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Visual completion and complexity of visual shape in children with pervasive developmental disorder

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Abstract Much evidence has been gathered for differences in visual perceptual processing in individuals with Autistic Spectrum Disorder. The presence of the fundamental process of visual completion was tested in a group of children with Pervasive Developmental Disorder (PDD), as this requires perceptually integrating visual structure into wholes. In Experiment 1, it was investigated whether visual completion is present for simple partly occluded shapes in a group of children with PDD and a typically developing group. In Experiment 2, the presence of contextual influences in visual completion was investigated for the two groups. A total of 19 children with PDD and 28 controls who were matched for chronological age and IQ took part in two primed-matching tasks. For both groups, visual completion was present and for both groups, contextual influences were found to be dominant in this process. However, only for the group with PDD no priming effects (PEs) were found from less regular primes on congruent test pairs. The group with PDD did integrate visual information into wholes and did this in a contextually dependent way. However, for more complex shapes, visual completion is weaker for this group.

Key words autistic spectrum disorder – visual perception – pervasive developmental disorder – visuo-spatial functioning

Introduction

More and more evidence is emerging for differential perceptual processing in individuals with autism compared to typically functioning individuals. Differences in performance in the field of visual perception have been found in various tasks, such as the Embedded Figures Test and the Block Design task [19, 34, 39, 40], the reproduction of impossible figures [24], in hierarchical tasks [31] and in visual search tasks [28]. Differences also appear in the perception of motion (e.g., on motion coherence tasks [15, 23] and in biological motion tasks [3]). Although many aspects of vision have been investigated, it is still unclear exactly how visual structure is processed in autism. One typical aspect of 'autistic' processing is the detail-oriented cognitive style and parallel to this, a deficiency in global processing [14]. This deficiency might extend to a failure to use and integrate visual information, we will therefore look at the ability of a group diagnosed with a disorder in the autistic spectrum to integrate visual information in the so-called process of visual completion. This refers to a basic process in the visual system that allows us to perceive partly occluded objects as whole objects. The presence of this process and contextual influences within this process will be tested using the primed-matching paradigm, a paradigm that has proven to implicitly test visual completion [38] and is therefore less susceptible to strategies by the participant.

As mentioned, people with autism tend to process information in a detail-oriented way, seemingly at the expense of more global characteristics of the visual world. Most studies have used this notion to look at global and local influences directly, for example by looking at embedded figures, hierarchical stimuli or Gestalt shapes [4, 31, 39, 40]. But the findings were not very univocal: initial evidence for a lowered vulnerability to visual illusions, showing a lowered influence of global aspects of an image in autism [16], turned out to be difficult to replicate, the reason of which may be sought in the nature of the instructions [33]. Also, results on hierarchical tasks are mixed. In a hierarchical task introduced by Navon [27], a large letter shape is made up of smaller letters and participants have to identify a letter at the global or at the local level. Usually, people perform better at the global level. For autistic individuals this effect sometimes decreases, but this seems to depend on the type of task that is used, being either a divided or selective attention task [26, 29, 31]. Many studies on visual perception in autism have focussed on these global and local aspects, but because higher-level processes, such as strategies, might have influenced performance in some experiments, it is not clear to what level this difference in processing extends.

This study therefore aims to investigate visual structure by looking at a fairly low level of visual integration, namely visual completion, in a group of children with Pervasive Developmental Disorders Not Otherwise Specified (PDD-NOS) and Asperger Syndrome (AS). Autism belongs to the class of Pervasive Developmental Disorders (PDDs) [1] and comprises a range of allied disorders, such as autistic disorder (AD), AS, Rett Syndrome, Childhood Disintegrative Disorder, and PDD-NOS. The group of children with PDD-NOS and AS is much larger than the group with AD [7], and is of great clinical importance. They are treated in clinical practice as if they were suffering from the same anomalies as are found in AD. In addition, there is a high similarity in the epidemiology and etiology in the pattern of AD, AS, and PDD-NOS, and there is evidence for commonalities in visual processing between these three disorders [36]. Since the group of children with (a weaker form of) AD, also have a more detail-based type of processing, this could be reflected in lesser degree of integration (visual completion) or contextual processes could be greatly diminished in visual completion.

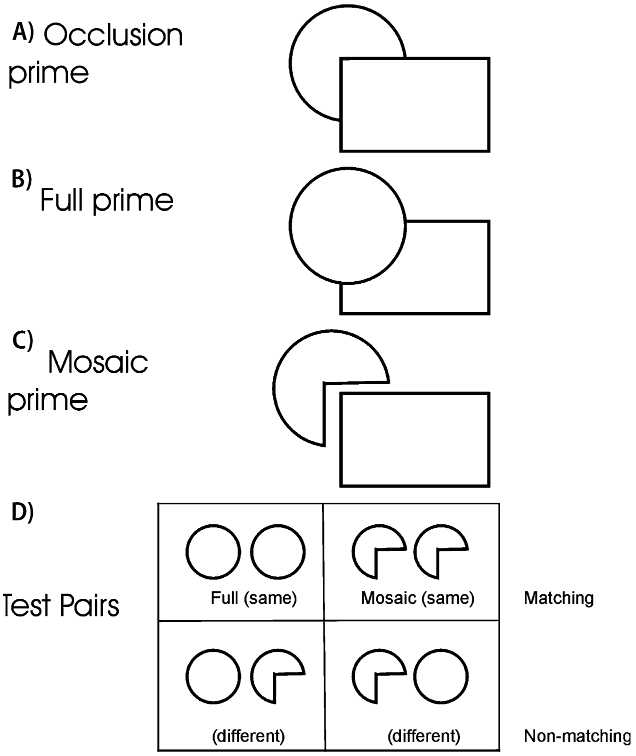


Fig. 1 A, B and C are primes. (**A**) The shape on the left is partly occluded by the rectangle, the occlusion prime. (**B**) Completion of the partly occluded shape as predicted by most theories, the full prime. (**C**) A mosaic version of the partly occluded shape, the mosaic prime. (**D**) The test pairs

Visual completion is a process that we are not aware of: we constantly encounter objects that are partly occluded, but we do not perceive these as fragmented objects, we perceive them as whole objects. For example, the three-quarter of a circle in Fig. 1A is usually perceived as a circle partly occluded by a rectangle. Alternatively, the left shape in Fig. 1A can also be perceived as a fragment of a full circle or a mosaic shape, as depicted in Fig. 1C. As the wholes are the simpler (more regular) shapes, generally, these sorts of configurations are mostly perceived as wholes partly occluded by another shape. This phenomenon is the result of the so-called process of visual completion, which is the ability of the visual system to generate sensations of whole objects from partly occluded objects. The first experimental support for the rapid completion for occluded objects comes from a study on the micro-genesis of visual completion by Sekuler and Palmer [38]. They showed that the percept of partly occluded shapes develops fairly fast into the percept of a whole shape, taking about 250 ms to develop. Using a visual search task, Rensink and Enns [32] showed that partly occluded shapes are harder to find among complete shapes as compared to parts, indicating that partly occluded shapes are perceived as being more similar to complete shapes, again showing the fairly low level at which visual completion operates. Furthermore, in an fMRI study by Kourtzi and Kanwisher [22] a pair of identical shapes was shown sequentially where one shape was in front of a grid of parallel bars, and the other was occluded by the same bars. Therefore, the contours were different, but participants perceived the same shape. Compared to a condition in which this was reversed (same contours, but different perceived shape) they found a smaller response in the lateral occipital complex (LOC). This indicates that perceived shapes and not contours per se, are represented in a visual area such as the LOC. In addition, visual completion is a process that is already present in 4-month-old infants [21].

Besides the perception of a whole shape, we even have a strong sense of the form of the occluded part. This perceived form can either be based on overall contextual information, or can just be based on information that is available at the intersections between the partly occluded shape and the occluder (see the arrows in Fig. 2A). Contextual information originates from the whole visible part of the partly occluded shape, and include stimulus aspects such as symmetry and iteration, see Fig. 2B [41–43]. Completions in which contextual information plays a role, can take any kind of form, depending on the structural properties of the visible part. By definition this results in the most regular or simple shape. Completions that are just triggered by intersections always proceed by way of linear or smooth continuation of the occluded contours, see Fig. 2C for an example [12, 20]. It is now generally agreed upon that the perceived completion depends on the nature of the stimuli such as the type of regularities or the degree of occlusion [37, 43, 44]. For example, for the kinds of shape shown in Fig. 2A, earlier experiments with adult participants showed that contextual influences dominate visual completion [8, 9, 11]. Unfortunately, to date there is no direct neurophysiologic substrate for visual completion nor for these intersectional and contextual influences. However, in an MEG study it was shown that there is an early left occipital component that is mainly sensitive to pure figural aspects, but that is already modulated by these global influences [9], this is line with an EEG study showing that the recognition of partially visible objects takes place relatively early in the visual stream [18].

Before investigating contextual influences in visual completion in PDD, we wanted to see if a difference exists in visual completion for simple shapes (in which both intersectional and contextual influences result in the same completions) between children and adults. Following earlier research on visual completion, we used the primed-matching paradigm, which can be used to implicitly test how different images are perceived. The paradigm has been extensively used to explore visual completion in adults [8, 10, 11, 37, 38], but has not yet been tested in children. In this paradigm, the participant's task is to decide whether a test pair consists of two identical shapes, or not. A test pair is termed to be "matching" if both shapes in the test pairs are identical and "non-matching" if this is not the case. In case of a matching test pair, the decision on similarity can be facilitated by showing a similar prime before this test pair [2]. The rationale behind the paradigm is that the facilitation depends on the *perceived* similarity between the prime and the two shapes in the test pair. When investigating visual completion, a partly occluded shape is shown as a prime ("occlusion prime"), which will speed up the reaction to a test pair that is perceived as being similar. The pattern in Fig. 1A can be seen either as a mosaic or a complete circle partly occluded by the rectangle. So the effect of the occlusion prime can be tested on a test pair containing either two mosaic forms of the shape ("mosaic test pair") or by two completed forms of the shapes ("full test pair"), see Fig. 1. When the occlusion prime facilitates a mosaic test pair most, the partly occluded shape is perceived as a mosaic shape. When full shapes are facilitated most, the partly occluded shape is perceived as complete shape, reflecting that a completion process did take place.

The performance of the group with PDD will be compared to a normally developing group that is

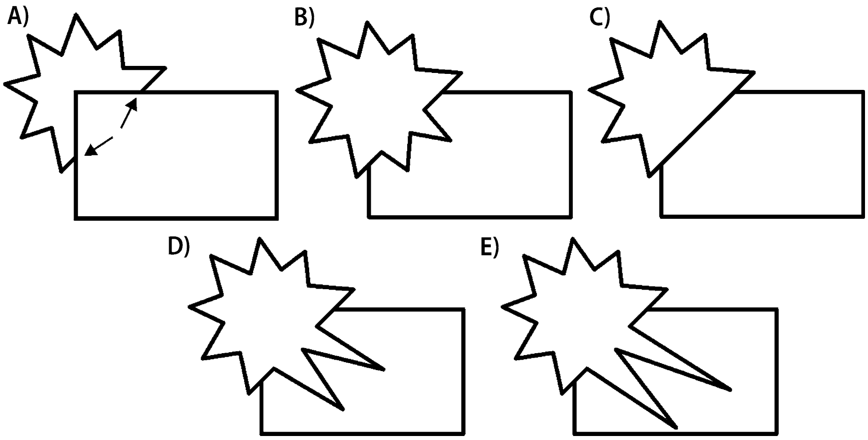


Fig. 2 (**A**) The shape on the left from set 1 is partly occluded by the right shape. (**B**) Contextual (global) completion, resulting in a simple regular overall shape. (**C**) Local completion, resulting in a less regular (more complex) overall shape. (**D**) Set 2. (B) Set 3

matched on age and intelligence. For both groups we expect general priming effects (PEs) from full primes on full test pairs, and mosaic primes on mosaic test pairs. For the occlusion prime, we expect a PE on the full test pairs in the control group. If visual completion is weaker in the group with PDD, we expect a smaller PE on the full test pair, as compared to the control group, or even a PE on the mosaic test pair. After testing the paradigm for this age group and comparing performance on simple shapes for the PDD group and the control group, the importance of contextual influences will be investigated in Experiment 2.

Experiment 1

Method

Participants

A total of 19 children with PDD-NOS (16) and AS (3) were recruited from regional outpatient clinics for Child Psychiatry (GGZ Nijmegen) associated with the outpatient Clinic of Child Behavioral Neurology and the Academic Centre for Child and Adolescent Psychiatry (ACKJON) of the University Medical Centre St. Radboud, Nijmegen, the Netherlands. Participants had been diagnosed by experienced clinicians, child psychiatrists and child psychologists both independently and together. The most effective scoring rule for PDD-NOS based on ICD 10/DSM-IV criteria [1, 5, 6] was applied, i.e., a short set of seven criteria that have all been derived from the original twelve criteria for AD defined in the DSM-IV. The threshold for inclusion in the PDD group was set at three out of seven criteria, of which at least one needed to be in the social interaction domain (also reported in [36]). The group did not contain any children with autism Children with co-morbidity were excluded. At the time of testing, none of the participants were using medication. A total of 28 healthy primary schoolchildren were selected from two primary schools to form the age- and intelligence matched control group. All participants were male, had normal or corrected-to-normal vision and functioned on an average cognitive level. The mental functioning of all participants was assessed with the Wechsler Intelligence Scale for Children—Revised, WISC-R, [45]. Table 1 presents the chronological age and performance on the WISC-R for the two groups.

Table 1 Chronological age and performance on the Wechsler Intelligence Scale for Children—Revised, between brackets standard deviation

Group	Age (years:months)	TIQ	VIQ	PIQ
Control group	11:0 (0.7)	108.1 (10.5)	106.9 (11.3)	107.1 (10.7)
PDD group	12:2 (1.7)	106.1 (14.1)	105.3 (15.9)	106.1 (14.4)

Stimuli

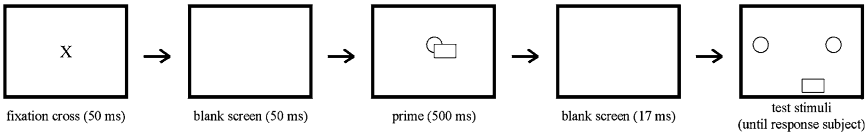
Three sets of stimuli were used, consisting of basic shapes (circles, squares, and rectangles). To check the presence of a general PE, there also is a control condition in which mosaic shapes and the full shapes serve as primes (as these are identical to the mosaic test pair and the full test pair respectively, PEs should appear in these conditions). These conditions will also be used to compare with the effect of the occlusion prime. Therefore there were three possible configurations: (1) the shapes could either be occluded by a rectangle (the occlusion primes), or (2) the full shapes shown in front of the rectangle (the full primes), or (3) the shapes formed a mosaic version of the occlusion prime, where the shapes were displaced with respect to the rectangle (see Fig. 1 for the primes and test pairs). The visual angle of the prime was 1.75°. A dot functioned as the no-prime condition.

The test pair consisted of two shapes of the same set as the prime. The task for the participants was to judge if the two shapes in the test pair were the "same" (matching) or "different" (non-matching) with respect to each other. There was either a matching test pair with two completed, full shapes, or two mosaic shapes, or a non-matching test pair. A non-matching test pair was a combination of a completed shape and a mosaic shape from the same set, and was controlled for left–right position. The matching test pairs were shown as often as the non-matching test pairs. The shapes in the test pair appeared on both sides of the prime. Note that the positions of the shapes were located away from the prime to inhibit masking by the prime, see [38]. The right shape of the prime appeared on the lower part of the screen. This inhibited the illusion of the rectangle moving and changing into one shape of the test pair, which could also exercise a hindering influence on the PE, also see [38]. The experiment was run with Presentation, version 5.2 (Neurobehavioral Systems).

Procedure

The clinical group was tested in the hospital. The control group was tested in their school. The same setup was used for both groups (same computer screen and same viewing distance). A trial started with a fixation cross being presented in the middle of the screen for 500 ms. After a blank screen was shown for 50 ms, a prime appeared on the screen for 500 ms. After a 17 ms interstimulus interval, the test display was shown until the participant responded with a button press (Fig. 3). To respond to a matching test

Fig. 3 Procedure of the primed-matching paradigm as used in Experiments 1 and 2



pair, the right index finger was used to press the right button, to respond to a non-matching test pair, the left index finger was used to press the left button. The order of the presentation was randomized for each participant and the reaction time (RT) was measured to the nearest millisecond. The trials were presented in eight blocks of 36 continuous trials, and after every block a pause was given. After each block, feedback was provided on the number of correct responses during this block.

To minimise attentional effects participants were instructed to pay extra attention to the left shape of the prime (because variations of this shape followed in the test pair) and to respond as accurately and as fast as possible when the test pair appeared on the screen. The experiment started with eight practice trials in which feedback was also provided. The experimental trials consisted of: set (3) × primes (4: occlusion, full, mosaic, and no-prime) × test pair (4: full (matching), mosaic (matching), full-mosaic (non-matching), and mosaic-full (non-matching)) × repetition (4). Note that, occlusion prime and no-prime conditions were shown twice as often, resulting in 288 trials.

Results

All correctly answered matching test pairs were analyzed (95.94% for the control group and 95.82% for the PDD group; the pattern of errors was similar between groups), see Table 2 for mean RTs and standard error of the mean (SEM). This has been done because PEs only occur for "same" test pairs, as "different" test pairs do not show a regular pattern [2, 38]. Responses shorter or longer than 2SD from the mean for each participant's responses (by participant) were removed from the analyses. First, note that the RTs for the full test pairs and the mosaic test pairs in the no-prime conditions did not differ between the two groups ($t(45) = 0.640$, $P = 0.525$ and $t(45) = 0.112$, $P = 0.911$, respectively). Therefore, differences between groups are specific for the PEs.

The PE is defined as the difference in RT between a prime condition and a no-prime condition:

PE (Test Pair | any Prime) = RT (Test Pair | No Prime) − RT (Test Pair | any Prime).

In Fig. 4A, mean PEs are plotted for the control group averaged over all test pairs as a function of type of prime, in Fig. 4B this is plotted for the PDD group. A repeated-measures ANOVA was performed for PE with Prime (3: occlusion, full, and matching), and Test Pair (2: full and mosaic) as within subjects variables and Group (2: PDD and control) as a between subjects variable. This revealed a significant main effect for Test pair $F_{1,45} = 4.633$, $P < 0.05$, where full test pairs were primed more than mosaic test pairs (also RTs for full test pairs were lower than for mosaic test pairs, $F_{1,45} = 140.240$, $P < 0.001$). Furthermore, an interaction effect was found for Prime × Test pair, $F_{2,44} = 36.818$, $P < 0.001$. Planned comparisons were performed to investigate the PE of occlusion primes on full test pairs compared with the no-prime condition; this was significant for both groups (Control: $F_{1,27} = 15.301$, $P < 0.005$; PDD: $F_{1,18} = 13.402$, $P < 0.001$). Also, the effect of full primes on full test pairs was significant for both groups (Control: $F_{1,27} = 13.182$, $P < 0.005$; PDD: $F_{1,18} = 6.308$, $P < 0.05$). However, the effect of the mosaic prime on the mosaic test pairs was only sig-

Table 2 Mean RTs (ms) and standard errors of the mean between brackets for all conditions and matching test pairs in Experiments 1 and 2

Prime	Control group		PDD group	
	Full test pair	Mosaic test pair	Full test pair	Mosaic test pair
Experiment 1				
Occlusion	628.52 (34.52)	785.92 (42.42)	664.33 (41.64)	800.46 (50.98)
Full	619.62 (33.17)	795.06 (44.85)	658.03 (39.98)	801.70 (53.85)
Mosaic	704.36 (34.90)	699.68 (37.67)	742.47 (42.00)	739.67 (44.03)
No-prime	666.18 (37.13)	761.27 (36.64)	703.56 (44.65)	754.81 (43.99)
	Local test pair	Global test pair	Local test pair	Global test pair
Experiment 2				
Occlusion	862.09 (36.29)	719.03 (30.69)	881.90 (44.05)	782.05 (37.26)
Local	795.27 (36.72)	862.61 (36.85)	821.06 (44.57)	845.73 (44.74)
Global	899.83 (38.75)	705.76 (32.61)	935.41 (47.05)	748.00 (39.59)
No-prime	868.29 (35.77)	776.00 (34.06)	852.58 (43.42)	820.20 (41.35)

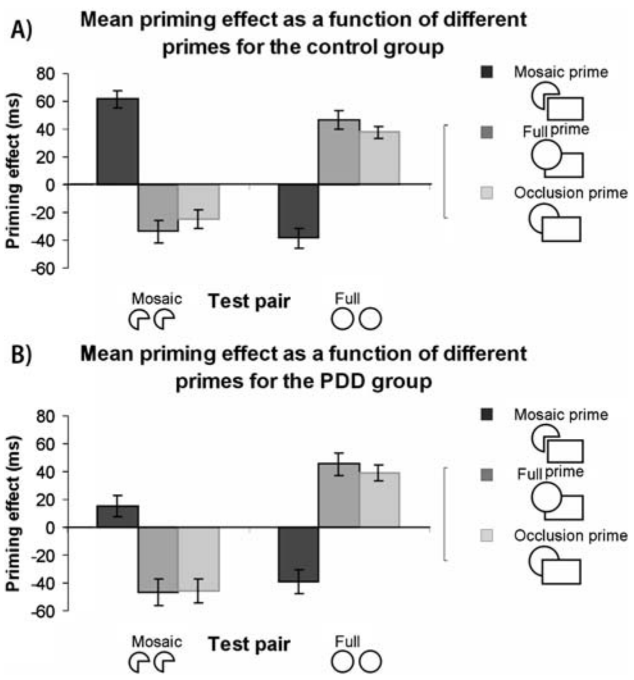


Fig. 4 Mean priming effect for the test pairs as a function of all primes for the control group (panel **A**) and for the PDD group (Panel **B**). The bars represent mean standard error

nificant for the control group ($F_{1,27} = 20.138$, $P < 0.001$), not for the PDD group ($F_{1,18} = 1.429$, $P = 0.247$). To test for group differences, a planned comparison was performed for an interaction between the effect of the mosaic prime and group and this was significant, $F_{1,45} = 5.572$, $P < 0.05$.

Discussion

Both groups do not differ from each other in the speed of reactions, which indicates that possible differences between the two groups are not caused by a difference in overall speed. For the control group, a PE was found for full primes on full test pairs and for mosaic primes on mosaic test pairs, which fits in with earlier findings on adults [38]. Thus, the basic PEs are present, showing that this paradigm is a valid method of investigating visual representations in this age group. As in earlier data from adults, these data also show that the occlusion primes facilitate performance on full test pairs, but not on mosaic test pairs, reflecting the presence of the visual completion in the control group. To our knowledge, the present study is the first to show that this sort of priming is already present for this age group. For the PDD group we found a similar pattern: occlusion primes and full primes also facilitate complete test pairs. This signals an intact visual completion process for the PDD group for these simple shapes, so the PDD group integrates visual information equally well into wholes. However, there is a difference between the PDD and the control group: the PE of the mosaic prime on the mosaic test pair is nearly absent in the PDD group. One way to explain this is to think of the complete circle as a simple (regular) shape. The mosaic could be interpreted as being a deviation of a simple (regular) circular shape. This might indicate that the PDD group has a difficulty in dealing with more complex shapes. We will return to this issue later on.

As it is clear that the PDD group can integrate information into wholes, we will turn to the question of the perceived form of occluded parts and see if contextual influences also play a role in visual completion in PDD.

Experiment 2

To investigate the effect of context in visual completion, stimuli from earlier experiments on visual completion were used [8, 11]. As in Experiment 1, the effect of an occluded shape was tested, but the shapes used in this experiment can give rise to qualitatively different completions. Take for example the shape in Fig. 2A, which can be completed in two plausible ways. The completion can either be triggered by contextual information resulting in a regular (simple) shape, which we will refer to as a *global* completion [37, 42, 43] (see Fig. 2B), or the completion can solely be triggered by information at the location where the partly occluded shape meets the occluder, resulting in a linear or curved continuation of the partly occluded contours, which we will refer to as a *local* completion [20] (see Fig. 2C). For the shapes used here, this latter completion is more complex in terms of regularity. Earlier experiments with the shapes used in this experiment showed that contextual influences dominate for adults [8, 9, 11]. That is, for the current shapes, global completions were preferred compared to local completions. As addressed in the introduction, there is a tendency in autistic individuals to be more focussed on details, seemingly at the expense of more global characteristics of the visual world. In line with this, we expect the PDD group to be less sensitive to contextual influences. For the control group we expect visual completions to be similar to that of adults, and therefore be dominated by contextual influences.

Method

Participants

The groups of participants were identical to Experiment 1.

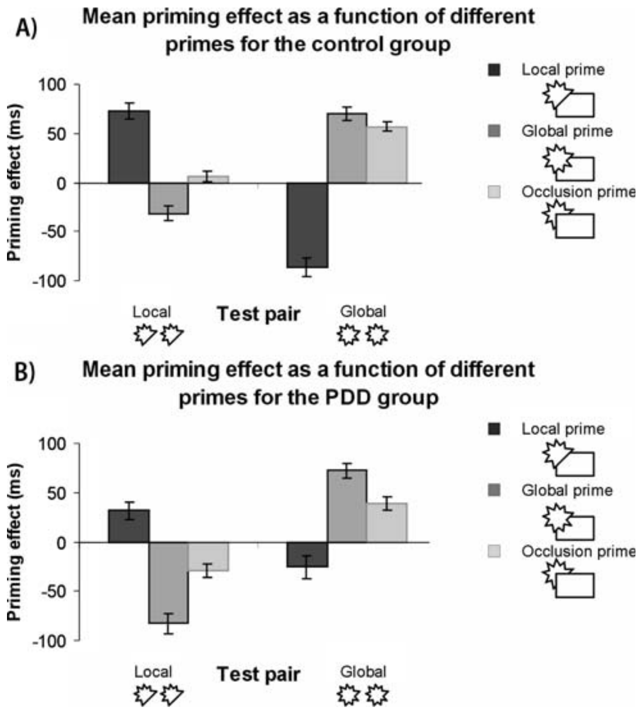


Fig. 5 Mean priming effect for the test pairs as a function of all primes for the control group (panel **A**) and for the PDD group (panel **B**). The bars represent mean standard error

Stimuli

Three sets of stimuli were used (Fig. 2A, D, and E), already used by De Wit et al. [8]. The shapes could either be occluded by a rectangle (the occlusion primes) or full shapes in front of a rectangle. The full primes comprised locally or globally completed shapes (i.e., the local and global prime, respectively) that were positioned in front of the rectangle. In the local prime, the contours that disappear behind the occluder in the occluded version are linearly continued until the lines meet. In the global prime, the same kind of protrusions available in the visible part were continued in the completion. The visual angle of the prime was 1.52°. A dot functioned as the no-prime condition.

Prime and test pair were drawn from the same set. This was either a matching ("same") test pair with two global or two local shapes or a non-matching ("different") test pair. Matching test pairs were shown as often as the non-matching test pairs. The test pairs appeared on both sides of the prime, to inhibit masking by the prime, as in Experiment 1. Also, the right shape of the prime appeared on the lower part of the screen.

Procedure

The procedure was identical to Experiment 1, again there was a total of 288 experimental trials: set (3) × primes (4: occlusion, local, global, no-prime) × test pair (4: local–local, global–global, local–global and global–local) × repetition (4). Note that occlusion prime and no-prime conditions were shown twice as often.

Results

All correctly answered matching test pairs (95.14% for the control group and 96.0% for the PDD group) were analyzed, see Table 2 for mean RTs and SEM. Responses shorter or longer than 2SD from the mean for each participant's responses (by participant) were removed from the analyses. Note again that the RTs for the local and global test pairs in the no-prime conditions did not differ between the two groups ($t(45) = 0.528, P = 0.781$ and $t(45) = 0.908, P = 0.414$, respectively). Therefore, differences between groups are specific for the PEs. In Fig. 5A, mean PEs are plotted for the control group for all test pairs as a function of all primes, in Fig. 5B these are plotted for the PDD group. A repeated-measures ANOVA was performed for PE with Prime (3: occlusion, global, and local), and Test Pair (2: global and local) as within subjects variables and Group (2: PDD and control) as a between subjects variable. This revealed a marginally significant main effect for Test pair ($F_{1,45} = 3.773$, $P = 0.058$), and a significant interaction between Test pair × Group ($F_{1,45} = 4.477, P < 0.05$). Also, a significant interaction effect was found for Prime × Test pair ($F_{2,44} = 57.332$, $P < 0.001$). Furthermore, a three-way interaction effect was found for Prime × Test pair × Group, $F_{2,44} = 3.666, P < 0.05$.

Planned comparisons were performed to investigate the PE of occlusion primes on local and global test pairs compared with the no-prime condition. The occlusion prime had no effect on local test pairs for both groups (Control: $F_{1,27} = 0.529$, $P = 0.473$; PDD: $F_{1,18} = 2.831$, $P = 0.110$), but it did have a significant PE on global test pairs for both groups (Control: $F_{1,27} = 26.628$, $P < 0.001$; PDD: $F_{1,18} = 7.324$, $P < 0.05$). Also, the effect of global primes on global test pairs was significant for both groups (Control $F_{1,27} = 26.314$, $P < 0.001$; PDD: $F_{1,18} = 23.486$, $P < 0.001$). The effect of the local primes on the local test pairs was significant for the control group ($F_{1,27} = 33.554$, $P < 0.001$) but not for the PDD group ($F_{1,18} = 2.094$, $P = 0.165$). To test for group differences, a planned comparison was performed for an interaction between the effect of the local prime and test pair and group but this was marginally significant, $F_{1,45} = 3.107$, $P = 0.085$. There was a difference between the groups in the magnitude of the PE of the occlusion prime on the global test pair. In the control group, the size of this PE did not differ from the PE of the global prime on the global test pair ($t(27) = 1.060$, $P = 0.298$), whereas in the PDD group this PE of the global prime on the global test pair was significantly larger than the PE of the occlusion prime on the global test pair ($t(18) = 3.085, P < 0.01$). To test for group differences, a planned comparison was performed for an interaction between the effect of the occlusion prime and global prime on global test pair between groups and this was not significant, $F_{1,45} = 1.375, P = 0.247$.

Discussion

For the control group it was found that local primes facilitate local test pairs and global primes facilitate global test pairs. Moreover, the occlusion primes facilitate the global test pairs, but not the local test pairs, similar to what has been found for adults [8, 9, 11]. For the PDD group a similar pattern was found for the occlusion and global primes: both facilitate global test pairs. Therefore, contextual influences in visual completions are apparent for both groups. However, there are three notable differences between the two groups.

First, the strength of the PE of occlusion primes on global test pairs differs between the control and the PDD group. For the control group the PE of the occlusion primes on the global test pairs is the same as the effect the global primes have on these global test pairs. However, for the PDD group the effect of the occlusion primes is significantly smaller than the effect of the global primes. Although this is not reflected in the test for group differences, these data suggest that visual completion for these stimuli is not as robust for the PDD group as it is for the control group.

Second, in the control group local primes do facilitate local test pairs, whereas in the PDD group, local primes do not facilitate local test pairs (the group comparison was marginally significant, $P = 0.085$). Note that there is facilitation from the regular (global) primes on regular test pairs in the PDD group. Although the absence of facilitation for the less regular (local) shapes does not relate to the process of visual completion directly, it does suggest a difference in the processing of visual structure which is modulated by the complexity of the shapes. This is analogous to the finding in Experiment 1, where mosaic shapes, being more complex than the completed (full) circles, also lack a facilitating effect.

Third, comparing the two groups in Fig. 5 reveals another difference between controls and individuals with PDD. In the controls, local primes exert a large inhibiting effect on global test pairs, while global primes do not have such an inhibiting effect on local test pairs. This effect is reversed in the PDD group, here the local primes do not effect global test pairs, but the global primes inhibit reaction to the local test pairs ($F_{1,45} = 7.191, P < 0.05$). To explain these clear differential effects between the two groups we can only speculate. For example, when considering the irregular (local) shape to be a deviation of the regular (global) shape, the pattern of results suggests an asymmetry with regard to pattern classification. For the PDD group a deviation from a simple, regular shape seems to be quite unrelated, whereas for the control group this is the other way around. This asymmetry might point to a difference in dealing with regular shapes and deviations of these shapes. It should be noted, however, that that the above suggestion calls for further investigation (e.g., dealing with recognition of prototypical structures versus subordinate structures). As this finding does not deal with visual completion per se we consider a full account beyond the scope of this article. Nevertheless, the results again show a significant difference between the PDD group and the control group obtained with the primed-matching paradigm.

General discussion

The presence of PEs in both experiments shows that the primed-matching paradigm is a suitable method to investigate visual perception in children in an implicit way. Mean RTs are not different for the two groups, therefore the results cannot simply be explained by a general slowing-down or speeding-up, but results are specific to the PE itself, indicating a different way of visual processing. Initially, these data suggest that the process of visual completion in PDD does not differ from visual processing in the control group. The PDD group also perceives partly occluded shapes as whole shapes, and the fact that the experienced form of the completions is the same as for the control group shows that this completion process can also be influenced by contextual factors. Inspecting the data more closely however, reveals two main effects that do differentiate between individuals with PDD and controls.

One is a difference specific to visual completion and the second is the lack of PE in certain conditions. The first indication for a difference between the two groups comes from the data of Experiment 2, which show that the visual completion process in the PDD group is present, but it is weaker as compared to an equivalent full (completed) prime. This finding differs from the results of Experiment 1, where we did not find a difference between the PE of partly occluded primes versus full primes between the groups when comparing completed shapes and mosaic shapes. The difference in results between these two experiments may lie in the fact that both intersectional and contextual information trigger the same (circular) completion in Experiment 1. However, in Experiment 2 they trigger different completions, resulting in a more ambiguous condition. In addition, in the difference in overall complexity of the shapes that were used in Experiment 2 as compared to the shapes in Experiment 1. That is, more complex stimuli reveal subtler group differences in completion processes in PDD.

The second indication for a difference between the two groups lies in the effect of the less regular shapes found for the PDD group in both experiments. Specific shapes (the mosaic shapes in Experiment 1 and the "local" shapes in Experiment 2) did not facilitate identical test pairs. This could mean that it is harder for the PDD group to process these irregular, more complex stimuli (as regularity is an important factor in object representation, [11, 44]). This might relate to the suggestion by Plaisted et al. [30] on enhanced discrimination in autism. In a study on perceptual learning they showed that high-functioning autistic individuals were equal to controls at discriminating familiar objects, but better than controls at discriminating novel objects, suggesting an absence of a perceptual learning effect. In the most regular shapes, which are also more familiar, in our experiments there were no differences between the groups. Differences arose when irregularity came in, there the PDD group might have more difficulty in processing those shapes in the same way as regular (more familiar?) shapes.

It is remarkable that a group of children with a lesser variant of PDD also appears to differ from typical developing children in the way they process visual stimuli even at a fairly low level of perception. This is in line with findings by Schlooz et al. [36] that showed fragmented visuo-spatial processing in this group, although not much more is known on performance of this group, it does imply a commonality between different PDD groups.

How do our findings relate to theories on perception in autism? Our findings do not directly confirm the Weak Central Coherence theory [13], as we did find contextual influences in completions. However, WCC was refined by Happé [17] by suggesting that individuals with autism are not impaired in the ability to integrate the various features and facets that make up a single object. Although this does agree with our data on simple partly occluded shapes, we do find a problem in processing more complex partly occluded stimuli. These more complex stimuli are likely to reflect less known categories in the visual world. In that sense, visual processing in PDD can be regarded as being more inflexible in dealing with new information. Another model of visual processing in autism is the Enhanced Perceptual Functioning model by Mottron and Burack [25], which states that the overdevelopment of low-level perceptual operations might result in an atypical relationship between global and local processes. This model is similar to the notion of enhanced discrimination by Plaisted et al. [30] and our findings also fit in with this notion. An alternative idea on why visual processing in autism is different suggests that autistic individuals are less influenced by prior knowledge [35]. Our results show that prior knowledge (or temporal context) in the form of the prime does influence performance, although we also find that it depends on the sort of shape (e.g., for the mosaic shapes this effect seems diminished). The difference in processing of visual structure in autism seems not to be in binding features into whole shapes, but rather at a more complex (categorical) level of perception.

Conclusions

Visual completion was apparent in the PDD group we tested and similar to the control group, contextual influences are apparent in the completion process for the stimuli that were used. However, complexity of the shape exerted an effect on the strength of visual completion and there also was a difference between the groups in the effect of regularity in shapes: the PDD group shows reduced effects from less regular shapes, also reflecting an effect of complexity.

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