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Enhanced local processing of dynamic visual information in autism: Evidence from speed discrimination

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Abstract

An important issue for understanding visual perception in autism concerns whether individuals with this neurodevelopmental disorder possess an advantage in processing local visual information, and if so, what is the nature of this advantage. Perception of movement speed is a visual process that relies on computation of local spatiotemporal signals but requires the comparison of information from more than a single spatial location or temporal point. This study examined speed discrimination in adolescents (ages 13–18 years old) with autism spectrum disorders (ASD). Compared to healthy controls ($n = 17$), individuals with ASD ($n = 19$) showed similarly precise speed discrimination when two comparison motion stimuli (random dot patterns) were presented closely in time (0.5 s). With a longer temporal interval (3 s) between the motion stimuli, individuals with ASD outperformed healthy controls on speed discrimination. On a second task—global motion perception—in which individuals were asked to detect coherent motion, individuals with ASD exhibited slightly degraded performance levels. The observed temporally selective enhancement in speed discrimination indicates that a local processing advantage in autism develops over a longer temporal range and is not limited to the spatial domain. These results suggest a dynamic perceptual mechanism for understanding, and therapeutically addressing, atypical visual processing in this neurodevelopmental disorder.

Keywords

Visual system; Motion; Autism; Local processing; Speed discrimination; Neurodevelopment

1. Introduction

One intriguing aspect of visual perception in individuals with autism spectrum disorders (ASD) is the so-called local processing advantage (Dakin & Frith, 2005; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). Superior performance on visual tasks relying on

spatially localized information has been reported in autistic individuals (Plaisted, O'Riordan, & Baron-Cohen, 1998; Shah & Frith, 1983). For example, when presented with complex line design targets, individuals with ASD are able to detect static embedded shapes more efficiently than healthy controls (Shah & Frith, 1983). This kind of result recommends a theory positing that an advantage in processing local visual information is associated with ASD (Mottron et al., 2006). According to this theory, superior performance in individuals with ASD is attributed to preferential processing of local over global visual information.

How the local processing advantage hypothesis—generated in the spatial domain—can be extended to understand general processing of visual and cognitive information in autism has not been systematically explored. One relevant domain is within visual motion processing, where movement information can be encoded either locally (but not restricted to a spatial location) or globally. Individuals with autism have exhibited deficient perception in processing the global direction of motion (coherent motion) in earlier studies (Gepner, Deruelle, & Grynfeltt, 2001; Spencer et al., 2000), and shown normal perception in more recent studies (Del Viva, Igliozzi, Tancredi, & Brizzolara, 2006; Koldewyn, Whitney, & Rivera, 2010). These conflicting results may be due to the use of different paradigms that involve additional motion-related cognitive and motor processes (Kaiser & Shiffrar, 2009). Normal perception of the local direction of motion—in a first-order motion task—was found among individuals with autism (Bertone, Mottron, Jelenic, & Faubert, 2005). These results suggest that only selective aspects of visual motion processing are altered in autism. However, whether the local processing advantage seen with static stimuli exists with performance on dynamic visual tasks has not been investigated.

Unlike processing the direction of coherent motion, which is global in nature (as it requires the integration of spatially distributed motion signals), the processing of movement speed requires neural computation that is based upon the spatiotemporal metrics of local visual signals. While local in nature, perception of movement speed does not rely solely upon the visual signals from, and attention to, a particular spatial location. Rather, the information about movement speed is extracted from visual stimuli spanning across a series of spatial positions and temporal points (McKee, 1981; Mikami, Newsome, & Wurtz, 1986; Nakayama, 1985). In fact, the encoding of movement speed, which can be defined as a ratio of the distance traveled over the time traveled, is highly precise even when compared to the encoding of spatial and temporal dimensions involved (Chen, Bedell, & Frishman, 1998; McKee, Silverman, & Nakayama, 1986); the thresholds for speed discrimination are actually lower (i.e. demonstrating better performance) than those for spatial frequency or temporal frequency discrimination, despite the fact that encoding speed requires knowledge of spatial and temporal frequency of the stimulus. Evaluation of speed discrimination may provide a dynamic analogue of the local visual processing assessment.

In this study, we examined performance on visual discrimination of movement speed in adolescents with ASD. The goal here was to determine whether the local processing advantage in autism exists in this specific aspect of motion perception. It has been suggested that individuals with autism may require a prolonged temporal window for visual processing (Townsend, Harris, & Courchesne, 1996). It was also reported that individuals with ASD detected a change in the visual object at the end of a person's movement more often than the

object at the start, like control subjects. However, the ASD group did not undergo the typical developmental improvement to detect changes in both the start and end objects, consistent with the hypothesis that the ASD group needs a prolonged time window to process visual information (O'Hearn, Lakusta, Schroer, Minshew, & Luna, 2011). If this temporal hypothesis holds true, the use of a prolonged temporal window would benefit visual motion processing in individuals with autism. On the other hand, it has also been suggested that individuals with autism may be impaired with regard to working memory (Bennetto, Pennington, & Rogers, 1996; Noland, Steven Reznick, Stone, Walden, & Sheridan, 2010; Hearn, Asato, Ordaz, & Luna, 2008; Poirier, Martin, Gaigg, & Bowler, 2011). If this working memory factor plays a more critical role, use of a prolonged temporal window would interfere with visual motion processing among individuals with autism. As such, this study employed two temporal conditions for the examination of speed discrimination. In the first, "regular" condition, two motion stimuli were presented closely in time (0.5 s interval), whereas in the second, "prolonged" condition, a relatively long time-interval (3 s) was imposed between the motion stimuli being compared. Performance under the prolonged condition, while normally used to assess visual memory, is also dependent upon the mechanisms for processing stimulus speed (McKeefry, Burton, & Vakrou, 2007; Pasternak & Zaksas, 2003). In addition, detection of coherent motion within a random dot pattern was assessed as an index of global processing.

Autism spectrum disorders were assessed using a standardized tool (the ADOS), and this clinical metric was compared with the perception of movement speed; such a relationship has not been systematically documented. Our working hypothesis was that, compared with healthy controls, individuals with ASD would show enhanced performance on speed discrimination, particularly under the prolonged testing condition, given that the additional time may be used for further processing.

2. Methods

2.1. Subject

Prior to the testing, all participants were debriefed about the general purpose of the study and signed assent forms. Their parents signed consent forms. The study protocol was approved by the institutional review board (IRB) and clinical evaluations and neurocognitive measurements described below were conducted as part of this study after the assent and consent processes.

Nineteen individuals with autism spectrum disorders (including Autism, PDD-NOS, and Asperger's Disorder) and 17 healthy controls participated in the study. Inclusion criteria for all participants were: (1) no history of any neurological disorders (such as seizure or stroke) or head injuries, (2) IQ $\geq$ 70, (3) age between 13 and 18 years old, and (3) no substance abuse in the six months prior to participation.

Individuals with ASD were recruited from McLean Hospital and throughout the Greater Boston area. Their diagnoses were based on a standardized observation/interview using the Autism Diagnostic Observation Schedule – ADOS (Lord et al., 2000), conducted by clinicians who were trained for research reliability, and a review of all available medical

records. Twelve of the ASD group had a diagnosis of autism, 5 of Asperger's, and 2 of Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS). Their average ADOS scores were 6.7 (SD: 3.7) for language-communication, 9.4 (4.7) for non-language communication, 0.4 (0.6) for imagination, 1.3 (1.7) for stereotypy, and 0.7 (0.7) for other. Healthy controls were recruited from the local community. They were screened for the absence of Axis I psychiatric disorders using a standardized interview based on the SCID-I/NP (First, Spitzer, Gibbon, & William, 2002). The two groups of participants were similar in terms of age ($t = 0.25$, $p > 0.05$).

The Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1949) was administered to all participants under 16 years and 9 months of age, and the Wechsler Adult Intelligence Scale was administered to participants over 16 years and 9 months of age. The participants had normal or corrected to normal vision, as assessed by the Rosenbaum Pocket Vision Screener. The table provides demographic information of the participants (Table 1).

2.2. Stimulus

The motion stimuli were random dot patterns (RDP) containing two hundred moving dots. The dots were small (2×2 min arc) and white (luminance: 105.0 cd/m^2) presented on an otherwise black background (luminance: 4.0 cd/m^2). Spatial location of the dots was randomly distributed within a circular window (7° of visual angle). The dots in each display were generated in different locations within the circular window, had the same speed, and did not overlap with each other. All dots had unlimited dot lifetime unless they moved outside of the circular window.¹ Display time of each RDP was 300 ms.

For speed discrimination, all of the dots of the RDP moved either to the left or to the right (Fig. 1). A speed discrimination trial included two presentations of RDPs (standard and comparison). The speed of the standard RDP was $5.25^\circ/\text{s}$. The speed of the comparison RDP was 5.41, 5.51, 5.78, 6.30, 7.35 or $9.45^\circ/\text{s}$. The speed difference between the standard and the comparison RDPs generated one of the six levels of signal strength for speed discrimination (2.5%, 5%, 10%, 20%, 40% or 80%).

For detection of coherent motion, the RDP included two types of dots—one moving coherently to the left or to the right (signal), and the other moving in random directions (noise). The proportion of the signal dots is defined as the coherence level (Fig. 1). A trial of detection of coherent motion included a single presentation of RDP in which coherence level was 5%, 10%, 20%, 40% or 100%. The coherence level of the RDPs generated one of the five levels of signal strength for detection of coherent motion.

2.3. Procedures

During speed discrimination, subjects determined which of the two presentations in each trial contained a faster moving RDP. The time interval between the two RDP presentations was either 0.5 s (regular testing condition) or 3 s (prolonged testing condition). The testing

¹Use of a limited dot lifetime would make the direction discrimination task more global in nature. However, under the unlimited dot lifetime condition used here, spatial integration of motion signals from randomly distributed dots is required for the direction discrimination task, which makes the task remain global.

sessions were blocked according to the time interval between two RDP presentations. With six levels of speed differences, two directions of motion (left and right) and each condition being repeated eight times, each testing session contained 96 trials. The percent of correct trials was used as a primary measure of visual performance.

During detection of coherent motion, subjects determined in which direction of motion the RDP moved in each trial. With five coherence levels, two directions of motion (left and right) and each condition being repeated eight times, each testing session contained 80 trials. The percent of correct trials was used as a primary measure of visual performance.

All stimuli and task procedures were programmed on a G3 Mac computer, which also recorded subjects' responses. The paradigm was created using C programming language within the Vision Shell as an interface. Subjects received instructions and practice time prior to formal data collection.

Two levels of analysis were performed on the speed discrimination data. First, the percent of correct responses, or accuracy, was analyzed as the dependent variable using an ANOVA. Second, perceptual discrimination thresholds – derived from the accuracy data using psychometric fitting functions² were analyzed as the dependent measure, using separate Student t tests.

3. Results

3.1. Speed discrimination under regular and prolonged conditions

The primary analysis was on the performance accuracy of speed discrimination. A three-way ANOVA [group (ASD and control) $\times$ signal strength (6 levels) $\times$ testing condition (regular and prolonged)] showed a significant main effect only for signal strength ($F = 131.4, p < 0.001$), indicating higher performance accuracies with increased signal strength. The interaction effect between group and testing condition was significant ($F = 4.3, p < 0.05$). To examine the nature of the interaction, follow-up twoway ANOVAS were performed on each of the testing conditions.

For the regular testing condition (0.5 s interval), a two-way ANOVA (group $\times$ signal strength) showed a significant main effect only for signal strength ($F = 68.2, p < 0.001$). Neither the main effect for group nor the interaction effect between group and signal strength was significant.

For the prolonged testing condition (3 s interval), a two-way ANOVA (group $\times$ signal strength) showed significant main effects for signal strength ($F = 60.6, p < 0.001$) and group ($F = 4.5, p < 0.05$). The group effect indicates higher performance accuracies in individuals with ASD than healthy controls. The interaction effect between group and signal strength was not significant. This pattern of result indicates that the significant interaction between group and testing condition, shown in the omnibus three-way ANOVA, is primarily due to the group difference during the prolonged speed discrimination.

² $P = 1.0 - 0.5 \times \exp[-(S/\alpha)^\beta]$ here, P is the performance accuracy, S is the signal strength (stimulus), α and β are the fitting parameters.

Speed discrimination thresholds were derived from the minimum signal strength level at which subjects performed at the 80% accuracy level, and were used as another dependent measure for each subject. The perceptual threshold differences between ASD and control groups were significant for the prolonged testing condition ($t = 2.13, p < 0.05$), but not for the regular testing condition ($t = 0.96, p > 0.05$), consistent with the analysis of performance accuracy. From the regular to the prolonged testing condition, the average thresholds decreased by 6.2% in the ASD group and increased by 8.3% in the control group (Fig. 2).

3.2. Detection of coherent motion

A two-way ANOVA [group (ASD and control) $\times$ signal strength (5 levels)] showed a significant main effect on signal strength ($F = 41.4, p < 0.001$). Neither the group nor interaction effect was significant.

Perceptual thresholds for detection of coherent motion were derived from the minimum signal strength level at which subjects performed at the 80% accuracy level and were used as another dependent measure for each subject. While the average perceptual threshold was slightly higher (degraded performance) in the ASD than in the control groups, the group differences were not significant ($t = 0.80, p > 0.05$), consistent with the analysis of performance accuracy.

3.3. Speed discrimination and other variables

In individuals with ASD, speed discrimination thresholds were used as a unitary measure to compare with other visual, cognitive and clinical variables. Here, the following results were found: (1) Between the regular and the prolonged testing conditions, speed discrimination thresholds were moderately correlated ($r = 0.43, p = 0.05$). (2) Neither the perceptual thresholds for regular speed discrimination nor for prolonged speed discrimination were significantly correlated with those for detection of coherent motion. (3) Perceptual thresholds were not correlated with IQ scores. (4) There were generally no correlations between the speed discrimination thresholds and the ADOS composite scores on Communication or Reciprocal Behaviors, except that the regular speed discrimination thresholds were moderately correlated with the ADOS Communication scores ($r = 0.42, p = 0.05$).

4. Discussion

This study found that individuals with ASD had precise speed discrimination performance scores similar to healthy controls when visual comparisons were made within a short time interval (0.5 s) and enhanced performance when visual comparisons were made over a prolonged period (3 s). On the coherent motion detection task, individuals with ASD showed similar performance to controls.

4.1. Speed discrimination as a local spatiotemporal process

Speed discrimination relies on the perceptual processing of dynamic information that is distributed over a limited range of space and time (McKee, 1981). The nature of motion requires its presence as a visual phenomenon distributed over space and time. If there were

no spatial distribution, the visual object would be still. If there were no temporal distribution, then we would only be viewing snapshots, and no motion would be perceived. The motion processing system integrates the spatial and temporal information and renders an independent perceptual metric – movement speed. Given that the computation of movement speed requires the signals from a series of spatial positions and temporal points, constant attention to a single spatial location does not provide additional benefits for, and may actually interfere with, this dynamic visual processing.

Extended attention to a specific spatial location could be a possible factor for superior performance on the tasks involving static visual signals. Restricted, stereotyped and repetitive behaviors, such as constant interest in a particular part of an object or extended selective attention on the same spatial locus, are often exhibited by individuals with autism (Cunningham & Schreibman, 2008; First, Spitzer, Gibbon, & Williams, 1994; Turner, 1999). Such an abnormal attention pattern might lead one to attribute superior visual performance in the ASD group to their lengthy attention to a specific spatial location. For static visual stimuli in which the same portion of the object remains in the attended location, this attribution seems to be sensible. For dynamic visual stimuli that are continuously changing over space and time, however, extended attention to a single spatial location can be detrimental.

When encoding movement speed, which is defined as a ratio of distance traveled over time spent on traveling, visual signals must be extracted and processed in different points of space and time, which is accomplished primarily in motion-sensitive brain areas such as the middle temporal area (MT) (Maunsell & Van Essen, 1983; Mikami et al., 1986). Restricted attention to one spatial point would occur at the expense of not attending to other locations simultaneously, since spatial attention is a limited resource (Alvarez & Franconeri, 2007). This scenario would lead to reduced, rather than enhanced, processing of speed information. The precise speed discrimination in individuals with ASD thus cannot be attributed to over-attending to a specific spatial location, although this is a problem that is often associated with autism.

The speed discrimination result instead can be interpreted as an extension of the local processing advantage model to the visual motion domain, especially on a prolonged time scale. One principal theme of the model suggests that the default setting of perception in autism is more locally oriented than that of perception among healthy controls (Mottron et al., 2006). Previous studies have found supporting evidence from ASD individuals' superior performance only on static visual tasks. If local processing of visual information is enhanced, as posited, superior performance in individuals with ASD should be observed not only in static but also in dynamic visual tasks. The lack of any indication of superior performance on dynamic visual tasks conducted in previous studies (Mottron et al., 2006) has, to this point, raised a question as to whether the notion of the local processing advantage can in fact be extended to dynamic visual processing domains. By employing speed discrimination, which involves neural computation at local levels, this study showed that individuals with ASD performed at normal or above normal levels for a visual task involving dynamic visual signals. This result provides evidence that for the perceptual process involving neural computations like those in speed discrimination, superior

performance can be manifest in a low level dynamic visual task, as suggested in the local processing advantage model (Motttron et al., 2006).

Our results of enhanced speed discrimination in autism parallel the results of several recent studies. Superior orientation discrimination in autism has been found using simple static gratings (Bertone et al., 2005). Consistent with this result, the present study found enhanced speed discrimination when simple coherent random dot patterns (100% coherence) were used. This result thus supports the notion that the local processing advantage in autism is not limited to visual processing of static stimuli.

It has also been found that children with ASD exhibit faster reaction times and no disruption in search efficiency on dynamic visual processing tasks (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009), suggesting that the ASD advantage derives from non-search processes such as an enhanced perceptual ability to discriminate between targets and distractors. This hypothesis is consistent with our finding of enhanced speed discrimination among adolescents with autism.

In a third study by Kaldy, Kraper, Carter, & Blaser (2011), it was found that toddlers with autism were able to search more visual items within a certain amount of time and were more successful in finding targets than controls (Kaldy et al., 2011). It is possible that enhanced local processing of each visual item facilitated visual search in this toddler group. Whether this relationship between local processing and visual search indeed exists will need to be verified by additional empirical data. Lastly, our finding of enhanced speed discrimination is also consistent with a recent meta-analysis on cortical activations in the visual system of individuals with autism, which found enhanced visual activity in the occipital, temporal and parietal cortices (Samson, Motttron, Soulieres, & Zeffiro, 2011).

4.2. Speed discrimination over a prolonged time scale

The finding that speed discrimination over a prolonged period is enhanced in autism is intriguing. For this time scale (3 s), working memory is presumably involved in normal visual processing. In previous studies, individuals with ASD exhibited either intact or impaired working memory during various perceptual and cognitive tasks (Bennetto et al., 1996; Noland et al., 2010; O'Hearn, Asato, Ordaz, & Luna, 2008; Poirier et al., 2011). If working memory played a major role in speed discrimination during the prolonged temporal interval, *intact to impaired* performance would be expected in individuals with ASD. The fact that this group exhibited *enhanced* speed discrimination over a prolonged period suggests that a different mechanism, rather than impaired working memory, may underlie abnormal processing of speed signals in this neurodevelopmental disorder.

Visual discrimination over a prolonged period, including in the motion domain, involves working memory (short-term storage) and encoding (Pasternak & Greenlee, 2005). Thus, instead of working memory, a likely alternative mechanism for abnormal processing of speed information in autism may be that the encoding of speed signals extends over a prolonged period. Encoding of speed signals is generally considered to occur in speed-tuned neural units of the visual system, such as those within the extra-striate cortex (Maunsell & Van Essen, 1983). The differences between an aggregate neural response (amplitude and

speed-tuning location) to one speed signal and that to another provide a neural basis for perceptual discrimination (Adelson & Bergen, 1985). One possible mechanistic change in the autism visual system is a shift of tuning in speed processing to a slow speed range. In this range, neural responses have longer latencies but more locally oriented (smaller receptive fields) (Priebe, Lisberger, & Movshon, 2006). As such, speed discrimination in autism would benefit from the availability of additional processing time given under the prolonged condition.

Speed information provides perceptual inputs for eye tracking of a moving target (Chen, Nakayama, Levy, Matthyse, & Holzman, 1999; Cisarik et al., 2010; Newsome & Wurtz, 1988). The possibility of preferential tuning toward slow speeds in autism is in line with the result from an eye tracking study, where individuals with autism, particularly those in late adolescence and older, showed reduced amplitudes of initial and maintained smooth pursuit to a moving target (Takarae, Minshew, Luna, Krisky, & Sweeney, 2004).

Extended encoding would afford additional processing of speed signals and allow for a perceptual advantage in this visual motion domain. As shown in this study, this predication fits well with the two aspects of the speed discrimination results: First, under the prolonged testing condition, the performance of individuals with ASD was better than that of controls; and second, from the regular to the prolonged testing conditions, average discrimination thresholds were decreased (better performance) in individuals with ASD, as opposed to increased in controls.

One feature of this putative extended encoding mechanism would be an association between enhanced processing and prolonged processing time. That is, the visual processing advantage in autism would be achieved only under the requirement of additional encoding time. This notion of a prolonged processing advantage appears to be consistent with several recent empirical studies on autism. For delayed temporal intervals (i.e. 'working memory' conditions), infant siblings of children with autism have demonstrated enhanced performance for identifying non-social visual targets (Noland et al., 2010), suggesting that this prolonged visual processing advantage may have a natural basis inherent in this neurodevelopmental disorder. Children with autism have also demonstrated an extended temporal range (of greater magnitude) for combining temporally unsynchronized visual and auditory signals into one perceptual entity (Foss-Feig et al., 2011), suggesting that the enhanced prolonged processing mechanism may not be limited to the visual domain. Individuals with autism have also been able to successfully ignore distracting stimuli under a higher level of perceptual loads (Remington, Swettenham, Campbell, & Coleman, 2009). This is consistent with the principal finding of this study, in which enhanced speed discrimination in individual with ASD was found under the prolonged condition for which perceptual information was maintained for an extended period of time.

However, this notion of a prolonged processing advantage appears to be at odds with those studies showing impaired working memory in individuals with ASD (O'Hearn et al., 2008). It is thus important to determine to which functional domains this notion of extended encoding is applicable. For example, better 'working memory' in infant sibling of children with autism—as discussed above—was found for non-social, but not for social, targets

(Noland et al., 2010), suggesting distinct mechanisms mediating different domains of information processing in autism. The framework of a prolonged processing advantage may thus be more useful for interpreting perceptual processing, rather than high level cognitive processing, in autism. This conjecture should be further examined in future studies.

4.3. Enhanced local processing of speed information

Previous studies have demonstrated a local processing advantage in autism using static visual stimuli (Mottron et al., 2006; Plaisted et al., 1998). The use of this type of stimulus left open the possibility that over-attention to the particular spatial location where static stimuli were presented was the responsible factor. The results of this speed discrimination study suggest that the local processing advantage in autism is not limited to the spatial domain (or attention to a particular spatial location). Rather, this special mechanism may represent a broad property of the visual system in individuals with autism, which extends to the processing of dynamic visual information.

Our finding of comparatively similar performances between individuals with autism and healthy controls on the coherent motion task suggests that there is no perceptual advantage in processing global motion information, although this null result should be duplicated in a larger sample size. However, this finding generally comports with the notion that ASD individuals' enhanced speed discrimination should be attributed to local processing in the motion domain.

Precise speed discrimination in autism may seem to contrast with deficient speed discrimination found in schizophrenia (Chen, Nakayama, Levy, Matthyse, & Holzman, 1999; Chen et al., 1999b; Clementz, McDowell, & Dobkins, 2007; Kim, Wylie, Pasternak, Butler, & Javitt, 2006), which is also considered a neurodevelopmental disorder (Lewis & Levitt, 2002). Comparing the two disorders, a recent theory posits that the social brain is under-developed in autism and over-developed in psychotic disorders including schizophrenia (Crespi & Badcock, 2008). Given that perceptual processing can be very different from the processing of social information, a perceptual analogy of this theory in the opposite direction may be useful for understanding speed discrimination or local processing of dynamic visual information in the two disorders. In such a perceptual analogy, over-developed local processing is posited for autism and under-developed local processing is posited for schizophrenia. This comparative notion would readily predict enhanced speed discrimination in autism and deficient speed discrimination in schizophrenia.

The processing of speed information receives visual signals from the early visual system. One question may be whether this local processing advantage on movement speed should be attributed to abnormal early visual processing. Previously, it has been found that infants at risk of autism had greater sensitivity to visual signals from the sub-cortical magnocellular pathway (McCleery, Allman, Carver, & Dobkins, 2007). Hyper-sensitivity in the magnocellular pathway could provide stronger signals for speed discrimination, leading to enhanced performance in autism. However, this interpretation is not fully supported by the finding that individuals with ASD and healthy controls had similar performance levels under the regular speed discrimination condition.

Increased activation in the left primary visual cortex (V1) has been found in individuals with ASD during the detection of coherent motion (Brieber et al., 2011). Note that this motion task first involves local processing of dynamic visual information, which occurs prior to global processing, and primarily in V1. Thus, enhanced speed discrimination in ASD may be associated with an over-functioning of the local processing stages in the visual motion system (Samson et al., 2011).

Enhanced speed discrimination in individuals with ASD may also be related to a brain network that integrates dynamic visual information through a feedback mechanism. The magno-pathway directly projects to and receives dynamic visual information as feedback from the frontal cortex (Kveraga, Boshyan, & Bar, 2007). It has been suggested that individuals with ASD may suffer from enhanced visual feedback, as shown by their poor performance during a texture discrimination task (Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2009). If visual feedback is altered in autism, either due to abnormal inputs from the magno-pathway or abnormal reentrance from the frontal cortex (Laycock, Crewther, & Crewther, 2007), the processing of dynamic visual information—as in speed discrimination tasks—would be affected. Further studying of the brain mechanisms underpinning enhanced speed discrimination may attest to whether this visual abnormality represents one of the broad autism phenotypes useful for deepening our understanding of this neurodevelopmental disorder.

4.4. Limitations

One limitation of this study is the moderate sample size. The findings of non-significant correlations between speed discrimination and IQ or ADOS scores should thus be taken with caution. To verify this aspect of the results, larger groups of subjects would be desirable in future studies, especially for detecting potential correlations between visual measures and cognitive or clinical variables. A larger sample size would also allow analysis and comparison of the perceptual results across subgroups that have different diagnoses within the autism spectrum.

Another limitation is the different gender composition of the two subject groups—more males than females in the group with ASD (consistent with the greater prevalence of autism in males than in females) vs. similar numbers of males and females in the control group. Although there is no evidence showing a gender effect in autistic visual processing, it will be prudent in future studies to match the two subject groups on gender, given that the two genders may differ in their developmental courses.

4.5. Concluding remarks

Through the application of the speed discrimination paradigms, this study found enhanced local processing of dynamic visual information in autism. The occurrence of this enhancement only in the presence of a prolonged time interval suggests that the local processing advantage may have a special temporal requirement. If this result is confirmed in independent studies, the temporally constrained perceptual mechanism should be translated for the improvement of visual and cognitive processing in autism. For example, it was reported that slow dynamic presentations facilitate recognition of social targets such as

facial expressions by children with autism (Gepner et al., 2001). However, to neutralize the local processing bias, target display time, as well as inter-stimulus interval, should be considered as a relevant factor for potential interventions in individuals with autism. In this regard, modulation of processing time of non-social targets may provide a complementary approach to normalizing perception and contributing to the improvement of social cognitive functions in this neurodevelopmental disorder.

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Fig. 1.

Schematic illustration of speed discrimination and detection of coherent motion paradigms. For speed discrimination (left), a pair of random dot patterns (RDPs) was presented sequentially in each trial. The task was to indicate which stimulus, the first or the second, moves faster. For detection of coherent motion (right), a single RDP was presented in each trial. The task was to indicate which direction, leftward or rightward, the stimulus moves.

Fig. 2.

(A) Performance accuracies as a function of stimulus strength levels – speed differences for speed discrimination and coherence levels for detection of coherent motion. The data points represent average results of the ASD (filled symbols) and control (open symbols) groups. For each group, the data were fit to a standard psychometric function, which is expressed as the Weibull equation: $y = 100 - 50 \exp[-(x/\alpha)^\beta]$, where y = percent of correct trials, x = stimulus strength levels, α and β are two fitting parameters, and $\exp$ is an exponential function (Chen, Bidwell, & Holzman, 2005). In both panels, the x axis denotes speed differences between a pair of random dot patterns in each trial. In both panels, the y axis denote the percent of correct trials. Shift of a psychometric function to the left signifies a requirement of low stimulus strength for performing the task (i.e. a better performance). (B) Summary of perceptual thresholds of speed discrimination and detection of coherent motion. Note that lower thresholds correspond to better performance levels for both tasks. The * indicates a significant group difference ($p < 0.05$). Error bars are for ± 1 standard error.

Table 1

Demographics of the sample.

	Sex	Age (year)	IQ ^a
Healthy Controls	M-9	15.7	106.4
(<i>n</i> = 17)	F-8	(1.9)	(15.6)
Individuals with ASD	M-16	15.6	98.2
(<i>n</i> = 19)	F-3	(1.8)	(13.8)

Group Mean (Standard Deviation). F, female; M, male.

^aBased on The Wechsler Intelligence Scale-Child Version.