Self-rated social skills predict visual perception: impairments in object discrimination requiring transient attention associated with high autistic tendency

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Lay Abstract

Autism is usually defined by impairments in the social domain, but has also been linked to deficiencies in specific visual pathways. The extent of these visual anomalies and their relationship to autism spectrum disorders (ASD) is still unclear. One possibility is that the ability of the visual system to rapidly activate attention to sudden events might be abnormal in ASD. We explored this hypothesis in a group of non-clinical participants with either higher or lower self-reported autistic traits. The Autism-spectrum Quotient (AQ) makes use of the idea that autism is merely one end of a spectrum that extends into the typically developing population. Participants viewed pictures of everyday objects in two separate tasks requiring recognition of a target object. In the first task objects were presented with an abrupt onset/offset, whilst in the second task the contrast of the object was gradually increased on, and decreased off. The High AQ participants performed worse than the Low AQ participants on both tasks. Importantly however, the High AQ group showed a greater impairment when objects were presented abruptly, compared with gradual onset/offset objects. Furthermore results suggested that one subscale from the AQ questionnaire in particular – self-reported social skills – predicted performance on the abrupt object task. This relationship between visual perception and autistic-like traits more generally, and social skills specifically, suggests that ASD could be related to a reduced utilization of fast activation of attention mechanisms for sudden or salient environmental changes.

Scientific Abstract

Autism is usually defined by impairments in the social domain, but has also been linked to deficient dorsal visual stream processing. However, inconsistent findings make the nature of this relationship unclear and thus we examined the role of stimulus-driven transient attention, presumably activated by the dorsal stream in autistic tendency. Contrast thresholds for object discrimination were compared between groups with high and low self-rated autistic tendency utilizing the socially-based Autism Spectrum Quotient (AQ). Visual stimuli were presented with either abrupt or with ramped contrast on/offsets in order to manipulate the demands of transient attention. Larger impairments in performance of abrupt compared with ramped object presentation were established in the High AQ group. Furthermore, self-reported social skills predicted abrupt task performance, suggesting an important visual perception deficiency in autism-related traits. ASD may be associated with reduced utilization of the dorsal stream to rapidly activate attention prior to ventral stream processing, when stimuli are transient.

Key words: autism, dorsal stream, ventral stream, object discrimination, attention

Introduction

Although autism spectrum disorders (ASD) are defined by impairments in behaviours relating to social interaction, communication and repetitive or stereotyped patterns of behaviour, research over the last decade indicates that individuals with ASD also show anomalies in visual perceptual processing (Dakin & Frith, 2005; Grinter, Maybery, & Badcock, 2010). Commonly, these visual abnormalities have been localised to either the subcortical magnocellular system (Jones et al., 2011; McCleery, Allman, Carver, & Dobkins, 2007), or to the dorsal visual stream which is dominated by magnocellular projections, and is often assessed by motion coherence detection (Grinter, et al., 2010; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005; Pellicano & Gibson, 2008; Spencer et al., 2000).

On the other hand ventral stream functioning in ASD has mostly been assumed to be unaffected when assessed by form coherence measures (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Milne et al., 2006; Spencer, et al., 2000). This type of finding has not been reconciled with the existence of reports of impairments in face processing by those with ASD (Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008; Scherf, Luna, Minshew, & Behrmann, 2010; Schultz, 2005) – a function usually considered to be subserved by the ventral visual stream (Brieber et al., 2010; Keehn & Joseph, 2008; Pitcher, Charles, Devlin, Walsh, & Duchaine, 2009).

Although impaired magnocellular or dorsal, but preserved ventral stream processing has not always been replicated using psychophysical measures (Grinter et al., 2009; Jones, et al., 2011; Pellicano & Gibson, 2008), a recent experiment has provided powerful electrophysiological evidence for magnocellular impairment in individuals scoring highly on self-rated autism traits, and suggests a framework for reconciling these mixed findings (Sutherland & Crewther, 2010).

Sutherland and Crewther (2010) found evidence for a delay in magnocellular signals in striate cortex in healthy adults who scored highly on the Autism Spectrum Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). It was proposed that a delay in the magnocellular response could decrease the ability of individuals with autism to benefit perceptually from feedback signals through the dorsal stream. Rapid feedforward and feedback magnocellular-driven signals through the dorsal stream have been associated with models of visual processing that emphasise the role of the dorsal stream in activating stimulus-driven attention mechanisms. This activation is suggested to be prior to, and in fact to influence the more detailed object specific processing though the ventral stream (Kveraga, Boshyan, & Bar, 2007; Laycock, Crewther, & Crewther, 2007).

Thus the inconsistent findings regarding impairment in dorsal and ventral visual streams may better be understood, as Tsermentseli et al. (2008) have argued, as an abnormality in the interaction between dorsal and ventral visual streams in ASD. Such an imbalance in cortical activation could be expected to occur if abnormalities in the critical timing of the magnocellular system negatively impact on rapid transient attention mechanisms, consequently causing an anomalous time-course of perceptual enhancement associated with ventral stream processing.

Evidence for an impairment in the role of the dorsal stream in driving transient visual attention in ASD has been suggested elsewhere (Greenaway & Plaisted, 2005; Keehn & Joseph, 2008). Keehn and Joseph (2008) for example explored the importance of novel stimulus onsets in a visual search paradigm. Utilising a preview search task, typically developing children and adolescents showed a reaction time advantage for target identification of new versus old items, whilst ASD participants showed no such advantage. This was argued to reflect reduced attentional prioritisation of abruptly presented novel letters in ASD. The authors showed that worse performance on the abruptly presented task was associated with greater severity of ASD symptoms.

Greenaway and Plaisted (2005) also investigated attentional modulation for bottom-up attentional capture using a spatial cuing task. Whilst ASD children were able to utilise coloured cues similarly to typically developing children for attentional modulation, they were not able to do so for abrupt onset cues. Greenaway and Plaisted interpreted this as evidence that ASD children were deficient at prioritising dynamic stimuli, and it was suggested this may have broader implications in ASD given that social stimuli are usually dynamic and furthermore that social interactions appear to be at the heart of ASD.

In the current study, we sought to extend the findings of Keehn and Joseph (2008) and Greenaway and Plaisted (2005). Here we were interested in investigating the importance of rapid attention acquisition through the dorsal stream (i.e., "bottom-up" attention) for object discrimination. Thus the role of abrupt onsets for object discrimination, and a non-abrupt (ramped onset) control task was tested in individuals with self-reported autistic tendencies. The stimuli chosen were recently compared in a normal population (Laycock, Cross, Lourenco, & Crewther, 2011) subdivided into 'good' and 'poor' motion coherence performers, taken as a proxy for dorsal stream functionality. As the 'poor' motion/dorsal stream group showed reduced performance only on the abrupt object discrimination task, but not the gradual onset/offset task, we predicted that the abrupt onset stimuli would discriminate high and low autistic tendency groups. This hypothesis rests on the assumption that the primary deficit in vision for those with ASD is related to the dorsal stream and its ability to influence ventral stream processing. Additionally, to test the relationship between the onset profile of object presentation and the sub-scales of the AQ test, we also undertook a regression analysis to examine whether subscales appearing to relate to the visual aspects of ASD (e.g. attention switching, attention to detail) or the more 'social' sub-scales (e.g. social skills, communication) are more important.

Method

Participants

This study recruited 75 participants currently studying at university aged between 18 and 41, who had normal or corrected-to-normal vision. Three of these participants did not complete the online AQ scale, leaving a sample of 72. Two participant groups were formed based on scores obtained on the Autism Spectrum Quotient (AQ) scale (Baron-Cohen, et al., 2001). The AQ scale was completed online using Qualtrics Survey Software and covers questions across five categories – social skills, attention switching, attention to detail, communication, and imagination. Using a similar criteria to previous reports (Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010;

Sutherland & Crewther, 2010) participants scoring 19 or above comprised a High AQ Group (n = 21), with participants scoring 11 or below comprising a Low AQ Group (n = 21). Summary statistics for the two groups are provided in Table 1, and closely resemble previous studies using AQ groups (Almeida, et al., 2010; Grinter, et al., 2009; Sutherland & Crewther, 2010). Participants, who were recruited via University recruitment posters and the La Trobe University School of Psychological Science Participant Registry, provided informed consent prior to participation. This study had ethics approval from the Faculty of Science, Technology and Engineering Human Ethics Committee.

Visual Stimuli

Ramped and abrupt object discrimination tasks were developed using VPixx software (VPixx Technologies) that involve correctly identifying line drawings of one of eight common objects (e.g. clock, iron, jug) when they briefly appear on the computer screen, as has been used previously (Laycock, et al., 2011). Stimuli were presented on an eMac computer with a screen refresh rate of 80 Hz and a screen resolution of 1152 x 864. Objects subtended approximately 9˚ by 9˚ at 57 cm from the monitor, and were presented with either ramped or abrupt onset/offset. The ramped condition involved the relative contrast of the image gradually increasing to a maximum contrast and then immediately decreasing to back to zero over a total of 26 frames (i.e., 13 frames onset, 13 frames offset), so that objects were presented for 325ms with only a single frame at maximum contrast. In the abrupt condition, an object rapidly flashed in the centre of the screen for 4 frames (50 ms). In both conditions, a white noise mask (9˚ by 9˚) replaced the target object.

Procedure

Participants completed the AQ scale online prior to the visual psychophysics testing session. The abrupt and ramped onset tasks were completed in counterbalanced order (with 11 participants in each group completing the abrupt task first, and 10 in each group the ramped task first), after familiarization and training in the task requirements. Each trial commenced with a 1 second blank black screen, and then an abrupt or ramped onset/offset object appeared in the centre of the screen.

Following object offset the blank screen remained for 500 ms before a mask appeared for a further 500 ms. At the offset of the mask four smaller objects appeared at the bottom of the screen (including the target and three distracters, subtending 3˚ by 3˚). A forced-choice match to sample decision was required by the participant providing a 25% chance of correctly responding (see Fig. 1). Participants had an unlimited time to indicate which object they had seen by keyboard press. Once a key had been pressed, the screen returned to a blank display and the next trial commenced immediately. A two-down one-up staircase procedure which, combined with a four-alternate forced-choice paradigm, converged on a 62.9% correct level was utilized to determine the threshold contrast required for correct object discrimination. The staircase was terminated after ten reversals with threshold contrast for accurate object discrimination taken as the mean contrast level from the final 6 reversals. Contrast was initially set at 0.3, with a staircase step size of 0.05, which was reduced to 0.02 after the first reversal, 0.01 after the second reversal, and then 0.005 after the third reversal and until threshold was determined. Each task took approximately 3 minutes to complete.

------- Figure 1 about here -------

Results

Firstly looking at the restricted sample (n = 42), one outlier was excluded from the High AQ group Prior to running a two way mixed design ANOVA, with onset type (abrupt versus ramped) as the within group factor, and AQ group (High AQ versus Low AQ) as the between group factor. Results revealed a significant main effect of onset type, $F(1,38) = 60.42$, $p < .001$, eta-square = .61, a main effect of AQ group, $F(1,38) = 7.23$, $p = .011$, eta-square = .16, and importantly a significant interaction between AQ group and onset type, $F(1,38) = 5.77$, $p = .021$, eta-square = .13. Simple main effects were used to interpret this interaction, and showed that the High AQ group had significantly higher contrast thresholds than the Low AQ group for the abrupt task, $F(1,38) = 6.97$, $p = .012$, eta-square = .16, but not the ramped task, $F(1,38) = 3.34$, $p = .08$, eta-square = .08.

Furthermore, simple main effects also established that the abrupt task was significantly harder than the ramped task for both the Low AQ group, $F(1,38) = 14.42$, $p = .001$, eta-square = .28, and the High AQ group, $F(1,38) = 51.77$, $p < .001$, eta-square = .56. As Figure 2 demonstrates, the interaction between AQ group and task type was primarily due to the larger increase in threshold for abrupt versus ramped onset for the High AQ group.

------- Figure 2 about here -------

The overall higher threshold performance for all participants on the abrupt compared with the ramped task ($p < .001$) was unexpected issue. In psychophysics measurements generally, given that the magnitude of a set difference between any two physical stimuli is proportional to the magnitude of the stimulus (i.e. Weber's law), some caution is required before concluding that AQ groups demonstrated a larger difference on the (more difficult, i.e. higher contrast at threshold) abrupt than the (less difficult, i.e. lower contrast at threshold) ramped task. According to Weber's law we would actually expect such an interaction even if the High AQ group showed a consistent (e.g. 10%) impairment for both tasks. To confirm that a greater difference between groups indeed exists on the abrupt task over and above this effect, a ratio score of abrupt versus ramped thresholds was established for each participant. After excluding two outliers, a paired sample t-test compared ratio scores and confirmed the original finding of a greater difference between groups on the abrupt discrimination task, with the High AQ group demonstrating a higher ratio than the Low AQ group $t(37) = .02.68$, $p = .01$, $d = .86$ (see Figure 3).

------- Figure 3 about here -------

To further explore the relationship between AQ and visual processing in the larger sample (n = 72) a standard multiple regression analysis was used. Indeed, performance on the object discrimination tasks predicted nearly 11% of variance in AQ scores, $R^2 = .109$, $F(2,66) = 4.02$, $p = .023$. However, only the abrupt onset task explained a significant amount of the unique variance in AQ scores, $\beta = .317$, $t(67) = 2.21$, $p = .03$, with the ramped onset task providing no unique variance, $\beta = .021$, $t(67) = 0.15$, $p = .88$. Next, a multiple regression was performed to determine which of the five AQ subscales contributed most to abrupt object discrimination performance. The results show that the five AQ subscales significantly predicted overall object abrupt performance, $R^2 = .24$, $F(5, 64) = 4.00$, $p = .003$, with the only significant contributor, over and above the other subscales to this prediction coming from the social skills subscale, $\beta = .541$, $t(67) = 3.41$, $p = .001$. A multiple regression assessing the contribution of the AQ subscales to object ramped performance was not significant, $R^2 = .13$, $F(5, 70) = 1.98$, $p = .09$.

Although not a hypothesis under explicit investigation, sex differences were explored given that autism is more prevalent in males, and that although in the general population some sex differences in the brain are real, they are often exaggerated and misinterpreted (Eliot, 2011). Analysing the larger sample, there were no sex differences in AQ score, $t(70) = 1.00$, $p = .32$, $d = .26$. The only subscale to show a significant sex difference was communication, with females self-reporting superior communication skills than did males ($p = .02$, $d = .59$). Similarly, for both the ramped ($t(69) = 0.94$, $p = .35$, $d = .27$) and abrupt ($t(70) = 0.19$, $p = .85$, $d = .05$) object discrimination tasks no sex differences were established.

Discussion

Participants with high self-reported autistic tendency demonstrated anomalies in visual object discrimination when compared with a low autistic tendency group despite all participants having been selected from a university population with no *a priori* reason to expect perceptual or cognitive differences. In particular, whilst the High AQ group only showed a trend towards higher threshold contrast required for accurate discrimination compared with the Low AQ group on a ramped onset object discrimination task, there was a large difference between groups for an abrupt onset task. This latter task was expected to require rapid activation of stimulus-driven attentional processes through the dorsal stream prior to object specific processing in the ventral stream. On the other hand, the ramped task, which demonstrated a relatively weaker impairment in the High AQ group, was expected to be less suited to such a rapid attention acquisition mechanism. Particularly interesting was the demonstration that the social skills self-reported by participants predicted visual processing performance on the abrupt task. From this observation, it is possible to speculate that a link between visual perception and social skills in ASD may be important.

The interaction between AQ group membership and the mode of visual stimulus onset indicates that the High AQ group had greater difficulty discriminating the abruptly presented object stimuli. This finding was reinforced by the ability of the abrupt task to predict AQ scores, whereas no such predictive power was established for the ramped task. We tentatively propose that the visual deficit in higher AQ individuals becomes more pronounced as the ability to activate stimulus-driven attention for object discrimination becomes more necessary. Impairments in attention have previously been shown in individuals with ASD (Keehn, Lincoln, Muller, & Townsend, 2010; Townsend, Harris, & Courchesne, 1996), and also in high AQ groups (Bayliss & Tipper, 2005), though investigations into the temporal constraints of attention utilising the attentional blink paradigm has provided mixed findings (Amirault et al., 2009; Rinehart, Tonge, Brereton, & Bradshaw, 2010).

Transient on/off visual events are likely to trigger transient flicker-like responses in the magnocellular system (Hicks, Lee, & Vidyasagar, 1983), which in turn provides the strongest early response through the dorsal stream (Nassi & Callaway, 2006). Indeed, the abrupt rather than the ramped onset task used here has previously been linked to superior psychophysical assessment of dorsal stream processing (Laycock, et al., 2011). Thus we hypothesize that severity of impairments in transient selective attention mechanisms, likely fed by dorsal visual processing, relates to severity of autistic behaviours.

Keehn and Joseph (2008) have suggested that children with ASD have problems with attentional prioritisation of abruptly presented letters in a visual search task. The current findings indicate this type of result may extend into a non-clinical adult population with high autistic-like traits. Keehn and Joseph also reported that the extent to which participants found the abrupt stimuli difficult related to the extent of their social and communication impairments, as assessed by the Autism Diagnostic Observational Schedule (ADOS). Interestingly, our own regression analysis indicates that whilst only the abrupt task performance predicted AQ scores, the only subscale of the AQ (social skills, communication, imagination, attention to detail, attention switching) to explain a significant amount of variance in the abrupt task performance was the social skills subscale.

A relationship between social skills and putative dorsal stream processing might at first glance be surprising. However, a reduced capacity for rapid analysis of global information could very plausibly impair the ability to respond to rapidly changing social communications in the environment such as is required for detecting subtle but rapid face expression changes. For example, regions such as the superior temporal sulcus within the dorsal stream are important for biological motion and for dynamic face processing (Arsalidou, Morris, & Taylor, 2011; Thompson, Hardee, Panayiotou, Crewther, & Puce, 2007), whilst Herrinton et al. (2007) found reduced activation in superior temporal regions including V5/MT+ in a sample of participants with Asperger syndrome. This region thus provides a promising locus for bridging the sensory and social features of autism (Dakin & Frith, 2005).

Given the complex nature of previously reported dorsal stream deficiencies in ASD (Bertone, Mottron, Jelenic, & Faubert, 2003; Brieber, et al., 2010; Milne, et al., 2006), models of normal visual processing that emphasise fast magnocellular activation of fronto-parietal global attention mechanisms prior to more detailed object processing in ventral stream regions (Bullier, 2001; Kveraga, et al., 2007; Laycock, et al., 2007) may provide a framework for better understanding such perceptual anomalies. For example, Bullier (2001) has shown that rapid feedforward/feedback connections through the dorsal stream in primates are important for an initial analysis of the scene and allow figure-ground segregation. In addition, Bar and colleagues used MEG to demonstrate fast processing of magnocellular-biased information projects through to orbitofrontal cortex, *prior* to object processing in ventral stream regions in temporal cortex (Kveraga, et al., 2007). Thus the contribution of the magnocellular system to initial global analyses may prove valuable to understanding the superior local and inferior global processing reported in ASD (see Dakin & Frith, 2005 for a review).

The application of such a model to understanding ASD, whilst not directly tested in the current experiment, has been suggested previously. Sutherland and Crewther (2010) recently reported that high AQ individuals showed a weaker initial magnocellular afferent for low contrast stimuli, with multi-focal VEP responses to high contrast stimuli evidencing a delay in magnocellular response completion. These findings were interpreted as evidence for a delay in re-entrant magnocellular responses into early visual cortex. If the ventral stream is deprived of the global-type information usually provided courtesy of the dorsal stream, and instead is more reliant on parvocellular inputs during development, Sutherland and Crewther argue that inappropriate visual perceptions within dynamic social interactions could be expected.

An interesting alternative explanation comes from the findings of Robertson et al (2012). Participants with a diagnosis on the autism spectrum were found to show motion coherence impairment, though importantly only when a brief stimulus (200 ms), rather than a medium (400 ms) or longer (1500 ms) duration was used. These results were suggested to indicate that autism may be not so much associated with a primary motion deficit, but with a deficit in “visual integration”. Participants with autism differentially benefited from an increasing window during which an accumulation of perceptual evidence could be gained. Thus, the longer overall time of the ramped stimulus compared with the abrupt stimulus in the current study may have provided sufficient time for accumulated visual information to be integrated into a perceptual representation of the objects in the High AQ group, and allowed them to minimize the gap in the performance deficit compared with the Low AQ group. Similar to the results from Robertson et al, our data showed that the largest deficit was seen when a very brief stimulus was presented, possibly allowing less time for “integration” of the low contrast visual information. This view does not rule out the possibility that, in addition, the High AQ group could still be less effective in utilizing stimulus-driven attention processes for the abrupt task. Our previous finding of an association between dorsal stream processing and the abrupt object task used here (Laycock, et al., 2011) indeed indicates the latter explanation may play an important role.

The conclusions from the current study are of course more restricted. Nevertheless, the importance of transience in visual object discrimination as suggested here indicates that abnormalities in certain aspects of dorsal stream functioning can generate deficiencies in functions normally associated with the ventral stream. An influence of deficient dorsal stream processing on ventral stream processing has also been suggested in schizophrenia (Doniger, Foxe, Murray, Higgins, & Javitt, 2002). Whilst we report deficits related to object perception in autistic tendency, exploration of the role of transience in face perception, as a more social ventral stream process widely reported as impaired in ASD (Dawson, Webb, & McPartland, 2005) remains to be tested. This seems particularly pertinent to understanding perceptual differences in ASD given the magnocellular contribution to subcortical regions (e.g. pulvinar, amygdala) for face and emotion processing (Vuilleumier, Armony, Driver, & Dolan, 2003). Indeed, Vlamings et al. (2010) have already suggested that young children with ASD show enhanced visual processing to both non-social (gratings) and social (faces) stimuli biased towards high spatial frequencies assumed to preferentially rely on parvocellular processing.

The finding here that an aspect of non-social object processing can discriminate between individuals with higher and lower autistic-like traits is important for understanding the nature of visual processing anomalies in autism spectrum disorders. It suggests that ASD could be related to a reduced utilization of rapid onset attention mechanisms to sudden or salient environmental events.

Future research should examine whether the results established here can be replicated in a clinical sample, and also whether the association between self-reported autistic-traits and visual perception will hold for more objective assessments of these traits. Further work is also required to determine if, and how, already existing abnormalities in magnocellular/parvocellular processing could negatively influence social development in ASD, for example by deficits in reacting to the rapid face movements required for appropriate social communication.

This relationship between visual perception and autistic-like traits more generally, and social skills specifically, suggests that ASD could be related to a reduced utilization of fast activation of attention mechanisms for sudden or salient environmental changes.

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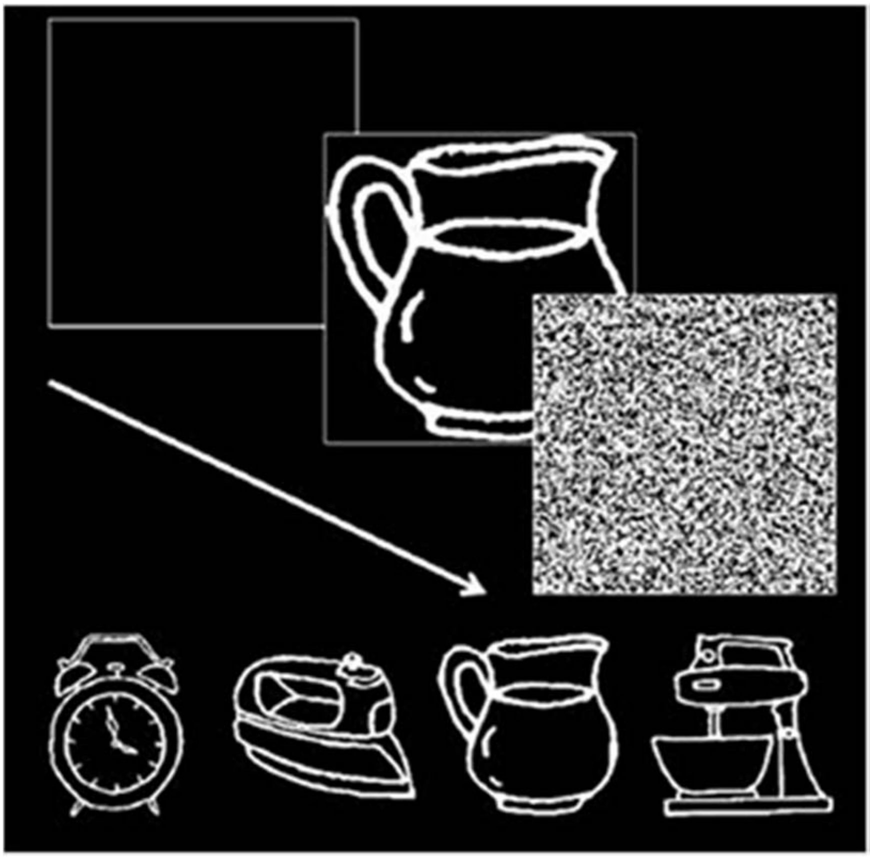

Figure 1. Object discrimination tasks. Both the ramped and abrupt conditions required participants to identify one of four objects.

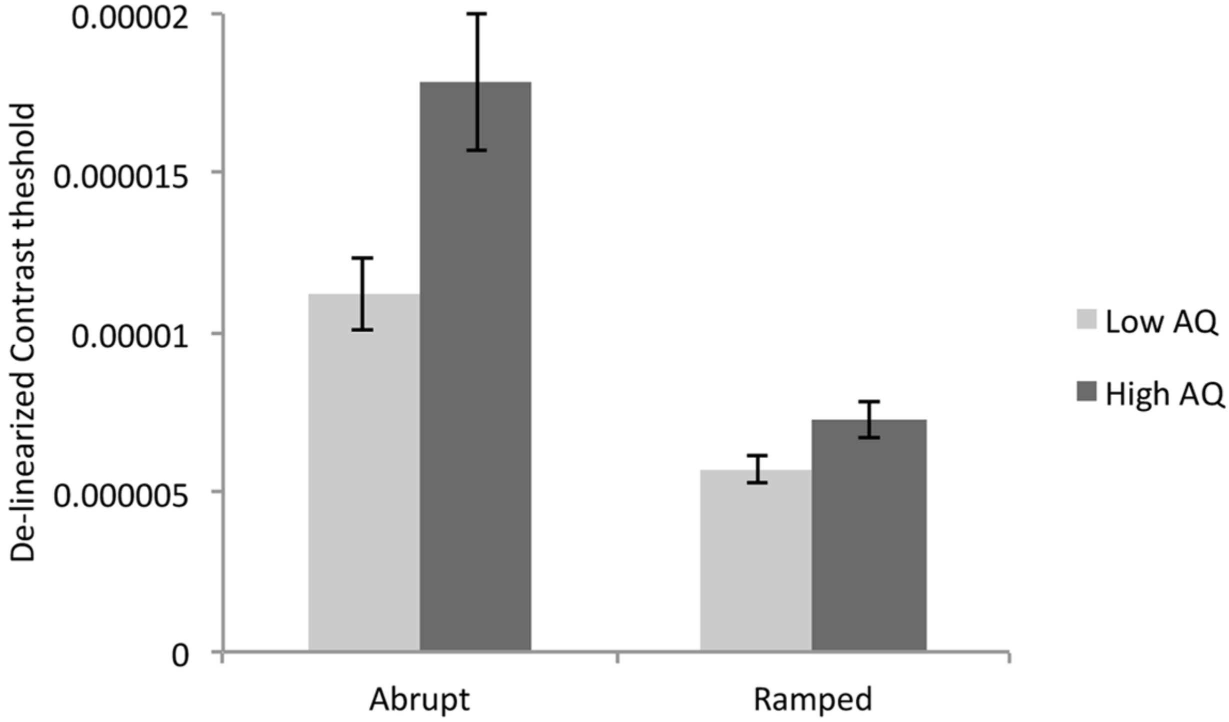

Figure 2. Mean differences in the transformed de-linearized threshold scores between Low and High AQ groups (+*SEM*) on the abrupt and ramped onset/offset presentation object discrimination tasks.

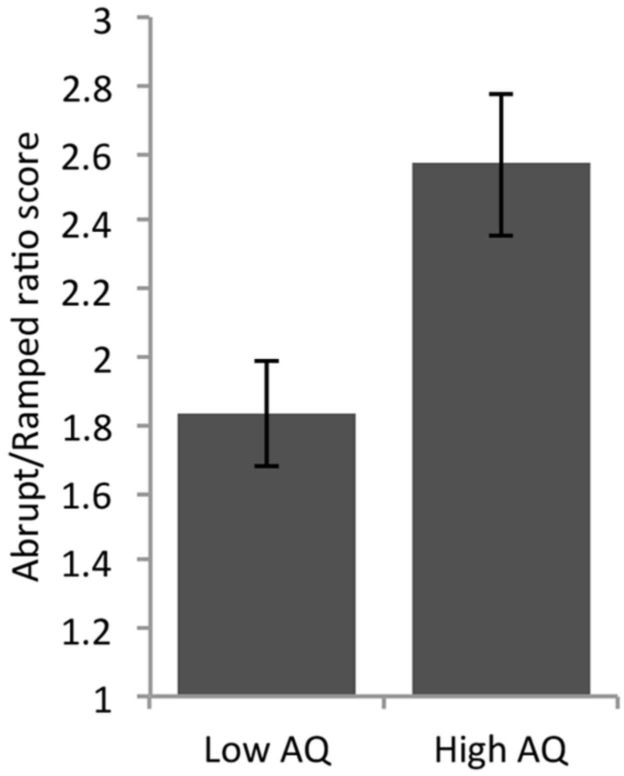

Figure 3. Comparison of object discrimination ratio scores (abrupt/ramped) between Low and High AQ groups (+*SEM*).