Individual differences in the local or global processing styles within individuals with Autism: an alternative explanation to the Weak Central Coherence and the Enhanced Perceptual Processing theories.

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Nidhi Trivedi

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Abstract

Previous studies have reported inconsistent results for people with Autism Spectrum Disorders (ASD) in both biological motion and Navon tasks. Each of these tasks require both local and global processing and were used in this study to compare processing styles of both ASD and typical groups. In the biological motion study, the ASD and the typical groups completed an emotion and a direction-discrimination experiment with happy and angry point-light walkers, which were presented in four different stimulus conditions: upright, inverted, scrambled and random. Overall, the ASD group had higher reaction times and lower accuracy, but the effect of condition did not differ between groups. Both groups performed worse in terms of accuracy and reaction times in the scrambled (i.e., local information only) conditions, therefore revealing a global bias in the processing of biological motion information. In the Navon task study with the same participants, typical individuals exhibited a global precedence effect, manifested as lower reaction times for global stimuli as well as global interference in "look for only local digits" task. However, individuals in the ASD group did not, on average, show a local or a global bias. In a subsequent analysis, the ASD group was divided into locally-biased and globally-biased sub-groups. Now, when a three way analysis between typical and the two ASD groups was performed, the globally-biased group's performance was not distinguishable from that of the typical group, while no global bias was observed for the locally-biased group. When these two groups were compared on the Biological Motion study, the locally-biased group had no reaction time difference across conditions including both biological motion and Navon tasks, unlike the globally-biased group, who displayed higher reaction times for the scrambled condition, just like the typical group did. Therefore, it is possible that the inconsistencies in the local-global processing literature of individuals with ASD may have resulted because the studies did not account for individual differences in processing styles within the ASD groups that may be variable, unlike typical individuals who have a global bias for most tasks.

Introduction

Autism Spectrum Disorders (ASD) are characterized by deficits in social perception and cognition, communication, and repetitive or stereotypical behaviours (*Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, DSM-IV; American Psychiatric Association, 1994). Of these three deficits, deficits in social perception and cognition have been most firmly established (Abell, Happe, & Frith, 2000; Dakin & Frith, 2005; Happe & Frith, 2006; Klin, 2000; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). In addition, some studies of perception have reported that individuals with ASD have a local advantage, exhibiting faster and more accurate perceptual processing of local stimulus elements rather than global structure (Behrmann et al., 2006; Caron et al., 2006; Jolliffe & Baron-Cohen, 1997; Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000; Shah & Frith, 1993). However, other studies have reported that individuals with ASD exhibit a global advantage, just as typical observers do (Mottron & Belleville, 1993; Mottron, Burack, Stauder, & Robaey, 1999b; Ozonoff et al., 1994; Plaisted et al., 1999; Rinehart et al., 2000).

Two theories have attempted to explain the superior performance of individuals with ASD on tasks consisting of local elements: the Weak Central Coherence (WCC) theory and the Enhanced Perceptual Processing (EPP) theory. The WCC theory states that in contrast to typical individuals, people with ASD do not spontaneously integrate small features into a coherent, global picture. On the other hand, EPP theory states that individuals with ASD do not have deficits in global processing, but rather have a superior local processing ability compared to typical individuals. Various stimuli have been used to study local-global processing in individuals with ASD. In the field of cognitive and visual neuroscience, both biological motion tasks and Navon tasks are used to study perception and processing styles. Likewise in this study this study, biological motion as well as Navon tasks will be used to study perceptual and social perceptual processing styles in people with ASD and control participants.

Biological Motion

Johansson (1973) demonstrated biological motion perception by attaching small lights to the joints of a moving person and showing that the moving points of light are sufficient to evoke a percept of a moving human figure. These point light walker (PLW) displays typically consist of 10-13 points of light located on the major joints of the body. Further empirical studies have validated the use of point-light walkers for biological motion perception by showing that these walkers allow the perception of emotional states (Dittrich, Troscianko, Lea, & Morgan, 1996; Roether, Omlor, & Giese, 2008), identity (Cutting & Kozlowski, 1977), gender (Kozlowski & Cutting, 1977; Barclay et al. 1978; Mather and Murdoch 1994; Troje, 2002) and actions (Vanrie & Verfaillie, 2004).

Previously, biological motion has been used to study to demonstrate deficits in the perception of both emotional and non-emotional point light walkers in individuals with ASD, and the results have been mixed for the perception of non-emotional point light walkers. Moore, Hobson, and Lee (1997) showed that children with ASD discriminated moving people and moving non-biological objects displayed in PLWs with the same accuracy as typically-developed children. However, Blake, Turner, Smoski, Pozdol, and Stone (2003) found that children with ASD performed worse than typical children in a task that required them to identify whether a person was present in a series of normal and temporally-scrambled human PLWs, and that performance was negatively correlated with the severity of autistic symptoms.

Rutherford and Troje (2011) found no ASD-related deficits in tasks that required participants to detect point light walkers or discriminate the direction (i.e., leftward or rightward) of the walker. Another recent study found that 3 to 7 year old children with ASD do not preferentially attend to point-light displays over phase-scrambled motion, but they do attend to a point light display of a spinning top compared to a human point light walker, while the controls attended to biological motion in both experiments (Annaz, Campbell, Coleman, Milne, & Swettenham, 2012). Also, a positive correlation between IQ and accuracy in a walker direction-discrimination task that used masked point light walkers has been found in people with ASD (Rutherford & Troje, 2011). These results raise the possibility that differences among these studies may be due to differences in the age and/or IQ of the ASD participants, or perhaps to differences in stimuli.

Emotional point light walkers have been used to study the effects of ASD on the perception of emotion. Although Moore et al. (1997) did not find any deficits in the perception of actions in children with ASD, deficits in the perception of emotions were observed. Atkinson (2009) also found deficits in perception of emotions as well: the ASD group was significantly less accurate than a control group in identifying anger and happiness, and was less accurate, though not significantly so, in identifying fear and sadness. In addition, Hubert et al. (2007) found no deficits in those with ASD when they were asked to verbally describe actions such as jumping and digging, and subjective states such as itchy tired and cold. However, they were significantly less accurate compared to the control group in when they were asked to verbally describe emotions such as happy, angry and sad. Another study reported that although children with ASD can perceive meanings from bodily movements, they are less sensitive to emotional information conveyed by human movement (Parron, Da Fonseca, Santos, Moore, Monfardini, & Deruelle, 2008).

Biological motion can be used to study local-global processing in individuals with ASD, as typical PLW stimuli contain both local and global information, but one can create modified PLW stimuli to determine the extent to which the observers rely on each type of information. For example in a scrambled-walker stimulus, the starting vertical positions of the walker's dots are randomly selected along the vertical axis of the walker, so that only the local dot motion, but not the underlying skeleton (global form information), was preserved. Studies have shown that the normal participants perform at chance level on these scrambled walkers, which indicates that global information is vital to the perception of biological motion (Pilz et al., 2009). However, a study by Troje and Westhoff (2006) has shown that local information is sufficient to identify the direction of an upright PLW, as the typical individuals performed above chance level in the scrambled condition task. Also, whether local motion information is sufficient may depend on the specific stimulus examined, so it is important to examine this condition for new stimuli.

Both Murphy et al. (2009) and Rutherford and Troje (2011) found that ASD and control groups performed worse on the direction discrimination task when the point light walkers were scrambled. Hence, they suggested that individuals with ASD were not able to use local visual information to discriminate the direction of the walker. In contrast, a study that used ASD subjects who were age and IQ-matched with typically developing controls found that adolescents and adults with ASD showed an increased response time, but not increased error, in an identification task (Freitag et al., 2008). Also, Rutherford and Troje (2011) found that both control and ASD groups had increased error in the scrambled walker conditions compared to the coherent walkers. This may be because they made use of local information at a lesser level when both local and global cues were present.

The current study will use both the scrambled-walker stimuli and random-position walkers, which disrupt local motion information but preserve global form. The performance of normal participants on these walkers in a direction discrimination task is similar to their performance on normal upright walkers (Pilz et al., 2009), which suggests that global form information is sufficient to discriminate walker direction. Through the use of these different types of walkers, the importance of both local and global information can be examined in individuals with ASD.

We used emotional point light walkers to study the differences in processing styles, emotion perception, and biological motion perception in typical and ASD groups. In one experiment, the control group and ASD group had to discriminate the walking direction of the PLWs, and in the second experiment subjects had to discriminate the emotions of the same PLWs. To investigate the relevance of local and global information, we used four different conditions for these PLWs: upright, inverted, scrambled, and random-position; and two different emotions: happy and angry. Not only does biological motion task shed some light on the local-global processing of individuals, but we also can use it to study emotional recognition and social perception in individuals with ASD.

Navon Study

Many studies have suggested that individuals with ASD are better than typically-developed at detecting local targets in visual tasks (Caron, Mottron, Berthiaume, & Dawson, 2006; Jolliffe & Baron-Cohen, 1997; Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Plaisted, O'Riordan, & Baron-Cohen, 1998; Shah & Frith, 1993). Individuals with ASD are limited in their abilities to perceptually organize wholes from small parts and understand overall visual context (Brosnan, Scott, Fox, & Pye, 2004, Happe, 1996).

Navon tasks have been used to study local and global processing in individuals. In these tasks, the stimuli consist of large letters made up of small letters, or large numbers made up of small numbers. When asked to name either the local or global elements, typical individuals exhibit a global advantage: they respond faster and more accurately to global forms than to local forms. Furthermore, when they are asked to name either the global or the local form, and if local and global stimuli are incongruent, typical individuals respond faster and more accurately to the global form. When the participants are asked to fixate on the local information, the global information interferes (when local and global forms are incongruent) with it, as typical are known to have global processing, and this manifests itself as lower reaction times in the incongruent condition. This effect is referred as global interference. When both global advantage and global interference are present, the combination of effects is termed the global precedence effect. This task to provides a quantitative measure of local and global bias, making it ideal to investigate local and global processing in individuals with ASD. Specifically, the local advantage that has been found in individuals with ASD should be associated with a reduced global precedence effect in those individuals.

Studies using Navon tasks to study local-global processing styles in individuals with ASD have obtained mixed results. Some of the previous studies have shown a local advantage (Behrmann et al., 2006; Rinehart et al., 2000) as well as local interference (Behrmann et al., 2006; Mottron & Belleville, 1993; Plaisted et al., 1999; Rinehart et al., 2000) in people with ASD. However, other studies have found a global advantage (Mottron & Belleville, 1993; Mottron, Burack, Stauder, & Robaey, 1999b; Ozonoff et al., 1994; Plaisted et al., 1999; Rinehart et al., 2000) and global interference (Ozonoff et al., 1994; Plaisted et al., 1999, Exp. 2) in people with ASD. Finally, some studies report typical processing of both global and local information in hierarchical visual stimuli (Deruelle, Rondon, Gepner, & Fagot, 2006; Iarocci, Burack, Shore, Mottron, & Enns, 2006; Mottron et al., 2003; Ozonoff, Strayer, McMahon, & Filloux, 1994; Plaisted, Dobler, Bell, & Davis, 2006). These discrepancies in the results could also be accounted to the differences in stimuli and distance from the screen.

In this study, two selective attention tasks involving hierarchical digit-based Navon stimuli were used to study local and global advantage and interference in typical and ASD individuals. These stimuli were presented with unlimited exposure time, constant visual angle and constant distance in order to control for the confounding variables. The instructions directed participants to be as accurate and fast as possible. Therefore, given sufficiently high accuracies, reaction times can then be examined to observe local-global processing styles. This task helped us obtain a measure of local-global bias in individuals and based on those measures, we will be able to test whether these individual differences are good predictors of processing style preference in either group.

Purpose of this study

In the current study, we used both biological motion tasks and Navon tasks to study local-global processing styles in typical individuals and individuals with ASD. Also, we examined the relationship between the processing styles in both tasks for both groups to see if the ASD and control groups used the same processing style in both tasks, which require local as well as global processing. Then, the groups were separately examined for any possible differences among individuals of the same group and the predictors of individual performance were further examined.

Biological Motion Study

Methods

Participants

In this study, the ASD group consisted of 14 adults (males) and the matched control group consisted of 14 adults (males) without any developmental disorders. The participants in the control group were recruited from the community through an online advertisement. Participants in the ASD group were recruited via a referral from a clinician and their diagnosis was confirmed using these two criteria: (1) Autism Diagnostic Observation Schedule (ADOS-G) (Lord et al. 1994) and (2) Autism Diagnostic Interview (ADI-R) (Lord et al. 2004). The experimental group participants were free from any other medical, psychiatric or developmental disorders. Groups were matched for IQ, age and sex.

Prior to the experiments, all participants were given Wechsler Adult Intelligence Scale (WAIS-IV) which provides us with perceptual speed, verbal IQ and full scores. Information regarding the age, IQ and diagnoses of the participants is listed in table 1.

Table 1: Demographic information for all participants

Number of subjects	Gender	Age	FSIQ	VIQ	PIQ	ADOS score
ASD 14	M	26.5(3.6)	97.6(9.5)	99.5(13.6)	97.5(10.5)	12.8(4.9)
Control 14	M	28.8(5.7)	103.3(13.7)	107.6(10.6)	98.5(16.1)	N/A

Apparatus

A Dell computer and Video and Psych Toolbox (Brainard, 1997; Pelli, 1997) extensions for MATLAB were used to present the stimuli in both experiments. Stimuli were presented on a 19-inch CRT that had a resolution of 1024x760 pixels and a refresh rate of 85 Hz.

Stimuli

Point-light walker stimuli were created using a modified version of Cutting's classic point-light walker algorithm (Cutting, 1978; Thornton, Pinto, & Shiffrar, 1998; Thornton, Vuong, & Bulthoff, 2003). Rather than translating across the screen, the point light walker appeared to walk in the same place on the screen, as if it were on a treadmill. The walker was made up of 11 point lights that simulated points on the head, near the shoulder, both elbows, both wrists, the hip, both knees and both ankles.

The point-light walker stimuli were presented in 4 different conditions – upright, inverted, scrambled and random. In the upright condition, the walker just appeared to walk, as if on a treadmill, in the left or right direction. In the inverted position, the normal point light walker was rotated 180 deg in the fronto-parallel plane so that it appeared as if it was walking on the ceiling. In the scrambled condition, the starting vertical positions of the walker's dots were randomly selected along the vertical axis of the walker, so that only the local dot motion, but not the walker's global form, was preserved. In the random condition, the possible positions of the points on the walker's form were distributed uniformly across the 10 body segments, with each segment defined by a virtual line connecting the joints. The segments corresponded to the neck, the body, and left and right upper arm, lower arm, upper leg and lower leg. The dots were randomly repositioned on their corresponding segments on each frame. The random stimuli therefore preserved the walker's global form but not the local dot motions.

The point-light walkers also varied in their emotion type: happy and angry in this case. For each emotion type, there were four different walkers that were created using gaits of four people walking either happily or angrily (for more details, see (Roether, Omlor, Christensen & Giese , 2009). Three walkers of each emotion type were created from each person, yielding a total of 12 happy PLWs and 12 angry PLWs. These particular walkers and their variations were used because pilot studies indicated that typical individuals were able to identify their correct emotion types with almost 100% accuracy.

Each walker had a unique emotion and condition associated with it. These walkers were speed matched so that the discrimination of emotion or direction is not influenced by the difference in speeds of the walkers. Also, the walkers were presented for 1.128 seconds at a frame rate of 25 fps, and a complete stride cycle was achieved after 80 frames.

Procedure

The study was conducted in a darkened room, where each subject viewed the stimuli binocularly from the distance of 60 cm. Viewing position was stabilized with a chin/forehead rest that aligned the eyes with the centre of the computer screen. In both experiments, the walker's direction of motion on each trial was either rightward or leftward. A happy or angry walker was presented in one of the four conditions- upright, inverted, form-scrambled or random-position. Each subject performed 96 trials per stimulus condition (9x4) and 192 trials per each emotion type resulting in a total of 384 trials.

All variables (4 conditions and 2 emotions) were randomly intermixed for the subjects in the mixed design. All participants were given both emotion-discrimination and direction-discrimination experiment. Also, both experiments used the same stimuli. The only difference was that the participants were asked to discriminate emotions of the walkers in the emotion-discrimination experiment and they were asked to discriminate direction in the direction-discrimination experiment. The emotion discrimination experiment was always presented first.

Emotion-Discrimination Task

In order to familiarize the participants with the four different condition-type, six point light displays of each type were presented to the participants in practice trials at the beginning of the experiments. Their responses were recorded and feedback was provided. On each test trial, subjects had to decide whether the walker that was presented was happy or angry, by pressing keys on the keyboard that were labelled “happy” or “angry”. Feedback was not given for the experimental trials. The subjects were asked to be both accurate as well as fast in their responses.

Direction-Discrimination Task

In order to familiarize the participants with the four different condition-type, six point light displays of each type were presented to the participants in the practice trials. Their responses were recorded and feedback was provided. On each trial, subjects had to decide whether the walker that was presented was moving leftward or rightward by pressing keys on the keyboard that were labelled “L” or “R”. Feedback was not given for the experimental trials. The subjects were asked to be both accurate as well as fast in their responses.

Results

Reaction Times

Mean reaction times from the Biological Motion experiment are shown in Figure 1. Reaction times were analyzed with a 2 (group) x 2 (task) x 4 (condition) ANOVA. The difference in mean reaction time between the ASD and control groups was not significant ($F(1,26)=1.49$, $p= 0.23$). However, reaction times were significantly greater for the emotion-discrimination task compared to the direction-discrimination task ($F(1,12)=17.47$, $p<0.001$). Also, the main effect of condition was significant, ($F(3,78) = 7.04$, $p<0.001$). Inspection of Figure 1 suggests that the main effect of condition reflects the fact that reaction times were higher in the scrambled condition than in the other condition, an observation that was confirmed by pairwise *t* tests. These results are consistent with the hypothesis that there is a global bias for both typical and ASD participants.

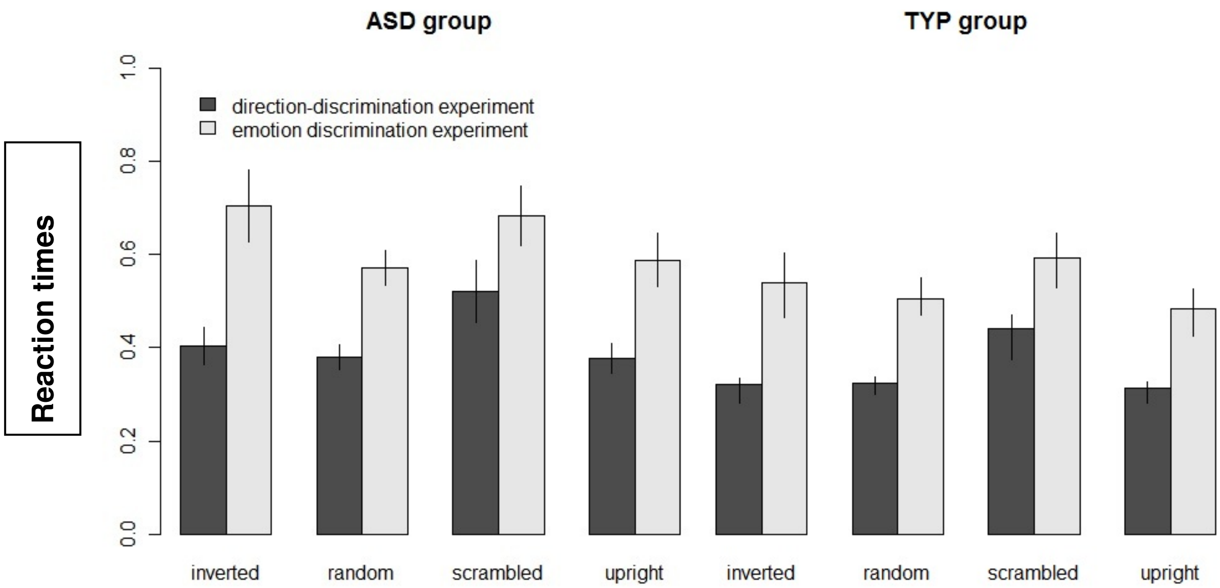


Figure 1: Reaction times for the emotion-discrimination and direction-discrimination tasks for the typical and ASD participants. Standard error is included as error bars.

Accuracy

Response accuracy (Figure 2) was analyzed with a 2 (group) x 2 (task) x 4 (condition) ANOVA. The difference in the accuracy between the ASD and the control group approached significance ($F(1,26)=3.59$, $p=0.07$): ASD participants were less accurate than the control group. There was a significant main effect of task ($F(1,26)=54.92$, $p<0.001$): Accuracy was greater for the direction-discrimination task than the emotion discrimination task. Also, the ANOVA revealed a significant main effect of condition that was driven by lower accuracy for the scrambled condition as we can see in Figure 2 ($F(3,78)=41.31$, $p<0.001$). Finally, there were significant interactions between task and condition ($F(3,78)=5.59$, $p<0.05$), and emotion and condition ($F(3,78)=6.15$, $p<0.05$). When the emotion x condition interaction was further analysed, we found that the accuracy was higher for the angry walkers in the scrambled condition. The task x condition interaction when further analysed showed that the accuracy in the scrambled condition for both tasks was not significantly different for the participants while their accuracy was higher for the other conditions in the direction discrimination task(see Figure 2).

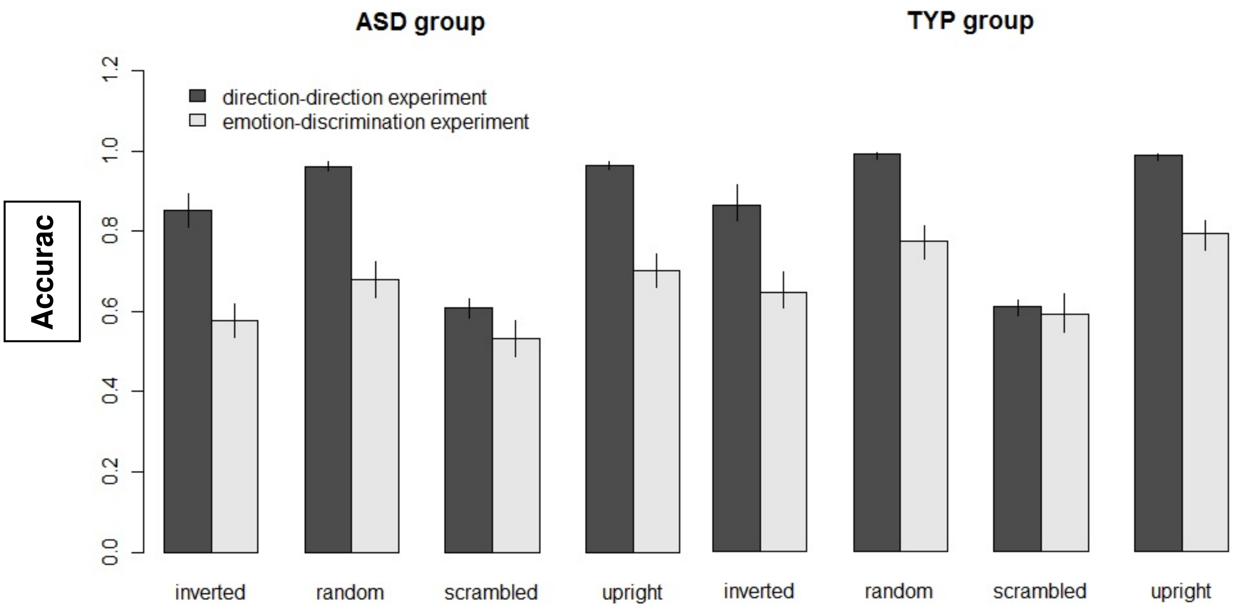


Figure 2: Accuracy for the emotion-discrimination and direction-discrimination tasks for typical and ASD participants. Standard error is included as error bars.

Individual Predictors of Performance

ADOS

In ASD participants, the ADOS score significantly correlated with reaction times in the scrambled conditions in the direction discrimination task (=0.77, p<0.001). No other task performance correlated with ADOS scores that were obtained for the ASD participants.

IQ

For the control group, response accuracy for the happy walkers in the scrambled condition in the direction discrimination experiment correlated significantly with Verbal IQ (VIQ) scores (r=0.56, p<0.05) and approached significance for Performance IQ (PIQ) score (r= 0.488, p=0.07 n.s.) and Full scale IQ (FSIQ) scores (r=0.464, p=0.09 n.s.). However, the correlations were not significant for scrambled angry walkers. For angry random-position walkers, correlation was significant with FSIQ (r=0.54, p<0.05) and marginally significant for VIQ (r=0.502, p= 0.067) and performance scores(r=0.458, p=0.09). However, it was not true of happy random-position walkers.

For the ASD group, the accuracy for the happy walkers in the inverted condition in the emotion discrimination experiment approached significant correlation with VIQ (r=0.514, p=.059) and for angry walkers, it approach significant correlation with FSIQ scores (r=0.479, p=0.08), replicating the finding of Rutherford & Troje (2011). No correlations with IQ scores were obtained for ASD and typical participants in relation to the reaction times for the emotion and direction discrimination experiment

Navon Study

Methods

Participants

The participants that performed the biological motion tasks also performed the local global tasks Refer to the Table 1 for more information about these participants.

Apparatus

The apparatus was the same as in the Biological Motion study.

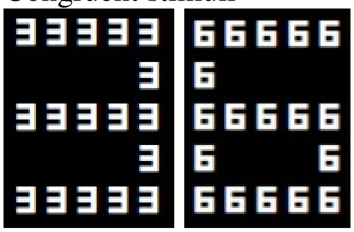
Stimuli

The stimuli in both local/global processing tasks were composed of hierarchical digits in which, a global digit is made up of many local digits. This is similar to the tradition Navon tasks that use letters instead.

In each of these two tasks, the size of the digit presented is 1.8X2.6 cm. The stimuli were categorized in three groups. In the congruent stimuli, global “3” is made up of local “3s” and global “6” is made up of local “6s”.In the incongruent stimuli, global “6” is made up of local “3s” and global “3” is made up of local “6s”. And in the neutral stimuli, global “2,5,8,9s” are made up of local 3s or 6s and global “3 or 6s” are made up of local “2,5,8,9s”. In the neutral stimuli, “3” and “6” do not occur together in one stimulus.

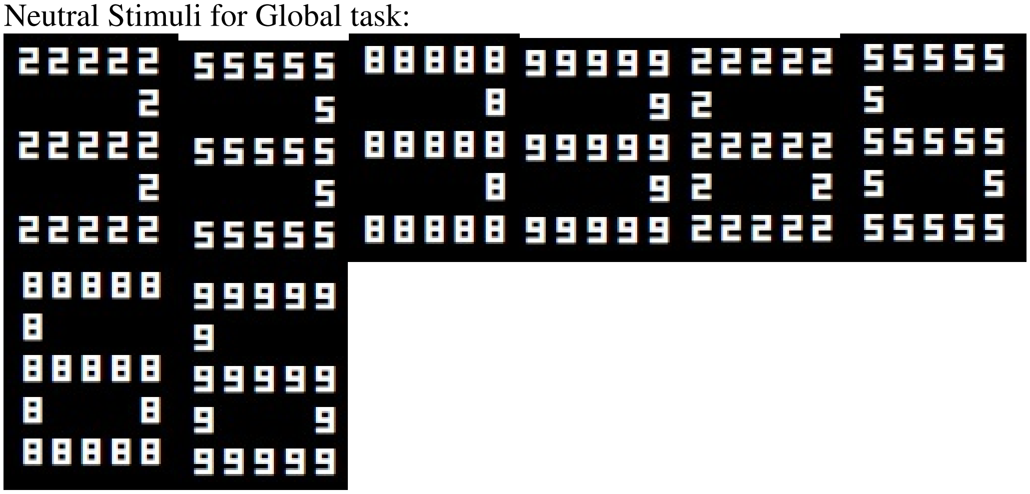
Figure 5 : Navon Task Stimuli

Congruent stimuli

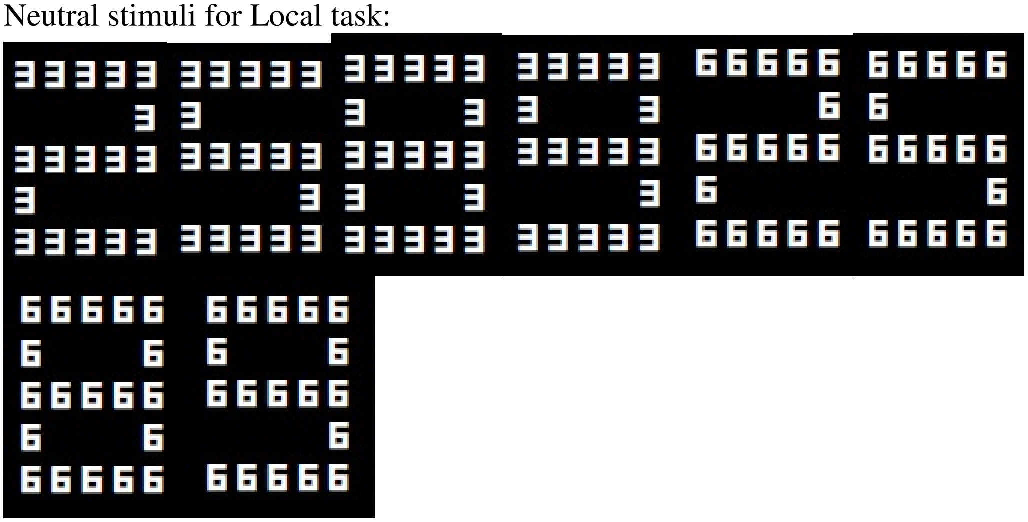


Incongruent stimuli

Neutral Stimuli for Global task:



Neutral stimuli for Local task:



General Procedure

The study was conducted in a dark room, where each subject viewed the stimuli from the distance of 100 cm. Their position was stabilized with their chin/forehead rest that aligned their eyes with the centre of the computer screen. In all the three tasks, the subjects are asked to look for a 3 or a 6 and to respond by pressing "3" or "6" on the keyboard, as fast and as accurately as possible. In both tasks, the number of stimuli was balanced by both task and condition-type.

Look for local digits only task

In this task, the subjects were presented 144 stimuli (48 neutral, 48 congruent, 48 incongruent). However, in this selective-attention task, the subjects were asked to only focus on the local numbers. Their reaction times were measured. Half of the participants in both ASD and control group did this experiment first. No practice trials were presented.

Look for global digits only task

In this task, the subjects were presented 144 stimuli (48 neutral, 48 congruent, 48 incongruent). However, in this selective-attention task, the subjects were asked to only focus on the global numbers. Their reaction times were measured. Half of the participants in both ASD and control group did this experiment first. No practice trials were presented.

Results

Reaction times

Mean reaction times, which are shown in Figure 6, were analyzed with a 2 (group) x 2 (task) x 3 (condition) ANOVA. There was a significant main effect of group ($F(1,26)=5.13$, $p<0.05$); reaction times were significantly higher for the ASD group compared to the typical group. Also, a main effect of condition was found ($F(2,52)= 6.16$, $p<0.01$), which was driven by significantly higher reaction times for the incongruent and the neutral conditions, compared to the congruent groups. Also, a task and condition interaction was obtained ($F(2,52)= 3.28$, $p<0.05$). Paired t-tests were conducted for both groups.

In the "look for only local digits" task, the typical participants had significantly lower reaction times for the congruent group compared to the incongruent condition ($t(13)= -2.05$, $p=0.05$). In the "look for only global digits" task, the typical participants did not differ significantly between any of the conditions. However, no such differences were found for the ASD group.

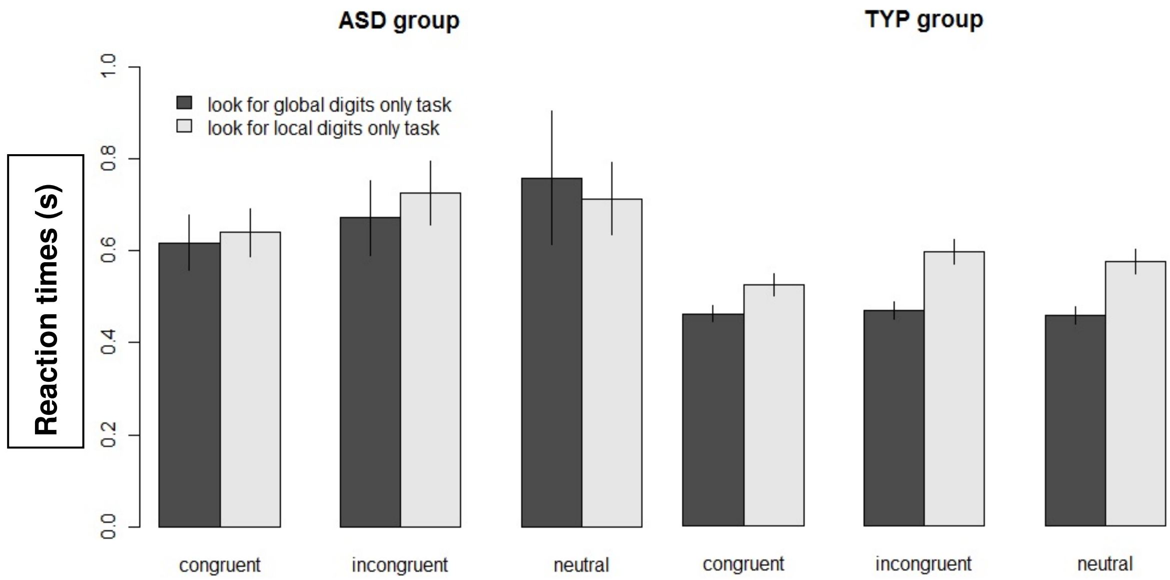


Figure 6: Reaction times for the local-global task for typical and ASD participants. Standard error is included as error bars.

Accuracy

Response accuracy (Figure 7) was analyzed with a 2 (group) x 2 (task) x 3 (condition) ANOVA. The main effect of group was not significant ($F(1,25)= 0.41$, $p=0.53$). A main effect of condition was obtained, which was driven by lower accuracy for the incongruent condition compared to the congruent condition ($F(2,50)= 9.85$, $p<0.001$) . Also an interaction between group and task was obtained ($F(1,25)= 5.71$, $p<0.05$). Also, a three way interaction between group, task, and condition was obtained ($F(2,50)= 3.49$, $p<0.05$).

In order to analyze the group x task x condition interaction, separate 2 (task) x 3 (condition) ANOVAs were performed on the two groups. For the typical group, the main effect of task was not significant ($F(1,13)= 3.54$, $p=0.08$), but the main effect of condition was significant ($F(2,26)= 10.5$, $p<0.0001$). Also, there was a significant task x condition interaction ($F(2,26)= 9.88$, $p< 0.001$). For the “look for local digits only” task, typical participants were significantly more accurate in the congruent condition compared to the incongruent condition ($t(13)= 4.09$, $p<0.001$). Also, accuracy was significantly less in the incongruent condition compared to the neutral condition ($t(13)= -3.24$, $p<0.01$). However, in the “look for only global digits” task, typical participants were more accurate in the congruent condition compared to the incongruent condition ($t(13)= 2.42$, $p<0.05$) and the neutral condition ($t(13)= 3.11$, $p<0.01$)

For the ASD group, only a main effect of condition was obtained, which was driven by the lower accuracy in incongruent groups in both tasks ($F(2,24) = 8.93$, $p < 0.01$). No other significant main effects or interactions were obtained.

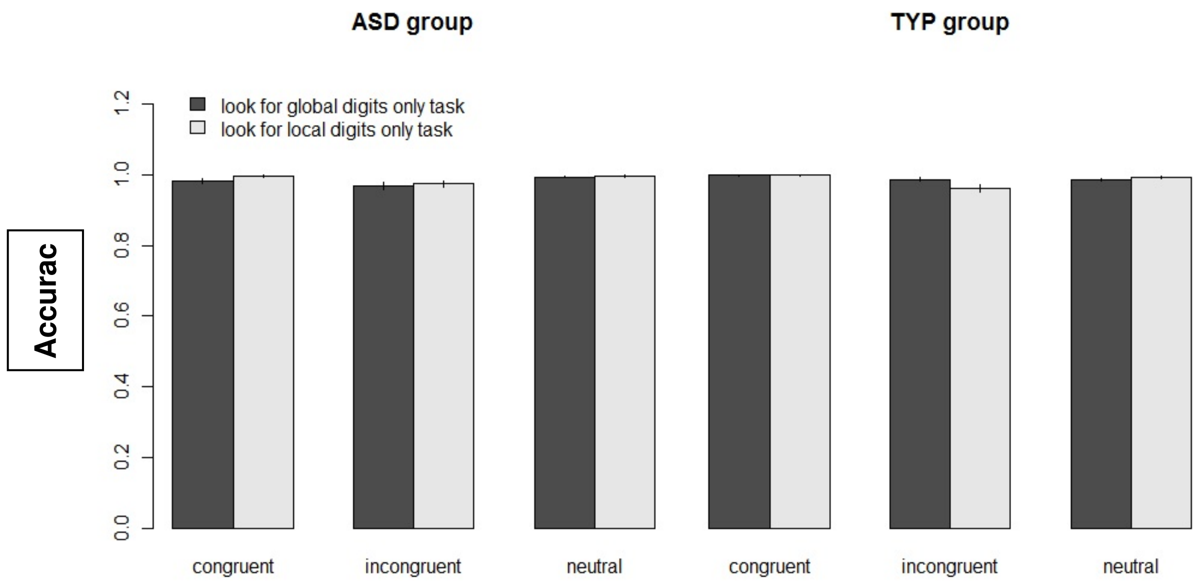


Figure 7: Accuracy for the local-global task for typical and ASD participants. Standard error is included as error bars.

Individual Predictors of Performance

ADOS

No ADOS and accuracy correlations were obtained in any tasks or conditions.

IQ

No significant correlations between reaction time and IQ scores were found for the ASD group. However, for the typical group, in the “look for only global digits” task, a correlation between VIQ and reaction times for the incongruent condition were obtained ($r = -0.58$, $p < 0.05$). Also, a correlation was also obtained between the VIQ and reaction times ($r = -0.703$, $p < 0.01$) as well as FS IQ and the reaction times ($r = -0.588$, $p < 0.05$) in the congruent condition in the same task.

For the ASD group, correlations were obtained between accuracy and IQ scores in certain condition types and task types. In the “look for only global digits” task, Full-Scale IQ correlated with accuracy in the neutral condition ($r = -0.61$, $p < 0.05$). For the typical group, in the “look for only local digits” task, the accuracy in the incongruent condition correlated with VIQ (r= -0.77, p<0.05), PIQ (r=-0.66, p<0.01) as well as FSIQ (r= -0.719, p<0.01)

Further Analyses

The purpose of the Navon tasks ("look for only local digits" and "local for only global digits task") was to see if the participants exhibited a local or global bias. Control participants were globally biased: in all conditions: their reaction times were shorter in the global task compared to the local task. Also, while responding to the global incongruent stimuli, local stimuli did not cause interference; hence no difference was obtained between their reaction times in congruent and incongruent condition. However, in the look for only local digits task, where the global stimuli interfered with the local stimuli, the performance of the control participants was significantly impaired, as the reaction times for the local incongruent condition were higher than the local congruent condition. Similar global precedence effect was not obtained for individuals with ASD. ASD participants did not significantly differ between tasks (F(1,13)= 0.02, p=0.588) or conditions (F(2,26)= 3.13, p=0.06) No other interaction was found. This led us to conclude that there are two possibilities 1) ASD participants did not differ between any of the tasks or conditions because they applied a different cognitive strategy to complete different tasks. 2) Some ASD participants are locally biased, while others are globally biased and it would be a mistake to categorise all ASD participants in the same category as they differ significantly based on their ADOS scores, WAIS scores as well as individual task performance.

In the previous research that examined the performance of people with ASD on Navon tasks, individuals from the ASD groups were treated as a whole entity and the entire group was labelled either "globally biased" or "locally biased" or with no perceived bias based on their results. However, they were not separated based on their individual differences. Therefore, what we did in this experiment is separate the ASD group in to two different groups "locally biased" and "globally biased". This was achieved by subtracting the reaction times of the congruent trials from the incongruent trials in the "look for local-digits only task". Then, individuals with the smallest difference or the least global-to-local interference were placed in the locally-biased group and the individuals with the greatest difference were placed in the globally biased groups. Reaction times were used to carry out this categorization as accuracy was above 90% for most participants in both tasks as well as all conditions.

After the ASD group was separated into two different groups, their performance was analysed again using between and within subjects ANOVA. When the analysis was conducted on "global processing biased", results were exactly the same as the control group. There was a main effect of task (F(1,6)= 17.28, p<0.01) and condition (F(2,12)= 11.05, p<0.01) for the locally biased control group. In addition to that an interaction between task and condition (F(2, 12)= 11.11, p<0.01) was also obtained for the globally biased group, similar to control participants. However, only a main effect of condition was obtained for the "locally biased group"($F(2,12)= 5.82$, $p<0.05$) (See Figure 8). These groups did not differ in terms of their ADOS or IQ scores.

This procedure was also performed for the typical group and the individuals were separated in to "locally-biased" and "globally-biased" groups according to their incongruence score. However, both of these groups showed global precedence effect, both through lower reaction times for the "look for global digits only" task as well as through global-to-local interference in the "look for local digits only" task. Therefore further analysis of these groups was not pursued.

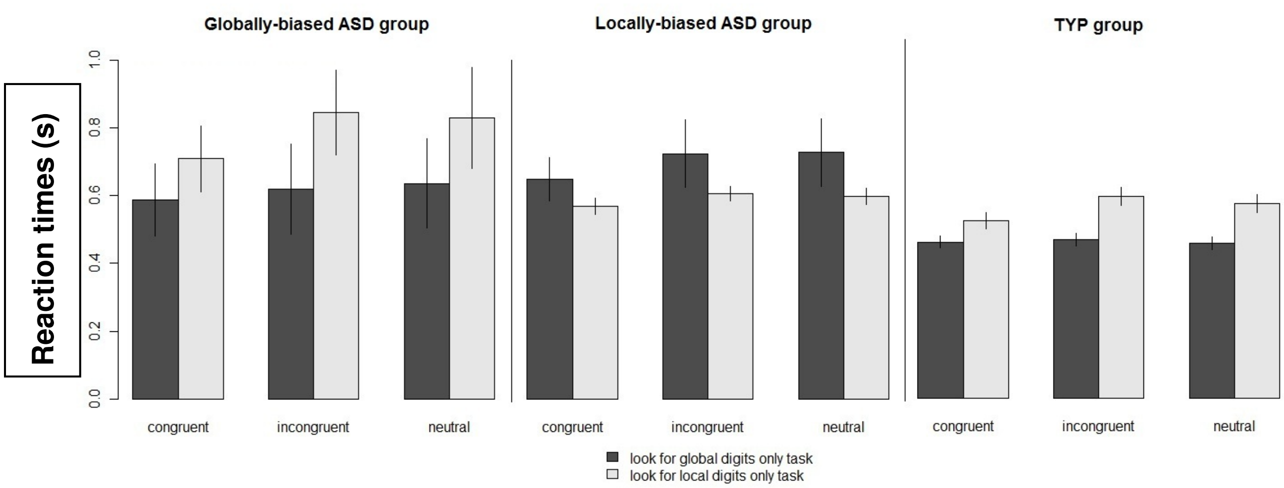


Figure 8: Reaction times for the local-global task for Globally-biased, locally-biased and typical group. Standard error is included as error bars.

The two ASD groups were then compared for the biological motion tasks to reveal any differences between the performance of "locally-biased group" and "globally-biased group" in the two biological motion tasks. When a mixed ANOVA was performed using the reaction times, no group-type main effect was obtained. However, a main effect of task ($F(1,12)= 8.57$, $p<0.05$) and condition ($F(3, 36)= 5.14$, $p<0.01$) was obtained, which was similar to typical participants and all ASD participants as a group (See Figure 9). Also a task, emotion and condition interaction was obtained ($F(3,36) = 3.48$, $p<0.05$). When the globally biased group was separately analysed, both main effects of task ($F(1,6)= 7.93$, $p <0.05$) and condition ($F(3,18)= 4.95$, $p<0.01$) were obtained again. However for the "locally biased group", only a main effect of task was found ($F(1,6) = 14.71$, $p<0.01$). Their reaction times for the scrambled condition were no different from the reaction times of any other condition. Therefore, we inferred that the individuals in the locally-biased group did not have higher reaction times for the scrambled condition as they have a local bias.

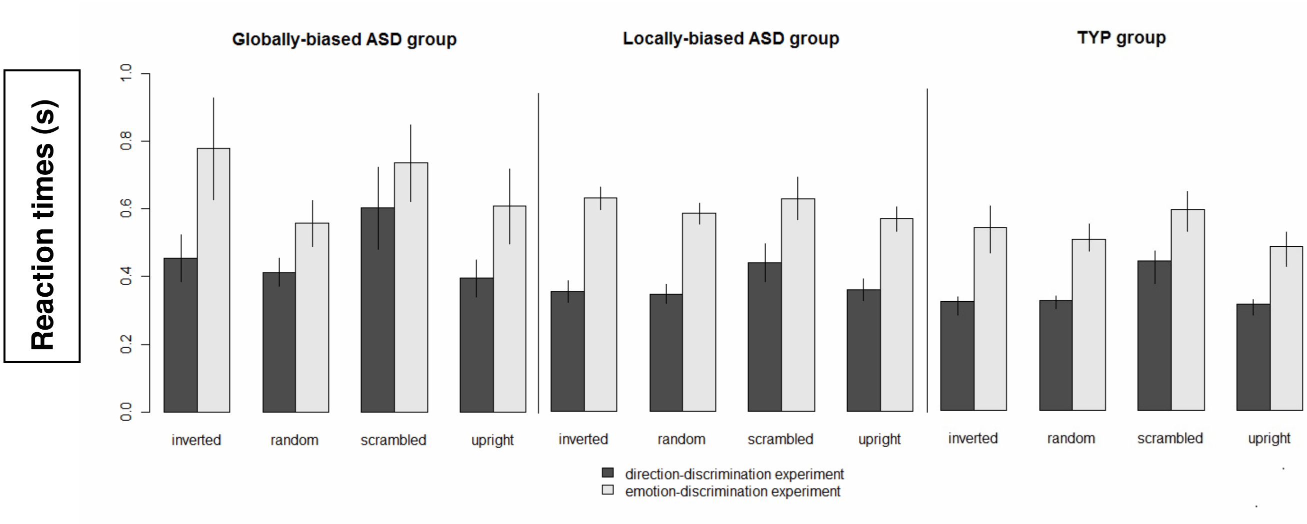


Figure 9: Reaction times for the Biological Motion tasks for Globally-biased, locally-biased and typical group. Standard error is included as error bars.

In contrast to reaction time results, when we looked at their accuracy in biological motion tasks, no significant differences can be seen between the locally-biased and the globally-biased group. There is no over-all main effect of group-type on the accuracy ($F=(2,25)= 2.71$, $p > 0.05$) of the participants. The locally-biased ASD group participants showed a main effect of task type ($F(1,6)= 58.57$, $p<0.001$) and condition type ($F(3,18)= 36.6$, $p < 0.001$). Even a task by condition interaction was obtained ($F(3,18) = 5.31$, $p<0.05$)(See Figure 10). Both the typical and the globally biased group participants have a main effect of task and condition as well a task condition interaction, just like the globally biased group. In addition, both the globally biased and the typical group have a condition by emotion interaction, not present in the locally-biased group. This suggests that the locally-biased group membership did not have an effect of emotions on their results but the globally biased group was affected by the emotions similar to the typical group.

Now, for the previous analysis, we used the local-global bias measure that we created using the "look for local digits only" Navon task. We also created another local-global bias measure using the biological motion task. We did so by subtracting the reaction times for the scrambled condition (local only) from the upright condition (both global and local information) trials for both emotions and tasks and then divided them by two. This gave a difference in the reaction times that suggested a local-global bias. If the reaction time difference between the two conditions was more, it suggested a global bias. However, if the reaction time difference was less, it suggests a local bias. In this case, the local bias does not mean that the reaction times for the scrambled condition trials would be less than that of the upright condition trials. However, it means that there is an absence of the cost attached to the presentation of only local information through scrambled walkers, in the form of increased reaction times. We did not use this as a local-global bias measure to analyse local-global processing because of the presence of the confounding variable emotion type. However, we compared the local-global bias measures across these two tasks.

We found that the local-global bias measure on one tasks predicts the local-global bias on the other task(r=.406, p<0.05). Also, when we just examined the ASD group, this correlation between the local-global bias across tasks was even stronger (r= 0.588, p<0.05). However, when we looked at the typical group only, this local-global bias did not have a significant correlation for both tasks (r= 0.244, p =0.4). This suggests that local-global bias is consistent in participants more strongly for the ASD group.

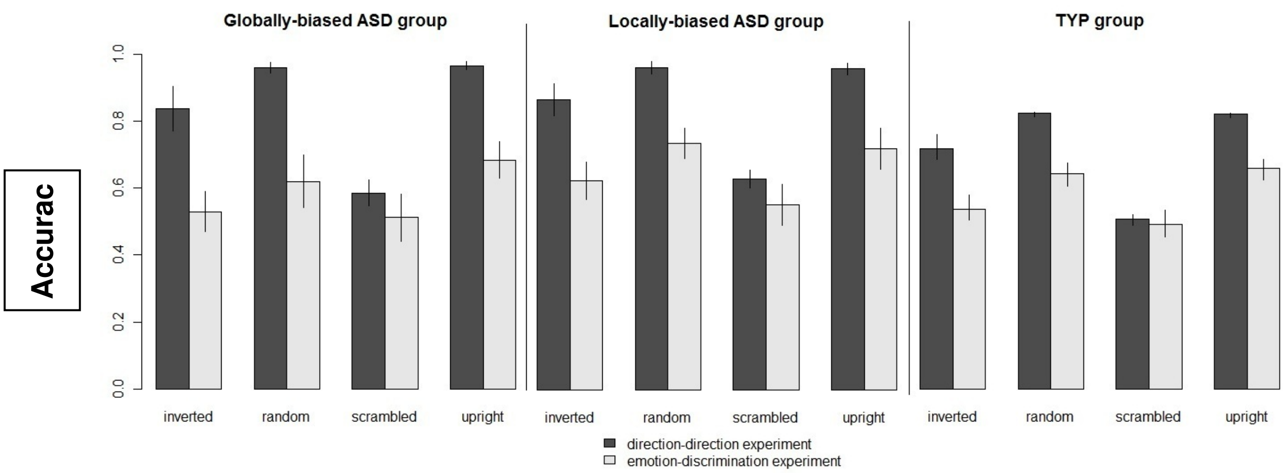


Figure 10: Accuracy for the biological motion tasks for Globally-biased, locally-biased and typical group. Standard error is included as error bars.

Discussion

For the emotion discrimination and direction discrimination biological motion tasks, we found no significant difference between the reaction times of the ASD and the typical groups. Response accuracy in the emotion discrimination task, on the other hand, did differ between groups: the accuracy of the ASD group was significantly lower than the control group for the emotion discrimination experiment. These results are consistent with other emotion discrimination studies that found deficits in the recognition of emotions in PLW displays among people with ASD (Hubert et al., 2007, Moore, Hobson & Lee, 1997, Parron et al., 2008). Our result is consistent with the hypothesis that people with ASD have deficits in emotion recognition but not in perception of biological motion more generally, as shown by previous studies (Moore et. al, 1997; Rutherford & Troje, 2011).

Both the ASD and the typical groups had significantly higher reaction times and lower accuracy for the scrambled walkers compared to the other walkers in both the emotion and direction discrimination tasks. Local dot motion, but not global form, is preserved in scrambled walkers, so the fact that performance was poor in that condition suggests that ASD participants successfully perceived global form in the biological motion experiment. Also, for the scrambled condition where only local information is presented, those with ASD had a hard time discriminating the direction as well as the emotion of the walker. Therefore, the claims made by the weak central coherence theory as well as the enhanced perceptual processing theory do not hold true for biological motion stimuli, as they do not display a local bias for both reaction time and accuracy measures, when seen as a group. Both WCC and EPP theories however hold true for some of the ASD participants in the group, as later suggested in the paper.

For the local-global task, ASD participants did not significantly differ between tasks or conditions. However, the reaction times of the typical participants were significantly lower for the global task compared to the local tasks. Reaction times were also lower for the congruent condition compared to the incongruent condition. In the "look for only local digits" task, the typical participants had significantly lower reaction times for the congruent group compared to the incongruent. In the "look for only global digits" task, the typical participants did not differ significantly between any of the conditions. Hence, we were able to replicate the well-known global precedence effect in typical participants. However, unlike previous studies, we were not able to find the local bias in ASD participants. For the ASD and the typical group, only a main effect of condition was obtained, which is driven by the lower accuracy in incongruent groups in both tasks. This suggested a global bias for both of these groups.

This study confirmed the findings of Rutherford and Troje (2011) who found that the IQ and ADOS scores are predictors of perceiving directionality in Biological Motion Study (see Results for details). This study shows that there is one more predictor of performance. In the previous research that that examined the performance of people with ASD on Navon tasks, individuals from the ASD groups were treated as a whole entity and were labelled either "globally biased" or "locally biased (Behrmann et al., 2006; Rinehart et al., 2000). However, they were not separated based on their individual differences. Therefore, what we did in this experiment is separate the ASD group into two different groups which were "locally-biased" and "globally biased" groups. When the analysis was conducted on "global processing biased", results were similar to those of the control group. However, only a main effect of condition was obtained for the "locally biased -group" and there were no task-based differences. Instead, lower reaction times for the "look for local digits only task" and local-to-global interference were obtained for the locally-biased group. This may have masked the group effect when the entire ASD group was analysed together, as the individual differences of the locally-biased and globally-biased group were probably nullified, when they were placed in the same group.

With respect to the Biological Motion tasks, for the globally-biased group, the reaction times for the global stimuli were lower compared to local stimuli, which was similar to typical participants' and that of the whole ASD group. People that were categorized as "locally-biased" in the Navon task did not show a local bias for the biological motion tasks. If they had a local bias for all the tasks, their performance in the scrambled condition would be better, with lower reaction times and higher accuracy for that condition, compared to the other conditions. However, that was not the case as even the people with local bias did not show a preference for the scrambled condition. The locally-biased group, in contrast, showed equal preference for all conditions, while the globally-biased group showed a preference for upright and random position conditions (primarily global stimuli). However, even in the locally-biased group, the accuracy for the scrambled condition was significantly lower than the other conditions which do not display a local bias. Hence, we can conclude that people with ASD did not have a local bias in biological motion task. We speculate that it may have been because the biological motion stimuli are too familiar. Even though the people in the ASD group have emotional recognition deficits, they are still quite familiar with the Biological Motion stimuli.

These results suggest that not all ASD participants have a local or a global processing bias. Perhaps, owing to the difference in their bias within the group, the results did not reveal a particular trend in the local-global tasks, when people with the ASD group were placed in the same group and compared to the typical group. This may have been the cause of several inconsistent findings in regards to the performance of the ASD group in the other Navon tasks. Although these previous studies were similar in design, stimuli-type and instructions given, the subjects that were tested might have had different processing biases. Hence, it is important to account for these individual differences before placing them in the same group. This is because it is possible that the studies that showed a local bias in individuals with ASD primarily consisted of the subject pools that were locally-biased.

In this study, we were able to show that certain individuals with ASD that had a local bias in the Navon task also performed differently in the biological motion task. Although these individuals did not display an overt local bias through lower reaction times in scrambled compared to random or upright condition, however, their local-bias was revealed through an absence of the difference between the upright and the scrambled condition, which is the absence of cost attached with the presentation of only local information. We saw that their performance in terms of reaction times was the same for all the conditions. Therefore, individuals in the ASD group that were locally biased showed a local bias in both tasks to a certain extent. This was confirmed by comparing the local-global bias measures for both tasks. Although the correlation was strong for ASD as well as typical individuals for the local-global bias measures for both tasks, only ASD participants continued to show this correlation when examined separately. This correlation between the local-global bias measure for both tasks disappeared for the typical. This suggests that individual differences were not obtained for the typical group, as they all displayed global bias in both Navon and Biological Motion tasks. However, individual differences were apparent for the ASD participants in both tasks.

It would be interesting to have more than one local-global task of a different nature, which would strengthen the reliability of this incongruence measure and findings. Then, we will be able to more confidently state that individual differences in processing styles and perception exist within individuals with ASD. Because of this variability, it would be wrong to place them in the same group and generalize the findings of one group to the rest of the ASD population. This is an alternative explanation to the WCC and EPP theories. These theories may be perfectly valid for the small subset of ASD population, however.

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