Hierarchical processing in ASD is driven by exaggerated salience effects, not local bias

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Hierarchical processing in ASD is driven by exaggerated salience effects, not local bias

Abstract

The role of relative salience in processing of hierarchical stimuli in individuals with autism spectrum disorder (ASD) was examined in this study. Participants with ASD and typically developing controls performed a Navon letters task under conditions of global salience, local salience or equal salience of both levels. Results revealed no group differences in level of processing (global or local) and no local bias for ASD. Rather, both groups showed better performance when targets were more salient compared to when distractors were more salient. Importantly, participants with ASD exhibited increased sensitivity to salience at the distractor level. We conclude that inconsistent findings in the context of global/local processing in ASD may stem from such exaggerated salience effects.

Autism Spectrum Disorder (ASD) is a term referring to a group of developmental disorders that appear in early childhood and includes symptoms from two main categories: Social and communication deficits along with fixated interests and repetitive behaviors (DSM-5, American Psychiatric Association 2013). From the first description of autism by Kanner (1943), up to the current diagnostic criteria according to DSM-IV and DSM-5(APA, 2000; 2013), people with ASD are often described as having an increased sensitivity to small details in their surroundings. Based on the above clinical descriptions and experimental studies (e.g. Jolliffe & Baron-Cohen 1997; Plaisted, O'Riordan & Baron-Cohen 1998; Shah &Frith 1983), leading theoretical approaches such as the Weak Central Coherence (WCC; Frith 1989; Happé & Frith 2006), and the Enhanced Perceptual Functioning (EPF; Mottron, Dawson, Soulieres, Hubert, & Burack 2006) have given a central role for the notion that people with ASD have an alternate perception processing style which is biased towards the local elements of the display unlike typically developed TD) individuals who tend to favor the global aspect of the percept (Navon 1977). Moreover, both theories tie these assumed unique patterns of perception with other characteristics of the disorder. According to the WCC hypothesis, the increased sensitivity to details among individuals with ASD is a result of a core deficit in global processing. On the other hand, according to the EPF model individuals with ASD are superior in their local perception and thus local perception becomes their perceptual default, while global processing is intact. The question of weak global processing and/or enhanced local processing among individuals with ASD was substantially examined during the last four decades using different types of behavioral tasks in which specific patterns of response were attributed to either enhanced local or global processing (e.g. the Block Design task, visual search tasks, the Embedded Figure Test, Navon letters task, etc.). However, findings from this large body of research are far from being consistent or conclusive and thus do not provide unequivocal support to either of the theories mentioned above (see Happé & Frith 2006; Muth, Hönekopp, & Falter 2014; Van der Hallen, Evers, Brewaeys, Van den Noortgate, & Wagemans 2015, for reviews).

One of the most familiar tasks for examining global and local perception is the Navon letters task. Navon letters (Navon 1977) are large letters (or numerals) representing the global level of the stimulus, built up of either congruent or incongruent small letters which represent its local elements (see Figure 1). Participants are instructed to identify one level while ignoring the other. Since both levels contain letters/numerals, they are semantically independent (one level cannot prime for the identity of the other), and are similarly coded. Thus, Navon letters enable the examination and comparison of the perception of both global and local levels of the stimulus within a single task (Kimchi 1992; Navon 1977; 1981). Navon (1977) found that among TD participants, reaction times for the global level were faster than for the local level (global precedence), and that in incongruent condition, the global level interferes with the perception of the local level (i.e. 'global to local interference') but not vice-versa. These findings have been substantially replicated and are commonly referred to as reflecting global processing bias among TD's (Kimchi 1992; Navon 1977; 1981). However, based on the predictions of WCC and EPF theories, one can expect that when asked to identify the letters in both levels, participants with ASD will exhibit improved local processing: Faster reaction times to the local level than to the global level (i.e. local advantage) and/or slowed reaction times to the global level in incongruent conditions (i.e. local to global interference). Regarding accuracy, one can expect fewer errors to local targets (local advantage) and/or increased error rates to the global level in incongruent conditions (i.e. local to global interference). However, results of studies that have used Navon letters among ASD participants were also inconsistent (see Baisa, Mevorach, & Shalev 2019; Muth et al. 2014; Van der Hallen et al. 2015, for reviews). Several studies exhibited local bias among ASD participants that was not found among TD participants (e.g. Wang, Mottron, Peng, Bertiaume, and Dawson 2007) while others found no differences between global and local levels (e.g. Koldewyn, Jiang, Weigelt, & Kanwisher 2013; Exp. 1) or even global advantage among ASD participants (e.g. Mottron, Burack, Stauder, & Robaey 1999).

However, performance on Navon letters in neuro-typical participants is known to be affected by the physical characteristics of the stimuli. The well-known effect of global advantage and/or global to local interference usually reported among TD individuals can be reduced or even reversed under manipulations such as increasing the visual angle of the stimuli, increasing the distance between local elements; prolonging exposure durations, etc. (see Kimchi 1992 for an extensive review). This dependency of global and local biases on the physical characteristics of the stimuli is often explained in terms of increasing the relative salience (or: relative discriminability) of one level with respect to the other (Kimchi 1992). It is therefore important to control (or at least consider) the possible influence of physical parameters of the stimuli when attempting to examine the global-local issue in ASD using Navon letters tasks. Indeed, in their recent review, Baisa et al. (2019) demonstrated substantial differences in the above mentioned physical parameters in studies investigating performance in Navon letters tasks in participants with ASD, which may have contributed to inconsistent findings. In other words, in many of the reviewed studies, attempts to examine local and global perception have co-varied with whether one level of the stimuli (the local or the global) was less or more salient than the other level in the particular displays, making it difficult to ascertain whether individuals with ASD show perceptual biases to a particular level of form (local or global) or rather to the more salient aspect of the hierarchical figure. To resolve this issue, in the present study we systematically manipulated the size of Navon letters stimuli (visual angle) so that in different conditions one level (the global or the local) was relatively more salient, relatively less salient, or equally salient compared to the other level. This orthogonal design allowed us to contrast the role of salience (whether the target level is more or less salient) with the role of perceptual level (whether the target is on the local or global level). To do that we analyzed the data as a function of both target level (global target or local target) and relative salience (target level is more salient than distractor, target level is less salient than distractor or target and distractor level are equally salient), which is derived from the visual angle manipulation. Before we report our experiment, we will briefly review relevant previous studies that manipulated visual angle.

Visual angle manipulations in Navon letters studies

Previous studies with TD participants have demonstrated that the global level is more salient at relatively small visual angles whereas the local level is more salient at relatively large visual angles (Granholm, Cadenhead, Shafer, & Filoteo 2002; Granholm, Perry, Filoteo, & Braff 1999; Kinchala & Wolfe 1979; Lamb & Robertson 1989; 1990; Lamb, Robertson & Knight 1990; Lawson et al. 2002). Currently, only two studies examined the influence of size manipulation of Navon letters stimuli with ASD participants and their findings are not consistent. In a study by Mottron, Burack, Iarocci, Belleville, and Enns (2003) 12 high functioning ASD participants aged 10-21 and their matched TD controls performed a divided attention task in which they had to search for a target letter (and respond by pressing corresponding button) that could appear in either the global or the local levels of Navon letters stimuli. All stimuli were neutral (i.e. the local and global letters were different but the irrelevant letter was never a possible response) and presented in three sizes of visual angle. The sizes of the global level were 2.17° x 1.37° (small); 4.34° x 2.74° (medium); and 8.64° x 5.46° (large). The sizes of the local level were 0.45° x 0.28° (small); 0.91° x 0.51° (medium); and 1.6° x 1.03° (large). They found similar patterns in both ASD and TD groups: faster responses to global targets compared to local targets in the smallest visual angle and to local targets compared to global targets in the largest visual angle. On the other hand, Wang, et al. (2007, Exp. 1) examined 12 pairs of participants aged 8:3 to 21:6, with and without ASD which were recruited from schools for children with intellectual disability. Participants were asked to name freely the numerals of the global and local levels of incongruent Navon letters stimuli. The order of naming was coded and reaction times for naming were measured. Stimuli were presented in three sizes. Global sizes were: 3.29° x 2.24° (small); 4.66° x 3.17° (medium); and 7.95° x 5.41° (large). Local sizes were: 0.55° x 0.34° (small); 0.82° x 0.62° (medium); and 1.51° x 1.1° (large). While the performance of control participants were significantly influenced by the relative salience of the global and local levels, exhibiting global advantage in the small and medium visual angles and local advantage in the large visual angle, ASD participants exhibited a local advantage in naming latency at all sizes. In light of the inconsistent findings of the above two studies, the present study was designed to examine whether ASD is associated with a general local bias even when relative salience is manipulated or whether they are sensitive to relative salience, similarly to TD participants. If ASD participants have a general local bias then we would expect local advantage (that is, better performance on the local level than on the global level) and /or local to global interference even when global level is more salient than the local level [similar to Wang et al.'s (2007) findings]. In contrast, if ASD participants are sensitive to salience manipulations like TD participants, then we would expect both groups to show precedence and/or interference effects that favor the more salient level compare to the less salient level regardless of whether the salient level is global or local [as in Mottron et al.'s (2003) study]. The specific sizes of visual angles that were used in the present study were chosen based on the parameters presented in Baisa et al.'s (2019) review. In addition, all other conditions were kept constant to avoid contamination by other salience factors (see Method section).

Methods

Participants

Participants were 61 adolescents. Among them 26 were typically developing participants. The other 35 participants were high functioning individuals with autism spectrum disorder (ASD) from which eventually only 26 met the inclusion criteria while nine did not (see details below). The 26 *Participants with ASD* were 22 males and four females aged 15-19years (Mean age=16:65, SD=1:15). All participants with ASD have community based diagnosis. They were first diagnosed as children at special child development institutes at their home town. These initial diagnoses were carried out by multi-disciplinary teams of medical specialists (neurologist or psychiatrist and psychologists) who have used various standard diagnostic tools, including ADI-R (Lord, Rutter, & LeCouteur 1994), ADOS-G (Lord et al.

2000), and CARS (Schopler, Reichler, and DeVellis 1980). This procedure ensures that all children met DSM-IV criteria[1] (APA, 1994; 2000). Importantly, all participants with ASD were affiliated with public special education for students with ASD, and thus their diagnoses were further confirmed at least three more times throughout their time in the public education system (before first grade, junior high, and high school). Eighteen participants attended special education classrooms for pupils with ASD within mainstream schools, seven participants were fully integrated in regular classrooms with personal assistance. One participant was homeschooled. In addition, within the current study, parents of 24 of the 26 participants in the ASD group completed the Autism Spectrum Quotient (AQ) questionnaire-Adolescent Version (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright 2006). Twenty one participants out of 24 scored above 26 (Mean= 30.58, SD=6.44, Range: 18-42), a cut-off score which have been argued to be a discriminative threshold for suspected cases of autistic disorder (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen 2005; Kurita, Koyama, & Osada 2005). Additional analyses without three participants whose scores were lower than 26, and without five participants (the above three and additional two participants with missing AQ) revealed the same significant results. Non-verbal intelligence was measured using the 'Raven's Progressive Matrices' (Raven, Court, & Raven 1979; Mean=55.654, SD=32.78). Parents' background questionnaires revealed that all ASD participants were healthy, and had no identifiable genetic, metabolic or infectious etiology for their condition. Participants were recruited by addressing them and their parents in letters sent by their teachers. As mentioned above, nine candidates were excluded at the beginning of the research for several reasons: Inability to follow instructions or claiming that presentation of the stimuli was too fast for them (n=3); Raven scores below normal (less than 5th percentile) (n=2); unclear diagnosis (n=1); inability to sit still during the tasks (n=1); suffering from active epilepsy (n=1); one participant refused to continue shortly after starting without giving a reason. *Control participants* were 26 typically developing (TD) pupils from main stream classrooms at the same high schools from which the ASD participants were recruited. Their parents were contacted in the same manner as the ASD participants. TD participants were 21 males and five females, aged 15-19 (Mean age=16:46, SD=1:06), with normal Raven scores (Raven et al. 1979; Mean=67.77, SD=25.78). Independent-samples t-test revealed no significant differences for age ($t_{(50)}$ =-0.598, p=0. 552) and for Raven scores $t_{(47.375)}$ =1.481, p=0.145) between ASD and TD participants. Parents' background questionnaire confirmed that all TD participants were healthy, with no known psychological, neurological or learning disorder of any kind.

The research protocol was approved by the ethics committee of Tel Aviv University and by the Ministry of Education's Chief Scientist. Participation in the study was with full consent of both the participants and a parent (in the case of minors). Participants signed informed consent and were told that they could stop their participation if they wished and that data collected would be kept confidential.

Stimuli

All stimuli were white on black background and were built in a 5 x 5 matrix. The numerals composing the global and local levels were 3 and 5 (see Figure 1). These specific numerals were chosen because they are easily distinguished from each other yet consist of the same number of "lines" needed to draw them. This decreases possible biases in discrimination. The stimuli were either congruent (both global and local levels were either 3, or 5, or incongruent (global level was 5 and local level was 3, or global level was 3 and local level was 5).

Insert Figure 1 about here

Stimuli were presented in three possible sizes: Small, medium, and large (see Table 1) which manipulated the relative salience of the global and local levels. That is, small enough to create global salience (similar to the smallest size in Mottron et al. 2003), large enough to create local salience (similar to the largest size in Mottron et al. 2003, and Wang et al. 2007), and medium size which gives no advantage in reaction times to either of the levels (similar to that used by Guy, Mottron, Berthiaume, & Bertone 2019, and Katagiri, Kassi, Kamio, & Murohashi 2013). The distance between local elements was of 0.1° across all three sizes. A white circle of 1° diameter served as a fixation sign prior to the presentation of the stimulus. This fixation circle appeared randomly half a degree above or below the center of the screen to prevent participants from focusing on a specific area of the visual field.

Insert Table 1 about here

Procedure

The experiment was held in a quiet room in the participant's school (during school time) or in the participant's home (after school time). A similar number of participants performed the experiments at home or at school in both ASD and control groups (ASD group: 11 at school, 14 at home; one in the Attention lab. TD group: 15 at school; and 11 at home. Participants and their parents signed an informed consent, after they had been informed about the experiments' tasks. The experiment was held in two separate sessions. In the first session the Raven test was administered to the participant and the parents completed the background questionnaires. Parents of ASD participants were also requested to complete the AQ questionnaire. The experimental task was performed during the second meeting.

Participants sat in front of the computer and placed their right and left index fingers on the 'A' and 'L' keys in the keyboard, respectively. The distance between the participant's eyes and the screen was approximately 45 cm. The experimenter measured the distance before the beginning of each block and verified that the participant was sitting still throughout each of the blocks. Participants performed six blocks of 48 trials Each and every one of the six blocks contained the four basic stimuli (5-5, 5-3, 3-3, 3-5, see Fig. 1) which were presented in random order and equally often. The size and the level of display that participants had to respond to (global or local) remained constant during each block. Thus, for each size condition (small, medium and large) two blocks were run, one for global identification and one for local identification. For the convenience of the participants, the target level (global or local) in the first 3 blocks remained constant and then changed for the final 3 blocks (e.g., global identification in blocks 1-3 and local identification in blocks 4-6). Half of the participants (in each group) started with the global level and the other half with the local level. The different sizes appeared in random order.

Each block was preceded by 12 practice trials. Eight ASD participants performed a second practice (in one experimental condition or more) after exhibiting accuracy rates of less than 80% in the first practice block. Each trial began with a fixation sign appearing on the screen for 1000 milliseconds (ms). Two hundred ms after its disappearance the stimulus was presented for 200 ms. Five hundred ms after the participant's reaction the fixation sign appeared again, and so on (see Figure 2 below).

Insert Figure 2 about here

The instructions for the participants were as followed: "You will see large numerals composed of small numerals. You have to respond to the large numeral and ignore the small numerals (or alternatively: You have to respond to the small numerals and ignore the large numeral). If the numeral/s you see is 3, press the 'A' key with your left index finger, and if it is 5, press the 'L' key with your right index finger.

Apparatus

Experimental tasks were presented using 13.6" X 7.68" Lenovo laptop computer. All experiments were designed by "presentation" software. Reaction times and accuracy rates were recorded.

Data Analysis

Mean reaction times were computed for correct trials only. Data trimming was done separately for each participant and for each experimental condition (+/- two standard deviations from the participant's personal average at the relevant condition)[2] . Accuracy rates were calculated as the number of correct responses divided by the total number of responses. Reaction times (RTs) of each experimental condition were divided by accuracy rates of the same condition to form an *Inverse Efficiency Score* (IES), used as the dependent variable (Townsend & Ashby 1983). Accuracy rates were generally high (above 89%) in both groups in all of the experimental conditions. Thus, the 'Inverse Efficiency Score' which quantifies both aspects of performance in a single measure, provides a better parsimonious measure of the performance in this case (Bruyer & Brysbaert 2011). Note that high values of 'Inverse Efficiency Scores' mean low efficiency (performance is slower and/or less accurate and thus less efficient).The data was analyzed using SPSS and Statistica programs. We conducted a four way mixed ANOVA with repeated measures with *Inverse efficiency scores* (IES) as the dependent variable: Level (global, local), size (small, medium, large) and congruency (congruent, incongruent) as within-subject factors, and group (ASD, TD) as between subject factor. Significant interactions were interpreted using Tukey HSD post hoc tests. In addition, we provide descriptive statistics and analyses of RTs and accuracy separately in a supplementary section. Importantly, the separate analyses supported the finding of the IES analysis with similar significant effects for RTs and similar non-significant trends in accuracy. To further contrast whether any effects obtained are driven by level of processing (global or local) or by the relative salience (salient target, salient distractor or equal salience (see Mevorach, Humphreys, & Shalev 2006; 2009; Mevorach, Shalev, Allen, & Humphreys 2009) we have re-coded the size factor to represent the relative salience (this was done following the initial analyses, which verified that the size manipulation was successful in changing the relative salience of the global and local elements; see Results below). Thus, the new factor of salience that replaced size was based on a combination of the current target level and the current size. A detailed description of the mapping between the size conditions and the salience condition is provided in the Results section below and in Table 3.

Results

Results of the four way ANOVA[3] (Level x Size x Congruency x Group) revealed significant main effects for Congruency ($F_{(1, 50)} = 149.54$, $p < .001$, $\eta_p^2 = .749$) and for Group ($F_{(1, 50)} = 4.27$, $p < .05$, $\eta_p^2 = .0786$). *Inverse efficiency scores* (IES) were significantly higher (indicating decreased performance) in the incongruent condition (Mean = 581, *SD*= 109), where there is a conflict between the two levels, compared to the congruent condition (Mean= 511, *SD*= 93) in which global and local levels are comprised of the same numerals, and among participants with ASD (Mean= 575, *SD* = 107) in comparison to TD participants (Mean = 518, *SD* = 90). Results also revealed two significant three-way interactions: (1) Level x Size x Congruency ($F_{(2, 100)} = 30.873$, $p < .001$, $\eta_p^2 = .381$) and, (2) Level x Size x Group ($F_{(2, 100)} = 5.084$, $p < .01$, $\eta_p^2 = .092$).

To identify the source of the *first interaction* (Level x Size x Congruency) we examined the intensity of the congruency effect as a function of level and size. We created a new variable for congruency effect by subtracting the performance in the congruent condition from the performance in the incongruent condition for each size at each level (see Table 2). The results of this subtraction depict, in fact, the intensity of the congruency effect (i.e. larger score reflects larger difference between congruent and incongruent conditions indicating a larger interference from the irrelevant level).

Insert Table 2 about here

We conducted a three-way ANOVA of Level x Size x Group with the above new congruency measure as the dependent variable. Results of the ANOVA revealed a significant interaction of Level x Size ($F_{(2, 100)} = 30.873$, $p < .001$, $\eta_p^2 = .381$), with no group effects. When comparing the global and local levels at each size (see Figure 3), Tukey HSD post hoc tests indicated that the congruency effect was significantly larger in the local compared to the global level at the small size suggesting that the global level was more salient, and in the global compared to the local level at the large size, suggesting that the local level was more salient (both *p's <0.001)*. No level differences were found in the medium size (*p= 0.95),* suggesting that no level was more salient than the other (i.e. equal salience).

Insert Figure 3 about here

Overall the observed within subject effects confirm that manipulating the visual angle created, as expected, different conditions of relative salience of the global and local levels: In the small size the global level was more salient than the local level; in the medium size both levels of processing were similarly salient; and in the large size the local level was more salient than the global one. Importantly, these results not only validated the manipulation of salience but also revealed similar patterns of global/local level of processing effects in both groups (see also Figure 4 below and Table 5 in the supplementary). Moreover, the above 3-way interaction revealed that the expected relative salience effect was irrespective of the specific level of processing (i.e., both the local and the global targets can be more or less salient depending on the specific size). Thus, each combination of level and size can be also described according to whether the target level (global *or* local) is more-, less- or equally-salient compared to the distractor (i.e. the irrelevant) level. Consequently, we ran another ANOVA to directly contrast effects of level (global vs. local targets) with effects of relative salience (relative salience of the target /distractor level). A similar approach was used in previous studies of Global/Local identification with manipulation of relative salience (e.g., Mevorach et al. 2006; 2009a; 2009b). This analysis was also useful in uncovering the *second interaction*, reported above which depicts *group* differences juxtaposed with level and size

(Level x Size x Group). To do that, we re-coded the size factor to represent the relative salience of the target and distractor levels. Based on the above level x size x congruency-interaction, the size factor was replaced by a salience factor as follows: the global level in the small size displays and the local level in the large size displays were both coded as 'salient target'. Similarly, the global level in the largest size and the local level in the smallest size were coded as 'salient distractor'. And finally, the global and local levels in the medium size were both coded as 'equal salience' (see Table 3 below). We conducted a four-way mixed ANOVA with repeated measures with *Inverse efficiency scores* (IES) as the dependent variable: Level (global or local), salience (salient target, equal salience, salient distractor), and congruency (congruent or incongruent) as within-subject factors, and group (ASD or TD) as a between subject factor. This analysis is therefore able to highlight possible group differences in the contribution of each of the two independent variables: global/local level of processing (irrespective of salience), and salience processing (irrespective of level), as well as the interaction between them.

Insert Table 3 about here

Insert Figure 4 about here

Alongside main effects that were reported above in the former analysis (i.e. main effects of congruency ($F_{(1, 50)} = 149.541$, $p < .001$, $\eta_p^2 = .749$), and of group ($F_{(1, 50)} = 4.27$, $p < .05$, $\eta_p^2 = .079$), the new analysis also revealed a significant main effect of salience ($F_{(2, 100)} = 51.096$, $p < .001$, $\eta_p^2 = .505$) resulting from lowered performance in the 'salient distractor' condition (Mean= 600, *SD* = 94) compared to 'salient target' (Mean= 508, *SD*= 124), and 'equal salience' (Mean= 530, *SD* = 99) conditions (both *p's <.001)*. Results also uncovered two significant two-way interactions: (i) Salience x Congruency ($F_{(2, 100)} = 42.344$, $p < .001$, $\eta_p^2 =$

.459) and, (ii) Salience x Group ($F_{(2,100)}$ = 8.921, p< .001, η_p^2= .151). Critically, there were no significant effects of level (all F's<1.94).

Interaction (i) (Salience x Congruency), replicates the original Level x Size x Congruency interaction we found in the original analysis (see above), under the new coding. Tukey HSD post hoc tests revealed that the differences between congruent and incongruent conditions were significant in all three salience conditions (i.e. 'salient target', 'equal salience', and 'salient distractor'), (all *p's <.001*). Thus, once again we examined the congruency effect (by subtracting performance in the congruent condition from performance in the incongruent condition in each salience condition). We found a significant effect ($F_{(2, 102)}$ = 41.2, p< .001, η_p^2= .446). Tukey HSD post hoc tests indicated that all the three salience conditions significantly differed from one another (all *p's <.01*), with the largest congruency effect in the 'salient distractor' condition (Mean= 113, *SD* = 77), followed by a smaller effect in the 'equal salience' condition (Mean= 74, *SD* = 54), and the smallest congruency effect in the 'salient target' condition (Mean= 23, *SD* = 40)

In *interaction (ii)* (Salience x Group) Tukey HSD post hoc tests revealed that the groups significantly differed in performance only in the 'salient distractor' condition (p< .05) where ASD (Mean= 652, *SD* = 153) performed worse than TD (Mean= 549, *SD* = 87). However, ASD and TD performance was comparable in the 'salient target' (*p=.75*), and the 'equal salience' (*p=.938*) conditions (see Figure 5). This analysis reveals that group differences between ASD and TD were not associated with a specific level of processing (global or local) but rather were uniquely linked to conditions in which the distractor level was more salient than the target level (irrespective of the perceptual level).

Insert Figure 5 about here

Discussion

In this study we examined the impact of relative salience on processing of hierarchical figures ('Navon letters') among ASD and TD participants. By using orthogonal manipulations of size and target level, we were able to isolate effects reflecting level of processing (i.e. global or local) from effects of relative salience (i.e. whether target level is more, less or equally salient compared with distractor level). Our manipulation of size (visual angle) resulted in the expected changes of relative salience of the global and local levels. We were able to induce global bias (in small displays), local bias (in large displays) or no bias (in the middle size displays). Importantly, these induced level biases were comparable across the two groups. Both ASD and TD participants exhibited significant global advantage in the small size and significant local advantage in the large size (precedence effects), as well as the corresponding interference effects (congruency difference was smaller for the advantaged level (see Figures 3 and 4). These results replicate the well-documented effect of size manipulation in Navon letters studies with TD participants (see Kimchi 1992). Regarding participants with ASD, our results are in line with Mottron et al.'s study (2003), who also found differential perceptual biases among their ASD participants as a function of the size of visual angle, but not with Wang et al.'s findings (2007), who demonstrated local advantage among their ASD participants regardless of size. Alongside several differences between Wang et al.'s study and the present study (e.g. task's demands, participants' profile), it is possible that the smallest size they have used was not small enough to produce distinctive global salience (Baisa et al. 2019).

No evidence for local bias in ASD

Results of the present study do not provide support for the notion of a local bias among ASD participants. Along with similar patterns of level response in both groups (i.e. global advantage in the small size, no level difference in the medium size and local advantage in the large size), there was also no difference in the magnitude of the salience effect as a function of level. In both groups responses to global and local targets were quite similar when targets were salient or when distractors were salient (see Table 3 and Figure 4). In other words, unlike the predictions of the WCC and EPF theories (Frith 1989; Mottron et al. 2006), ASD participants did not exhibit better performance for salient local targets (in comparison to salient global targets) nor a greater interference effect when responding to global targets under conditions of local salience (compared to local targets presented under conditions of global salience). Moreover, results also indicate that performance of ASD participants as a group was generally lowered (slower and/or less accurate) compared to the performance of TD participants. Thus, the results cannot support the claim that ASD participants are characterized by normal global perception (as claimed by the EPF theory), nor by a superior local perception (as expected by both WCC and EPF theories) (see also Shalev 2007). Significantly (or marginally significant) lower performance of ASD participants in comparison to their controls that was not associated with specific global/local level of processing were also reported by most of the previous Navon letters studies (e.g. slower RTs in Behrmann et al. 2006; Katagiri et al. 2013; Mottron et al. 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge 2001; Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008; lower accuracy rates by Plaisted, Swettenham, & Ress 1999). Indeed, previous extensive meta-analyses (Muth et al. 2014; Van der Hallen et al. 2015) looking at a range of locally oriented tasks (e.g. visual search, block design, embedded figure test, hierarchical figures, etc.) reported no evidence of improved visuo-spatial abilities in ASD. If anything, performance was possibly slower in a subset of tasks (Van der Hallen et al. 2015), which fits with our finding here too.

Effects of salience

While we found no group differences in regard to global/local level of processing we did find differences in sensitivity to relative salience. Both groups showed better performance when the target was more salient compared to when the distractor was more salient, but participants with ASD were significantly worse than their TD counterparts when distractors were more salient.

A greater deterioration in performance among ASD participants when distractors are more salient compared to salient targets may result from two interacting processes. One is the need to ignore or filter out the irrelevant (but now more salient) distractor. The other is the need to process the less salient target – that is, regardless of the need to filter out a distractor, participants are required to identify a low salience target in this condition. Thus, poor performance in distractor salient condition could stem from impaired suppression of salience (e.g., Mevorach et al. 2006) impaired ability to process low salient information, or both.

Either way, the main finding here is that relative salience plays an augmented role in processing of compound stimuli in participants with ASD compared to TD participants. Such increased sensitivity to salience manipulation was also reported by several previous studies using different tasks in different modalities (Leader, Loughnane, McMoreland, & Reed 2009; Russell, Mauthner, Sharpe, &Tidswell 1991; Todd, Milles, Wilson, Plumb, & Mon-Williams 2009; Wang et al. 2015). In the context of Navon letters studies, our results suggest that between- group effects in response to 'unbalanced' globally or locally salient compound figures may actually reflect different sensitivity to salience rather than to global/local level of processing.

Importantly these group differences need to be taken in the context of tasks which are designed to reflect differences in RTs when accuracy is at ceiling or approaching ceiling. Note that similar high accuracy rates were also reported by former Navon letters studies with ASD participants (e.g: Behrmann et al. 2006; Guy et al. 2019; Wang et al. 2007). When higher cognitive and/or attentional demands are introduced, other patterns may emerge.

Summary and conclusions

Examining performance in a 'Navon letters paradigm' while controlling for salience revealed three main findings. First, participants with ASD exhibited no evidence for local bias. Rather, similarly to TD participants their performance was best when the target level was more salient than the distractor level, independent of global/local level of processing. However, ASD participants differed from TD participants by exhibiting general lowered performance and by being more sensitive to salient information, particularly in the distractor level. Together with previous evidence suggesting that global- local differences in ASD are negligible (Muth et al. 2014; Van der Hallen et al. 2015), the present results support the suggestion of Baisa et al. (2019), according to which, inconsistent findings in former Navon letters studies with ASD participants are related to the difference in the physical characteristics of the stimuli that may have contributed to differences in the relative salience of each level.

The increased sensitivity to salience at the distractor level that was found in the present study needs to be further examined to unravel which factors (perceptual and/or attentional) underlie the amplified vulnerability to salient irrelevant information that characterizes individuals with ASD. Whichever the case, given that efficient (or: automatic) processing is characterized by being fast and less vulnerable to interference (Kahneman 1973; Kahneman & Treisman 1984), the current study may indicate that hierarchical perception of individuals with ASD is less efficient (or: immature). In this respect, future studies could further investigate developmental trajectories of hierarchical perception in ASD and in TD to ascertain whether efficiency of hierarchical processing is achieved at a later stage in individual with ASD (see Scherf et al. 2008; Van der Hallen et al. 2015 but also Guy et al. 2019). The present findings also raise questions regarding the potential of cognitive training that will target the ability to cope with salient irrelevant information to improve the efficiency of hierarchical processing in individuals with ASD (e.g., Spaniol, Shalev, & Mevorach 2018).

Compliance with ethical standards:

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Conflict of interest: each and every one of the authors declares that he/she has no conflict of interest.

Ethical approval: All procedures with human participants were in accordance with the ethical standards of the Tel Aviv university ethics committee and by the Ministry of Education's Chief Scientist and with the 1964 Heisinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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Footnotes

1. All of the participants were born before 2013 and were diagnosed according to the existing DSM version at the time.

2. Mostly, only 1-2 trials were excluded (on rare occasions there were three excluded trials) in a block of 48 trials, but never more than that). This was the case for all of the participants, in all conditions, in both groups.

3. An additional statistical analysis with 'Raven's Progressive Matrices' scores as a co-variate (ANCOVA) replicated the significant level, size and group interaction on IES that were obtained in the original analysis.

Figure captions

(All graphs were performed using Excel)

Figure 1. Examples of the compound stimuli

Figure 2. Schematic description of a trial

Figure 3. Congruency effect by level and size. Dark bars refer to the global level, and light bars to the local level. Note that 'congruency effect' is the difference between congruent and incongruent conditions at each size in each level of processing (global or local). This difference depicts the interference from the irrelevant level.

Figure 4. Inverse efficiency scores (IES) by level, size, and group. Panel A: Inverse Efficiency Scores (IES) by level and size in the ASD group. Panel B: Inverse Efficiency Scores (IES) by level and size in the TD group. Dark bars refer to the global level and light bars refer to the local level. Note that small global and large local stimuli are mapped to 'salient target' condition whereas large global and small local stimuli are mapped to 'salient distractor' condition.

Figure 5. Inverse efficiency scores (IES) by relative salience and group. Inverse Efficiency Scores (IES) are presented by relative salience and group. Dark bars refer to the ASD group, and light bars to the TD group. Note that 'salient target' condition comprised of small global and large local stimuli, 'equal salience' condition comprised of medium global and local stimuli, and 'salient distractor' condition comprised of large global and small local stimuli

Figure 1 top

Congruent stimuli

Incongruent stimuli

Figure 2 top

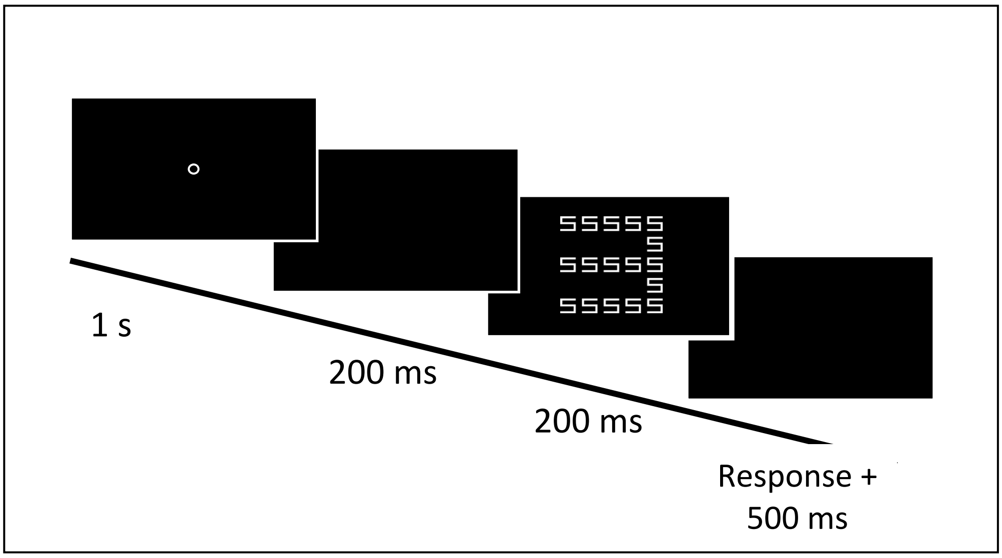

Figure 3 top

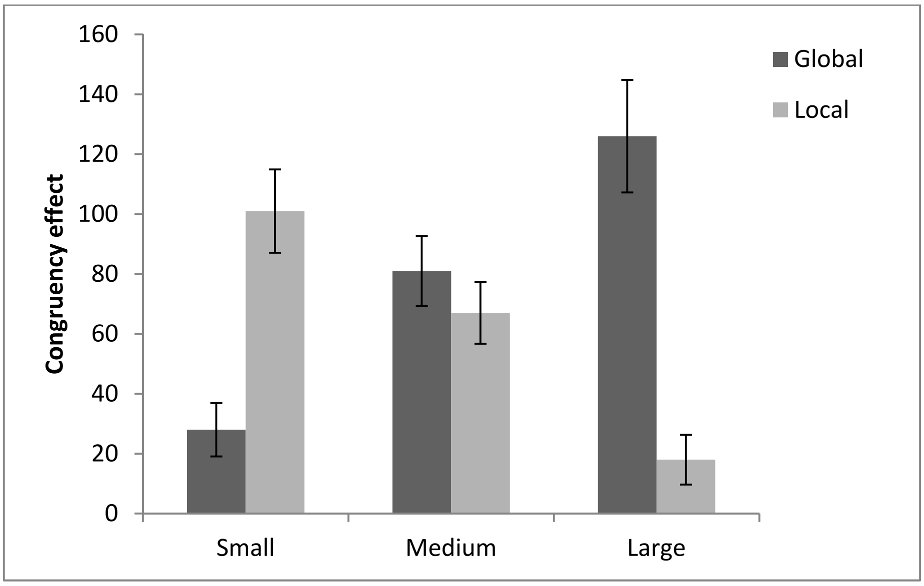
160
140
120
100
80
60
40
20
0
Congruency effect
Small
Medium
Large
Global
Local

Figure 4 top

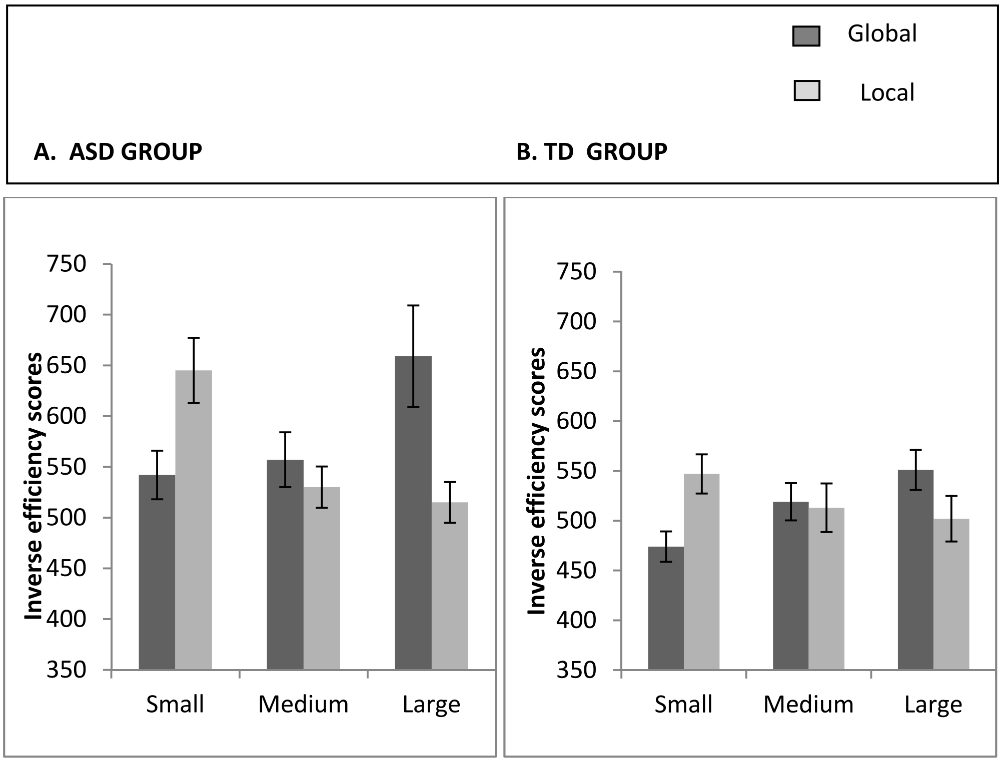
Global
Local
A. ASD GROUP
B. TD GROUP
Inverse efficiency scores
750
700
650
600
550
500
450
400
350
Small
Medium
Large
Inverse efficiency scores
750
700
650
600
550
500
450
400
350
Small
Medium
Large

Figure 5 top

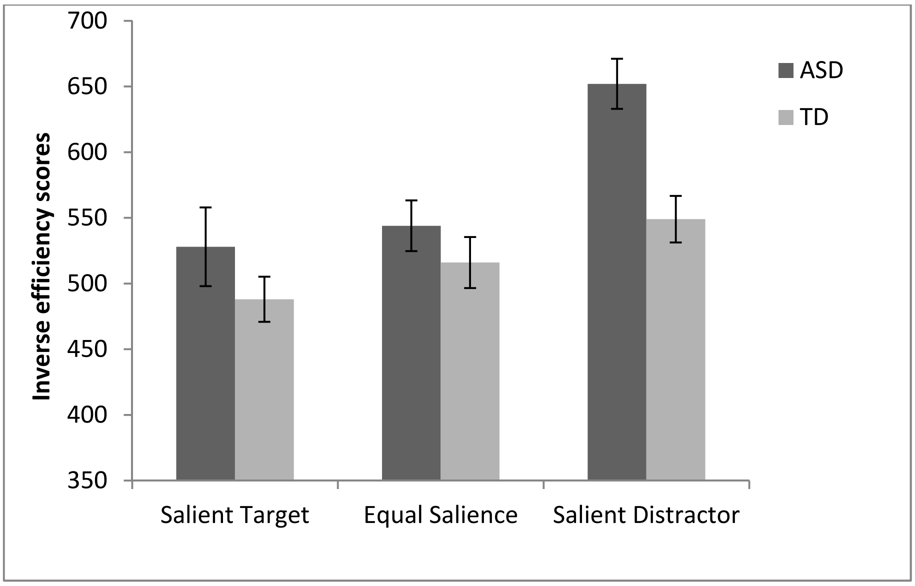
700
650
600
550
500
450
400
350
Inverse efficiency scores
Salient Target
Equal Salience
Salient Distractor
ASD
TD

Table 1: *The sizes of visual angles of the stimuli (in degrees)*

	Local level	Global level
Small	0.25° x 0.25°	1.65° x 1.65°
Medium	0.625° x 0.625°	3.525° x 3.525°
Large	1.5625° x 1.5625°	8.2125° x 8.2125°

Table 2: *Inverse efficiency scores (IES) by level, size, and congruency*

		Congruent		Incongruent		Congruency effect	
		Mean	S.D	Mean	S.D	Mean	S.D
Global							
	Small	494	93	522	115	28	64
	Medium	498	110	579	135	81	83
	Large	542	155	668	237	126	135
Local							
	Small	545	123	646	159	101	104
	Medium	488	88	555	138	67	74
	Large	500	107	517	115	17	59

Table 3: *Inverse efficiency scores (IES) by level, size, and group*

		ASD		TD	
		Mean	S.D	Mean	S.D
Global					
	Small (salient target)	542	119	474	75
	Medium (equal salience)	557	133	519	96
	Large (salient distractor)	659	248	552	97
Local					
	Small (salient distractor)	645	160	547	98
	Medium (equal salienc)	530	100	513	119
	Large (salient target)	515	101	502	113