Visual perception in preschool children with atypical development

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ABSTRACT

The authors study specific participation of parvo- and magnocellular visual processing pathways in image formation in preschool children with atypical development.

In comparison with typically developing children, children with autism spectrum disorder (ASD) and mental retardation (MR) had higher thresholds of contrast detection during sequential change; higher thresholds were observed only in high ASD cases. Global motion thresholds were lower in children with MR and low ASD. Children with high ASD could discern stimuli only with their slow shift.

Deficit of global motion thresholds based on stationary object orientation was found only in ASD cases; manifestation of such deficit depended on the autistic disorder severity.

In MR and low ASD cases, figure recognition time increased only with increasing number of locations of targets among demonstrated figures. Children with high ASD demonstrated constant increase in detection time. The authors found correlations between visual processing deficit severity and the language development level.

Keywords: Visual perception; dorsal and ventral streams of visual system; preschool children; autistic spectrum disorders; mental retardation

1. INTRODUCTION

The priority direction of modern developmental psychology is investigation of mechanisms ensuring global perception and the specifics of their implementation in deviating development (Gibson, 1979).

The most obvious example of an atypical child development is autism spectrum disorders (ASD), which are often accompanied by mental retardation (MR), language disorders (Kanner, 1943). Currently, modern researchers often mention primary cognitive deficit specific for autism; that determined the new vector for searches — the study of initial stages of information processing, namely — the study of perception in people with autistic disorders (Bertone, 2013; Pellicano, 2012).

An important aspect for the analysis of anomalous perception in autism is identification of the brain structures and their functioning mechanisms, which are crucial for image formation. In recent years, researchers have developed a concept of parallel visual information processing pathways: parvocellular, magnocellular and koniocellular (Ungerleider & Mishkin, 1982). This morphological and functional separation begins at the level of the retina (Perre & Cowey, 1985) and continues at the level of the lateral geniculate nucleus (Hendry & Reid, 2000) and the primary visual cortex (Merigan, Byrn, & Maunsell, 1991). The signals from magno- and parvocellular pathways mix at the level of extrastriate cortical regions (Shomstein, Kravitz, & Behrmann, 2012), forming ventral and dorsal visual processing pathways; each of them brings something specific in the object image perception process. Thus, the magnocellular system provides perception of the object motion and its spatial localization, and the parvocellular system provides perception of the object shape, its fine details and colors.

In recent years, there have been more and more scientific evidences that various abnormalities of language and cognitive development (for example, in case of dyslexia and autism) are accompanied by magnocellular system disorders (Fiorentini, Gray, Rhodes, Jeffery, & Pellicano, 2012; Pellicano & Gibson, 2008; Scottun, 2000). The level of perception integrity is commonly lower in people with autism (Pellicano, 2010); this dysfunction is primarily caused by abnormal processes of cross-modal and intra-modal interaction (Charbonneau et al., 2013; González, Ramón, & Maiche, 2013). The latter has led to the hypothesis of “weak central coherence” (Frith & Happe, 1994; Happe & Frith, 2006), which assumes that global perception is based on integration of local features into a single image. It is assumed that people with autism have a higher sensitivity of visual sensory system pathways that are related to processing of high-frequency spatial information (parvocellular pathway or ventral stream) (Frith & Happe, 1994); the pathways related to processing of information on low spatial frequencies are underdeveloped (magnocellular pathway or dorsal stream) (Plaisted & Davis, 2005, 2009). However, these hypotheses have been questioned. For example, some researchers experimentally proved that global motion perception is not dependent on the information on low spatial frequencies (Badcock, Whitworth, Badcock, & Lovegrove, 1990; Smith, Snowden, & Milne, 1994).

Another competing hypothesis (Mottron, Belleville, & Menard, 1999; Ozonoff, Strayer, & McMahon, 1994) is based on modern understanding of the hierarchical structure of visual perception, which includes different levels of information processing (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). Thus, "low-level" processes ensure handling of information about the physical properties of the visual field components; "intermediate" processes provide perceptual grouping; and "high-level" ones are related to identification of the objects image. The hypothesis of a hierarchical structure of visual perception takes into account information about some super-optimal capabilities of visual perception of people with autism (Mottron et al., 2013) and presumes excessive development of "low-level" perception mechanisms; their hyperactivity leads to advantages in processing the properties of individual components but prevents implementation of "intermediate" and "high-level" mechanisms that provide perceptual "association" of components and their integration into a holistic image (Mottron et al., 2006).

Recent studies of the anomalies in information processing mechanisms in the dorsal stream of visual pathway have shown that children with autistic symptoms have difficulties in detection of global movement (Bertone, Mottron, Jelenic, & Faubert, 2003; Milne et al., 2002; Robertson, Martin, Baker, & Baron-Cohen, 2012), which is a consequence of abnormal integration of information at the "higher" levels. It is noteworthy that the same deficit was found: 1) in people with dyslexia — in the form of hyposensitivity to flicker (Martin & Lovegrove, 1988; Scottun, 2000) and in the form of reduced ability to perceive the global motion (Conlon, Sanders, & Wright, 2009; Hansen, Stein, Orde, Winter, & Talcott, 2001; Nandakumar & Leat, 2008; Roach, Edwards, & Hogben, 2004); 2) in individuals with Williams syndrome and hemiplegia – in the form of abnormally high global motion thresholds combined with relatively normal shape perception thresholds (Atkinson et al., 1997; Gunn et al., 2002). It is assumed that the most probable explanation for the increase of global motion thresholds in the case of developmental disorders is poor integrative processes in the higher cortical regions, which provide perception of global, coherent motion (Edwards & Badcock, 1996). Behavioral studies showed that global motion stimuli are processed in two steps (Edwards & Badcock, 1996). The first step is extraction of information about local features, which is likely to occur at initial stages of information processing (region V1) (Dow, 1974). At the second step, these local features are integrated in region V5 (Britten, Shalden, Newsome, & Movshon, 1992; Newsome & Pare, 1988). At that, early stages of visual processing may have no abnormalities, whereas higher stages of visual processing may be characterized by abnormal processes that evidently appear due to integration mechanism disorders.

A part of the problem under review is the issue of the relationship between the deviations in the extrastriate cerebral cortex activity related to motion estimation and the degree of visual-spatial coherence observed in autism (Bertone et al., 2003; Milne et al., 2002; Rivest, Jemel, Bertone, McKerral, & Mottron, 2013). It was shown that in children with autism, the success of a task to detect global motion is inversely proportional to the success of a task to choose an embedded image (Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). This correlation suggests that the deficit of grouping processes in autism suppresses perception of both dynamic and static stimuli. Hence, if the problem of global motion detection requires global perception, then the task of finding a hidden figure (the task to focus on particular image components), on the contrary, may prevent formation of the global gestalt. However, this argument is primarily based on the data on overall deficit of grouping processes in dorsal and ventral streams of an autistic visual system. Taking relate works (Field & Hayes, 2004; Gilbert, 1995) into account, it is evident that some contour grouping processes can be appropriately fulfilled at the level of V1 area, but other tasks require grouping at higher levels of the ventral stream (Braddick, Atkinson, & Wattam-Bell, 2003).

Thus, the question of what causes disturbances in integration process in case of autism is still unclear; the problem requires further study. Theoretically, it is suggested that autistic organization of the local information processing is combined with weak information integration at the same level (Frith & Happe, 1994). However, some researchers question this point of view, adducing that intactness of autistic global processing is combined with excellent local information processing (Badcock et al., 1990; Mottron et al., 1999, 2006). The idea of weak global grouping processes in autism is well consistent with the concept of weak central coherence (Happe & Frith, 2006) as the neural basis of the integration of object components into a global visual image.

Another example of neurologic disorders, which can cause abnormal visual object perception, is mental retardation. It is known that this neurologic disorder is inhomogeneous in composition and includes groups of ontogenetic development abnormalities different in terms of etiology and pathogenesis. Deterioration of language functions is noted as a key element (Nelson et al., 2006). A complex chronological process of speech development suggests that formation of speech is the most vulnerable structural component in mental development defects of various genesis. Systemic impact of this kind of defects, obviously, goes far beyond the children's speech status as such. In recent years, the researchers focus on the problem of relationship between perceptual and cognitive deficits. Modern literature provides rich factual material indicating the presence of correlation of language disorders with defects in the object visual perception (Bertone, 2013; Mendzheritsky, Karantysh, Muratova, & Korsunova, 2012; Muratova, Karantysh, & Mendzeritsky, 2013). Thus, many researchers note that children with language function disorders have significant abnormalities of global perception, which is primarily manifested in fragmentary and situational nature of perception (Chukhutova, 2013; Yukhina, 2011). The research results provide a basis to suggest undeveloped relationship between speech and sensory brain regions (Bertone, 2013; Pellicano & Burr, 2012).

Analysis of the current research in the field of visual perception features in atypical development shows that most studies concerned adults or adolescents and were usually related to the specifics of visual system functioning at a certain level of information processing. It is also important that the attempts to simultaneously compare the specifics of functioning of these information processing pathways in various forms of mental abnormalities were rare, although this aspect is significant in terms of the development of approaches to early diagnostics of mental disorders and the search for possible markers of destabilized integrative brain function.

In this regard, the current study is aimed to compare the contribution of different levels of magno-parvocellular channels of processing visual information to the formation of cognitive and speech processes in children with typical and atypical development.

2. METHOD

2.1 Partecipants

All studies were performed for the same group of preschool children with typical development (TD), atypical development ("residual-organic-based mental retardation" (MR) and "autism spectrum disorder" (ASD) accompanied by MR). The group included 20 TD children TD (the mean age, months (MA) = 71, SD = 6), 19 children with MR (MA = 74.5, SD = 6.1) and 19 children with ASD (MA = 71.5, SD = 6.1). The children under study attended pre-school department of primary school-kindergarten No. 687 "Child Rehabilitation Center" (Saint-Petersburg, Russia). The study was approved by the Ethics Committee of Saint-Petersburg State University and performed with parents' official consent for the child's participation in the study. All children were right-handed and had no problems with vision and hearing.

The children with typical development were tested by Wechsler method for preschool age (WHHSI), adapted for the Russian Federation (Ilina, 2009). The test results showed that all the children had a normal level of intelligence (Table 1).

Table 1. Description of participants

	Group					
	Children with typical development	Children with mental retardation (F83 by ICD-10)			Children with autism spectrum disorder+mental retardation (F.84.11 by ICD-10)	
Level of speech disorder		IV	III	II	I	II
N	20	6	7	6	10	9
Ages (in months)						
M	71	74	76	73	73	76
SD	6	5	6	5	6	4
Verbal IQ (in scores)						
M	134					
SD	10					
Range	121-142					
Non-verbal IQ (in scores)						
M	130					
SD	9					
Range	120-141					
CARS (in scores) (Schopler et al.,1980)					31.7	40.4
M					1.7	4.1
SD						
Range					30-34	36-48

The speech cards, which were compiled and adapted for children with mental retardation and autism (Nischeva, 2013), allowed determining the level of the child's language function development (Table 1).

The children with autism were tested for severity of autistic disorders (Table 1) by the Childhood Autism Rating Scale (CARS) (Schopler, Reichler, DeVellis, & Daly, 1980).

2.2 Equipment

A Samsung R40-1 notebook with 15-inch screen was used to show signals. The sequence of signal presentation and recording of the child's reaction parameters was maintained by Presentation, Version 14.4 Build 04.02.10 computer software.

2.3 Stimuli

2.3.1 The task to determine contrast sensitivity

To determine the effectiveness of magno- and parvocellular pathways of information processing, we used a task proposed by J. Pokorny (2011); the task was based on different degrees of these pathways elements activation in response to the changing contrast of stimuli.

The visual stimuli were represented as an array (pedestal) of four squares of 1 angular degree each, located in the center of a grey screen of 8 angular degrees. The screen illumination was 30 cd/m^2, the illumination of squares was 34 cd/m^2. In the course of the experiment, the illumination of one square ranged within 10 cd/m^2 in steps of 0.1 cd/m^2. The duration of each signal presentation was 50 ms, the interval between stimuli was 1.5 – 2 sec. The stimuli specifications were chosen on the basis of the parameters of temporal and spatial summation of the visual system (Pokorny, 2011) and the peculiarities of activity of children with developmental disorders (Cherenkova, Sokolova, & Naumova, 2013).

2.3.2 The task to determine global motion threshold

To evaluate the effectiveness of visual processing at the *higher* levels of the dorsal stream, we used the task proposed by Spencer et al. (2000). We have modified this method for children with developmental disorders (Cherenkova, Sokolova, & Naumova, 2014).

A black square (illumination - 1 cd/m^2, size - 8x8 angular degrees) was placed in the center of a white computer screen (illumination – 80 cd/m2). Vertical rows of 20 white spots (size – 0.1 angular degree, brightness – 80 cd/m^2 each) were used as stimuli. They moved at a speed of 5 deg/s from one edge of the square to another within 100 ms. The first stimulus was a single vertical row of spots, which moved from the left to the right edge of the square. The second stimulus included two rows of spots that moved towards each other, crossing the black square in opposite directions. The stimuli were shown randomly with an inter-stimulus interval of 1.5-2.0 sec.

2.3.3 The task to determine global motion threshold by the properties of stationary objects

This task allows evaluating the effectiveness of visual processing at the *higher* levels of the ventral stream.

Images of birds were used as stimuli. The orientation of their beaks and wings pointed to the direction of motion. A bright square of 8x8 angular degrees and illumination of 80 cd/m^2 was placed in the center of a computer screen on a gray background with illumination of 30 cd/m^2 for 300 ms. A series of nine birds the size of 3 angular degrees each appeared on the background of the square. In the first stimulus, the beaks were directed to the left, and in the second – to the right.

2.3.4 The task to determine capabilities for invariant recognition of the visual object shape

This task allows evaluating the effectiveness of visual information integration at the *higher* levels of the ventral stream (Cherenkova & Sokolova, 2016).

The stimuli were geometric shapes, which appeared on the screen with illumination of 30 cd/m^2. The size of the geometric shapes was 2 angular degrees. The duration of each signal was 100 ms in case of a single image, 300 ms – when showing three images, and 500 ms when showing six images; the interval between the stimuli was 1.5-2 sec.

2.4 Procedure

An experimental study was conducted in the environment familiar and comfortable for the child. The child was sitting in front of a computer, the distance to the monitor was about 50 cm. The general illumination in the room was 120 cd/m^2.

2.4.1 Testing of contrast sensitivity

In the first series of the study, the illumination of one of the 4 squares placed in the center of the screen was varied, and the child was asked to press a key if he or she noticed a change in the square brightness. Thus, we changed the characteristics of only one element out of the whole stimulus. Such a change is registered at the level of magnocellular pathway as a sequential contrast ("magnocellular condition").

In the second series of the study, all 4 squares appeared simultaneously (a grey background with a black fixation point in the center appeared on the screen between the attempts). In every attempt, one of the squares was lighter than others. The child had to see the difference between the brightness of 4 the squares on the basis of distinguishing the simultaneous contrast and press a key. Under these conditions, the small-celled pathway of visual system ("parvocellular condition") functions more effectively.

The threshold of the child was identified in three sessions (60 presentations each): by reducing illumination of one square, by increasing its illumination and by random presentation of more or less illuminated square. The results of three sessions allowed plotting psychometric curves for the number of correct answers vs. illumination level. The threshold value was determined on the basis of these curves by using the methods of minimal changes and constant stimuli. The resulting data were averaged for each child; the average threshold contrast value was determined according to the formula $K= (I_1- I_0) / I_0$, where I_0 is background illumination, I_1 is new illumination; the contrast sensitivity was determined by the formula $C = 1/K$, where K is the contrast value.

2.4.2 Testing of global motion thresholds

During the training session, the child was taught to press a computer key upon presentation of the first stimulus (a vertical row of spots, which moved from the left edge of the square to the right was a positive signal) and not to react to presentation of the second stimulus (two rows of spots that moved towards each other were a negative signal).

In the first testing session, we removed one spot from the row of the negative stimulus after every two attempts, starting from the top edge, until the child perceived it as a positive signal within two attempts. In the second session, on the contrary, we were adding spots (one by one) to the rows of the positive stimulus, which moved to the left side, until the child perceived it as a negative signal within two attempts. After these sessions, we determined the minimum number of spots to be removed or added in order to make the child change his or her response to the opposite, and calculated the difference between the total number of spots in the row and the number of spots when the child's response changed. The results of the first and the second session were averaged; we also calculated the percentage of the difference between the number of spots in the complete and shortened row relative to the total number of spots in the row (n=20). This value was the minimum difference, at which the child perceived global spot motion direction, i.e. the perception threshold of coherent motion direction.

2.4.3 Testing of global motion thresholds by the properties of stationary objects

During the training session, children were taught to press the left key if the beaks of all birds in the row were directed to the left or the right key if the beaks of all birds were directed to the right. In the first test session, the orientation of one bird flying to the right was changed from attempt to attempt. At the end of the session, all nine birds were directed to the left. In the second session, all stimuli (they included different numbers of birds with changed orientation) were shown in a random order. In both sessions, we registered the number of oppositely directed birds, at which the child pressed only one key. The results of the first and second testing sessions were averaged, and global motion detection threshold for all objects was determined.

2.4.4 Testing of capabilities for invariant recognition of the visual object shape

All children were preliminarily taught to distinguish a circle and a square: the child was asked to press a computer key upon appearance of a circle (*positive stimulus*) and not to press a key if a square appeared on the screen (*negative stimulus*). Stimuli were shown randomly (40 presentations).

One figure - a circle or a square - appeared on the screen during the *first test block*. The circle varied in size (10 presentations), color (10 presentations), or position (10 presentations) in a random order. Three different colors, sizes and positions were used in the first session, and six - in the second one. The properties of squares did not change in all the test blocks (30 presentations in a random mix with circles).

A group of three figures, which included either a circle or a square, was shown in the *second test block*. In the first session, the properties of figures did not change, in the second session, three colors, sizes and circle positions were used (5 changes of each property in a random order). In the third session, the number of each property used was increased to six (3 changes of each property).

Six figures were present on the screen in the *third test block* – one circle or one square was among them. The property of circles did not change in the first session of this block; circles of three different colors, sizes and positions on the screen was shown in the second session (5 presentations of each color, size and position relatively other figures). In the third session, the number of possible properties was increased to six (3 changes of each property).

3. RESULTS

3.1 Testing of contrast sensitivity thresholds under a sequential change in the stimulus illumination ("magnocellular condition")

Analysis of the average values of contrast sensitivity in children with typical development showed that the thresholds varied between 60 and 120 and averaged to 78.1±38.2 in case of sequential contrast.

Comparison of the average thresholds in children with different neurological status by the Mann-Whitney test (Figure 1) showed significant differences a) between the group of TD children and the group of ASD children (U = 10, p = 0.001), and b) between the group of MR children and the group of ASD children (U = 9.5, p = 0.001).

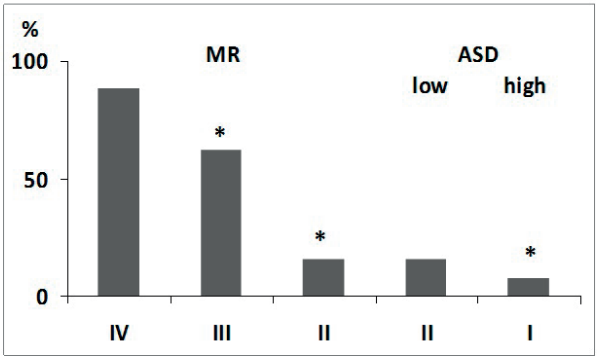

Figure 1. Testing of contrast sensitivity thresholds under a sequential change in the stimulus illumination ("magnocellular condition"). Vertical bars show the average threshold value for each group of children (MR, ASD, IV-I level of language disorder), divided by the average threshold value in the group of children with typical development. Asterisk marks significant differences between the data in neighboring groups of children at p<0.05

Comparison of the average contrast sensitivity thresholds in children with ASD showed significantly higher values for children with high ASD (U = 2.0, p = 0.05). At the same time, children with low ASD demonstrated significantly higher values of sequential contrast detection as compared with TD children (U = 2.5, p = 0.001) and MR children (U = 43, p = 0.01).

Comparison of the contrast sensitivity in ASD and MR children showed significant differences between groups with different levels of language disorders: II and I (U = 2.0, p = 0.01), IV and III (U = 1.0, p = 0.01). At the same time, the thresholds in MR and ASD children with the same level of language disorders (II) were not significantly different. Correlation analysis of the obtained data confirmed significant dependence between the level of language disorder and contrast sensitivity thresholds (R = -0.9, p<0.001). The MANOVA procedure also revealed significant importance of the "level of language disorder" factor (F(1.38) = 7.25; p = 0.0003).

Therefore, in the presence of speech disorders both in children with MR and children with ASD, contrast sensitivity thresholds increase in case of intensification of the speech deficiency level.

These data may indicate dependence of the contrast sensitivity thresholds on the degree of global language disorder regardless of etiology of neurological deficit.

3.2 Testing of contrast sensitivity thresholds under comparison of stimuli with different illumination ("parvocellular condition")

Analysis of the average values of contrast sensitivity in TD children showed that thresholds varied between 9 and 13 and averaged to 10.0±1.4.

Comparison of the data obtained for children with different neurological abnormalities (Figure 2) showed that the contrast sensitivity thresholds of children with high ASD were significantly higher compared to those of TD children (U = 42, p = 0.01), MR children (U = 22.5, p = 0,001) and low ASD children (U = 4.5; p = 0.037).

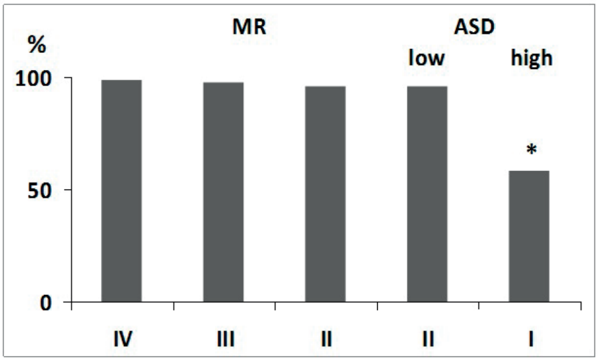

Figure 2. Testing of contrast sensitivity thresholds under comparison of stimuli with different illumination ("parvocellular condition"). Vertical bars show the average threshold value for each group of children (MR, ASD, IV-I level of language disorder), divided by the average threshold value in the group of children with typical development. Asterisk marks significant differences between the data in neighboring groups of children at p<0.05

When comparing the thresholds of children with varying degrees of general speech underdevelopment, significant differences could be identified only for the ASD children with I and II level of language disorders (U = 5.5, p = 0.05). Thus, weakening of parvocellular channel activity was observed only in children with high ASD.

3.3. Determination of global motion thresholds

The average percentage of the total number of spots, at which TD children distinguished motion in a certain direction, was 21±8%: the minimum value was 10% and the maximum value was 35%.

Analysis of data obtained for the groups of children with different neurological status (Figure 3) showed that the average visual object global motion thresholds in TD children were significantly lower than in low ASD children (U = 11.5, p = 0.001) and MR children (U = 1.5, p <0.01). Significant differences between the groups of ASD and MR children were not found.

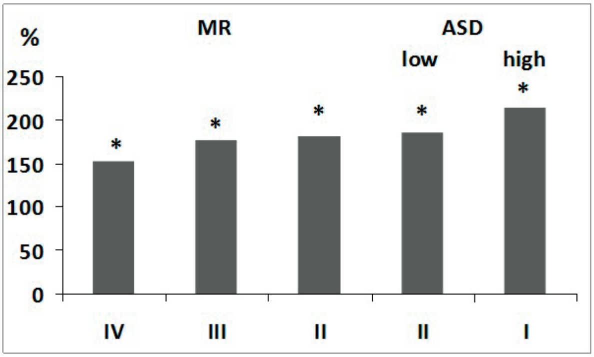

Figure 3. The task on detection of global motion direction on the basis of object dynamic properties. Vertical bars show the average threshold value for each group of children (MR, ASD, IV-I level of language disorder), divided by the average threshold value in the group of children with typical development. Asterisk marks significant differences between the data in neighboring groups of children at p<0.05

In children with high ASD, stimulus distinction was possible only in case of slow shift of stimuli on the screen (500 ms compared with 100 ms). Their motion perception threshold was significantly higher than in TD children (U = 3.5, p = 0.01), but did not differ from that of MR children (U = 54.5, p = 0.6) and low ASD children (U = 17.5, p = 0.05).

Analysis of global motion threshold values for children with varying degrees of language disorders allowed establishing significant differences only in groups II (U = 5.0; p = 0.046) and I (U = 4.8; p = 0.049). However, the correlation analysis of data for all groups confirmed significant dependence between the degree of language disorder and average global motion thresholds (R = 0,52; p <0,01). These data indicate that all groups of children with atypical development are deficient in motion information processing, and its intensity depends on the nature of neurological abnormality and the level of general language disorder.

3.4 Determining global motion thresholds by the properties of stationary objects

In TD children, the decision that "all objects have changed the motion direction" was registered when the number of figures with changed orientation reached an average of 78±12% of the total number; in this case, the pattern of location of stationary figures was perceived by children as motion in one direction.

There were no significant differences between the groups of TD children and MR children (Figure. 4). At the same time, ASD children showed significantly lower global motion thresholds (U = 8.5, p = 0.001). In this case, the observed deficit depended on the severity of autism spectrum disorder. It was shown that when a much smaller number of figures with "new" orientation appear, high ASD children tend to define the entire row as moving in this direction. Significant differences between these groups (U = 5.5, p = 0.05) were established when comparing the study results for the children with different forms of ASD.

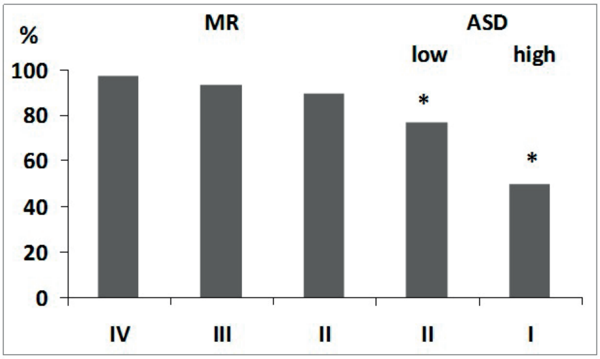

Figure 4. The task on detection of global motion direction on the basis of object stationary properties. Vertical bars show the average threshold value for each group of children (MR, ASD, IV-I level of language disorder), divided by the average threshold value in the group of children with typical development. Asterisk marks significant differences between the data in neighboring groups of children at p<0.05

However, comparison of results for children with different levels of language disorders regardless of their neurologic status revealed a progressive decrease in the ability to distinguish global motion direction with increasing level of child language function disorder. Significant differences in the thresholds were observed in the groups of children with language disorder levels IV and III (U = 6.5, p = 0.05), II and I (U = 4.0, p = 0.001). Correlation analysis of the obtained data confirmed significant dependence between the degree of language disorder and average global motion thresholds (R=-0,8; p<0.0001). The MANOVA procedure revealed a significant importance of the "level of language disorders" factor – (F(1.38) = 4.6; p = 0.02).

The above results indicate that the more pronounced autistic and language disorders, the lower the children's ability to distinguish global motion direction on the basis of a stationary property.

3.5 Determination of children's aptitude for invariant recognition of the visual object shape

Assessment of invariant recognition in TD children showed that the time to identify a circle did not significantly increase upon changing its color, size and position (Table 2). However, the response time significantly increased with initial increase in the number of the visual object properties (t = 3.2; p = 0.03), followed by its significant decrease at further increase in the number of variable circle properties (t = -2.9; p = 0.05).

In MR children, the nature of changes in the response time upon changes in the number of properties of the watched figure (color and size of the circle) is similar to that in children with typical development. If case of circle identification among six figures while increasing the number of its positions from one to six, identification time consistently and significantly (t = 5.8; p = 0.001) increased. Analysis of children with different levels of language disorders showed that this phenomenon occurred only in case of the II level of language development.

Analysis of testing results for ASD children revealed that, depending on severity of autistic disorder, children showed various results in the posed task.

In children with low ASD, circle identification time consistently and significantly increased only along with increase in the number of possible circle positions on the background of three and six figures (t = 4.9; p = 0.01; t = 3.8; p = 0.03). Therefore, children with autism have more difficulties in circle identification when its position changes among other figures, as compared with children with mental retardation.

High ASD children showed a significant gradual increase in circle identification time with changing color (t = 4.6, p = 0.01), size (t = 3.7, p = 0.02) and position (t = 4.8, p = 0.01) at both one-time demonstration (t = 3.9, p = 0.01), and on the background of three (t = 4.2, p = 0.001) and six (t = 4.7, p = 0.01) figures. Thus, the children of this group were completely deficient in the ability for invariant object identification in relation to the change in the above parameters.

Table 2. Response time of recognition of a geometrical figure with varying color, size, and position (- significant differences of mean values at p < 0.05)*

Group	Number Figures	Reaction Time (mc)	Properties								
			color			size			position		
			Number of properties								
			1	3	6	1	3	6	1	3	6
TD	1	M	822	827	795	822	903*	809*	822	845	799
		SD	71	55	47	71	71	56	71	74	60
	3	M	887	892	863	887	857	874	887	967*	948
		SD	75	60	51	75	46	56	75	63	61
	6	M	944	860	853*	944	872	864*	944	975	948
		SD	57	47	41	57	48	43	57	58	59
MR IV	1	M	798	933*	771	798	892	772	798	956	808
		SD	56	52	51	56	52	59	56	66	54
	3	M	838	778	732*	838	986*	783	838	944	841
		SD	51	53	56	51	61	50	51	51	60
	6	M	825	898	825	825	953*	853	825	1014*	859
		SD	53	57	59	53	58	52	53	52	54
MR III	1	M	827	895	839	827	987*	830	827	940	764*
		SD	55	52	55	55	52	59	55	66	53
	3	M	921	981	886	921	986	825*	921	994	945
		SD	51	53	66	51	51	50	51	51	60
	6	M	961	992	945	961	996	932	961	1178*	1063*
		SD	54	57	59	54	58	52	54	52	54
MR II	1	M	847	1026*	917	847	1055*	928	847	967*	862
		SD	55	52	55	55	52	59	55	66	54
	3	M	975	1060	1045	975	1030	1070	975	999	1014
		SD	51	53	68	51	61	50	51	51	60
	6	M	1008	1025	1045	1008	1092	1028	1008	1230*	1280*
		SD	53	57	59	53	58	52	53	52	54
Low ASD II	1	M	954	1162*	1078	954	1198*	1115	954	1148*	1076
		SD	74	75	66	74	72	66	74	70	66
	3	M	1071	1161	1228*	1071	1135	1226	1071	1195*	1327*
		SD	70	69	64	70	65	66	70	71	69
	6	M	1118	1195	1207	1118	1135	1226	1118	1308*	1365*
		SD	72	64	60	72	65	65	72	65	67
High ASD I	1	M	1129	1304*	1400*	1129	1333*	1514*	1129	1372*	1748*
		SD	72	74	69	72	70	75	72	65	49
	3	M	1164	1471*	1653*	1164	1532*	1659*	1164	1683*	1773*
		SD	80	78	73	80	82	82	80	81	88
	6	M	1593	1656*	1762*	1593	1689*	1773*	1593	1763*	1999*
		SD	73	80	75	73	79	88	73	80	77

4. DISCUSSION

The problem of global visual perception mechanisms is one of the oldest in psychological science (Rubin, 1958). Currently, this problem is intensively developed with the use different experimental models in the framework the neurocognitive approach to the study of psychics. It is assumed that global object image perception is not an integrated process, but it has an internal hierarchical structure and includes several successive and recursively interacting stages for processing the information about the properties of visual pattern (Bertone, 2013; Mottron et al., 2006; Pellicano, 2010). The study of the structure of perception disorders in children with atypical mental development is of particular interest in terms of the ontogenetic aspect. The very nature of perceptual anomalies in developmental disorders gives enough material for the study of the processes that ensure visual image integrity.

An important aspect for the analysis of the anomalous perception in children with atypical mental development is identification of the brain structures and the mechanisms of their functioning, which are crucial for global image formation. In this regard, the data on reduction in the function efficiency of magnocellular visual processing pathway in children with a variety of developmental abnormalities (Grinter, Maybery, Pellicano, Badcock, & Badcock, 2010) is of great interest. Our data indicate that compared with TD children of preschool age, children with different neurological disorders and impaired language function have poor magnocellular pathway activity, which is manifested in a decrease in sensitivity to low-contrast stimuli perception. However, the effectiveness of parvocellular pathway activity in MR children does not differ from that of TD children. Different results can be traced in ASD children, especially children with high ASD. In their case, there is a deficit of functioning of both magno- and parvocellular pathways at all visual system levels. This contradicts the data obtained by other authors; they showed that ASD children inefficiently perceive only low-contrast stimuli (Pellicano & Gibson, 2008; Plaisted & Davis, 2005). Such differences of opinions can be connected with the fact that the existing studies are devoted to autistic children of school age with intact intelligence. Perhaps, when ASD is accompanied by MR, there is a decrease in efficiency of both visual processing pathways.

Indeed, a comparison of contrast sensitivity level in children with low and high ASD shows that decrease in efficiency of both visual processing pathways is specific only for children with high ASD complicated with MR (36 scores on the Childhood Autism Rating Scale). At the same time, children with low ASD (up to 34 scores on the CARS) show a reduced efficiency of only magnocellular pathway, like in case of severely abnormal autists (Pellicano & Gibson, 2008). This leads to the assumption that highly severe autistic disorders can include not only defective mechanisms of visual processing at certain levels, but also defective mechanisms for adjusting the sensitivity of the entire system to low stimulus intensity, as well as the mechanisms for selective visual signal perception due to weakened attention (Sinzig, Morsch, & Lehmkuhl, 2008).

Currently, there is convincing evidence that the dorsal stream is able to carry information from the higher cortical regions to the primary visual cortex through feedback loop (Bullier, 2001; Laycock, Crewther, & Crewther, 2007). The speed of information processing in the magnocellular pathway is sufficient enough to ensure the integration with afferent information coming through the parvocellular pathway. Such early arrival of impulses through magnocellular pathway to striate cortex (10-20 ms according to the studies performed on primates (Maunsell & Gibson, 1992; Maunsell et al., 1999) and 25-45 ms according to the data on registration of multifocal induced potentials in humans (Baseler & Sutter, 1997; Klistorner, Crewther, & Crewther, 1997) is called the "magnocellular advantage" phenomenon (Laycock, Crewther, & Crewther, 2007). It is assumed that it is an important mechanism for ensuring the integration of global information, which exposes the activity of striate cortex to retro-inspection to receive information through the parvocellular pathway (Bullier, 2001). Thus, the delay in information processing in the magnocellular pathway of MR and ASD children may lead to disturbance in the "magnocellular advantage" mechanism found in TD children (Jackson et al., 2013).

Studies of visual object motion perception showed that this process is mediated by the activity of the higher levels of visual processing (Goodbourn et al., 2012; Schiller, Logothetis, & Charles, 1990). Processing of the motion information consists of two stages. At the first stage, the brain registers information on local signals; that is shown in the study of V1 region neuronal activity (Dow, 1974). At the second stage of information processing, local directional signals form global perception of motion, which requires inclusion of additional integration mechanisms at the level of extrastriate cortical regions (Britten et al., 1992). Our results confirmed the data of several authors that children with developmental disorders have deficient functioning of the highest level of the magnocellular visual processing system (Cornelissen, Mason, Fowler, & Stein, 1995; Plaisted & Davis, 2005).

The studies of invariant shape identification show that the temporal identification parameters are determined by the number of distinguishing characters required for selection within a specific set of images described (Gleser, 1978). If the variants of one image are different images for the visual system, differing from each other by specific properties (size, color, position, etc.), the introduction of these variants increases the identification time. If the visual system identifies this image as single, identification time is not changed. The study of adult subjects showed that a change in such properties of visual objects as color, size and position does not cause any increase in the identification time (Allport, 1971; Nevskaya & Leushina, 1990). There is no consensus among researchers regarding the dynamics of ontogenetic development of invariant identification. Some researchers cite data on the possibility of invariant description of the visual system form for children of the first or the second year of life (Ruff, 1978); according to others, time parameters of invariant identification reach "adult" values by 13-14 years of life, which correlates with the functional maturation of the anterior associative cortex areas (Nevskaya & Leushina, 1990). Analysis of data on shape identification invariance in our study showed that the mechanisms underlying identification invariance relating to these image transformations are functionally developed in TD children at the age of 6 years. However, upon the first introduction of several variants of one property, there was a temporary increase in the response time followed by its decrease. This suggests the need for learning processes for normal functioning of this mechanism, as it was shown in adult subjects in the analysis of complex visual object transformations (Nevskaya, Leushina, & Bondarko, 1996).

Detailed systematic studies of invariant shape identification in children with atypical development have not been conducted to date. In this regard, we attempted to analyze capabilities of invariant shape identification with respect to color, size and position in ASD and MR children.

In children with MR, progressive increase in the response time was identified only in case of varying position of the circle during its identification among 6 figures. This may be due to the fact that magnocellular visual processing system functions less effectively in this group of children, as shown in the previous series of the study. Insufficient processing of information about dynamic image properties, apparently, reduces efficiency of integration of local dynamic signals into a global image, invariant to transformation of the object localization property.

In children with low ASD, significant progressive increase in the identification time was also observed only with an increase in the number of positions of the watched figure. However, unlike in the case of MR children, an increase in the identification time was found in the analysis of images of both three and six figures. Identification of this property in the visual system of ASD children apparently involves a different type of image description – a single complete specific image description. In this case, the variants of position transformation form separate images treated by the visual system as positions that are non-invariant relatively separate position transformations (Gleser, 1978). This way of describing the image is even more pronounced in high ASD children. In this case, it relates not only to a change in the object position. Starting with identification of one figure, the response time significantly progressively increased along with increase in the variants of such properties as color, size, and position.

This group of children did not use the method of image description peculiar to children with typical development, i.e. the method of forming an abstracted and invariant-to-transformations description of shape with parallel independent description of individual image properties. It can be assumed that preference for one type of image description in the visual system of ASD children is associated with changes in gnostic neuronal activity, the activation of which does not depend on transformations of the local features of the visual object (Collignon et al., 2013; Ishizu & Zeki, 2013), i.e. with a change in integrative processes at the highest levels of visual processing.

Our findings on the correlation between severity of visual perception abnormalities and the level of speech or language disorders of children are of particular interest. The more pronounced is language function disorder, the greater the degree of visual perception disorder in children. We can make several assumptions to explain these phenomena. One of them is based on the fact that the effectiveness of the higher levels of magnocellular system is the key to full integration of local dynamic features, and, at the same time, one of the key elements in formation of coherent speech. Besides, the magnocellular pathway of the visual system is closely related to the cerebellum structures (Derrington, Allen, & Delicato, 2004) involved in development of motor programs, including language-motor programming. Weak activity of this system can lead to difficulties in constructing the grammatical structure; and the geometric figures, which we used as stimuli, are related to verbal stimuli (it is assumed that they are coded in the form of names) (Bartusevicius, 1987). Another assumption is based on the fact that implementation of both speech and visual function requires efficient mechanisms for integration of local features into a global image at the level of the higher zones of the cerebral cortex. Neurophysiological studies showed that in identification of complex visual scenes, interaction of visual and prefrontal cortical regions is enhanced in the interval of 400 ms after the stimulus, which is associated with semantic visual processing (Chaumon, Kveraga, Barrett, & Bar, 2013; Kveraga, Boshyan, & Bar, 2007). Disturbance or decrease in the efficiency of these processes can lead to impairments in visual object identification and language function disorders.

In general, the obtained results allowed comparing the contribution of magno- and parvocellular pathways of visual sensory system to the formation of a global image in preschool children. The study also allowed defining the impact of information processing in the visual system on the forecast of children's cognitive function development, which opens new ways to determining the children at risk and conducting the events for early detection of difficulties with learning at school.

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