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Pursuit Eye Movements in the Context of Speech Development in Children with ASD Ruchy śledzące oczu w kontekście rozwoju mowy dziecka z zaburzeniami ze spektrum autyzmu

ABSTRACT

RESEARCH OBJECTIVE: The main goal of the presented research was to assess the pursuit eye movement of five- and six-year-old children with ASD in the context of speech development.

RESEARCH PROBLEM AND METHODS: The research concerns the oculomotor activity of children with ASD in the situation of tracking slowly moving objects. The research questions refers to the relationships between the tracking movements and the dynamics of the speech development of the research participants, and to their current abilities in this area. The eye tracking method was used in the research.

THE PROCESS OF ARGUMENTATION: We presented the basic information about the vision process, with particular emphasis on the role of the pursuit eye movement. We also described the research on the importance of eye movement in the process of acquiring communication skills, building social relationships and effective functioning.

RESEARCH RESULTS: The obtained results indicate the correlation between the independent variable (the pattern of smooth pursuit presented by the children taking part in the research), and the dynamics of disorder development and the level of speech development in the children with reference to the analyses of other authors.

CONCLUSIONS, INNOVATIONS AND RECOMMENDATIONS: The conducted analyses revealed strong and moderate correlations between the variables and made it possible for the author to confirm the main hypothesis that the eye movements while tracking slow-moving objects in all directions are characterized by variability related to the dynamics of speech development in early childhood and the current abnormalities in this area among the research participants. The obtained results indicate the necessity to start vision training in children with ASD as early as possible.

→ **KEYWORDS:** **AUTISM SPECTRUM DISORDER, EYE TRACKING, SMOOTH PURSUIT, LANGUAGE COMMUNICATION, EARLY INTERVENTION**

STRESZCZENIE

CEL NAUKOWY: Celem prezentowanych badań była ocena wolnych ruchów śledzenia dzieci pięcio- i sześciolletnich z ASD w kontekście rozwoju mowy.

PROBLEM I METODY BADAWCZE: Problematyka badawcza dotyczy aktywności okoruchowej badanych dzieci z ASD w sytuacji śledzenia obiektów wolno poruszających się w polu widzenia. Sformułowane pytania badawcze odnoszą się do związków pomiędzy ruchami śledzącymi a dynamiką rozwoju mowy badanych, jak również aktualnymi umiejętnościami badanych w tej sferze. W badaniach zastosowano technikę eye trackingu.

PROCES WYWODU: Zaprezentowane zostały podstawowe informacje dotyczące procesu widzenia, ze szczególnym uwzględnieniem roli ruchu śledzącego. Dokonano prezentacji badań na temat znaczenia ruchu gałek ocznych w procesie nabywania umiejętności komunikacyjnych, budowania relacji społecznych i skutecznego działania.

WYNIKI ANALIZY NAUKOWEJ: Przedstawiono wyniki dotyczące korelacji pomiędzy zmienną niezależną (wzorzec wolnego ruchu śledzenia prezentowany przez badanych) a dynamiką rozwoju zaburzenia oraz poziomem rozwoju mowy badanych w odniesieniu do analiz innych autorów.

WNIOSKI, INNOWACJE, REKOMENDACJE: Przeprowadzone analizy ujawniły silne i umiarkowane korelacje pomiędzy zmiennymi i pozwoliły na potwierdzenie hipotezy głównej, zakładającej, że zapisy ruchu oka podczas śledzenia wolno poruszających się obiektów we wszystkich płaszczyznach odznaczają się zmiennością związaną z dynamiką rozwoju mowy we wczesnym dzieciństwie oraz prezentowanymi obecnie przez badanych nieprawidłowościami w tym obszarze. Uzyskane wyniki wskazują na konieczność jak najwcześniejszego podjęcia treningu widzenia u dzieci z ASD.

→ **SŁOWA KLUCZOWE:** **ZABURZENIA ZE SPEKTRUM AUTYZMU (ASD), AKTYWNOŚĆ OKORUCHOWA, OKULOGRAFIA, KOMUNIKACJA JĘZYKOWA, WCZESNE WSPOMAGANIE ROZWOJU DZIECKA**

Introduction

Current classifications identify clinically significant and consistent abnormalities in social communication and interaction in children with autism spectrum disorders as one of two basic diagnostic criteria for the disorder (DSM-5, 2013). The analysis of literature on the subject indicates that communication-related abnormalities in children with ASD are varied and may involve language and speech development, as well as non-verbal communication (Winczura, 2013, 2018). The results of the research using the eye-tracking method are certainly important for understanding the nature of variability and differentiation in the difficulties presented (Bleszyński et al., 2019). Measuring eye movement and assessing its quality in situations related to social interaction provides information that is important not only for explaining the reason for the difficulties experienced by children, but also for pedagogical practice, as it may enable the proper selection of goals, methods and therapeutic aids to work with a given child.

The aim of the research presented in this article was to assess the patterns of oculomotor activity of five- and six-year-old boys with ASD when tracking slow-moving objects in the context of speech development, as well as to make recommendations for the practice of early development support for children with autism spectrum disorders.

The research problem was formulated in the form of the following question:

What patterns of slow tracking movements in the horizontal, vertical and oblique planes are exhibited by the children with ASD studied, and what is the relationship between the identified patterns and speech development?

The main hypothesis:

Eye-movement records when tracking slow-moving objects in all planes are characterised by the variability related to the dynamics of speech development in early childhood and the current abnormalities of the research participants in this area.

Also, the following specific problems were determined:

1. Is there a relationship/what is the relationship between the children's current level of functioning and the dynamics of development of disorder-specific abnormalities in the area of speech in early childhood?

Hypothesis 1. – open.

2. Is there a relationship/what is the relationship between the tracking movement patterns exhibited by the children and the developmental dynamics of disorder-specific abnormalities in the area of speech in early childhood?

Hypothesis 2. – open.

The present study assesses the children's oculomotor activity with two primary independent variables:

- the disorder dynamics marked by the time of the occurrence of the first symptoms (Jaklewicz, 1993),
- the current level of the participants' speech development.

Method and tools

The study involved 43 five- and six-year-old boys with autism spectrum disorders, whose intellectual development was determined as normal on the basis of psychometric tests. Due to the changes taking place in the development of visual skills with age, and the level of the severity of symptoms of the autism spectrum, according to the DSM-5 classification, the children were divided into two groups (Table 1).

Table 1. Structure of the analysed group according to the age

Group	Age (months of life)	The number of the research participants (n)
I	48-59	19
II	60-71	24

Source: The author's own research

The boys were also divided according to the severity of their current symptoms, according to the DSM-5 classification, and according to the time of the occurrence of the first abnormalities in the area of speech development (Jaklewicz, 1993) (Table 2).

The information about the participants' functioning was obtained using the child version of the Autism Quotient Questionnaire (Auyeung et al., 2008), which was completed by the children's teachers. In addition, we carried out the analysis of the documentation describing the child's development in terms of the occurrence of the first symptoms of abnormalities in speech and communication development, as well as the participants' current skills in this area. Such analysis was supplemented by the interview with the teachers in order to clarify the data in this area.

Table 2. Structure of the analysed group of children by the level of functioning and the time of the occurrence of the symptoms of the disorder, with the division into age groups

Time of the occurrence of the symptoms \ Level of functioning	Early development of autism		Late development of autism	
	I group	II group	I group	II group
	n	n	n	n
I	–	–	–	3
II	7	11	1	1
III	11	9	–	–

Legend:

Level 1. Requiring support

Level 2. Requiring substantial support

Level 3. Requiring very substantial support

Source: the author's own research

The method of testing was applied in the research (Rubacha, 2008).

The empirical material was collected using the myGaze eyetracker, which is a device that enables real-time tracking and recording of eye activity. The device is equipped with training software.

The task included in the “Attention and looking” training module, which involved tracking objects moving across the screen in the vertical, horizontal and oblique planes, taking into account the rising and falling movements of the eye, was used to assess slow tracking movements. The children taking part in the research were given the opportunity to choose the figure and the character they wanted to watch. In the case of figures, they also chose their colours. The test task not only identifies eye movement patterns, but it is also related to visual attention and discrimination of visual stimuli.

The main part

According to modern scientific knowledge, the process of vision is related to the formation of representations of reality in the mind and, at the same time, to effective action (Milner & Goodale, 2008). All the visual perception, including eye movements, which are responsible for the formation and maintenance of the image representation on the retina, is essential for the process to work properly.

One of the basic movements of the eye are slow tracking movements: smooth, associated (synchronous) eye movements whose primary function is to stabilize the moving image on the retina. Slow tracking movements are responsible for changing the direction of gaze. During the initiation of a tracking movement, all the available information about the movement is averaged, and the cognitive factors, including attention, anticipation and learning, can influence the performance of the tracking movement (Leigh & Zee, 2006).

The ability to follow moving objects with one’s eyes develops between the second and fourth months of life and undergoes intensive development during the first three years of life, making it possible to freely explore the dynamically changing environment and to direct attention to those elements of it that will be subjected to cognitive analysis. Already in the first weeks of life, a child is able to follow with their eyes slowly moving objects located at a short distance from their eyes, observing the movement first horizontally and then vertically. Between the second and third months of age, a child begins to look at the objects and persons moving within his or her field of vision (Oleszczyńska-Prost, 2011). It is worth mentioning that one of the abilities that is particularly important from the perspective of the development of social interaction and communication skills is following others with one’s gaze (Białecka-Pikul et al., 2014).

The results of the eye-tracking studies among people with autism spectrum disorders demonstrate a relationship between the participants’ speech development and eye movement patterns (Stagg et al., 2014). The differences in information processing, revealed through scientific analysis, can significantly affect the daily communication and functioning of people with ASD. The data from the eye-tracking analyses conducted in the areas of social interaction and speech and language development are consistent and

indicate, among other things, the inability of the children with ASD to detect important social cues, such as words or phrases that condition proper understanding of a situation or a task (Howard et al., 2019).

In the typical course of development, the child uses innate mechanisms of preference for faces and human voices to allow for the maturation of the social brain and development of the language system and speech acquisition. Patterns of development of social deficits suggest that early, limited exposure to social stimuli, which may result not only from environmental conditions but also, as is the case with ASD, from the child's inability to recognize social cues, leads to delayed or atypical development of the area related to social adaptation, as well as communication and language skills (Klin et al., 2002). This fact was reflected in the research of H. Jaklewicz (2000) indicating the relationship between the image of speech and communication disorders in children with ASD and the dynamics of the disorder development. The author distinguished two groups of children depending on the period in which the abnormalities characteristic of the disorder are manifested:

- I. children with early development of autism (before the 12th month of life),
- II. children with late development of autism (after 12th month of life).

In case of the children belonging to the first group, poor eye contact with their significant caregiver, the lack of emotional compliance, impoverished vocalisation, stereotypical behaviour and atypical exploration of objects, as well as the lack of understanding of socially meaningful gestures, are observed in the first year of life. What is typical of them is the inability to follow a person or an object with their eyes, as well as (at the end of the first year of life) the lack of imitation plays. The lack of the correct response to one's own name and the lack of interest in other people were considered the most diagnostic. Speech does not usually develop naturally in these children, or if it does, it is significantly delayed.

Late autism, on the other hand, develops before the age of three, but, after a period of the child's normal functioning, it goes through subsequent phases of speech development. However, after a time of proper development we can notice a significant regression and withdrawal from social contacts (usually between 15 and 24 months of age). Non-verbal communication also becomes impoverished (Winczura, 2013).

Taking into account those characteristics, as well as the assumptions of the social deficit development pattern, it can be assumed that there is a relationship between the patterns of tracking movements and the speech development of the children. The course of such development is also influenced by the time in which the first symptoms of the autism spectrum disorder appear.

In the literature on the subject, the research related to slow tracking movements in the discussed group of children is not broadly represented. Scharre and Creedon (1992) found that most children with ASD are unable to perform the task of following slow moving objects. Y. Takarae and colleagues (2004), on the other hand, noted that in case of slow tracking movements there were no differences in the latencies between people with ASD and those from the control group.

However, abnormalities are revealed in the second phase of the movement (the so-called closed loop). The research participants with ASD have difficulty performing the first saccade towards grasping the target in a precise manner and following it, both in the right-to-left movement and in the opposite direction. The obtained results indicate that the movement efficiency was related to praxis. It was also found that the difficulties associated with the performance of this movement were related to the inability to predict the trajectory of the movement based on the data gathered during the performance of the tracking movement (Park et al., 2021).

Research results

The author's own research revealed varied patterns of oculomotor activity among the children tested when following slowly moving objects on the screen with their eyes. Considering the age of the children, one could have expected that the tasks given to them were quite easy. However, none of the children, despite their great interest in the activity and the positive emotions revealed during the test, performed the tracking movement correctly. For both horizontal and vertical movement, the revealed patterns did not differ regardless of the direction of movement. For the majority of the participants, the tasks involving tracking along oblique lines proved to be the most difficult, especially in the case of the rising motion (23 people did not attempt to track the object). In all the task series, the most attention-activating stimulus was the movement of the object itself, especially when it was associated with a sound (e.g. a dragon breathing fire and making a murmur). It turned out that the children did not achieve the age-appropriate skill of free gaze movement in all planes of motion, which, taking into account the normative development, is already revealed in the first months of life and then improved during the first three years of life (Oleszczyńska-Prost, 2011).

Based on the analysis of the heat maps, the most common difficulties revealed during the survey were identified:

- the lack of the fluency of movement,
- fixations appearing in different points of the screen, unrelated to the object or around the object,
- maintaining the gaze at the point in which the object appears and failure to make the tracking movement,
- maintaining the gaze at the point where the object has made an additional movement.

It was also found that, instead of the tracking movement, the saccades ending with random fixation points usually located at the edges of the monitor appeared (cf. Bleszyński et al., 2019).

This data may confirm the importance of cognitive factors such as attention, anticipation, and learning for the course of movement (Uwe, 2002). Also, they may reflect the research participants' problems related to praxis.

In order to answer the research questions, the relationships between the quality of object-tracking task performance and the developmental dynamics of the disorder, as well as the children’s current level of speech, were analysed. Spearman’s non-parametric R test was used to assess the correlations between variables.

Table 3 shows the results regarding the correlation between the quality of slow tracking movements and the developmental dynamics of autism spectrum disorders.

Table 3. The Spearman’s rank correlations between the quality of movement and the dynamics of the development disorder

Tracking movement	Dynamics of the disorder development
	<i>rho</i>
Eye movement in the horizontal plane	0.5936
Eye movement in the vertical plane	0.39413
Eye movement in the oblique plane, falling	0.49750
Eye movement in the oblique plane, rising	0.34555

$p < 0.05$

Source: the author’s own research

Table 4. includes the results of the correlation for the dependent variable and the current level of the children’s speech development.

Table 4. Coefficients of the Spearman’s rank correlations between the quality of movement and the current level of the children’s speech development

Tracking movement	Level of speech development
	<i>rho</i>
Eye movement in the horizontal plane	0.727
Eye movement in the vertical plane	0.683
Eye movement in the oblique plane, falling	0.675
Eye movement in the oblique plane, rising	0.854

$p < 0.05$

Source: the author’s own research

The results indicate a positive correlation between the variables studied. In the case of the correlation between the quality of movement and the developmental dynamics of the disorder, the highest correlation concerns movement in the horizontal plane, which is the first to be revealed in development, influencing, among other things, the ability to trace the movements of people within the child’s field of vision. In turn, the data presented in Table 4. reveals a strong positive correlation between the research participants’ current level of speech development for all types of tracking movements. The analysis of

the available materials on the child development shows that as many as 19 of the children who took part in the research do not communicate verbally; 21 boys use speech to a limited extent (14 use only single words, while 7 were found to have direct and/or deferred echolalia); and 2 children communicate verbally through sentences, but, in both cases, according to the kindergarten teachers, there are deficits in the use of non-verbal messages and in initiating contact.

The analysis of the collected empirical material also made it possible to establish a positive correlation between the child's current level of speech development and the time of the occurrence of the first symptoms of the disorder.

Research conclusions

The children's construction of adequate representations of the surrounding world is limited both by the difficulties associated with the intentional control of the environment through the eyes (the sensory level) and the categorization of data which takes place on the level of perception and association. In most cases, the eye-movement records indicate the predominance of bottom-up information processing, so the information about the features of the stimulus, rather than about the object as a whole in a specific context, was primarily received.

The analyses indicate a positive relationship between the children's level of functioning characterised by the quality of social communication and language skills, and the patterns of tracking movement. Based on the presented analyses, we may confirm the main hypothesis assuming that the quality of the tracking movement is connected with both the current level of speech development and the course of the disorder itself, the dynamics of which is determined by the time of occurrence and intensity of the first symptoms related to speech and communication development (Jaklewicz, 1993; Winczura, 2013). The existence of a link between speech development and oculomotor activity in people with autism spectrum disorders is also indicated by the reports from eye-tracking studies (Stagg *in.*, 2014; Howard *et al.*, 2019), but these focus primarily on saccade and fixation movements.

Revealing the strong correlation between the pattern of tracking movements and the dynamics of speech development of the research participants in their first three years of life (hypothesis 2), confirms the importance of fluent tracking movements in the child's acquisition of skills related to communication, especially language, and to social-emotional functioning in the surrounding reality. In the case of children whose first symptoms of the disorder appear early, *i.e.* before the age of 12 months, there is an impoverishment of social interactions, which, as indicated by researchers, leads to further development of social and communication deficits (Klin *et al.*, 2002; Cierpiatowska & Lubińska-Kościółek, 2017). This fact confirms the existence of a positive correlation between the current level of speech development of the children and the time when the first symptoms of the disorder occur (hypothesis 1).

The research was aimed not only at identifying and describing the patterns of tracking movements as relevant to the speech development of children with autism spectrum disorders, but also at formulating recommendations for pedagogical practice that are important from the perspective of the process of supporting the child's development.

Taking into account the significance, in the first months of life, of the oculomotor activity for both cognitive and socio-emotional development, it would be appropriate to consider extending the diagnosis of autism spectrum disorders to include the study of visual activity. Early visual training, including eye-tracking exercises introduced into the daily interactions between the child and the significant caregiver, can be extremely important for the child's further functioning when there is a risk of autism spectrum disorders or when the first alarming symptoms occur. While formulating the recommendations for the process of supporting visual development in the home environment, particular attention should be paid to the selection of toys compliant with the correctness of the visual process, as well as the organisation of the child's environment in a way that ensures the optimum level of sensory information.

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