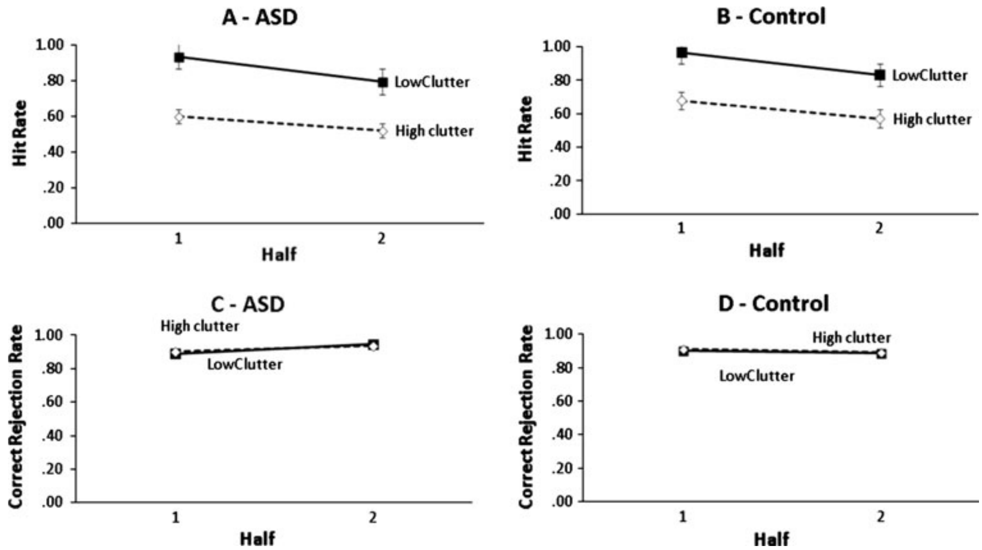


Fig. 2 Hit rate for the ASD group (**a**) and the control group (**b**), and correct rejection rate for the ASD group (**c**) and control group (**d**), for each of two halves (first 160 bags, 80 *high-clutter* and 80 *low-clutter*; and last 160 bags, 80 *high-clutter* and 80 *low-clutter*) of the experiment

half of the bags ($M = .89$, $SE = .01$) to the second half of the bags ($M = .94$, $SE = .01$). In contrast, the control group showed a slight, albeit not significant, $F(1,12) = 1.11$, $p = .31$, decrease in correct rejection rate from the first half ($M = .91$, $SE = .01$) to the second half ($M = .89$, $SE = .01$).

The effects above are consistent with the analyses of d′. Although there was no difference in d' between the ASD group (4.4) and control group (4.3), $F(1, 24) = .02$, $p = .89$, the ASD and control groups differed in their d′ with task practice (half × group), $F(1,24) = 4.95$, $p < .05$, *Partial* $\eta^2 = .17$. The ASD group maintained their d′ from the first half (4.4) to the second half (4.3) while the control group reduced their d′ from the first half (4.9) to the second half (3.7), $F(1,12) = 6.51$, $p < .05$, *Partial* $\eta^2 = .35$.

Figure 3 specifically illustrates the effect of practice on the correct rejection rate for the ASD and control groups, averaged across the high- and low-clutter bags for the first and second halves of bags. There was no difference in correct rejection rate for the ASD group ($M = .90$, $SE = .01$) and for the control group ($M = .91$, $SE = .01$), $F(1, 25) = .08$, $p = .78$, in the first half; but, on average, the ASD group ($M = .94$, $SE = .01$) exhibited a higher correct rejection rate than the control group ($M = .89$, $SE = .01$) in the second half of bags, yielding a marginally significant difference, $F(1,25) = 3.16$, $p = .08$, *Partial* $\eta^2 = .12$.

Figure 4 shows the response time for hits (panels a and b) and for correct rejections (panels c and d). As seen in panels a and b, the mean response time for the control group ($M = 2{,}061$ ms, $SE = 25.53$) was faster than for the ASD group ($M = 2{,}594$ ms, $SE = 30.74$) for hits, $F(1, 24) = 11.46$, $p < .01$, *Partial* $\eta^2 = .32$. Both groups were slower for high-clutter bags ($M = 2{,}591$ ms, $SE = 34.31$) than for low-clutter bags ($M = 2{,}136$ ms, $SE = 24.32$) for

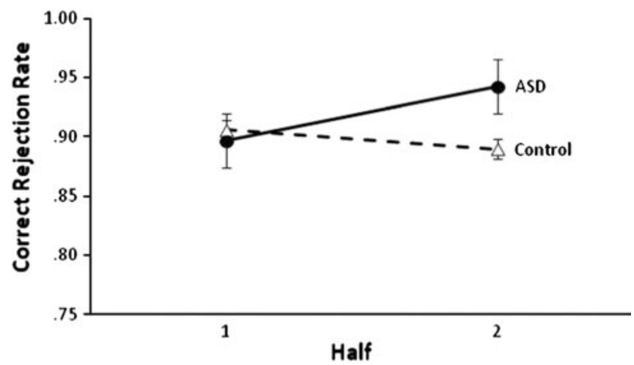


Fig. 3 Correct rejection rate during the first and second halves of practice bags (first 160 bags, 80 *high-clutter* and 80 *low-clutter*; and last 160 bags, 80 *high-clutter* and 80 *low-clutter*) for the ASD and control groups

hits, $F(1, 24) = 119.11$, $p < .001$, *Partial* $\eta^2 = .83$, although this pattern diminished with practice for both groups (clutter × half), $F(1, 24) = 5.08$, $p < .05$, *Partial* $\eta^2 = .18$. The response time for hits decreased in the high-clutter bags across the two halves (from $M = 2{,}627$ ms, $SE = 49.31$ to $M = 2{,}549$ ms, $SE = 47.05$) and increased in the low-clutter bags across the two halves (from $M = 2{,}074$ ms, $SE = 33.39$ to $M = 2{,}209$ ms, $SE = 35.35$).

In contrast, the response time measures for correct rejections (illustrated in panels c and d of Fig. 4) indicate that members of the ASD group ($M = 4{,}313$ ms, $SE = 33.23$) were as fast as those in the control group ($M = 3{,}711$ ms, $SE = 29.33$) at correctly rejecting target-absent bags, $F(1, 24) = 3.35$, $p = .07$. Overall, both groups were slower to correctly reject high-clutter bags ($M = 4{,}089$ ms, $SE = 33.64$) than low-clutter bags ($M = 3{,}942$ ms, $SE = 30.47$), $F(1, 24) = 22.56$, $p < .001$, *Partial* $\eta^2 = .54$; and this pattern changed with practice (clutter × half), $F(1, 24) = 9.45$, $p < .01$, *Partial* $\eta^2 = .28$. Response time for correct

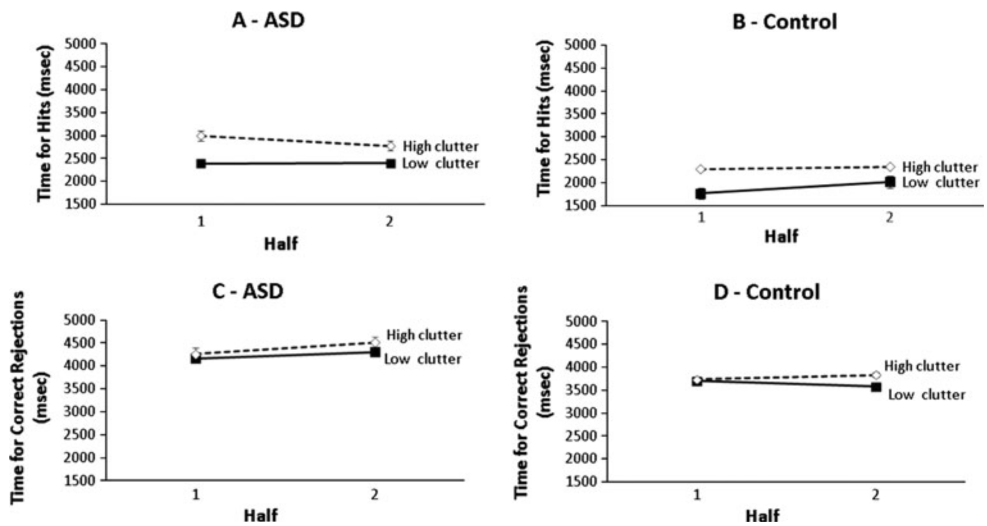


Fig. 4 Response time for hits by the ASD group (**a**) and the control group (**b**), and for correct rejections by the ASD group (**c**) and control group (**d**), for each of two halves (first 160 bags, 80 *high-clutter* and 80 *low-clutter*; and last 160 bags, 80 *high-clutter* and 80 *low-clutter*) of the experiment

rejections increased in the high-clutter bags (from $M =$ 3,995 ms, $SE = 44.42$ in the first half, to $M = 4{,}181$ ms, $SE = 50.32$ in the second half), and was stable in the low-clutter bags ($M = 3{,}928$ ms, $SE = 40.93$ in the first half, to $M = 3{,}956$ ms, $SE = 45.05$). That the ASD group did not differ from controls in the speed to correctly reject bags corroborates their performance in terms of their accuracy. Commonly, ASD individuals are slower than their control counterparts, as evident in their speed for hits described above; yet, the finding that speed is equated across the two groups for correct rejections suggests that the ASD individuals were performing relatively well in this condition, and this is compatible with their relatively improved accuracy at correctly rejecting bags.

There was no significant difference in response time for false alarms between the ASD and control groups, $F(1,24) = .39, p = .54$, but there was a significant difference for misses, $F(1,24) = 12.66$, $p < .01$, *Partial* $\eta^2 = .49$. Members of the ASD group were slower ($M = 4{,}384$ ms, $SE = 62.28$) than those of the control group ($M = 3{,}500$ ms, $SE = 58.89$) when they missed a target.

Correlations Between Performance in the Luggage Screening Task and FSIQ

To explore one potential predictor of performance on the Luggage Screening task, we correlated hit rate, correct rejection rate, and response time performance for the first and second halves of the trials with participants' FSIQ scores. In the control group, there was a positive correlation between correct rejection rate and FSIQ for both the first half, high clutter: $r(13) = .86$, $p < .05$; low clutter: $r(13) = .78$, $p < .01$, and for the second half, high clutter: $r(13) = .74$, $p < .01$; low clutter: $r(13) = .56$, $p < .05$. These correlations were not significant in the ASD group, and no other correlations between FSIQ and performance measures were significant. Thus, as FSIQ increased, so did correct rejection rate in the control group, but FSIQ did not affect the correct rejection rate or any other outcome measures in the ASD group (see Fig. 5). This result suggests that, to the extent that ASD individuals are more veridical in their search (higher correct rejection rate and similar response time compared to controls), this is independent of their FSIQ and perhaps more related to their autism diagnosis.

Discussion

It is not difficult to describe tasks that present disproportionate hurdles for individuals with ASD. However, a more optimistic view—and the one that we take in this paper—is that ASD individuals have unique abilities that can give them an advantage over others at performing some tasks (Happe 1999). Previous research has highlighted visual search as one such domain in which ASD people exhibit superior accuracy and speed (e.g., Kemner et al. 2004). The present research extends this work by testing participants' visual search performance in a Luggage Screening scenario that represents the sort of complexity that people face in everyday work and life situations: in scanning the visual field, they need to identify the presence of anomalous items and be able to correctly reject the absence of abnormal items, and do both as rapidly as possible.

Although ASD adults were as accurate as control adults in hits (correct identification of targets), as well as in their response time (an interesting observation given that ASD individuals are invariably slower than controls in many non-visual search tasks, see review by Gowen and Hamilton 2012), we found that ASD adults improve in their correct rejection (elimination of target-absent instances)

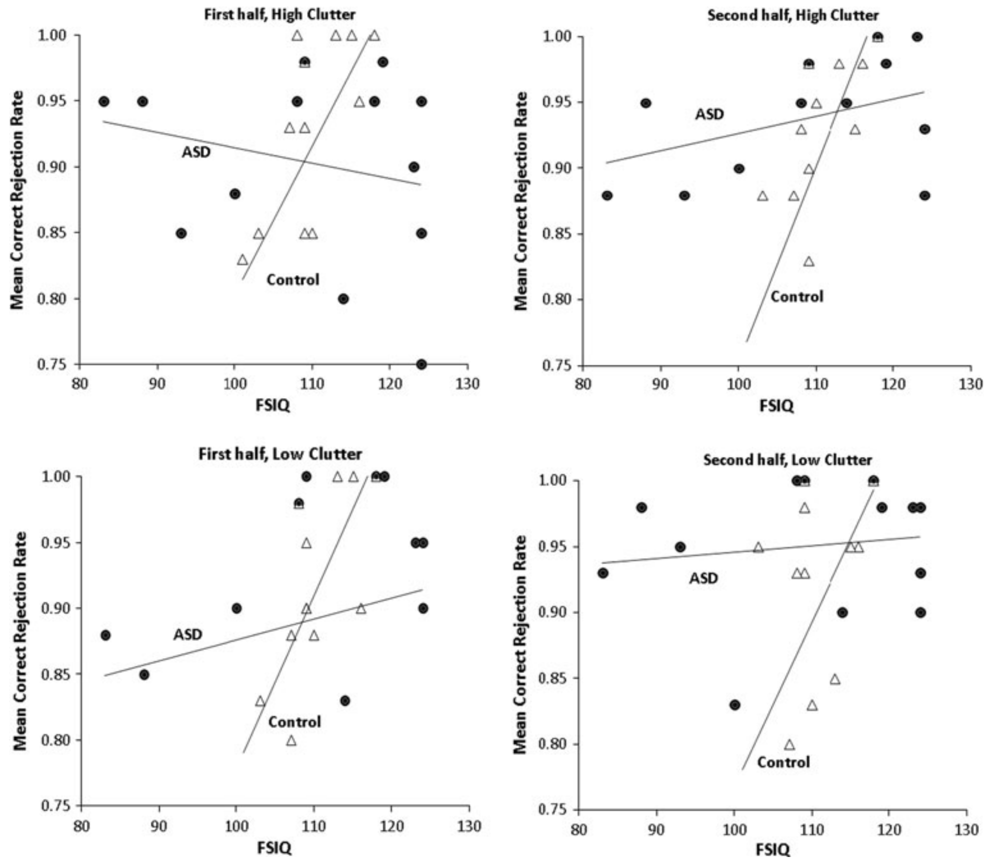


Fig. 5 Relationship between correct rejection rate and FSIQ for ASD and control groups. The *top row* shows the correlations with the correct rejections in the *high clutter bags* for the first (*left panel*) and second (*right panel*) halves. The *bottom row* shows the correlations in the *low clutter bags*, again first and second halves (*left* and *right panels*)

faster than control adults. This improvement with increased practice in the task, appeared regardless of the bag clutter (low-clutter and high-clutter bags). This feature of the ASD adult behavior is extremely important for many real-world monitoring tasks that require sustained attention. The value of correct rejections in everyday visual search situations is quite substantial, but it is sometimes underestimated relative to the value of hits. While correct rejections prevent unnecessary delays and additional screening, which could save time and money in the long-term, the "savings" from hits are recognized immediately (e.g., when a dangerous weapon is prevented from passing through security at the airport). Furthermore, the value of improvement in correct rejections of ASD adults is especially important given that long vigilance tasks such as luggage screening are particularly challenging for non-ASD adults, whose task performance often decreases after long time periods of sustained attention (Ballard 1996; Parasuraman 1986; Parasuraman and Davies 1976).

So why do ASD participants demonstrate a higher rate of correct rejections, and specifically why are they improving over the course of the experiment? We speculate that it is a combination of several factors. First, people with ASD may be inherently better at visual search tasks, but take longer to ramp up to peak performance as they become accustomed to the task. In our results, while ASD adults maintained their d' with practice, the non-ASD group reduced it. This decrease in vigilance in non-ASD adults is evidenced by the decline in hits, slight decline in correct rejections, and sustained response time. In contrast, while ASD individuals also decline on hits, they show an increase in correct rejections with task practice. Because of the tradeoff between accuracy on target-present instances (hits) and target-absent instances (correct rejections), it may not be surprising that ASD participants are not substantially better than controls at both (Wolfe et al. 2007), but separate controlled studies manipulating base rates are necessary to determine whether ASD individuals show differential ability on these two performance metrics relative to controls. We also looked at response time for a clue as to why the ASD group improved to a greater extent than the control group. Since the participants with ASD were slower on average than controls for both hits and misses, with no difference in speed for correct rejections or false alarms, we cannot attribute the improved performance simply to faster motor skills. Further, while FSIQ was positively correlated with correct rejections for control participants, FSIQ did not predict performance for individuals in the ASD group.

Second, people with ASD may not get bored as quickly with an individualistic detail-oriented task, and may therefore have a sustained drive to do well. Future studies should investigate the motivational and cognitive factors that may influence vigilance and sustained task performance (Gonzalez et al. 2010). As suggested by recent studies in decision making with ASD children (South et al. 2010), high anxiety of the ASD group may lead to increased motivation due to the fear of failure, and explain the longer sustained attention in the ASD group.

Third, ASD participants may be better at inhibiting an impulsive "trigger" response (i.e., clicking "Yes" even though the target has not been precisely detected) even after many repetitions of the task. Although we did not measure personality factors that would lead us to relationships to impulsive behavior, it is known that in repeated decision tasks behavior may be biased by "inertia", or the tendency to repeat a decision without awareness or attention (Dutt and Gonzalez 2012; Nevo and Erev 2012). Given recent studies related to motivation, anxiety and risk taking in children with ASD (South et al. 2010), it seems plausible that ASD participants may inhibit this inertial behavior better than control adults.

Fourth, those with ASD may be less subject to the "gambler's fallacy" by which people expect the representation of random events, even in short sequences, to match the base rate probability (Clotfelter and Cook 1993). Although our participants were not told the base rate target presence in 50 % of bags, control participants may have been more apt to infer it after many trials and to fall prey to this cognitive bias of expecting to find a target if they did not find it in recent trials. ASD individuals may remain impervious to these kinds of contingencies.

Implications and Limitations

One of the key implications of this paper is that when tasks tap into particular strengths of ASD individuals, enhanced performance may be observed. Above we suggest a number of possible reasons for the apparently superior performance of ASD individuals on the Luggage Screening task. From a pragmatic point of view, identifying a domain in which the perceptual tendencies of ASD individuals might serve them well in a practical task is an exciting result. While the present study reflects an initial foray into this domain, related paradigms, especially those tuned to career possibilities, should be vigorously pursued in future research.

Additionally, in this paper, as an initial investigation of a possible distinction between the ASD and control groups, we opted for a rather simplified experimental design in the Luggage Screening task. We attempted to make the stimuli as naturalistic as possible (using an algorithm that renders images) and only measured two points along the continuum of complexity; in one condition, the target 'threat' item was embedded in a sparse display (low-clutter), while in the other condition, the target was partially obscured and made less obvious in a dense display (high-clutter). We also only had participants perform a rather restricted number of trials (n = 320) so as not to tax them unduly. Further characterization of the performance of individuals with ASD under similar conditions, perhaps with more gradated complexity and for an extended set of trials, is warranted to offer a fuller description of the naturalistic visual search capacities of ASD individuals compared to others in the general population. It would also be of great interest to examine whether there are individual differences in this skill amongst the population with ASD and whether, as has been suggested, this might be a consequence of local overconnectivity (Kana et al. 2011; Keita et al. 2011), or a local bias in visual processing (Behrmann et al. 2006; Brosnan et al. 2004; Dakin and Frith 2005; Scherf et al. 2008). In future work, it will also be important to test extensions of this paradigm over longer time periods, in more distracting environments, and with differing target base rates, and to test a larger number of ASD and control participants. In other words, it is promising—but remains an empirical question—whether ASD individuals are especially well suited to specific real-world visual search tasks. If so, there is potential for this area of inquiry to uncover new ways of enhancing the self-efficacy and career prospects of adults with ASD.

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