

# Locomotor activity, object exploration and space preference in children with autism and Down syndrome

Rafal Kawa, Ewa Pisula\*

Faculty of Psychology, University of Warsaw, Warsaw, Poland; Email: ewa.pisula@psych.uw.edu.pl

There have been ambiguous accounts of exploration in children with intellectual disabilities with respect to the course of that exploration, and in particular the relationship between the features of explored objects and exploratory behaviour. It is unclear whether reduced exploratory activity seen with object exploration but not with locomotor activity is autism-specific or if it is also present in children with other disabilities. The purpose of the present study was to compare preschool children with autism with their peers with Down syndrome and typical development in terms of locomotor activity and object exploration and to determine whether the complexity of explored objects affects the course of exploration activity in children with autism. In total there were 27 children in the study. The experimental room was divided into three zones equipped with experimental objects providing visual stimulation of varying levels of complexity. Our results indicate that children with autism and Down syndrome differ from children with typical development in terms of some measures of object exploration (i.e. looking at objects) and time spent in the zone with the most visually complex objects.

Key words: autism, object exploration, locomotor activity, space preference, visual stimulation

## INTRODUCTION

Autism is a neurodevelopmental disorder with complex and multifactor aetiology. Individuals with autistic spectrum disorders (ASD) experience difficulties in social relationships and social communication, and have restricted interests, patterns of activity and behaviour (American Psychiatric Association 2000).

Studies on autism focus primarily on the social functioning of people with that condition. However, the analysis of behaviours not linked directly with social interaction may bring important new information about the specifics of their functioning. Atypical object exploration has been demonstrated in infants as young as 12 months old, who were later diagnosed with autism (Ozonoff et al. 2008). Compared with typically developing children, these infants demonstrated more spinning and rotating of objects, as well as unusual visual exploration of objects. The results of that study have shown that the analysis of exploratory

behaviour may yield information on abnormal child development even before the onset of more typical symptoms of autism.

There have also been reports of reduced environmental exploration in individuals with autism (e.g., Baranek 1999, O'Neil and Happé 2000, Pierce and Courchesne 2001). Reduced exploration may be associated with core symptoms of autism, which include restricted patterns of interests (APA 2000). So far, the underlying neurobiological causes of autism have not been determined. In the last decade, some authors have explored links between limited exploration and cerebellar abnormality in autism. Pierce and Courchesne (2001) found that children with autism spent significantly less time than their typically developing peers on exploring containers placed in a large room, while demonstrating more stereotyped behaviours. The study found that decreased exploration correlated with the magnitude of cerebellar hypoplasia of vermal lobules VI-VII in the group of children with autism but not in the control group. There was also a negative relationship between rates of stereotyped behaviour and area measures of cerebellar vermis lobules VI-VII and positive correlation of the intensity of

Correspondence should be addressed to E. Pisula  
Email: ewa.pisula@psych.uw.edu.pl

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these behaviours with frontal lobe volume in the autism sample. The authors of that study have suggested that there are links between the development of exploratory and stereotyped behaviour in children with autism, and that it is associated with abnormalities in the above brain areas.

Research on animal models has also confirmed the role of the cerebellum and its connectivity to the forebrain in decreased exploration in autism (Walker et al. 2007). The study using a rodent model (cerebellar suction lesions in rats) demonstrated not only a relationship between abnormal brain function and intensity of exploration, but also the possibility of restoring the correct level of this behaviour (i.e. the same observed in the control group) by using anticonvulsant treatment or inhibition of the medullary nucleus tractus solitarius. In a mouse model of Purkinje cell loss (Martin et al. 2010), a negative correlation was found between Purkinje cell number and measures of exploratory behaviour. It should be noted that the cerebella of people with autism are found to have fewer Purkinje cells, and that their cells are of abnormal size (Kern and Jones 2006). It is hypothesised that these cells may have a unique selective vulnerability to various types of damage (e.g., ischemia, metabolic disorders, viral infections, vitamin deficiencies and poisoning). These factors are sometimes considered in the aetiology of autism, although such claims remain controversial. Studies on animals have also revealed a reduction in exploratory and locomotor activity, and social interaction deficits in the offspring of mice injected during pregnancy with the human influenza virus (Shi et al. 2003) or given thimerosal, which has neurotoxic properties (Hornig et al. 2004). The potential significance of thimerosal in the aetiology of autism is currently hotly debated (see other articles in this issue). It is, however, too early to make sweeping conclusions about the role of individual factors participating in the pathogenesis of autism in the development of atypical exploratory behaviour patterns, especially that our understanding of these patterns is still incomplete.

In 1999, Williams and coworkers found that “the currently influential theoretical accounts of autism have relatively little to say about object use, restricting their attention largely to pretend play” (p. 369). Despite the passage of years, little has changed in that regard. Exploration is a complex system of behaviour aimed at obtaining information about the environment. It comprises such basic behaviours as orienting reflex and

locomotor activity, as well as more advanced ones, such as perceptual exploration and investigatory responses (Pisula 2009). It is still unclear whether the differences between children with autism and their typically developing peers are present both in the least complex exploratory behaviours and their more sophisticated forms. Besides, relatively few studies have focused on these differences, and, apart from the information about reduced exploration, they have not reported consistent data on potential specificity of exploratory forms. Similar analyses performed with respect to children with Down syndrome (e.g., MacTurk et al. 1985) indicated a similar (parallel) level of overall exploratory activity in this group of children as in typically developing children, while revealing differences in the rates of specific forms of exploration. Differences included time spent looking at individual objects and social behaviours directed at the experimenter or the mother. However, the results of studies in this area are inconsistent, as some findings suggest that children with Down syndrome demonstrate reduced exploration compared to their typically developing peers (Venuti et al. 2009). Animal models of Down syndrome also indicate an atypical level of exploratory activity, although the results of these studies are also ambiguous (e.g., Belichenko et al. 2009, Costa et al. 2010).

By comparing children with autism with typically developing peers and children with Down syndrome, we can find out more about the intensity of exploration, as well as the distribution of specific forms of exploratory behaviour in these groups. This project was undertaken by O’Neil and Happé (2000), who demonstrated that 22 month old children with autism differed from their peers with Down syndrome and typical development in terms of showing interest and involvement with toys, while there were no such differences between children with Down syndrome and those with typical development. These results would indicate the presence of reduced object directed exploration in children with autism. Similar results were obtained by Pisula (2003), who found that preschool children with autism looked at toys less frequently than children with Down syndrome and typically developing children. There were no differences between the groups in the study in terms of locomotor activity measures, which might suggest that basic exploration of children with autism is similar to that of their peers. However, no differences were found in the frequency of smelling, lick-

ing and touching objects, i.e. behaviours considered to be more advanced forms of exploration.

The relationship between the features of explored objects and exploratory behaviour of children with autism have not been investigated so far, although there is solid evidence from animal studies that such features may affect exploratory activity (e.g., Karl et al. 2007, Márquez-Arias et al. 2010). By contrast, there is a substantial amount of data showing that children with autism demonstrate many atypical visual behaviours, e.g., differences in eye-movement behaviour and reaction time to novel stimuli, allocating attention to significant stimuli, search behaviour, impaired prioritization of onset stimuli, tendencies toward over-selectivity and perseveration in attentional focus and weaknesses in orienting adaptively to relevant environmental stimuli (Deruelle et al. 2006, Keehn and Joseph 2008, Mottron et al. 2007). The present study attempted to determine whether the differentiation of objects in terms of complexity of visual stimulation has an effect on exploration in children with autism and their peers with Down syndrome and typical development. The study was part of a larger research project on exploration in children with autism.

The purpose of the study was to answer the following questions:

1. Do children with autism differ from their peers with Down syndrome and typical development in terms of the basic level of exploration, i.e. locomotor activity?
2. Are there differences between children with autism, children with Down syndrome and children with typical development in terms of object exploration?

3. Does the complexity of visual stimulation profile of objects affect exploration in children with autism?

## METHOD

### Participants and sample selection procedure

27 children participated in the study (age range 3-5 years), including 9 children with childhood autism (7 boys and 2 girls; mean age = 50.88 months, SD=8.32), 9 children with Down syndrome (7 boys and 2 girls; mean age = 47.77, SD=9.45) and 9 typically developing children (5 boys and 4 girls; mean age = 51.44, SD=8.63). Childhood autism was diagnosed by a child psychiatrist using the ICD 10 criteria (World Health Organization 1992). According to child psychiatrics diagnosis, no comorbid disorders were present in participants. The level of intellectual development in children with autism varied from normal, through mild to moderate intellectual disability and in children with Down syndrome from mild to moderate intellectual disability. In addition, the level of functioning of all children in the study was measured with the Psychoeducational Profile – Third Edition – Caregiver Report (Schopler et al. 2005). This tool consists of three scales, measuring respectively:

Problem behaviours - 10 items measuring the severity of the child's behavioural problems (e.g., "Has impaired eye contact, facial expressions, and communications gestures", "Fails to form friendships appropriate to age level"). The score range in this scale is 0-20 pts, with lower scores indicating more difficulties in the child's behaviour.

Table I

Estimated mean differences and standard deviation for PEP-3 scales in the studied samples				
Group	Problem behaviours Mean (SD)	Personal self-care Mean (SD)	Adaptive behaviour Mean (SD)	Total score
Children with autism	7.66 (2.87)	15.77 (2.48)	17.88 (5.94)	41.33 (8.47)
Children with Down syndrome	12.77 (2.27)	16.11 (2.61)	24.11 (3.37)	53.00 (6.10)
Typically developing children	20.00 (0)	24.44 (1.74)	30.00 (0)	74.44 (1.74)

Personal self-care – 13 items measuring the child's self-care skills (eg., “During mealtime does your child use a spoon and fork without your assistance?”, “Can your child bathe him- or herself without your assistance?”). The score range in this scale is 0-26 pts. Higher score indicates better self-care skills.

Adaptive behaviour – 15 items measuring adaptive skills (e.g., “Does your child respond positively to a hug from you?”, “Does your child regularly show interest in what is taking place in his or her immediate surroundings?”, “Does your child spontaneously walk over to interesting activities and attempt to join in?”). The score range in this scale is 0-30 pts; higher scores indicate better-developed adaptive skills.

The original version of PEP-3 – Caregiver Report is characterised by solid reliability ( $r_{tt}$  from 0.98 to 0.99). An experimental Polish version of this questionnaire was used in the present sample. The scores in the questionnaire are shown in Table I.

There were no statistical differences between children with autism and children with Down syndrome in the personal self-care skills. The highest score obtained by children with autism on the problem behaviours

scale is due to the fact that the scale measures primarily the behavioural problems typical for children with that condition. The same is true of the adaptive behaviour scale, which measures the severity of autism-specific difficulties. Thus, the results of PEP-3-Caregiver Report may serve as confirmation for psychiatric diagnosis. In addition, parents completing the PEP-3-Caregiver Report provide information on diagnostic criteria that their children meet in accordance with specialist diagnosis. This section of the questionnaire, although not analysed statistically, is a source of information about the child's disorders identified by specialists. In the present study, questionnaire results served as an additional criterion (along with psychiatric diagnosis) to include only those children who had no comorbidities such as ADHD, Asperger syndrome, schizophrenia, pervasive developmental disabilities not otherwise specified or Rett syndrome. Parents completed the questionnaire prior to children's inclusion.

Information on comorbid disorders obtained from PEP-3 served as exclusion criterion also in the group of children with Down syndrome and typically developing children. Children with typical development were

Table II

Demographic characteristics of the sample									
Group	Children with autism			Children with Down syndrome			Typically developing children		
Age Mean in months (SD)	50.88 (8.32)			47.77 (9.45)			51.44 (8.63)		
Number of siblings	Only child	One sister or brother	Two siblings	Only child	One sister or brother	Two siblings	Only child	One sister or brother	Two siblings
	3	5	1	3	4	2	0	6	3
Parent's education level	Basic	Secondary	Higher	Basic	Secondary	Higher	Basic	Secondary	Higher
Mother	0	2	7	0	5	4	0	3	6
Father	1	3	5	1	4	4	0	4	5
Mean mother's age in years (SD)	35.11 (6.23)			37.11 (7.43)			34.78 (4.60)		
Mean father's age in years (SD)	37.56 (6.08)			37.67 (7.28)			36.56 (4.60)		

matched with children with autism for age and gender. Initial criterion for selection to this group was absence of any developmental problems reported by parents and kindergarten teachers. In addition, none of the children in the study had any sight or hearing problems or locomotor disorders restricting overall locomotion. The demographics of the sample are shown in Table II.

All children were living in a large city in central Poland and attending kindergartens (typically developing children) or early intervention centres (children with autism or Down syndrome). Parents of children with autism and Down syndrome were contacted through therapy centres and associations helping individuals with these conditions. Parents of typically developing children were contacted at kindergartens. Out of the initial group of 32 children with autism, 20 children with Down syndrome and 11 typically developing children, 17 children with autism, 15 children with Down syndrome and 10 typically developing children were selected using the criteria described above. Ultimately, 15 families withdrew from participation, mainly due to organisational difficulties or child's health problems (viral infections). The parents were informed about the purpose and procedures of the

study. A written consent of each participant was collected. The research has been conducted in accordance with local legal and ethical regulations for scientific research in Poland.

### Experimental room

Three experimental zones were created in the experimental room (5 m x 5 m x 2.5 m) (Fig. 1). They were equipped with objects of varying profiles in terms of complexity of visual stimulation.

Zones with differing complexity of visual stimulation were sectioned off by means of 95 cm high wooden partitions. The whole floor was fitted with grey carpeting and windows were covered with laminated boards. At the centre of each zone was a table (77 cm x 55 cm x 48 cm). An analogous set of experimental objects were arranged on and around each table: 4 objects on the table and 6 objects on the floor. The objects were solid figures with identical shape and dimensions in each set. They were made of a 3 mm thick transparent plastic. The objects differed between zones in terms of visual stimulus complexity: in the first zone they were white, in the

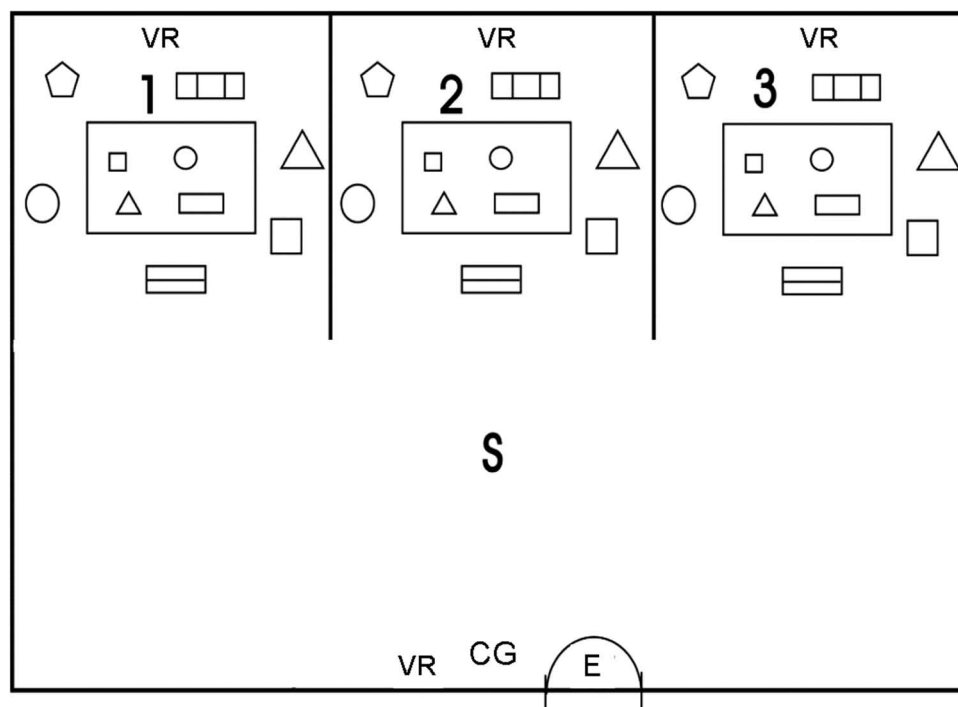


Fig. 1. Layout of the experimental room. Description of symbols: 1 – highest visual stimulation zone; 2 – lowest visual stimulation zone; 3 – medium visual stimulation zone; CG – caregiver chair, E - entrance, S - start point for children at the beginning of session, VR - video recorder. Geometric figures represent experimental objects.

second their walls were painted in various colours (e.g., one wall yellow, one blue, one red), and in the third zone they were transparent and filled with multicoloured plastic, paper and metal items permanently fixed inside each solid figure (Fig. 2). The objects were unfamiliar and previously unseen for all children in the study. Location of individual zones of varying visual stimulation (right, middle or left section of the room) was randomized for each tested child.

### Procedure

The child entered the experimental room with caregiver and experimenter. The caregiver sat in a designated chair, and the experimenter lead the child to the starting point (see: Fig. 1). Then, the experimenter instructed the child to "Go play", and left the room. The caregiver spent the entire session in the designated chair (he/she was asked not to initiate interaction with the child). The child was allowed to explore the room freely. After the lapse of 15 minutes the session was stopped by the experimenter.

The children's behaviour was recorded with 4 video cameras. Three were located directly above zones 1-3, and one above the entrance to the experimental room. With this setup, children could be followed throughout the experimental room. The set of four compact cameras was connected to a PC with Microsoft Windows XP Home Edition OS, equipped with a video recording card with 100 frames per second PAL resolution recording capability. The PC was located in the adjacent room, allowing the experimenter to follow sessions in real time. Recording started when the child reached the starting point.

The recorded material was then assessed by two trained competent raters blinded to the diagnostic status of children. They analysed the recording in 15-second intervals, marking the occurrence of the following behaviours in the monitoring sheet: (1) crossing the line

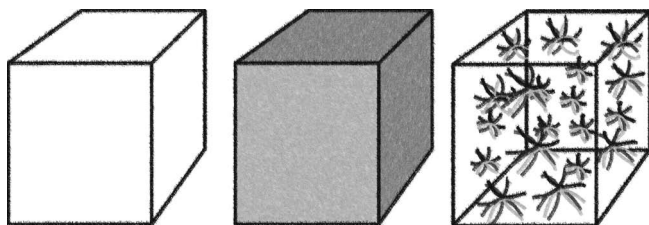


Fig. 2. Schematic diagrams of sample objects of exploration.

dividing the room's zones (measure of locomotor activity), (2) looking at experimental objects, (3) touching experimental objects with hands, (4) touching experimental objects with the mouth or other parts of the face, (5) manipulating experimental objects (placing them one on top of the other or adjacent to one another) (behaviours 2-5 served as measures of object exploration). In addition, raters measured the time spent by each child in the zone containing objects with lowest, medium and highest visual stimulation complexity (index of space preference). The test-retest reliability of the competent raters' measurements was  $r_{tt}=0.89$  (number of analysed time intervals  $N=1080$ ).

### RESULTS

Due to differences in variance, a Kruskal-Wallis one-way ANOVA was used to compare study groups in terms of frequency of measured behaviours and time spent in each zone of the experimental room. Table III presents descriptive statistics of variables measured in the study and results of statistical analysis.

In cases where KW ANOVA revealed the presence of between-groups differences, Mann-Whitney *U*-test was used to break down this general effect. The Mann-Whitney *U*-Test showed that children with typical development looked at experimental objects more than children in the other groups, with no differences found between children with autism and children with Down syndrome ( $U=13$ ,  $N=18$ ,  $p<0.05$ ). The comparison of time spent in individual zones revealed that children with autism and children with Down syndrome spent less time in the zone with the highest visual stimulation complexity compared with typically developing children ( $U=12$ ,  $N=18$ ,  $p<0.05$ ). There were no differences between children with autism and children with Down syndrome.

No differences between groups were found for other variables, i.e. locomotor activity, touching objects with hands, touching objects with the mouth, as well as the time spent in the zone with the lowest and with medium visual stimulation complexity.

### DISCUSSION

The results of the present study confirm some earlier reports on exploration in children with autism and bring new information on this type of activity.

Similarly to the results of other studies (Pisula 2003), no differences were found between this group of children and children with typical development and Down syndrome in terms of locomotor activity. Studies on animal models of autism (e.g., Balemans et al. 2010) have also indicated reduced activity and exploration, as well as lack of differences in locomotor activity during exploration compared with animals with typical development. Thus, when using this basic measure of exploration, which refers to exploratory activity with low level of complexity, there are no differences

between individuals with autism and other subjects. It is, however, worth pointing out major individual differences in terms of locomotor activity found in the autism group. The within-group differentiation was much greater than in the groups of children with Down syndrome and typical development. This finding may reflect the variation in the overall level of activity, including locomotor activity, observed in the population of children with autism (Pisula 2005).

The study group also differed in the frequency of looking at experimental objects. The rate of looking at

Table III

Descriptive statistics of behaviours measured in the study and results of Kruskal-Wallis one-way ANOVA.				
Variables	Children with autism Mean (SD)	Children with Down syndrome Mean (SD)	Typically developing children Mean (SD)	<i>H</i> ( <i>p</i> )
Locomotor activity (number of intervals)	27.89 (20.42)	22.78 (8.90)	22.44 (8.35)	0.091 (0.955)
Looking at objects (number of intervals)	25.56 (19.19)	37.22 (17.28)	51.11 (8.43)	8.495 (0.014*)
Touching objects with hands (number of intervals)	6.11 (13.51)	10.44 (15.55)	3.67 (4.55)	0.257 (0.879)
Touching objects with the mouth (number of intervals)	2.33 (6.28)	1.00 (1.58)	0.56 (0.73)	0.744 (0.689)
Manipulating objects (number of intervals)	4.56 (6.95)	0.33 (0.71)	3.67 (5.32)	2.329 (0.312)
Time spent in the zone with the lowest level of visual stimulation complexity (in seconds)	149.89 (142.14)	57.44 (30.65)	102.67 (75.20)	1.750 (0.417)
Time spent in the zone with medium level of visual stimulation complexity (in seconds)	87.67 (77.65)	106.56 (80.73)	161.22 (69.13)	4.840 (0.089)
Time spent in the zone with the highest level of visual stimulation complexity (in seconds)	115.00 (102.77)	112.11 (75.06)	266.33 (134.28)	8.384 (0.015*)

\*  $p < 0.05$

those objects was lower in children with autism than in their typically developing counterparts. This result confirms earlier findings (Pisula 2003). It would suggest the presence of reduced involvement with objects in children with autism. Similar conclusions were reported by other authors (Rodman et al. 2010), who also pointed out unusual visual exploration of objects in that group (Ozonoff et al. 2008). In the light of the results of the present study we cannot conclude, however, that reduced object exploration is autism-specific. Children with Down syndrome also looked at experimental objects less frequently than their typically developing peers. The results of other studies in this area are also inconclusive. Some reports (Gowen et al. 1992, Ruskin et al. 1994) suggest, that involvement with objects is greater in typically developing children than in children with developmental disabilities. On the other hand, O'Neil and Happé (2000) demonstrated that, while involvement with objects is lower in children with autism, it does not differ between children with Down syndrome and children with typical development. It is worth pointing out again the substantial individual differences within the autism and Down syndrome groups in the present study in terms of looking at objects, which were much greater than among typically developing children.

A general conclusion that children with autism demonstrate reduced object exploration would nevertheless be unfounded in the context of our study. After all, we found no differences between children in this group and other participants with respect to other forms of exploring experimental objects: touching them with hands and mouths and manipulation. Similar results were obtained by Pisula (2003). This shows that differences between children with developmental disabilities and typically developing children are particularly apparent in visual exploration of objects.

Another aspect of object exploration was revealed by the comparison of times spent by study groups in individual zones of the experimental room. There was an interesting effect of interaction manifested in the fact that differences in time spent in a given zone were revealed in the case of the zone with the greatest visual stimulation complexity, while no differences were seen in the remaining two zones, i.e. with medium and the lowest level of complexity of visual stimulation. Children with typical development spent much more time in the highest complexity zone than children with autism and Down syndrome. This zone

contained solid figures filled with items of various colours and shapes; these objects were the most complex, and at the same time, the most absorbing to children with typical development. Children with developmental disabilities showed significantly less interest in them, with no differences in that respect between children with autism and children with Down syndrome. Behaviour of typically developing children appears to be consistent with the pattern documented in animal studies, suggesting preference for more complex objects and spending more time on their exploration than on less complex ones (e.g., Durier and Rivault 2002, Pisula and Siegel 2005). Studies conducted in the 1960s did not confirm this pattern in the case of children with intellectual disability. Unlike children with typical development, those children preferred objects with the same or even lower visual stimulus complexity than those to which they have previously been adapted (Sackett 1967). Our result shows, on the other hand, that while children with developmental disabilities spent the same amount of time as typically developing children in the zones with low or medium visual stimulation complexity, they spent significantly less time in the zone with the most visually complex objects. Thus, the characteristics of objects determined the index of exploration intensity which was the time spent in the zone with a given type of objects. This interesting result may inspire further research. It should be noted that studies on object exploration in children with autism may have important applications in therapeutic practice. It was found that the level of object exploration skills' development may be an important predictor for the child's language development (Schlosser and Wendt 2008). Consequently, efforts are being made to develop object exploration skills in children with autism (Yoder and Stone 2006).

The picture of differences in exploratory behaviour between children with developmental disabilities and typically developing children obtained in this study is somewhat complex. It should be taken into account that the present study examined children's behaviour in a unique, novel situation, towards unfamiliar objects that did not resemble typical toys. The analysis concerned a set of specific behaviours. The results show few differences between groups (related to looking at experimental objects and time spent in the zone with the highest visual stimulation) and no differences in many other areas (e.g., time spent in other zones, loco-



motor activity, touching objects). Both finding between-groups differences and absence thereof brings significant new information about the exploration of children with developmental disabilities. The results show similarity in exploratory behaviour of children with developmental disabilities and typically developing children. It is consistent with the results of other studies, which have also demonstrated similarity of children with Down syndrome and typically developing children in patterns of responding to novel objects (e.g., O'Neil and Happé 2000).

Any interpretation of the present results must take into account its limitations. The study groups were small. In addition, the inference process is hampered by the aforementioned significant amount of variation within the groups. The results would also have been much more informative if the groups were matched for the level of participants' intellectual development. Despite those limitations, the findings of the study were informative and may serve as inspiration for further investigations.

## CONCLUSIONS

On the basis of our results, we can draw the following conclusions:

We found no differences between children with autism, children with Down syndrome and children with typical development in terms of locomotor activity while exploring unfamiliar environment. This result, which is consistent with earlier findings, reveals parallels between these groups with respect to this basic form of exploration.

The picture of differences in terms of object exploration was ambiguous: while children with developmental disabilities looked at objects significantly less often than their typically developing counterparts, no such differences were found for touching and manipulation of these objects. An interesting finding was the lack of significant differences between children with autism and with Down syndrome.

The measure of involvement with objects, which was the time spent in individual zones of the experimental room was related to the degree of the objects' visual stimulation complexity. Children with typical development spent more time than other participants in the highest visual stimulation complexity zone. No between-groups differences were detected in the zones with lower complexity.

There were sizeable individual differences in terms of indices of exploration measured in the study within the group of children with autism and the group of children with Down syndrome.

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