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Belimova Polina Andreevna

PSYCHOLOGICAL CONCEPTS OF PERCEPTION OF ALTERNATIVE COMMUNICATION IN INTELLECTUAL DISORDER

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INTRODUCTION

Relevance of the study. Communication as a tool of social interaction plays a fundamental role in the formation and socialization of personality. People with cognitive impairments, in particular, with intellectual disorder, experience problems in the field of communication. Intellectual disorder is defined as a state of general mental retardation, which is characterized by a persistent decrease in the level of mental abilities in combination with low communicative potential. According to the Federal State Statistics Service, intellectual disorder is one of the most common clinical diagnoses among mental disorders. At the same time, mild forms occur in 75% to 90% of cases in patients with intellectual disorder (Mikheykina O.V., 2012). In 2020, the diagnosis of "mental retardation" was registered in relation to 87.7 thousand children aged 0-14 years and in 39.5 thousand adolescents aged 15-17 years. Cognitive impairment is combined with disorders of perception and speech production.

Alternative and augmentative communication (AAC) is an area of correctional practice that complements and compensates for speech disorders. AAC includes oral and written communication tools and serves as a tool for social and pedagogical interaction in correctional psychology. With a variety of forms of alternative communication, the attention of researchers is focused on studying cognitive interventions using auxiliary communication tools, taking into account the development of adolescents with disorder of intellectual development.

The features of the cognitive sphere in cases of intellectual disabilities can be considered as a system of factors that directly influence the perception and decoding of visual information, including graphic symbols – pictograms of various alternative communication systems. For scientific and practical perspectives in the field of education of adolescents with intellectual disorder, the study of psychological concepts of perception of AAC is of particular interest.

In this dissertation, the concept (lat. *conceptus* – thought, notion) is understood as a statement of specific properties of the process and result of decoding symbols (pictograms) of the AAC (Zhmurov V.A., 2012). In the conditions of an experimental study, when performing cognitive tasks with different graphic representations while simultaneously taking into account the psychological and physiological indicators of oculomotor activity in the process of perception, it is possible to study the phenomenology of psychological concepts of perception of the AAC. The prognostic model of psychological concepts of perception of the AAC has the potential to expand the prospects for providing corrective assistance to students with intellectual disorder.

Degree of development of the problem. The communicative sphere of people with intellectual disorder has been studied by many Russian authors (Vygotsky L.S., Leontiev A.N., Rubinstein S.Ya., Dulnev G.M., Boykov D.I., Isaev D.N. and others). General characteristics of communication skills in intellectual disorder include limited vocabulary, difficulties with articulation, problems with understanding and producing oral and written speech, underdevelopment of social skills. These limitations are significantly manifested in decoding abstract content in situations with non-verbal communication: in cases of intellectual disorder, understanding gestures, facial expressions and tone of voice is difficult.

One of the ways to compensate for speech disorders for people with communication deficits is alternative and additional communication, which involves the use of special non-speech types of information exchange, as well as the methodology for their application (Dada S. et al. al., 2021). AAC communication systems based on images in the form of graphics, drawings, pictograms and symbols make it possible to partially overcome speech difficulties, improve communication skills, increase the child's linguistic potential, expand his knowledge of the world, and form vital autonomy and independence (Baryaeva L.B., Tetzchner S., Musselwhite C.R., Russello D.M., Sevcik R.A., Romski M.A., Schlosser R.W., Sutherland D., McNaughton S.).

The reasonableness and desirability of the intervention of the AAC in the correctional work with individuals with intellectual disorder is determined by the frequency of manifestation of communication deficit in this group of individuals (Agaeva I.B., Vecher M.V., Kozlova K.M., Kanyukova V.V., Dada S., Mirenda P., Lund S.K., Light J.).

At present, there is a limited number of scientific works related to the study of the mechanisms of perception and interpretation of graphic means of AAC by Russian adolescents with intellectual disorder, including the use of precise methods of cognitive processing analysis. It seems relevant to search for patterns in the perception and interpretation of pictograms by persons with intellectual disorder in the context of comparing several graphic systems of alternative communication.

As a result of the analysis of scientific literature devoted to the prospects and limitations of the intervention of graphic tools of the AAC in the communication practice of persons with intellectual disorder, the following *contradictions were identified*:

– between the large amount of evidence in favor of the general usefulness of AAC interventions in intellectual disorder and the small number of evidence-based studies revealing the effectiveness of specific methodologies;

– between the increasing saturation of the public and digital environment with graphic non-verbal means of communication and the insufficient study of the perception of these means by people with intellectual disorder, taking into account the characteristics of their cognitive sphere.

Thus, at present there is a limited number of scientific works related to the study of the perception and decoding of graphic means of the AAC by adolescents with intellectual disorder, including the use of hardware methods for analyzing cognitive information processing.

Based on the identified contradictions, *a problematic research field was defined* – the search for psychological concepts in the perception and decoding of pictograms by persons with intellectual disorder in the context of comparing several graphic systems of alternative communication.

The aim of the study: to study the phenomenology of psychological concepts in the perception and decoding of graphic images of various alternative communication systems, taking into account the oculomotor activity of adolescents with intellectual disorder.

Research objectives:

1. To develop a model for an experimental study of the perception and decoding of pictograms from various AAC systems using the eye movement recording method.

2. To study the specifics of decoding pictograms as a component of the AAC in the context of various cognitive tasks by adolescents with intellectual disorder.

3. To determine the specificity of the parameters of oculomotor activity in the process of perception of the visual acuity by adolescents with intellectual disorder.

4. To identify the relationships between the results of decoding various AAC systems and the parameters of oculomotor activity in adolescents with intellectual disorder.

5. To substantiate the content of psychological correction of communication disorders in adolescents with intellectual disorder using graphic alternative communication tools based on a predictive model of psychological concepts of pictogram perception.

Object of the study: perception of pictograms of various graphic alternative communication systems by adolescents with intellectual disorder.

Subject of the study: decoding of graphic images in different AAC systems taking into account the oculomotor activity of adolescents with intellectual disorder.

The main hypothesis of the study: in young men and women with intellectual disorder, the result of decoding pictograms is conjugated with a significant number of incorrect interpretations and differs from their normally developing peers in the specificity of oculomotor activity. Underdevelopment of perception complicates the cognitive processing of the AAC, which is associated with a shorter duration of gaze fixations. The result of decoding pictograms is interconnected with the parameters of oculomotor activity: the number of fixations and returns, viewing time and duration of fixations. The factor of pictograms belonging to different AAC systems in intellectual disorder affects the success of their decoding and the parameters of oculomotor activity.

The specific hypotheses of the study reflect the process of perception and the result of decoding the pictograms of various AAC systems, taking into account the following factors:

– graphic representation of a human figure on pictograms;

– the part of speech to which the verbal meaning of the pictogram belongs, assigned by a specific AAC system using nouns and verbs as an example;

– repetition of pictograms when implementing various cognitive tasks.

Scientific novelty of the study. A model has been developed experimental study of the perception and decoding of pictograms from various AAC systems using the eye movement recording method.

For the first time, patterns of oculomotor activity in visual perception of pictograms as elements of the AAC were studied using the oculography method in adolescents with intellectual disorder.

A study of various alternative communication systems was conducted with the inclusion of a previously unstudied pictographic system “LoCoS©” in the experimental design, as well as standardized signs of public spaces that are associated with the daily communication of adolescents with intellectual disorder in their real life.

Within the framework of this experimental study, the specificity of psychological concepts in the perception and decoding of pictograms in students with intellectual disorder was determined, taking into account the properties of the graphic representation of pictograms as symbolic components of the AAC systems.

Theoretical significance The research consists of:

– confirmation of the possibility of replicating the data obtained in earlier studies of alternative communication on new experimental material in the form of modern alternative communication systems (Mizuko M., 1987; Mirenda P., Locke P.A., 1989; Wilkinson K.M., Light J., 2014);

– supplementing existing ideas about the perception of graphic symbols in cases of intellectual disorder based on data on oculomotor activity, taking into account cognitive mechanisms in the perception of non-verbal means of communication;

– defining psychological concepts of perception as a result of decoding symbols of the AAC while simultaneously taking into account psychological and physiological indicators of oculomotor activity.

Practical significance. The obtained experimental data on the cognitive specificity of graphic symbols as elements of the AAC are applicable for effective compensation of communication problems in cases of intellectual disorder.

The design of the study allows us to study the perception of pictograms as elements of the AAC using the associative method. It consists of stimulus material of four AAC systems, which is applicable for developing correctional classes with children with intellectual disorder.

The studied phenomenology of perception and decoding of the AAC systems allows the use of the obtained results in correctional and pedagogical practice in the creation of teaching aids with communicative graphic symbols to compensate for communicative difficulties in cases of intellectual disorder.

The definition of psychological concepts of perception of AAC contributes to the targeted development of the content of teaching aids for specialists working with children with disorder.

The developed recommendations for the use of graphic symbols as elements of the AAC and signs of public spaces contribute to the effective inclusion of persons with intellectual disorder in the communicative field and social environment by creating inclusive conditions for interaction and navigation in their daily lives.

Theoretical and methodological basis of the study. The interdisciplinary nature of the research problem determined the need to apply scientifically based theories, approaches and principles:

1. General scientific ideas about the peculiarities of the communicative sphere in intellectual disorder (Vygotsky L.S., Leontiev A.N., Rubinstein S.Ya., Dulnev G.M., Boykov D.I., Bablumova M.E., Petrova V.G.., Lalaeva R.I. and others), as well as characteristics of perception (Veresotskaya K.I., Meleshkina M.S., Goryainova I.A., Stephenson J., Linfoot K. and others).
2. Empirical, practice-oriented and review studies devoted to alternative and augmentative communication (Baryaeva L.B., Lopatina L.V., Agaeva I.B., Kondratieva S.Yu., Gaidukevich S.E., Churakova G.G., Tetzchner S., Musselwhite C.R., Russello D.M., Sevcik R.A., Romski M.A., McNaughton S. Mizuko M., Mirenda P., Dada S., Huguet A., Bornman J., Schlosser R.W., Sigafoos J., Haupt L., Alant E., Emms L., Gardner H. et al.).

3. Methodological justifications for the use of the oculography method in studies of cognitive processes in the perception of visual stimuli (Barabanshchikov V.A., Light J., Vakil E., Gliga T., Poulton E.C., Manor B. R., Gordon E., Rayner K., Carlin M., O'Neill T., McIlvane W.J., Fletcher-Watson S., Riby D.M., Hancock P.J.B., Smilek D., Thiessen A.), including alternative and augmentative communication tools (Dube W. V., Wilkinson K.M., Madeleine M.).

4. Concepts of the manifestation of direct cognitive control in the process of activation of lexical processing during the perception of visual stimuli (Rayner K., Reingold E.M., Reichle E.D., Engbert R.).

Research methodology. To achieve the stated goal and objectives of the study, the following methods were used:

– *an experimental method* as a fixed system of means, techniques and procedures that allow obtaining reliable and valid knowledge about mental phenomena by modeling the conditions for their manifestation (Barabanshchikov V.A., 2011). In this study, the situation and conditions for perceiving pictograms were modeled, and the psychological content of the phenomenon under study was assessed by recording eye movement activity.

– *a method of oculography* that allows determining the coordinates of the gaze (the points of intersection of the optical axis of the eye and the plane of the screen on which the visual stimulus is presented), as well as its movement during the perception of the visual stimulus. In this study, the method of recording oculomotor activity made it possible to analyze the cognitive processes of students with intellectual disorder when perceiving pictograms.

– *the associative method* was used in the development of stimulus material and included three systems of pictographic alternative communication: Blissymbols, LoCoS©, Pictogram, as well as public space signs.

– *methods of mathematical and statistical data analysis:* assessment of internal consistency of stimulus material series (Cronbach's alpha); descriptive statistics (mean value, standard deviation); frequency analysis (chi-square); parametric criterion for comparison of means (Student's t-test); nonparametric criterion for comparison of means

(Mann-Whitney U-test); parametric one-way analysis of variance (Fisher's test) and Tukey's post hoc test ; nonparametric one-way analysis of variance (Kruskal-Wallis test) using the Dwass-Steele-Critchlow-Flinger pairwise comparison method; factor analysis (using the principal component analysis method and promax rotation).

The total number of study participants was 184 people. The control group included 92 students of secondary schools with normo- typical development (46 girls and 46 boys, average age – 14.7 years). The experimental group consisted of 92 subjects with intellectual disorder, clinical diagnosis “F70 – mild mental retardation” according to ICD-10 (66 boys and 26 girls, average age – 15.1 years).

Provisions for defense:

1. Psychological concepts of perception as a cognitive effect of pictogram decoding in the AAC systems of adolescents with intellectual disorder are interconnected with the graphic representativeness of pictograms. The most iconic pictograms, visually close to the referent, reduce the cognitive complexity of processing visual stimuli in their contextual configuration.

2. Psychological concepts of pictogram perception in AAC systems are interconnected with parameters of oculomotor activity. In adolescents with intellectual disorder, direct cognitive control during activation of the lexical processing process is less pronounced due to their specific cognitive processes, which is expressed in a reduction in the duration of gaze fixations on pictograms.

3. *perception* of the AAC in adolescents with intellectual disorder, three psychological concepts were identified. *Cognitive simplification* is expressed in the reduced duration of fixations of the gaze on pictograms. *Conjugated contextuality* is based on a greater number of fixations and returns of the gaze in the process of decoding pictograms. *Continuity with life* contributes to a reduction in the time of cognitive processing of familiar visual symbols of public spaces.

Reliability and validity of the results obtained ensured by the use of interdisciplinary methods corresponding to the objectives and subject of the study - the psychological associative method and the physiological method of oculography ; high-quality representativeness and sufficient sample size; wide application of methods of mathematical and statistical analysis corresponding to the specifics of the experimental data.

Testing of the research results. The research results were presented at meetings of the Department of Pedagogy and Educational Psychology of the Faculty of Psychology of St. Petersburg State University, as well as at the following conferences:

1. 30th International Conference on Computer Graphics and Machine Vision (GraphiCon), ITMO University, Saint Petersburg, Russia, September 22-25, 2020.
2. International scientific conference "Human abilities and mental resources in the world of global changes" dedicated to the 65th anniversary of V.N. Druzhinin, Institute of Psychology of the Russian Academy of Sciences, Moscow, Russia, September 16-17, 2020.
3. Ananyev Readings – 2020. Psychology of Service Activity: Achievements and Development Prospects (in honor of the 75th Anniversary of Victory in the Great Patriotic War of 1941–1945), Saint Petersburg State University, Saint Petersburg, Russia, December 8–11, 2020.
4. All-Russian scientific and practical conference with remote and international participation "Current problems of modern education: experience and innovation", Ulyanovsk, Russia, December 21–22, 2020.
5. 5th International Conference on Neurobiology of Speech and Language, Saint Petersburg State University, Saint Petersburg, Russia, October 8–9, 2021.
6. VI All-Russian scientific and practical conference with international participation "Modern reality in the socio-psychological context", Novosibirsk State Pedagogical University, Novosibirsk, Russia, March 16–17, 2022.
7. International Scientific Conference "Integrative and Cross-Cultural Approaches to the Study of Thinking and Language", Russian State University for the Humanities, Moscow, April 5–6, 2022.
8. Ananyev Readings – 2022. 60 Years of Social Psychology at St. Petersburg State University: From the Origins to New Achievements and Innovations, St. Petersburg State University, St. Petersburg, Russia, October 18–21, 2022.

9. International scientific and practical conference "Socio-psychological adaptation of migrants in the modern world", Penza, Russia, March 25–26, 2022.

10. XVII Sretensky scientific and practical conference with international participation "Psyche and Pneuma: resources, potentials, human capabilities in different life situations", St. Petersburg, Russia, February 21–22, 2024.

11. VIII All-Russian scientific and practical conference with international participation "Modern reality in the socio-psychological context", Novosibirsk, Russia, March 9–20, 2024.

The dissertation research was carried out within the framework of a research project that received financial support from the Russian Science Foundation – grant No. 24-28-01653 “Psychophysiological indicators of decoding graphic means of communication in persons with intellectual disorder” (performer).

The research materials are reflected in 21 publications, including 2 articles in peer-reviewed scientific journals recommended by the Higher Attestation Commission in Psychological Sciences under the Ministry of Science and Higher Education of the Russian Federation in the specialty 5.3.8. Correctional Psychology and Defectology; 2 articles in publications indexed in the scientometric database Scopus.

Structure of the dissertation. The dissertation consists of an introduction, four chapters, conclusions, a summary of 136 sources (81 of which are in English), and 6 appendices. The work contains 17 figures and 10 tables. The main text is 104 pages. The total number of appendices is 38 pages.

Main scientific results:

1. The specificity of perception and decoding of pictograms as a component of the AAC in the context of various cognitive tasks by adolescents with intellectual disorder is characterized by passivity of thinking and a shorter duration of activation of lexical processing compared to peers with normative intelligence. The result is presented in the publications: Belimova P.A., Zashchirinskaia O.V., Turchaninov E.E., Nikiforov A.A., Ivanyukhin R.R. Manifestations of psychological defenses in decoding graphic means of communication in individuals with intellectual disorder // Society: sociology, psychology, pedagogy. 2024. No. 5. pp. 34–42. DOI: 10.24158/spp.2024.5.4 on pages

37–38; Belimova P.A. Pictograms as a method of non-verbal communication for adolescents with intellectual disorder // Society: sociology, psychology, pedagogy. 2024. No. 2. pp. 34–40. DOI: 10.24158/spp.2024.2.3 on page 37. The contribution of the dissertation author's personal participation consists of collecting, processing and analyzing data, formulating conclusions about reliable differences in decoding and visual perception of pictograms of various alternative communication systems of adolescents with different levels of intelligence.

2. The cognitive complexity of pictograms of various AAC systems depends on their graphic representation. Pictographic systems that occupy an intermediate position between iconicity and schematicity are the most effective in conveying syntactic constructions, which may be important when developing remedial teaching methods for adolescents with intellectual disorder. The results are presented in the publications: Zashchirinskaia O.V., Belimova P.A. Cognitive impairments in adolescents with intellectual disorder when decoding alternative communication symbols of different iconicity // Russian Psychiatric Journal. 2024. No. 2. pp. 46–52 on pages 49–50; Zashchirinskaia O.V., Belimova P.A. Impaired interpretation of pictographic systems by adolescents with mild mental retardation // Russian Psychiatric Journal. 2022. No. 1. pp. 46–54. DOI: 10.47877/1560-957X-2022-10106 on pages 50–52. The contribution of the dissertation candidate's personal participation consists of collecting, processing and analyzing data, formulating conclusions about the cognitive complexity of AAC systems of different iconicity.

3. Students with intellectual disorder demonstrate a lower ability to decode public signs compared to their normotypical peers. The arrangement of complex sign elements has a negative effect on decoding informationally significant stimuli for orientation in the social environment. The result is presented in the publications: Zashchirinskaia O.V., Belimova P.A. Impaired Interpretation of Pictographic Systems by Adolescents with Mild Mental Retardation // Russian Journal of Psychiatry. 2022. No. 1. pp. 46–54. DOI: 10.47877/1560-957X-2022-10106 on pages 51–52; Belimova P.A. Ability of Persons with Intellectual Disorder to Interpret Public Signs // Psychology and Psychotechnics. 2023. No. 2. pp. 101–109. DOI: 10.7256/ 2454-0722.2023.2.40902 on pages 105–107.

The contribution of the dissertation candidate's personal participation consists of collecting, processing and analyzing data, formulating conclusions about the peculiarities of perception of navigation signs of public spaces in case of intellectual disorder.

4. Visual communication means have a high information capacity, which determines the difficulties in their decoding and modifies the complex of individual and socio-psychological characteristics of the subjects of interaction. The result is presented in the publication: Belimova P.A., Miklyaeva A.V. How does the use of visual images change communication mediated by digital devices? A review of empirical research // SibScript . 2024. Vol. 26, No. 5(105). pp. 782–794. DOI: 10.21603/sibscript-2024-26-5-782-794 on pages 784–788. The personal contribution of the dissertation author consists in the analysis of scientific publications for the period 2019–2024 devoted to the study of digital communication using visual images, published in the CyberLeninka, PubMed, Google Scholar, eLibrary, ResearchGate databases.

Chapter 1. Perception and Decoding of Alternative Communication in Intellectual Disorders

1.1. Alternative and augmentative communication technologies as an auxiliary means of learning and communication

Alternative and augmentative communication (AAC) is a generalized name for auxiliary tools and techniques that are used in the practice of supporting people with disorder and speech communication disorders (Baryaeva L.B., Lopatina L.V., Agaeva I.B., Kondratieva S.Yu., Gaidukevich S.E., Churakova G.G., Tetzchner S., Musselwhite C.R., Russello D.M., Sevcik R.A., Romski M.A., McNaughton S. and others). AAC tools are used in work with a wide range of disorders, including autism spectrum disorders, musculoskeletal disorders, mental retardation, and intellectual disorder.

According to the American Speech-Language-Hearing Association, AAC means all nonverbal forms of communication that either supplement or replace oral speech for people with disorder. The frequency of communication disorders in people with intellectual disorder determines the relevance of AAC intervention (Agaeva I.B., Kozlova K.M., Kanyukova V.V., Sutherland D., Schlosser R.W., Siu E., Mirenda P., Tincani M.). Even in adulthood, there is a deficit in speech development, which affects self-sufficiency in everyday life (Abbeduto L. et al., 2021).

AAC involves the use of various non-verbal types of communication, as well as the methodology of teaching their application (Dada S. et al., 2021). Non-verbal means of communication include gestures and facial expressions, but of greatest interest are artificial pictographic languages, which can be used both as a set of cards in a communication book and as analog and digital interface solutions. The results of review studies indicate the need to combine high-tech and low-tech AAC tools (Simacek J. et al., 2018). Thus, for young children (6–10 years old), interventions have been shown to improve communication skills, including phonological awareness and vocabulary (Langarika-Rocafort A., Mondragon N.I., Etxebarrieta G.R., 2021).

Surveys of employees of specialized educational institutions on the prevalence and success of the implementation of AAC show that speech therapists, social workers, physiotherapists, as well as health workers highly rate the need for training in alternative communication (Siu E. et al., 2010). At the same time, the assessment of the effectiveness of the use of AAC in school age is higher than in adults (Sutherland D.E., Gillon G.G., Yoder D.E., 2005). It is noted that the availability of AAC in terms of the physical and cognitive capabilities of the individual is a necessary characteristic for successful intervention, otherwise the loss of the motivational component in the study of AAC may lead to a refusal to use and a decrease in communicative competencies (Schlosser R., Lee D., 2000).

The problem of using auxiliary communication tools by children with intellectual disorder was studied in the context of the formation of vital skills mainly on an English-speaking sample of children (Stancliffe R.J. et al., 2010). The degree of assimilation of AACs, subjective motivation in their use and, consequently, communicative involvement directly depend on the individual characteristics of a person (van der Meer L. et al., 2011). Thus, studies show that the majority of AAC users prefer to exchange images for everyday communication (Tincani M., 2004).

Of decisive importance for the effectiveness of alternative and augmentative communication technologies is not only the user's motivation, but also his environment, as well as the active participation of communication partners, such as parents and teachers (Rensfeld Flink A. et al., 2024). The introduction of AAC into the educational process contributes to the development of communication skills and spontaneous speech (Srinivasan S. et al., 2022). Play activities in combination with learning play an important role in the development of children with intellectual disorder at the initial stage of education (Kryazhevskikh E.G., Tsvetova O.A., 2021). It has been shown that the use of AAC in educational and play activities helps to form more complex communication skills in the early stages of social interaction (Chapin S. E. et al., 2022).

AAC is an important tool for compensating for communication deficits in schoolchildren with special needs, requiring an individual approach to each child to improve the effectiveness of the educational process. This contributes to the development of social skills and reduces the risk of social isolation (Carnett A. et al., 2023; Dada S. et al., 2021; Rensfeld Flink A. et al., 2024; Srinivasan S. et al., 2022).

Communication boards, as well as programs and devices such as PECS, Makaton and modern applications for mobile devices (Proloquo2Go, TouchChat), provide a variety of opportunities. The most popular pictographic communication systems in Russian correctional and pedagogical practice are PECS and Makaton (Kozlova K.M., 2018). These tools are a set of color or black and white images placed in a communication book and are used in accordance with a certain methodology for developing communication skills.

Thus, the picture exchange system PECS is an effective alternative communication technology that helps improve communication skills in people with autism spectrum disorders and intellectual disorder (Denche Gil S. et al., 2023; Tamanaha A.C. et al., 2023; Zhang Y. et al., 2023). PECS, developed in 1985 by E. Bondy and L. Frost, is based on the use of cards to exchange information. Research shows that children with social communication disorders rarely initiate communication, preferring to avoid interaction, which leads to their communication occurring only when directed. In PECS, children need to learn to interact with others by selecting pictures of desired objects in order to obtain them in reality.

PECS training consists of six sequential stages:

1. Motor response – forming the child's response with the help of prompts.
2. Distance and persistence – learning a new skill through practice.
3. Recognizing cards – attracting the child's attention and choosing a picture to obtain an object.
4. Sentence structure – learning to form sentences using images.
5. Phase "What do you want?" – spontaneous choice of an object in response to a question.
6. Commenting – selection of an object and its description according to its characteristics (Andrusenko V.M., 2023).

This learning algorithm can be useful in mastering any system of pictographic communication within the framework of the approach of natural developmental interventions (ABA therapy) (Pope L. et al., 2024). PECS provides children with opportunities to engage in communication and experience concrete outcomes in social contexts. Despite its effectiveness in a variety of settings (Lendio J.G. et al., 2023), there are problems with mastering more complex phases and expanding symbols for more complex communication (Forbes H.J., 2024).

To understand how people with intellectual disorder respond to different categories of AAC interventions, it is important to consider long-term outcomes. One longitudinal study evaluated the effectiveness of AAC in a group of seven young men diagnosed with cerebral palsy who had used AAC systems for at least 15 years, beginning in preschool age. The level of cognitive dysfunction and intervention setting were analyzed as potential factors influencing the effectiveness of AAC systems such as PECS and speech generation devices. Both methods were effective in improving speech outcomes, but speech generation devices were more effective in patients without concomitant intellectual disorder. This study also used qualitative interviews to identify factors influencing outcomes: interpersonal barriers, cultural differences, and access to technology hindered positive outcomes, while community and family support facilitated them (Lund S.K., Light J., 2007).

Pictograms or symbols are widely used in everyday life as a visual language, providing a quick transfer of information regardless of language or literacy. Common elements of the sign environment include road signs, transport signs (airport, train station, etc.), clothing care symbols, navigation symbols (Tijus C. et al., 2007). The effectiveness of pictograms as wayfinding elements in public spaces was studied in the context of preparations for the 2020 Tokyo Olympic Games, where a survey was conducted among people with disorder on the understandability of JIS (Japanese Industrial Standards) and ISO (International Organization for Standardization). Nineteen adults with intellectual disorder rated the comprehensibility of pictograms, and in each pictogram, graphic elements that enhance comprehension were identified. The study showed a relationship between comprehensible graphic elements and IQ. In particular, the following graphic elements influence comprehension of pictograms: a) a person symbolizing a location; b) a movement line (a line representing movement, emphasis, sound, etc.); c) a real orientation; d) a location element; e) an arrow, the length of the axis of which influences the degree of comprehension (Kudo M., 2022).

Despite the advantages of AAC, there are implementation challenges: insufficient teacher training, limited resources, and the lack of a unified methodological framework for working with children with different levels of intelligence. A review of scientific sources revealed shortcomings in existing studies: most of them focus on children with autism spectrum disorders or severe multiple developmental disorder, which limits understanding of the needs of children with intellectual disorder.

Existing studies are often based on small numbers of participants or limited samples, which makes it difficult to generalize the results and apply them in practice. For example, many studies focus on adult samples, which does not allow for consideration of the developmental characteristics of adolescents, as well as school-age and preschool-age children. In addition, studies pay insufficient attention to the development and implementation of standardized methods for assessing the effectiveness of AAC for children with intellectual disorder. This leads to variability in approaches, therefore, making it difficult to compare results. Finally, many studies do not take into account individual differences in children's sensory and cognitive abilities, which may affect the perception of graphic symbols. All this leads to the creation of universal solutions that may be ineffective for individuals who need AAC technologies.

1.2. Features of the communicative and cognitive sphere in cases of intellectual disorder

Intellectual disorder as a condition of delayed or incomplete mental development is characterized by underdevelopment of higher psychological functions in the context of the unity of dynamic systems: imagination, perception, memory, thinking, speech (Vygotsky L.S., 1935; Leontiev A.N., 1989; Rubinstein S.Ya., 1986). A decrease in skills that arise in the process of development and determine the general level of intelligence is expressed in the underdevelopment of cognitive abilities, motor skills, language, as well as social capacity in general (Isaev D.N., 2003). Communicative difficulties of individuals with intellectual disorder are associated with a complex of cognitive features that manifest themselves in this condition.

The condition clinically diagnosed as "mental retardation" (F70-F79 according to ICD-10) can occur both against the background of another mental disorder and without it. In the International Classification of Diseases, Eleventh Revision (ICD-11), the term "mental retardation" has been replaced by the term " disorders of intellectual development". The degree of intellectual disorder is assessed by standardized tests that determine the diagnosis based on the identified level of skill development. The most common form of mental retardation is mild mental retardation, which accounts for 75–90% of the entire population of people with intellectual disorder (Mikheykina O.V., 2012). The range of the intelligence quotient for this diagnosis is 50–69 in IQ.

Mild intellectual disorder is characterized by a fairly high ability to attend school. Children diagnosed with mild intellectual disorder can study in special schools or classes according to an adapted basic general education program for students with intellectual disorder (intellectual disabilities). A satisfactory level of attention and memory development in children with mild intellectual disorder determines their ability to learn based on concrete and visual methods. They are able to master professional skills, mainly related to production and economic activities.

The lack of development of communicative activity in individuals with intellectual disorder leads to significant difficulties in communication, learning and various types of activities. Communicative problems are often expressed in weak communicative involvement (Bablumova M.E., 2013). The degree of communicative involvement of individuals with intellectual disorder varies, but communicative actions are mainly performed in response to the initiative of the communication partner (Ilyina Yu.S., 2017). Most children with intellectual disorder experience significant difficulties in selecting lexical means, as a result of which the volume of statements is limited to one or two phrases (Emelyanova I.A., 2009). Difficulties in the use and understanding of expressive communication tools associated with the peculiarities of the cognitive, emotional-personal and behavioral components are noted (Solodkov A.S., 2016; Zashchirinskaia O.V., 2009).

Thus, the violation of communicative abilities is associated with the underdevelopment of higher psychological functions, regulation of behavior and adaptation in society as a whole. First of all, we will consider speech and language disorders as the basis of communicative activity.

Speech skills in individuals with intellectual disorder are interconnected with the severity of cognitive impairment and are systemic. The consequence of underdevelopment of speech as an integral functional system is the disruption of such components of speech as grammatical structure, vocabulary, phonetic-phonemic aspect (Lalaeva R.I., Serebryakova N.V., Zorina S.V., 2003). It is noted that the contextual form of speech is the most difficult for children with intellectual disorder, while situational speech based on visual aids and a specific situation is easier (Petrova V.G., 2002). The following speech features are also characteristic: smaller vocabulary, preference for simple grammatical structures, reduced level of understanding of oral and written speech (Isaev D.N., 2003). The limited vocabulary is expressed in the fact that most of the words are in the passive dictionary and the child is able to actively operate only a small part of it (Egorova A.V., 2015). Children with intellectual disorder have a later onset of verbal behavior, low rates of expansion of active and passive vocabularies, assimilation of semantically false referents of words, difficulties in constructing and perceiving expanded syntactic constructions (Petrova V.G., 2002). With a mild degree of intellectual disorder, speech development difficulties can be compensated for in the process of correctional and pedagogical intervention, however, in adolescence, individuals with intellectual disorder show a noticeable variability in the degree of mastery of language skills, which may be due to concomitant impairments of vision, hearing, speech apparatus, etc.

Reading and perception of visual information as a component of the communicative field are of interest in the context of the characteristics of cognitive functions in intellectual disorder. Reading skills, as well as the ability to understand and comprehend what has been read, lag significantly in students with intellectual disorder (Meleshkina M.S., 2017). One of the characteristics of written speech impairment is optical dysgraphia, associated with the lack of differentiation of ideas about similar forms and the underdevelopment of optical-spatial perception, visual analysis and synthesis

(Goryainova I.A., 2018). Studies devoted to the perception of tests and graphic images by students with intellectual disorder show that, in comparison with normotypical peers, they experience difficulties in tasks of grouping and classifying depicted objects, establishing connections between an object, image and name (Stephenson J., Linfoot K., 1996). Mastering the reading skill is possible for this group provided that special pedagogical approaches are used (Mamaeva A.V. et al., 2019).

Interdisciplinary studies of visual perception in children with intellectual disorder were conducted by Veresotskaya K.I. in 1963, where it was shown that the duration of viewing images of objects affects the success of their recognition. Rubinstein S.Ya. noted narrowed volume, slowness, and weak differentiation among the characteristic features of perception in intellectual disorder. In the cognitive sphere of persons with intellectual disorder, inactivity of perception is observed, associated with the motivational component, which is found in the lack of desire to examine, understand the details and properties of an image or object (Kalmykova E.A., 2007). Difficulties in spatial orientation, establishing cause-and-effect relationships in the perception of plot pictures, image perspective, and motion image are also described (Antipanova N.A., Datsko M.A., 2016). From the point of view of fundamental processes associated with learning, the peculiarities of perception by individuals with intellectual disorder can be explained by a decrease in short-term and long-term memory (Sparrow W.A., Day R.H., 2002).

1.3. Prospects and limitations in the use of pictographic alternative communication in intellectual disorder

Despite the fact that the perception of visual stimuli by people with intellectual disorder is associated with greater difficulties compared to the normal intellectual development, graphic images are used in work with this group for the purpose of diagnosing and correcting speech disorders. In particular, means of alternative and additional communication in the form of graphic images help to compensate for communication difficulties in intellectual disorder.

Among the basic prerequisites for understanding alternative communication by persons with intellectual disorder, the development of impressive speech and the development of visual perception stand out. To determine the readiness of students to use pictographic means of communication, it is proposed to use sets of tasks aimed at understanding simple and highly functional objects and actions based on visual aids (Artemyeva N.V., Zadorozhnaya T.V., Mamaeva A.V., 2018). Extensive methodological recommendations for the implementation of AAC systems in correctional practice are given by L.B. Baryaeva. In the pictographic systems being developed, it is proposed to use different background colors for encoding parts of speech (Baryaeva L.B., Lopatina L.V., 2018).

For effective intervention of AAC means for persons with intellectual disorder it is necessary to have an idea of the properties of symbols that are most preferable within the framework of graphic coding. The study of these properties began in the middle of the 20th century. The most important criterion for choosing pictograms as a component of AAC is recognition, that is, the perceptibility of the symbol in the correct meaning without additional prompts or training (Mizuko M., 1987; Bellugi U., Klima E.S., 1976). Research shows that the best recognition effect is demonstrated by visual (iconic) symbols, that is, images that visually correspond to their verbal referent or the designated object (Vanderheiden G.C., Lloyd L.L., 1986; Mizuko M., 1987; Musselwhite C.R., Ruscello D.M., 1984). The learning process also influences recognition, but in the context of learnability as a result of repetitions and instruction (Mizuko M., 1987). Since individuals with intellectual disorder require more repetitions to learn the connection between the symbol and the designated (Keogh W., Reichle J., 1985), relying on visuality or iconicity seems to be a more promising strategy for the intervention of graphic means of AAC in their communicative field.

Various pictographic languages used as AAC tools have been studied for recognition and learnability. Evidence is provided that the hierarchy of intuitive understanding of symbols of five pictographic systems (Rebus, PIC, PCS, Blissymbolics, Pictogram) is the same for different parts of speech: adjectives, nouns, verbs (Bloomberg K., 1984). Similar data were obtained for all parts of speech using three AAC systems:

Pictogram, Blissymbolics, PCS (Mizuko M., 1987). It is worth noting that the above data pertain to the group of subjects with normative intelligence. In a sample with intellectual disorder, it was found that the level of comprehensibility of noun symbols of the Blissymbolics system is lower than that of ten other AAC systems and corresponds to the level of text comprehensibility (Mirenda P., Locke P., 1989). Other studies have noted that the comprehensibility of the Blissymbolics system is still higher than the comprehensibility of the textual representation (Clark C.R., 1981).

The key point in studying the effectiveness of pictographic communication tools is the properties of images that determine their readability and comprehension. The literature describes many variables that can influence the iconicity of graphic symbols used as auxiliary communication. These variables can be grouped into symbolic, referential, educational, and individual effects (Dada S., Huguet A., Bornman J., 2013). Interactions are possible between these effects.

Symbolic effects of iconicity may include the material on which the symbol is printed, the outline and shape of the symbol, its relationship to the referent, the color of the symbol, the animation of the symbol, the motivational value of the symbol, the comprehensibility, complexity, convergence of the set or system of symbols of which it is composed, and its graphic structure. In *type 1 symbols*, the iconic component plays a role in their representation in the sense that the elements of the symbol reflect the main visual characteristics of the referent. These symbols are processed as a whole (gestalt), or as arrays of patterns, relatively directly and without linguistic encoding. In *type 2 symbols*, the visual representation does not play a role in the symbol -referent links and, therefore, does not depend on visual correspondence. In determining iconicity in *type 2 symbols*, the connection between the referent and the symbol occurs through other domains, such as phonological and semantic. Iconicity does not play a role in their processing (McNaughton S., 1993).

The second group of effects that influence the iconicity of graphic symbols are referential effects. The concreteness, or simplicity, with which the referent offers an image of this symbol is an example of a potential referential effect (Schlosser R.W., Sigafoos J., 2002). Concreteness is often influenced by the class of the word (part of speech). Graphic symbols representing nouns may be more iconic than symbols representing other parts of speech (Haupt L., Alant E., 2002).

The third group of effects that influence iconicity are learning effects. A number of studies have shown positive effects of more explicit, analytical learning, especially for partially obvious/non-obvious graphic symbols. Learning helps people see tangible similarities when explaining the relationship between a symbol and its referent (Emms L., Gardner H., 2010).

The fourth group of effects are individual effects that may influence judgments of iconicity and may include knowledge or literacy (Pierce P.L., McWilliam P.J., 1993), school education (Martlew M., Connolly K.J., 1996), culture (Basson M., Alant E., 2005; Haupt L., Alant E., 2002; Hetzroni O., Harris O., 1996; Huer Blake M., 2000), age (Emms L., Gardner H., 2010), cognitive or thinking style (Bornman J., Alant E., Du Preez A., 2009), sensorimotor functioning (Mineo B.A., Peischl D., Pennington C., 2008), outlook (Light J., Lindsay P., 1991), symbolic experience (Stephenson J., Linfoot K., 1996) and language competence (Barton A. et al., 2006).

To achieve greater effectiveness of AAC interventions, software tools are developed based on co-design, characterized by the active participation of users in the process of developing content and software (Carniel A. et al., 2019).

Recent research on the effectiveness of AAC for individuals with intellectual disorder suggests that structured and clearly defined interventions have a positive impact on student outcomes. However, interventions must be implemented in an environment similar to the one in which communication skills are needed. Teachers' familiarity with the AAC intervention methodology has a decisive influence on students' communication skills (Klefbeck K., 2023). The potential of interventions in specific settings, such as lunch, recess, or consultation periods, is emphasized (Biggs E.E., Robison S.E., 2023).

The study of psychological concepts in the perception of AAC, conditioned by the specificity of the graphic representation of picograms, seems to be a relevant task for identifying effective means in the communicative practice of persons with intellectual disorder, taking into account their cognitive characteristics. A promising direction is the implementation of graphic means of AAC in digital devices, such as a tablet, smartphone and personal computer, with the possibility of personalization of communication tools.

1.4. Application of the oculography method to study pictographic alternative communication

A perceptual image arises and is transformed in the process of direct interaction of the subject with the surrounding reality, with the dynamics of visual perception playing a special role (Barabanshchikov V.A., 1990). Since the effectiveness of the use of AAC means depends on the ability of individuals with intellectual disorder to perceive and operationalize visual graphic symbols, it is of interest to consider the recorded parameters of oculomotor activity, which can reveal the content of mental activity during perception.

The oculography (eye-tracking) method allows you to record eye movements, determine the coordinates and time characteristics of the direction of gaze. Among such characteristics are the time of viewing the stimulus, the number of returns of the gaze to the stimulus, the duration of saccades, the number and duration of fixations. Fixation of the gaze is a temporary stop in scanning the visual space to maintain a narrow area of focus in the field of foveal vision. During the fixation period, detailed information about the object of perception is collected. It is believed that fixation is a measure of attention, and data on fixations provide important information about perception, emotional response and understanding of visual information (Dube W.V., Wilkinson K.M., 2014; Wilkinson K.M., Light J., 2011; Vakil E. et al., 2011). For example, the parameter of the number of fixations on the zone of interest correlates with the complexity of the presented stimulus (Gliga T., 2009). In studies of reading using the oculography method, it is indicated that the average duration of fixation when reading text is 200 milliseconds (Poulton E.C., 1962). Fixation durations of more than 100 milliseconds are taken into account in studies of the perception of complex stimuli and visual scenes (Manor B.R., Gordon E., 2003).

Eye-tracking technology allows us to determine which areas of a visual stimulus attract more attention, how long this attention lasts, and in what order the components of the image are examined. The interdisciplinary nature of the method is expressed in its application in various scientific fields: neuropsychological and psycholinguistic research, human-machine interaction research, etc.

A large body of scientific work is devoted to modeling the cognitive processes that occur during the perception of verbal and nonverbal stimuli, based on data on oculomotor activity. When reading under normal lighting conditions, 50-60 milliseconds of gaze exposure is sufficient to perceive a written word, while more than 150 milliseconds are required to perceive a graphic image (Rayner K., 1992). Additional time is needed for semantic processing of perceived information.

Studies of reading texts of various visual formats by children with mild intellectual disorder show that text on a black background and with a shortened line length is more accessible for perception than illustrative text (Dinevich K.V., Dunaevskaya E.B., 2019). The difficulty of comprehending works of art and the uniqueness of the development of the skill of conscious reading are noted (Meleshkina M.S., 2014). Understanding of plot pictures and text depends on the clarity of the visual stimulus: studies using images of varying degrees of blurring showed a consistent deterioration in the perception and understanding of stimuli by students diagnosed with mild intellectual disorder. At the same time, the degree of blurring determines the parameters of oculomotor activity, such as the number and duration of fixations during viewing, which turned out to be significantly greater in the group with intellectual disorder compared to the control group (Zashchirinskaia O.V., Nikolaeva E.I., Shelepin E.Yu., 2016).

The specificity of perception of visual information as a component of the public communicative field is expressed in maladaptive defensive reactions in individuals with intellectual disorder. Adolescents with intellectual disorder have different patterns of oculomotor activity in visual perception of pictograms with various manifestations of psychological defenses. The choice of psychological defense mechanisms that distort reality to a greater extent or displace information is manifested in a decrease in the quality of interpretation of visual information (Belimova P.A., Zashchirinskaia O.V., Turchaninov E.E., Nikiforov A.A., Ivanyukhin R.R., 2024).

One of the main concepts of the activation of mental processes during the perception of a visual stimulus is the mechanism of direct cognitive control. According to the hypothesis, the duration of gaze fixation is controlled from moment to moment by cognitive processes associated with the processing of the lexical and linguistic properties of the fixated word (Rayner K., Reingold E.M., 2015). The EZ Reader model suggests that the primary and shallow stage of lexical processing often begins parafoveally and, therefore, is completed during or before the onset of the first fixation on the target word (Reichle E.D., Rayner K., Pollatsek A., 2003). In contrast, the SWIFT model implements a direct control interference mechanism. According to this model, saccades are triggered by an autonomous random timer, rather than by the completion of any cognitive process (Engbert R. et al., 2003). The hypothesis about the mechanism of direct cognitive control is of interest not only in relation to the study of reading, but also in studies of the perception of visual information of a non-verbal or symbolic nature, in particular, pictograms of alternative and additional communication.

The study of AAC using eye tracking is subject to challenges related to calibration, participant characteristics, behavioral patterns, and/or the number of calibration points. However, the technology can be applied to ask structured experimental questions of direct clinical relevance, emphasizing the unique contributions that oculography can make: (a) assessing skills that are difficult to assess using traditional methods, and (b) accessing information about underlying cognitive processes that is not available using traditional behavioral assessments (Wilkinson K.M., Mitchell T., 2014).

The types of tasks most commonly used in eye movement recording studies are free viewing and target search tasks . In free viewing paradigms, the participant is asked to look at one or more images while the pattern of eye movements is recorded. Free viewing is typically used to study what naturally attracts and holds attention and has been used in studies with infants and adults, as well as with people with and without disorder (Fletcher-Watson S. et al., 2009; Gliga T. et al., 2009; Riby D.M., Hancock P.J.B., 2008; Smilek D. et al., 2006; Wilkinson K.M., Light J., 2014; Thiessen A. et al., 2014).

In a visual search task paradigm, gaze fixation patterns were examined prior to target selection or identification to determine whether search patterns differed depending on response accuracy (Carlin M. et al., 2003; Wilkinson K.M., O'Neill T., McIlvane W.J., 2014). For example, eye fixation patterns on four-line drawings on a screen were assessed before and after the presentation of a speech message that matched one of four items as a means of exploring the use of eye tracking as a method for assessing spoken language comprehension (Brady N.C. et al., 2014). Many studies have been devoted to studying attention to individual elements in multi-element stimuli within the framework of a matching task (Dube W.V., Wilkinson K.M., 2014).

To quantify the data recording the *xy* coordinates of the participants' gaze, each stimulus image is divided into regions of interest using eye-tracking software. The region that constitutes the region of interest is determined by the experimental question (Wilkinson K.M., Mitchell T., 2014). From the output stream, dependent measures of oculomotor activity can be obtained, including patterns of fixations, saccades (rapid eye movements between fixations), and pupil dilation. These data provide important information about which elements attract and hold visual attention, for how long and in what sequence, how quickly information is fixed and processed, what causes distraction, and what may be sources of errors (e.g., items that a person does not pay attention to but should; or items that a person pays attention to but should not). This information can be used to improve the design of AAC systems by maximizing attention to important information and minimizing distractions that may interfere with processing and reduce the speed of communication (Light J., McNaughton D., 2014).

Fixations during perception of visual scenes were studied in a sample with intellectual disorder (people with typical development, autism, Down syndrome and other intellectual disorder) when viewing photographs with human figures of different sizes, located next to other interesting and potentially distracting elements. It was shown that human figures attracted attention quickly (within 1.5 seconds). The proportions of time spent by each participant fixating human figures were the same in all groups, as were the proportions of the total number of fixations (Wilkinson K.M., Light J., 2014).

In comparative studies of the AAC, it was revealed that the difficulty of decoding individual pictograms of the Blissymbolics system is associated with its cognitive complexity, which is confirmed by an increase in the number of fixations in subjects with intellectual disorder (Zashchirinskaia O.V., Belimova P.A., 2022).

Oculography is used to investigate the phenomenon of excessive stimulus selectivity (superselectivity), which may affect the learning and use of AAC by individuals with intellectual disorder. Superselectivity refers to a limitation in the number of stimuli or characteristics of stimuli to which a person pays attention. In the case of AAC, this may refer to characteristics of pictograms: for example, attention is noted only to the color of the sign and not to the content, leading to confusion with other symbols of the same color. Attention is noted only to the first letter of written words, leading to confusion with other written words beginning with the same letter. Thus, excessive stimulus selectivity limits learning and generalization (Dube W.V., Wilkinson K.M., 2014).

Eye-tracking studies of alternative and augmentative communication show that even small changes in the organization of the AAC stimulus display affect the visual search patterns of people with Down syndrome and autism. Grouping symbols by background color facilitates search and reduces attention to distractors, given that individuals with intellectual disorder may be prone to distraction (Wilkinson K.M., Madeleine M., 2019).

Thus, it is possible to investigate the efficiency and validity of using the oculography method for studying visual stimuli in the context of studying the perception of graphic means of alternative and additional communication. Oculographic studies can be focused both on the interface solutions of digital assistive systems and on individual elements of the AAC in the form of pictograms.

1.5. Conclusions for Chapter 1

Features of the cognitive and communicative sphere in cases of intellectual disorder have a significant impact on their learning ability and social adaptation. Cognitive processes in individuals with intellectual disorder are characterized by a decrease in short-term and long-term memory, limited attention span, and difficulty in perceiving abstract concepts. In cases of intellectual disorder, speech underdevelopment, limited vocabulary, and difficulty using complex grammatical constructions are observed. These features affect the ability for expressive and receptive communication, which complicates interaction in the educational and social environment. Impaired perception and understanding of information requires the specific use of visual and concrete teaching methods.

The perception of texts and graphic information in cases of intellectual disorder is difficult due to the underdevelopment of optical-spatial perception and visual analysis. Children and adolescents with intellectual disorder have difficulties in establishing cause-and-effect relationships and spatial orientation, which is especially noticeable when working with plot images. These features make it difficult to understand educational material and require adapted methods. Special pedagogical approaches can improve reading skills, but full mastery of this skill requires an individual approach.

A review of the literature highlights the importance of using alternative and augmentative communication (AAC) to improve the communication skills of individuals with intellectual disorder. The use of pictographic systems such as PECS and Makaton, as well as the use of technologies with the ability to personalize communication tools, helps expand the communicative arsenal of children, adolescents and adults with intellectual disorder, increasing their ability to self-care and social adaptation.

Research shows that the selection of iconic graphic symbols that are visually relevant to their referents and their systematic use in AAC practices can improve the acquisition and effectiveness of communication, especially for users with limited cognitive abilities. To be most effective, AAC interventions should be structured and implemented in natural environments that are close to real-life situations, with the active participation of teachers and specialists. The relevance of AAC use is also emphasized in the context of age-related features: data indicate that the highest results are achieved when AAC is taught at school age.

The results of the literature review indicate the effectiveness of eye-tracking technology for studying the perception of graphic stimuli as components of alternative and additional communication in individuals with intellectual disorder. The dynamics of oculomotor activity, including fixation and saccade parameters, allows for a deeper understanding of the processes of cognitive control, selectivity of attention, and the peculiarities of the perception of graphic symbols. Eye-tracking allows for identifying areas of increased visual interest and patterns of perception of visual stimuli, which opens opportunities for visual optimization of AAC graphic systems.

Research has shown that individuals with intellectual disorder exhibit specific characteristics of visual perception. Thus, increased attention to background structure and color characteristics, as well as the phenomenon of hyperselectivity of stimuli, can limit the generalization of knowledge and make it difficult to recognize individual pictograms. These features are important to consider when developing modern adaptive and effective AAC systems.

Chapter 2. Organization and methods of research

2.1. Study design

In this dissertation research, the author's method for studying the ability of adolescents with intellectual disorder to decode pictograms of four alternative communication systems: Blissymbolics, LoCoS©, Pictogram and signs of the social environment was developed. The method was used in combination with the oculography method – registration of gaze movement (eye tracking), which allows analyzing oculomotor activity when perceiving pictograms. The design of the study takes into account the interdisciplinary aspect when studying the effectiveness of graphic representation of pictograms of various AAC.

The main research method is an experiment, which includes the author's set of tasks for correlating visually encoded concepts and verbal referents.

The stimulus material consists of 69 screen changes:

a) Task 1: 10 slides (6 tasks + 1 example + 3 instructions);
b) Task 2: 13 slides (9 tasks + 1 example + 3 instructions);
c) Task 3: 28 slides (12 tasks with nouns + 12 tasks with verbs + 1 example + 3 instructions);
d) Task 4: 15 slides (11 tasks + 1 example + 3 instructions);
e) 2 slides with general instructions + 1 final slide.

The stimulus material for the study is presented in Appendix A.

Arial font was used for the instructions. 60 pt size , black on white background, one and a half line spacing, left alignment.

Task 1 is a task of choosing an extra pictogram that does not relate to the verbal referent among pictograms that designate the referent in accordance with the semantics of the sign system (see Appendix A).

A referent word (80 pt , Arial , all capital letters) is presented on the screen – a noun or verb 50/50 in the initial form, under which 4 pictograms with ordinal numbers are located in a row. 3 pictograms, one from each system used – Blissymbolics, LoCoS©, Pictogram – include the meaning of the referent word (are "distractors" in the task), the fourth pictogram has a different meaning and is the answer to the question: "What is extra?". The "extra" pictograms are presented by each system twice: one verb and one noun per system, three systems (Blissymbolics, LoCoS©, Pictogram). The order of the pictograms on each slide was randomized. Images from the Pictogram system were inverted to comply with the "black on white" principle.

Task 2 involves matching a set of pictograms with the most appropriate verbal referent sentence (see Appendix A).

A sentence encoded by three pictograms belonging to the same system is presented on the screen. Below are three translation options for the visually encoded sentence into Russian with ordinal numbers (60 pt, Arial, left-aligned, ordinal numbers are located from top to bottom). One of the options is the most suitable, the second is partially suitable, and the third is not suitable at all (not a single element of the sentence corresponds to the semantic meaning of the pictograms). The ordinal number of the answer options is randomized.

Task 3 involves spontaneous translation of a pictogram replacing one word in a three-word sentence (80 pt, Arial, all capital letters). The subject is asked to read the sentence aloud, substituting the word that, in his opinion, the pictogram replaces (see Appendix A).

The proposals are conditionally divided into 3 groups:

a) Including the pictogram from Task 1, which corresponded to the verbal referent and was a "distractor;

b) Including the pictogram from Task 1, which did not correspond to the verbal referent and was a conditionally "correct" answer;

c) Including new icons not found in previous tasks.

All three groups of sentences include two nouns and two verbs.

Each sentence from the group occurs 3 times due to the fact that in each case it contains a pictogram from different systems (Blissymbolics, LoCoS©, Pictogram). To reduce the effect of recognition of the semantic composition of identical sentences, the words and the pictogram itself are rearranged in each case, preserving the semantic meaning.

Pictograms of each system occur with the same frequency: 4 times in each of the 3 positions.

Proposals are presented in a randomized order.

The respondents' answers were assessed according to the following gradation:

Rep_1 – The answer that is as close as possible to the value prescribed by the symbolic system;

Rep_2 – A response that is more detail or attribute oriented and relevant in meaning.

Rep_3 – A response that is less detail-oriented or attribute-oriented and relevant in meaning;

Rep_0 – A response without orientation to context or symbol, specifics out of context, abstract interpretation.

All concepts and corresponding symbols of the stimulus material were selected in accordance with the following criteria: *(a)* nouns are not abstract concepts, and verbs are actions and processes performed by a person, *(b)* all concepts can be encoded by each of the pictographic systems, *(c)* all concepts are included in the Frequency Dictionary of Living Oral Speech and have a frequency of ipm (*instances per million words*) above 85 (Lyashevskaya O.N., Sharov S.A., 2009).

LoCoS© pictogram "floor" has two variations due to the lack of a direct designation of this concept in the system - the study was interested in assessing the effectiveness of these variations (Appendix A). For the same reason, the LoCoS© pictograms "lives" and "lies" were designated the same way, in the form of a straight horizontal line. To study the effect of assimilation of pictograms through repetition, 16 pictograms were repeated in the 1st and 3rd series of tasks (Appendix A).

Task 4 contains a target pictogram selected from the database of public space signs (warning signs, information signs, etc.), as well as three options for verbal designation. The subject is asked to choose the most appropriate answer. Public space signs were selected in accordance with the government standards GOST ISO 3864-1-2013 and GOST R 52131-2019. This series of stimulus material took into account the likelihood of the study participants becoming familiar with the meaning of the symbols, so a non-standardized sign "Caution, bicycle" was added to the series: a bicycle is depicted on a yellow background. The sign had the shape of a diamond, which does not comply with GOST standards.

All icons of this task are colored, unlike the 3 previous tasks, and are located on the left side of the screen. Three verbal answer options are located on the right side (60 pt, Arial, left alignment, ordinal numbers are located from top to bottom). One of the answer options corresponds to the official name of the sign, the other two describe the elements of the image. The order of the answer options on each slide was randomized (see Appendix A).

Research procedure . The research was conducted during daytime school hours on school grounds, in premises specially provided by the administration, with the condition of excluding distracting factors. All subjects provided informed consent to participate in the research. Informed consent from parents was obtained with the help of educational psychologists who were school employees. Research sessions were conducted individually with each participant, mainly during lessons, so as not to limit the participants in resting during breaks. A personal computer (laptop), oculograph (eye-tracker), voice recorder, and response forms were used. The workplace was adapted to the individual needs of each participant.

When meeting each participant, the researcher introduced himself, briefly and clearly explained the purpose of the meeting, and offered voluntary cooperation. After receiving the subject's consent to cooperate, the workplace was adapted and the eye tracker was calibrated.

The participant saw instructions on the screen, written in large text size (black on a white background) and voiced. To move to the next instruction or stimulus, the subjects were asked to use the space bar. Before each series of stimulus material, the subject saw an example that was not taken into account when analyzing the results of the experiment. At the same time, the researcher could make sure that the subject understood the task correctly.

Instructions and task sequences were presented in a fixed order, whereas the order of stimuli within sequences was randomized.

The subjects' answers were recorded on paper forms and on a dictaphone; eye movements were recorded automatically using the Neurobureau software.

The average examination time was 20 minutes, taking into account the eye tracker calibration and other measures. At the end of the session, the researcher made sure that the participants were feeling well and thanked them for their cooperation.

Neurobureau software was used. The average distance to the monitor is 60–70 cm, the angle of inclination is 10–15°.

The subjects' answers are recorded manually by the moderators, using a video camera, and also on the Neurobureau recording device. The recording of the answers is a sequential entry into a table of the numbers of pictograms or verbal designations that the subject selects as the correct answer to each task and names out loud. The raw data are then subjected to scaling and subsequent mathematical processing.

The presentation of visual stimuli includes the following stages (to move between slides, the participant presses the space bar):

1. eye tracker calibration for maximum accuracy of eye movement recording (using automatic eye tracker position adjustment by GazePoint software and 9-point calibration by Neurobureau software);
2. General instructions for the experiment, displayed on the screen in text form and simultaneously voiced on the recording;
3. Private instructions for Task 1, displayed on the screen in text form and simultaneously voiced on the recording;
4. An example of an exercise from Task 1, to which the participant must give an oral answer;
5. A generalized positive reaction to completing an example exercise, without identifying the correctness/falsity of the answer, or clarification and assistance in correctly understanding the task;
6. 6 exercises Task 1, to which the participant gives oral answers (says the serial number of the selected pictogram);
7. Generalized positive reaction to the completion of Task 1;
8. Repeat points 3-7 for Tasks 2, 3, 4.

To study the characteristics of oculomotor activity, a hardware method of recording eye movements is used (GazePoint eye-tracker with a sampling frequency of 60 Hz). The following parameters are analyzed:

a. duration of task completion (total time spent studying the stimulus);

b. total number of screen fixations during the task;

c. average duration of fixations;

d. the total number of fixations and their average duration on areas of interest (individual pictograms);

e. number of gaze returns to areas of interest (individual pictograms).

2.2. Description of the alternative communication systems under study

The scientific **novelty** of the work is due to the inclusion in the experiment on studying the perception and understanding of pictograms of three systems of pictographic writing: Blissymbols, LoCoS©, Pictogram.

Blissymbolics is a system of pictographic images and is used in modern correctional pedagogy to include a non-speaking child (hearing, speech impairment, cerebral palsy) in the space of social communication. Blissymbolics was invented by Charles Bliss and first described by him in 1949. Since the beginning of 1970, Blissymbolics has been used as a graphic communication system for people with speech impairments and disorder who need AAC (Jennische M., Zetterlund M., 2015). Blissymbolics received therapeutic use in 1971, at the Rehabilitation Center for Disabled Children in Ontario, Canada. In the same year, the charitable organization Blissymbolic Communication International was created, aiming to popularize the language system throughout the world. The symbols in the Blissymbolics structure (about 100 most frequently used symbols) are not directly oriented towards iconicity and are outline images composed of combinations of geometric figures, diacritical marks, signs of mathematical operations, etc. Blissymbolics has a syntax similar to natural language, as well as rules of word formation. While a pictogram can be deciphered with a greater or lesser degree of certainty due to its iconicity, Bliss symbols are endowed with morphology, especially in expressing abstract and derivative concepts. This fact enriches Blissymbolics as a language, but complicates its intuitive understanding. In a pictogram, everything “superfluous” is thrown out, but everything “differentiating” is preserved. However, the question remains open as to whether iconicity works as effectively with children as with adults. If the child has difficulty in correlating a schematic image with a referent, then in some cases a more complex but structured non-verbal sign system, such as Blissymbolics, can serve as a support in his communicative activity (Jennische M., Zetterlund M., 2015).

LoCoS© language (Ota Y., Macaulay C., Marcus A., 2012) was developed in 1964 by the Japanese graphic designer Yukio Ota, who was involved in the standardization of the sign environment (International Organization for Standardization). LoCoS©, like Blissymbolics, has the property of complementarity, that is, its symbols can be combined to form other concepts. However, according to the author, LoCoS© is a more intuitive, authentic to the modern world and flexible language. Currently, LoCoS© is not used in correctional pedagogy and is of interest for research.

The Pictogram pictographic base is a functional visual language designed for people with cognitive impairments by the National Agency for Special Needs Education and Schools in collaboration with users, teachers, speech therapists, psychologists and occupational therapists with extensive experience working with alternative communication tools. The Pictogram System used for various purposes, both for communication and as an aid to memorization. Currently, the system includes about 2000 images. Pictograms are the most iconic , compared to the two previous ones, system of depicting words and concepts, which may limit its expressive capabilities.

While the Pictogram system uses “icons” (i.e. the system’s images are intended to reflect in a schematic form what they represent, and have a visual resemblance to their referent), Blissymbolics and LoCoS© consist to a greater extent of “symbols”, i.e. abstract forms, which, in turn, do not necessarily have a visual resemblance to the concept that is encoded in them. Another difference between these two groups is that in the Pictogram system the order of icons corresponds to that which the user resorts to in his natural speech, however, symbolic systems such as Blissymbolics and LoCoS© have their own grammar: syntactic rules for constructing a semantic phrase (Bal’ N.N., 2015).

2.3. Description of the study sample

The total number of study participants was 184 people. The control group included 92 students of secondary schools with typical development (46 girls and 46 boys, average age 14.7 years). The experimental group consisted of 92 subjects with intellectual disorder, clinical diagnosis "F70 - mild mental retardation" according to ICD-10 (66 boys and 26 girls, average age 15.1 years).

The inclusion criteria were: a) normal or corrected to normal vision; b) the presence of reading and expressive speech skills. The exclusion criterion was the presence of experience in special training of pictographic languages of the AAC among the participants.

The criterion for the presence of reading and expressive speech skills was determined by the research task of studying the mechanism of activation of lexical processing during the perception of pictograms, as well as the need to collect data in the form of verbal responses reflecting the operational component of thinking during the perception of visual stimuli.

The criterion of the absence of experience in learning pictographic languages of the AAC among the participants was determined by the task of comparing three alternative communication systems (Blissymbolics, LoCoS©, Pictogram) in terms of the degree of intuitive comprehensibility in the conditions of the first acquaintance with symbols, taking into account the different degrees of iconicity of the systems being studied.

Participants were recruited with the consent of parents with the help of representatives of the administration of schools in St. Petersburg.

2.4. research model

The experimental model for studying psychological concepts of perception of alternative communication in cases of intellectual disorder is based on stimulus material, including pictograms of various AAC systems in the context of various cognitive tasks with simultaneous analysis of oculomotor activity in the process of visual perception and analysis of the results of decoding pictograms (Fig. 1).

Figure 1. Experimental model for studying psychological concepts of perception of alternative communication

The presented model is aimed at studying psychological concepts of perception of AAC pictograms as a result of decoding symbols with different graphic representations when performing cognitive tasks with simultaneous analysis of psychological and physiological indicators of oculomotor activity in the process of perception. The model assumes that psychological concepts of perception and decoding of pictograms are conditioned by psychophysiological reactions and depend on the graphic properties of the pictographic symbol.

2.5. Methods of mathematical and statistical analysis of experimental research results

For mathematical and statistical processing of data and testing of research hypotheses the following methods were used: assessment of internal consistency of stimulus material series (Cronbach's alpha); descriptive statistics (mean value, standard deviation); frequency analysis (chi-square); parametric criterion for comparison of means (Student's t-test); nonparametric criterion for comparison of means (Mann-Whitney U-test); parametric one-way analysis of variance (Fisher's test) and Tukey's post hoc test ; nonparametric one-way analysis of variance (Kruskal -Wallis test) using Dwass-Steele-Critchlow-Flinger pairwise comparison method; factor analysis (using principal component analysis and promax rotation). Statistical calculations were performed using Microsoft Excel tabular data processing package and Jamovi 2.3.21 statistical analysis package.

The choice of nonparametric criteria was based on the fact that the data distribution did not correspond to normal. Averaged eye-tracking data were processed using nonparametric methods due to the presence of outliers and a small number of stimuli in each task. To process qualitative data, an analysis of heat maps obtained using eye-tracking was used.

Chapter 3. Results of the study of the perception of pictograms as a component of the AAC by adolescents with intellectual disorder

3.1. Internal consistency of stimulus material in the context of different cognitive tasks

The consistency of tasks including stimuli from three alternative communication systems and social signs was assessed using Cronbach's alpha coefficient. The consistency was assessed based on the results of the experimental group of adolescents with intellectual disorder.

The reliability statistics for Task 1 (selecting an extra pictogram that does not correspond to the verbal referent) showed a medium degree of consistency, $\alpha = 0.670$. Low reliability values were found for Task 2 (translating a sentence from pictograms), $\alpha = 0.198$, and Task 4 (decoding social signs), $\alpha = 0.496$. The low consistency of Task 2 is due to negative correlations with the general scale of stimuli 2Q1, 2Q7, 2Q8. Cronbach's alpha after excluding negatively correlated stimuli: $\alpha = 0.315$.

A sufficient reliability index was revealed with respect to Task 3 (translation of a pictogram in a verbal context), $\alpha = 0.715$. In this task, negative correlations with the general scale were found in stimuli 3Q12, 3Q21. Cronbach's alpha after excluding negatively correlated stimuli: $\alpha = 0.726$.

The low degree of internal consistency of tasks 1, 2, 4 allows us to conclude that this set of stimuli is not testing and cannot be used to assess the ability of adolescents with intellectual disorder to perceive pictograms. Task 3 showed a high degree of reliability and can be used to analyze the ability of adolescents with intellectual disorder to decode pictograms in a verbal context. In this study, the stimulus material is exclusively the basis for collecting qualitative and quantitative data on the patterns of perception of pictograms of various pictographic systems by adolescents with intellectual disorder.

3.2. Decoding of pictograms by adolescents with intellectual disorder

Comparison of the results of passing the author's method for decoding pictograms in the control and experimental groups made it possible to obtain reliable differences in individual parameters of oculomotor activity and in the number of "correct" answers. The concept of "correct" answers here and below refers to the extra pictograms of Task 1 and to the values assigned to pictograms by the authors of a particular system (GOST ISO 3864-1-2013 and GOST R 52131-2019) in Task 4. Nevertheless, the interpretation of the meanings of pictograms by the subjects cannot be interpreted according to absolutely objective indicators of correctness, since the pictographic sign itself does not have a strictly determined meaning, but only reflects individual subjective experience (Khersonsky B.G., 2003). To assess the statistical significance of the number of overall “correct” answers to Task 2 (translating a sentence from pictograms) and Task 3 (decoding pictograms in a verbal context), as well as the overall score, the Student’s t-test was used. To assess the overall “correct” answers to Task 1 (choosing the odd one out) and Task 4 (decoding public signs), the nonparametric Mann-Whitney test was used due to the non-normality of the distribution. Descriptive statistics on the number of overall “correct” answers of the respondents are presented in Appendix B. The results of comparing the overall “correct” answers of the respondents to the four tasks separately and in combination are presented in Table 1.

The number of overall “correct” answers to all tasks of the stimulus material, as well as the overall score, were statistically significantly lower in the group with intellectual disorder than in the control group.

Table 1. Statistically significant differences in the number of “correct” interpretations of pictograms between the group with intellectual disorder and the group with typical development

Exercise	Criterion	Statistics	df	p	Effect size (ES)
Task 1	U Mann-Whitney	2911	182	<0 ,001	0.312
Task 2	Student t	-3.32	182	0,001	-0.490

Task 3	Student t	-7.64	179	<0 ,001	-1,136
Task 4	U Mann-Whitney	3251	182	0,005	0.232
Overall score	Student t	-7.28	179	<0 ,001	-1.08

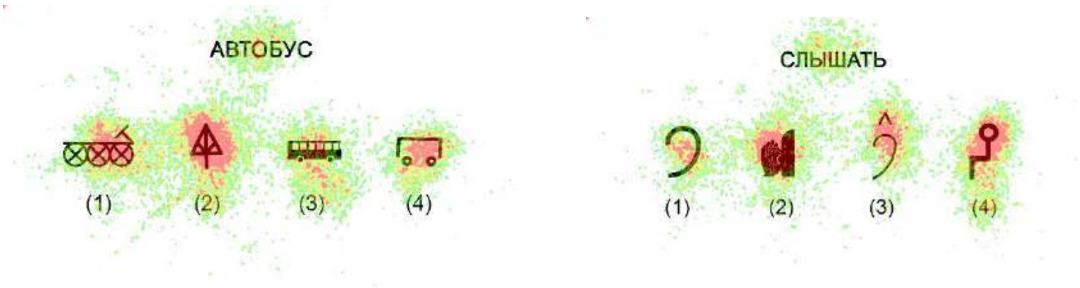
Note: Three people's responses to task 3 were not recorded and were not taken into account when comparing the overall score.

Adolescents with typical development performed better in the cognitive task of choosing the odd one out than adolescents with intellectual disorder at a very high level of statistical significance, U(182) = 2911, $p < 0.001$, ES = -0.609. Differences at a very high level of statistical significance were also found in the task of translating a pictogram in a verbal context, t (179) = -7.64, $p < 0.001$, d = -1.136. The total score was statistically significantly higher in the group with typical development (M = 45.1, SD = 6.42) than in the group with intellectual disorder (M = 38.4, SD = 4.49), t (179) = -7.281, $p < 0.001$, ES = -1.08.

A comparison was made of the number of "correct" responses of subjects from the control and experimental groups to individual stimuli for all tasks. The sample size allowed for a comparative assessment of the dichotomous scale using the Student criterion. In all the cases described below, no intersection of confidence intervals was found; tables with statistical conclusions for all tasks are presented in Appendix C. The results of the comparative analysis for individual task stimuli are described below.

3.3. Cognitive specificity of excluding an extra pictogram from a series of those corresponding to a verbal referent

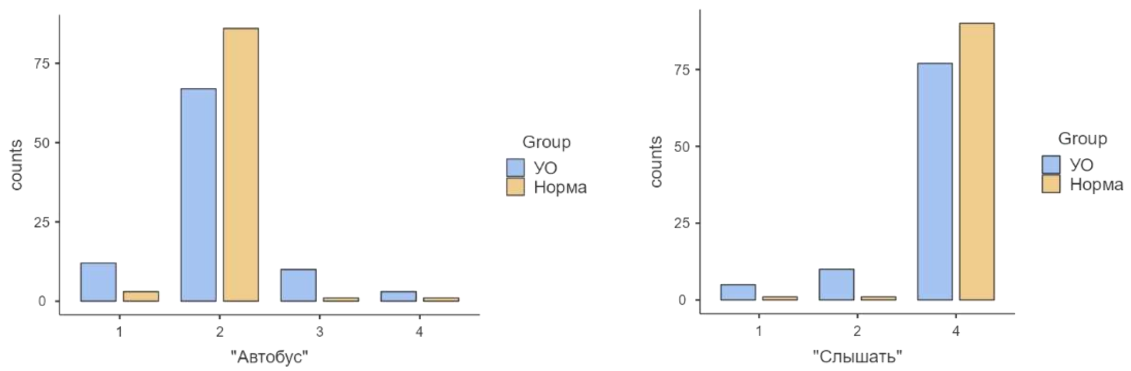
Comparison of the two groups by the number of responses to individual stimuli of Task 1 showed reliable differences in relation to stimuli 1Q2 "Bus" and 1Q5 "Hear". Stimuli with visualization of eye-tracking data obtained in the group of subjects with intellectual disorder, and the designation of the system to which individual stimuli belong (from left to right) are presented in Figure 2.



a) *b)*

Figure 2. Stimuli of Task 1 to choose the odd pictogram with visualization of eye tracker data (group with intellectual disorder) in the form of heat maps: a) 1Q2 "Bus" (Bliss, LoCoS, Pictogram, LoCoS); b) 1Q5 "Hear" (LoCoS, Pictogram, Bliss, LoCoS)

The number of correct responses to the “Bus” stimulus is statistically significantly lower in the group with intellectual disorder than in the control group, t (181) = -4.12, p < 0.001, d = 0.0526. Also, the number of correct responses to the “Hear” stimulus is statistically significantly lower in the group with intellectual disorder, t (181) = -3.39, p < 0.001, d = -0.05. The small effect size indicates a small difference between the average indicators in each group, accordingly, we can conclude that the difference in the results is insignificant. The distribution of response frequencies for the above stimuli is shown in Figure 3.



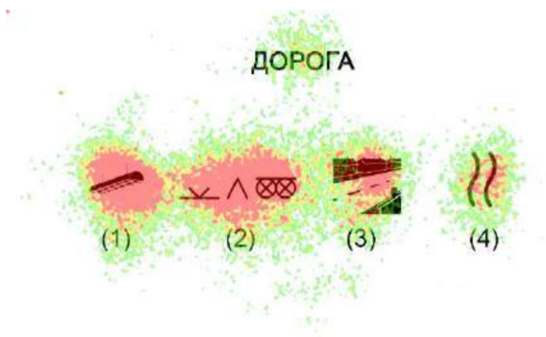
a) *b)*

Figure 3. Frequency of respondents’ choice of response options to the stimuli of Task 1 from both groups: a) 1Q2 “Bus”, correct answer – 2; b) 1Q5 “Hear”, correct answer – 4

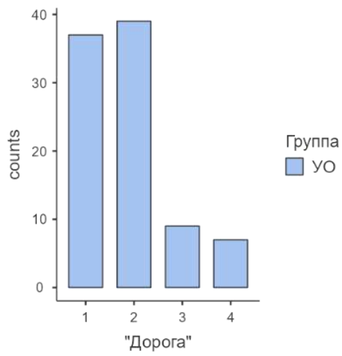
Note: " counts " – number of responses; " group " – group; "УО" – group with mild intellectual disorder; "Норма" – group with typical development.

Students with intellectual disorder more often correctly selected the extra pictograms in the “Bus” stimulus, χ^2 (3) = 114, p < 0.001, and in the “Hear” stimulus, χ^2 (2) = 105, p < 0.001, which indicates their ability to perform tasks to find an extra object and identify pictograms as related or not related to the verbal referent. The result to some extent contradicts the data that schoolchildren with intellectual disorder experience difficulties in tasks to select the “extra”, relying on an incorrectly selected feature or their preferences (Kashtanova S.N., Golovanova I.N., 2021). No one from either group selected the “Hear” symbol, which is related to the Bliss system, as odd, which may indicate the intuitive understanding of this symbol as a reflection of the concept of “hearing”.

Frequency analysis conducted for all stimuli of Task 1 showed that in the group with intellectual disorder the number of “incorrect” answers was higher only for stimulus 1Q3 “Road”, χ^2 (3) = 39.3, p < 0.001 (Fig. 4).



a)



b)

Figure 4. Stimulus 1Q3 "Road" Pictogram*, Bliss, Pictogram, LoCoS) Tasks 1 for choosing the odd pictogram out: a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps; b) frequency of answer choices by subjects from the group with intellectual disorder

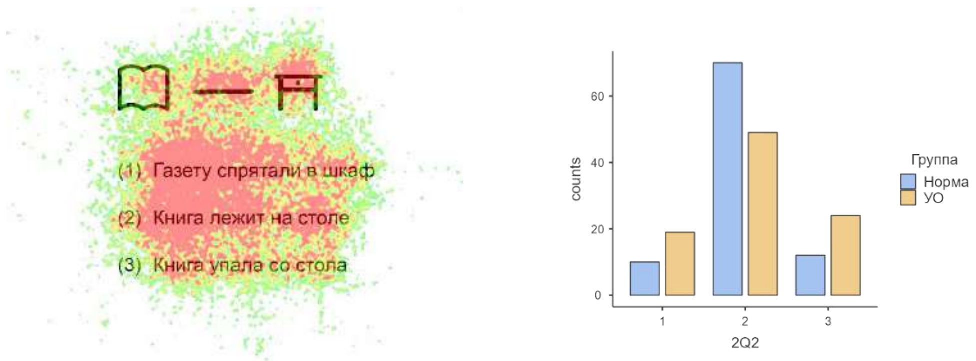
*Note: " counts " – number of answers; "УО" – group with mild intellectual disorder; *"correct" answer.*

The eye-tracking data shows that the subjects' gaze switches between the "lamp" pictogram of the Pictogram system (1), which is the correct response to this stimulus, and the "road" pictogram of the Bliss system (2). This pattern is also reflected in the response frequencies of the subjects from the group with intellectual disorder. It can be assumed that this effect, together with the large number of choices of the "road" pictogram of the

Bliss system as "superfluous", is due, on the one hand, to the graphic complexity of the Bliss pictogram , and, on the other hand, to the low degree of representativeness of the Pictogram system . Since no statistically significant differences with the control group were found, the conclusion can be extended to adolescents with typical development. Frequency tables for all stimuli of Task 1 on choosing an extra pictogram that does not correspond to the verbal referent are presented in Appendix D.

3.4. Decoding sentences from pictographic symbols

Comparison of the control and experimental groups in the number of responses to individual stimuli of Task 2 showed reliable differences at a very high level of significance in the number of correct responses to stimulus 2Q2 “The book is on the table”, $t(182) = -3.317$, $p = 0.001$, $d = -0.489$ and stimulus 2Q5 “Father is writing a letter”, $t(182) = -3.565$, $p < 0.001$, $d = -0.26$. Adolescents with typical development more often correctly determine the exact verbal translation of these sentences written in pictographic language (Figs. 5, 6).

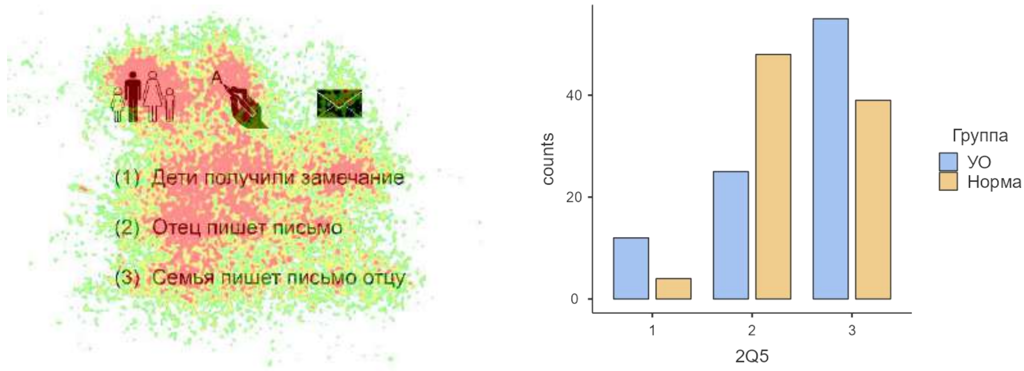


a) *b)*

Figure 5. Stimulus 2Q2 “The book is on the table” (LoCoS, “correct” answer – 2) Task 2 on translating a sentence composed using pictograms a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps; b) frequency of answer choices by subjects from both groups

Note: " counts " – number of responses; " group " – group; "УО" – group with mild intellectual disorder; "Норма" – group with typical development.

Subjects with intellectual disorder more often identified the “correct” translation of the sentence, χ^2 (2) = 16.8, p < 0.001, while the choice of other answer options was distributed approximately equally. It can be assumed that when perceiving the stimulus, students were guided by the intuitively understandable pictograms “book” and “table”, while the pictogram “lies”, which is a derivative of the pictogram “place” of the LoCoS system, reveals ambiguity of interpretation (Ota Y., Macaulay C., Marcus A., 2012).



a) *b)*

Figure 6. Stimulus 2Q5 “Father writes a letter” (Pictogram, “correct” answer – 2) Task 2 on translating a sentence composed using pictograms a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps; b) the frequency of answer choices by respondents from both groups

Note: " counts " – number of responses; " group " – group; "УО" – group with mild intellectual disorder; "Норма" – group with typical development.

In relation to stimulus 2Q5, it can be assumed that the graphic identification of the father as a person in the context of other family members is ineffective for understanding by adolescents with intellectual disorder. This pictogram is more often perceived by students with intellectual disorder in the meaning of the word "family", which determines a more frequent choice of answer No. 3, χ^2 (2) = 31.7, p < 0.001. Heat maps show that the gaze of subjects with intellectual disorder was more often directed to the areas of the "father" and "writes" icons, while the "letter" icon was given less attention. It can be concluded that the "letter" icon was not particularly difficult to recognize.

Frequency analysis conducted for all stimuli of Task 2 showed that in the group with intellectual disorder the number of “incorrect” answers was higher for stimuli 2Q3

“The tiger jumps in the grass”, χ^2 (2) = 42, $p < 0.001$ and 2Q7 “The boy likes to walk”, χ^2 (2) = 51.3, $p < 0.001$ (Figure 7).

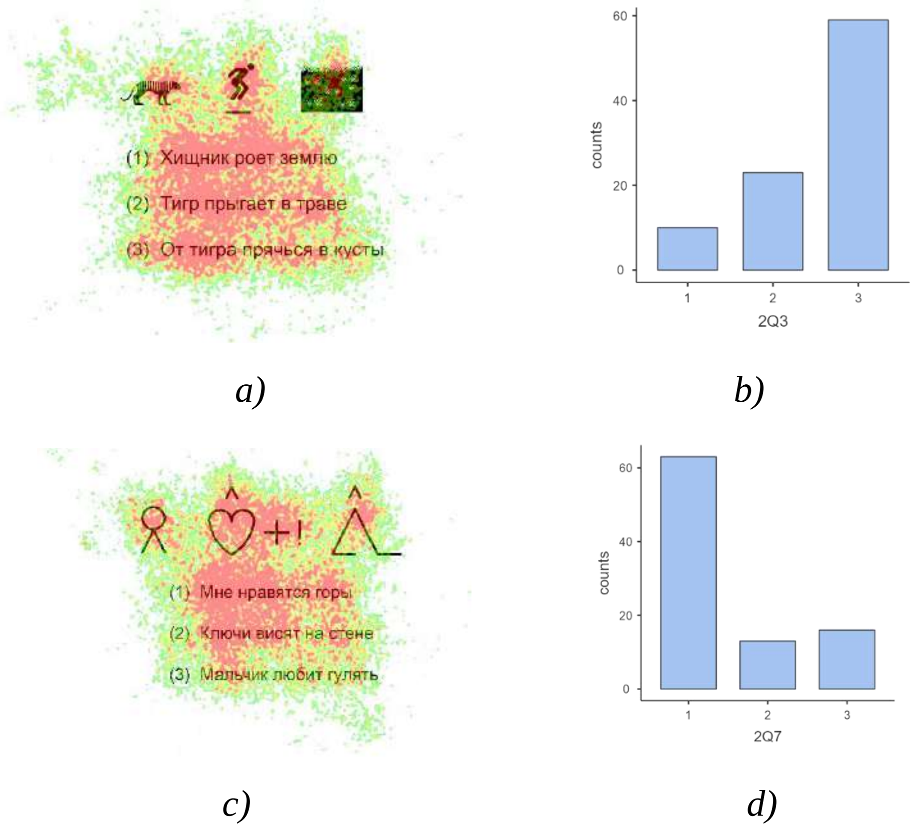


Figure 7. Stimuli for Task 2 on translating a sentence from pictograms with a high frequency of “incorrect” answers: a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps of stimulus 2Q3 “A tiger is jumping in the grass” (Pictogram, “correct” answer – 2); b) frequency of choosing answer options for 2Q3; c) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps of stimulus 2Q7 “The boy likes to walk” (Bliss, “correct” answer – 3); d) frequency of choosing answer options for 2Q7

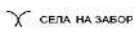
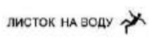
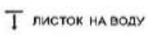
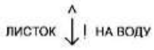
Note: " counts " – number of responses.

The predominant frequency of interpreting the pictogram "jump" in stimulus 2Q3 as a person performing an action (hiding from a tiger) suggests that it is difficult for adolescents with intellectual disorder to distract themselves from the concreteness of the image in order to switch to a more abstract meaning of "jump". The high frequency of interpreting the human figure from the first person in stimulus 2Q7 may confirm the egocentric nature of empathic reactions in children with intellectual disorder (Koneva I.A., Karpushkina N.V., 2021). At the same time, the pictogram "walk" from the Bliss system turned out to be rarely recognized in its original meaning, which may indicate the cognitive complexity of this pictogram. Tables for all stimuli in Task 2 on translating a sentence written using pictograms are presented in Appendix D.

3.5. Decoding pictograms in verbal context

The comparison of the control and experimental groups in the number of responses to individual stimuli of Task 3 (decoding pictograms in a verbal context) was made without taking into account the stimuli that the participants skipped due to random switching. The skipping of stimuli due to the absence of a hypothesis about the interpretation of the pictogram in the subjects was counted as an “incorrect” answer. The Student's t-test for independent samples showed reliable differences at a very high level of statistical significance in the number of correct responses to stimuli 3Q4 ("there is a book on the floor", Pictogram), 3Q17 ("a bird sat on the fence", Bliss), 3Q25 ("a leaf fell on the water", Pictogram), 3Q26 ("a leaf fell on the water", LoCoS), 3Q27 ("a leaf fell on the water", Bliss), 3Q29 ("a squirrel is sitting on a tree", Bliss), 3Q30 ("a squirrel is sitting on a tree", Pictogram), 3Q34 ("Kolya is looking for the keys", Pictogram), 3Q36 ("Kolya is looking for the keys", LoCoS) (Table 2).

Table 2. Statistically significant differences in the number of “correct” responses to the stimuli of the pictogram decoding task in a verbal context between the control and experimental groups

Incentive code	Pict. system	Stimulus content	Student t	df	p	Effect size
3Q4	Pictogram		-6.11	179	<0 ,001	-0.909
3Q17	Bliss		-3.36	167	<0,001	-0.517
3Q25	Pictogram		-4.05	178	<0,001	-0.603
3Q26	LoCoS		-4.41	177	<0,001	-0.660
3Q27	Bliss		-4.67	180	<0,001	-0.693

3Q29	Bliss	БЕЛКА НА ДЕРЕВЕ	-3.61	174	<0,001	-0.545
3Q30	Pictogram	БЕЛКА НА ДЕРЕВЕ	-3.77	177	<0,001	-0.563
3Q34	Pictogram	КОЛЯ КЛЮЧИ	-3.44	179	<0,001	-0.512
3Q36	LoCoS	КОЛЯ КЛЮЧИ	-3.51	178	<0,001	-0.524

Adolescents with typical development reliably more often gave answers to the above stimuli that were close to the meaning prescribed by the symbolic system, which may indicate that these pictograms are the most difficult to decode for adolescents with intellectual disorder due to the graphical representation. Descriptive statistics for all stimuli are presented in Appendix B.

The ratio of the number of "correct" and "incorrect" answers to the stimuli of Task 3 demonstrates that the main difficulties of students with intellectual disorder arose with the interpretation of stimuli 3Q4 ("there is a book on the floor", Pictogram), 3Q5 ("there is a book on the floor", Bliss), 3Q6 ("there is a book on the floor", LoCoS), 3Q11 ("the lamp is hanging above the door", Bliss), 3Q14 ("Dasha gave a flower", Bliss), 3Q22 ("the girl sees a puppy", Bliss), 3Q32 ("Masha is cooking food", Bliss), 3Q35 ("Kolya is looking for the keys", Bliss), 3Q36 ("Kolya is looking for the keys", LoCoS): in these cases, the number of incorrect answers in the experimental group is greater (Fig. 8).

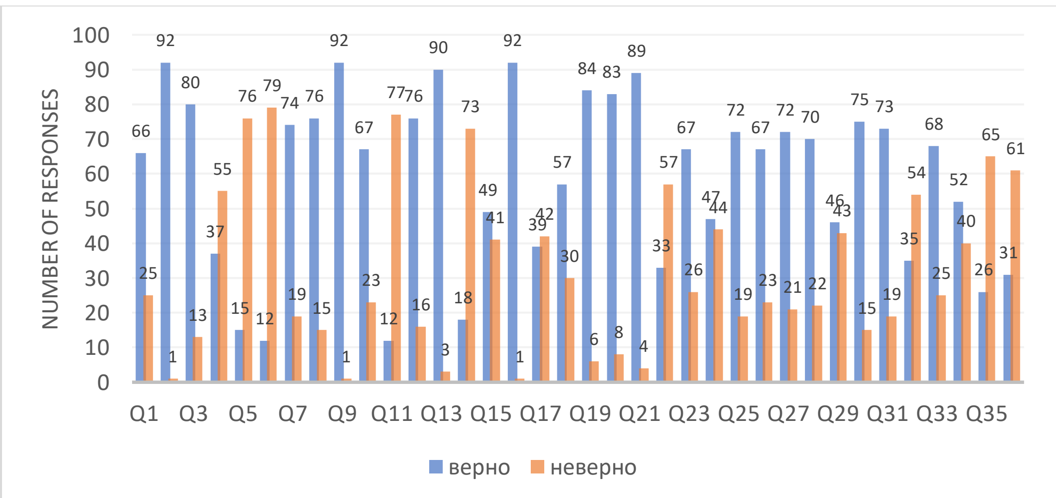
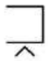


Figure 8. The ratio of the number of "correct" and "incorrect" answers of subjects with intellectual disorder to the stimuli of Task 3 (decoding a pictogram in a verbal context)

Of particular interest are stimuli for which a relatively large number of responses (more than 50%) do not fall into the first category of the gradation of response interpretation, i.e., into the “incorrect” interpretation. These stimuli are presented in Table 3.

Table 3. Frequency of responses of subjects with intellectual disorder to stimuli of the task of decoding pictograms in a verbal context

Incentive code	Stimulus content	Gradation category and students' answers	Counters (n)	% of total quantities
3Q5 (Bliss) "Floor"	ЛЕЖИТ НА  КНИГА	**Rep_1:** On the floor	15	16.5%
		Rep_2: On the table, on the closet, on the desk, on the chest of drawers, on the bed, on the sofa, on the shelf, on the TV, on the nightstand	71	78%
		Rep_3: Under the table, on the surface, on the book, on the side, on the house	3	3.3%
		Rep_0: Boy, on a piece of paper	2	2.2%
3Q6 (LoCoS) "Floor"	ЛЕЖИТ КНИГА НА 	**Rep_1:** On the floor	12	13.2%
		Rep_2: On the table, on the closet, on the desk, on the chest of drawers, on the bed, on the sofa, on the shelf, on the TV, on the nightstand, on the refrigerator	75	82.4%
		Rep_3: On the door, on the whale, on the house	3	3.3%
		Rep_0: Book	1	1.1%
3Q14 (Bliss) "Flower"	ДАША ПОДАРИЛА 	**Rep_1:** Flower (dandelion, rose, etc.)	18	19.8%
		Rep_2: Chupa Chups, lollipop, candy, poem, book, person, bird, keys, glasses, doll, ball, gift, song, magnifying glass, friend, picture, rattle, soap bubbles, camera, fish, headphones, ball, net, photo, boy, brush, toy, charger, first aid kit, racket, hook, girlfriend, voice, bee	72	79.1%
		Rep_0: No answer	1	1.1%

Note to Table 3: Rep_1 – Response that is as close as possible to the meaning prescribed by the symbol system; Rep_2 – Response that is more detail- or attribute-oriented and appropriate in meaning. Rep_3 – Response that is less detail- or attribute-oriented and appropriate in meaning; Rep_0 – Response that is not oriented toward context or symbol, specifics outside of context, abstract interpretation.

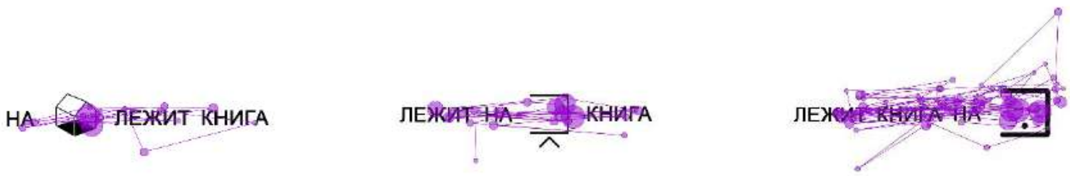
It can be concluded that within the cognitive task of translating a pictogram in a verbal context, the pictogram “floor” of the Bliss system (3Q5) is not interpreted in the meaning prescribed by the system, despite the fact that this pictogram appeared in Task 1 (choosing the odd one out) as corresponding to the word “Floor”. A greater number of interpretations are associated with different designations of furniture (Rep_2), χ^2 (3) = 141, $p < 0.001$, which may indicate that the pictogram is interpreted based on the overall context of the sentence rather than on its graphic representativeness.

The pictogram “floor” of the LoCoS system (3Q6) is composed according to the combinatorial possibilities of the system and is a derivative of the pictograms “room” and “here” (Ota Y., Macaulay C., Marcus A., 2012). Its graphic representation differs from the pictogram “floor” that appears in Task 1. It can be assumed that this graphic variation is not effective for denoting the concept of “floor” in a verbal context; a greater number of interpretations are associated with furniture designations (Rep_2), χ^2 (3) = 163, $p < 0.001$. Since the correct answers to the stimulus "Gender" of Task 1 prevail among the responses of the group with intellectual disorder, χ^2 (3) = 31.6, $p < 0.001$, and there are no statistically significant differences in the number of "correct" answers to this stimulus between the groups, the intuitive comprehensibility of the "gender" pictograms of the Bliss and LoCoS systems is expressed in their non-exclusion from the series of pictograms corresponding to the concept of "gender". However, one can judge the absence of a memorization effect within the framework of the two proposed cognitive tasks.

Bliss system flower pictogram (3Q14) was named according to its meaning by only 19.8% of the subjects with intellectual disorder, which indicates a low degree of its intuitive comprehensibility for the group of adolescents with intellectual disorder. A greater number of subjects' interpretations are associated with various objects that fit into the general context of the sentence (Rep_2), χ^2 (2) = 90.6, $p < 0.001$. The graphical representation of this pictogram is associated with a variety of interpretations.

Thus, it is possible to identify groups of synonymous pictograms and individual pictograms that, in a free interpretation task, cause the greatest difficulties for adolescents with intellectual disorder.The most difficult to interpret groups of pictograms related to the same verbal referent but belonging to different AAC systems include the following concepts: “floor”, “fall”, “search”.

The pictogram "gender" of the Pictogram system (3Q4) causes more difficulties for adolescents with intellectual disorder, however, a large proportion of the respondents' responses to the perception of this pictogram fall on the "correct" designations, in contrast to similar pictograms of the Bliss and LoCoS systems. It can be concluded that the pictogram "gender" of the Pictogram system (3Q4) from this series shows the best result of recognition and interpretation (Fig. 9). The data are confirmed by the one-sample Student's criterion with a large effect size, t (90) = 7.85; $p < 0.001$, d = 0.823.



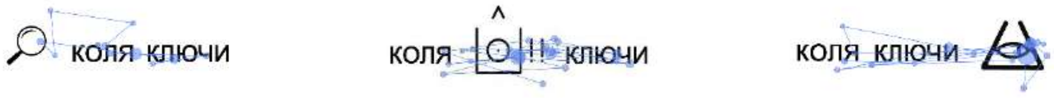
a) *b)* *c)*

Figure 9. Group of stimuli “gender” Task 3 for translating a pictogram in a verbal context with visualization of the gaze path of one subject with intellectual disorder:
a) Pictogram; b) Bliss; c) LoCoS

The number of “correct” interpretations of the group of pictograms “to fall” by adolescents with intellectual disorder is significantly lower than that of adolescents with typical development. However, the number of exact “correct” responses to these stimuli predominates. No differences in the number of “correct” interpretations were found with respect to the three AAC systems. Consequently, the graphical representation of the concept “to fall” causes difficulties for adolescents. with intellectual disorder and the most appropriate graphical representation may be the subject of further research.

When analyzing responses to stimuli that included the concept of “search,” reliable differences between the control and experimental groups were found in relation to the

Pictogram and LoCoS pictograms . At the same time, the number of “correct” responses prevails when interpreting the pictogram related to the Pictogram system by students with intellectual disorder, whereas “incorrect” responses prevail when interpreting the LoCoS and Bliss pictograms (Fig. 10). It can be concluded that the “search” pictogram of the Bliss system causes approximately equal difficulties for students with intellectual disorder and those with typical development. The pictogram of the Pictogram system is the best option for displaying the concept of “search,” which is confirmed by the one-sample Student’s t-test with a large effect size, t (90) = 10.71; p < 0.001, d = 1.123.



a) *b)* *c)*

Figure 10. Group of stimuli “search” Task 3 for translating a pictogram in a verbal context with visualization of the gaze path of one subject with intellectual disorder:
a) Pictogram; b) Bliss; c) LoCoS

The most difficult to decode individual pictograms for subjects with intellectual disorder include those that yielded a relatively large number of “incorrect” answers: “lamp” Bliss, “see” Bliss, “cook” Bliss, “flower” Bliss. The use of these pictograms is not recommended when interacting with students with intellectual disorder: in these cases, the choice of similar pictograms from other systems under study – Pictogram and LoCoS – is more justified. It can also be concluded that the graphic expression of these pictograms is ineffective in relation to adolescents with typical development, since no reliable differences in the number of “correct” answers were found when compared with the control group.

The number of “correct” responses to stimuli containing the picograms “bird” Bliss, “sit” Bliss and “sit” Pictogram is significantly lower in the group of subjects with intellectual disorder than in the group with typical development.

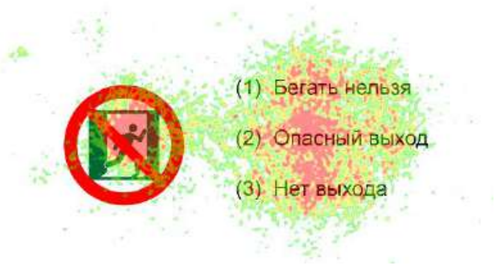
Bliss bird icon resembles the LoCoS icon, but the latter demonstrates better decoding results for adolescents with intellectual disorder due to fewer misinterpretations in this group.

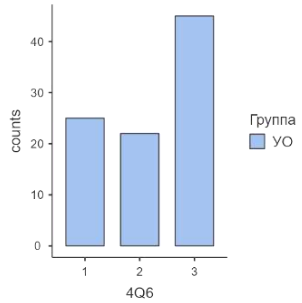
Bliss "sit" pictogram causes approximately the same ratio of "correct" and "incorrect" answers of subjects with intellectual disorder, whereas when decoding similar pictograms of other systems, "correct" answers prevail. At the same time, no significant differences were found with respect to this pictogram with the control group, which indicates the difficulty of its perception in both samples. It can be concluded that the "sit" pictograms of the Pictogram and LoCoS systems are preferable when interacting with adolescents with intellectual disorder, however, further research can be devoted to finding a more optimal version of graphical representation.

Tables of the frequencies of responses of subjects with intellectual disorder to the above-mentioned stimuli of Task 3, considering the gradation of interpretation levels, as well as specific examples of responses of subjects are presented in Appendix E.

3.6. Decoding public space signs

When comparing the subjects' responses to the stimuli of Task 4, it was found that there were statistically significant differences in the number of correct responses to stimulus 4Q6 "No Exit" $t(181) = -3.763$, $p < 0.001$, $d = -0.5548$. Teenagers with intellectual disorder gave fewer correct responses when perceiving this stimulus, which may indicate that the addition of an additional symbol in the form of a crossed-out circle complicates the interpretation of the sign (covers the informative part of the "Exit" sign) (Fig. 11).





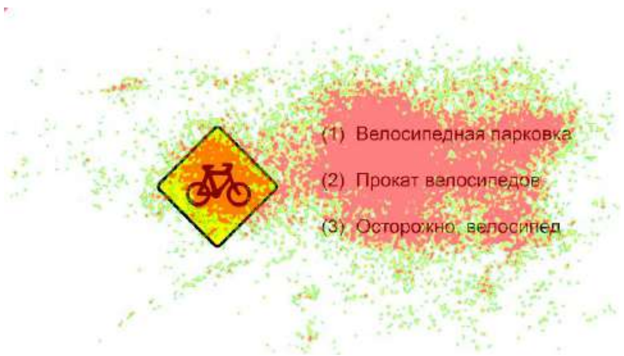
a) *b)*

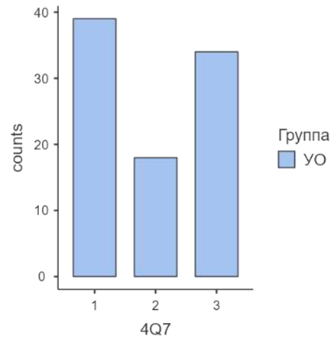
Figure 11. Stimulus 4Q6 “No exit” (the “correct” answer is 3) Task 4 on decoding public signs: a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps; b) frequency of answer choices by subjects from the group with intellectual disorder

Note: " counts " – number of responses; "УО" – group with mild intellectual disorder.

Presumably, the visual load of the "No Exit" sign is responsible for the fact that the "Exit" sign is not readable against the background of the crossed-out circle. It is worth noting that the original "Exit" sign, as one of the most common in the public environment, was provided to the subjects as a training stimulus for Task 4 - only after the researchers were convinced that the participant understood the essence of the task and correctly indicated the designation of the "Exit" sign, he was asked to move on to the target stimuli of the task. Thus, the partial obscurity of the "Exit" sign worsens its perception and interpretation in the group of adolescents with intellectual disorder. Despite this, the frequency analysis showed the predominance of "correct" answers in the group with intellectual disorder at a high level of statistical significance, χ^2 (2) = 10.2, p = 0.006.

One of the stimuli of Task 4 "Bicycle" (4Q7) is a non-standardized sign, i.e. it does not meet the requirements of GOST ISO 3864-1-2013, as it has a diamond shape. For this reason, it is impossible to single out a clearly correct or incorrect answer. Nevertheless, in accordance with the hypothesis that the yellow color will be perceived by the subjects as a warning, the option "Caution, bicycle" was accepted as a conditionally "correct" answer (Fig. 12).





a) *b)*

Figure 12. Stimulus 4Q7 “Bicycle” (non-standardized public sign) Task 4 for decoding public signs:
a) visualization of eye tracker data (group with intellectual disorder) in the form of heat maps;
b) frequency of answer choices by subjects from the group with intellectual disorder

Note: " counts " – number of responses; "УО" – group with mild intellectual disorder.

The Student's t-test for two independent samples shows that there are no statistically significant differences in the number of correct responses to stimulus 4Q7 "Bicycle" between the control and experimental groups, t(181) = 0.987, p = 0.325, d = 0.146. Frequency analysis showed the predominance of "incorrect" responses in the group with intellectual disorder at a low level of statistical significance, χ^2 (2) = 7.93, p = 0.019. Approximately the same ratio of the choices of answer options by subjects with intellectual disorder between the interpretation options "Bicycle parking" and "Caution, bicycle" suggests that the yellow color is rather not perceived as a warning sign. With respect to both samples, it is also impossible to judge that the yellow color is an indicator of danger for the subjects.

Frequency tables for all stimuli of Task 4 on decoding public signs are presented in Appendix D.

3.7. Parameters of oculomotor activity in the perception of pictograms

The role of oculomotor activity parameters in the perception of pictograms as a component of the AAC of adolescents with mild intellectual disorder was studied based on the factorization of data obtained using eye-tracking (Neuroburo SAE software). Data were obtained for five oculomotor activity parameters when viewing individual pictograms included in the stimuli of all tasks:

- All_Fix – average number of fixations. Reflects how thoroughly the subject examined individual pictograms;
- Returns – the average number of repeated returns to the pictogram. Shows how many times the subject looked at the pictogram during the entire time of interaction with the stimulus (excluding the first fixation on the area). Reflects the degree of attention to this area;
- First_fix – average duration of the first fixation of the gaze within the pictogram area upon first fixation;
- Mean_fix – average duration of fixations on the pictogram (total time the gaze is in the area, divided by the number of fixations in this area);
- Fix_time – the average total time that the gaze was within the area of a separate picogram. Reflects the degree of interest in the object.

Under the assumption that the oculomotor activity parameters, and therefore the factors, may be correlated, the factor analysis used Varimax rotation. The factor loadings from the exploratory factor analysis, performed using the maximum likelihood method, are presented in Table 4.

Table 4. Factor loadings of oculomotor activity parameters in the perception of pictograms

Parameter	**Factor**		**Uniqueness**
	1	**2**	
Returns	0.955		0.06598
All_Fix	0.971		0.00460
First_fix	0.364	0.595	0.51415
Mean_fix		0.992	0.00500
Fix_time	0.826	0.534	0.03287

It was suggested that the Fix_time parameter (time spent viewing a single picogram) violates the simplicity of the factor structure due to the fact that, from a logical point of view, it is integral and directly interrelated with all other parameters. For this reason, this variable was excluded from the factor analysis. After excluding the Fix_time variable, the Promax rotation method was used, and the factor model acquired a clear structure. As a result, the following factors were identified: the factor of quantitative parameters of oculomotor activity and the factor of duration of fixations (Table 5).

Table 5. Factor loadings of oculomotor activity parameters of adolescents with intellectual disorder when viewing pictograms of various AAC

No.	Paragraph	FL
Factor Eye Quan: *Quantitative parameters of oculomotor activity*		
1	All _ Fix (average number of fixes)	0.945
2	Returns (average number of repeat returns)	0.985
Factor Eye Duration: *Duration of fixations*		
1	First _ fix (average duration of the first fixation)	0.703
2	Mean _ fix (average duration of fixations on the icon)	0.887

The factor of quantitative parameters of oculomotor activity reflects detailed viewing of pictograms with gaze returns in the context of search and analytical activity when performing different cognitive tasks included in individual tasks of the stimulus material. The average number of fixations on all pictograms and the average number of returns are strongly positively interrelated at a high level of significance, Spearman's correlation coefficient $r_s(98) = 0.971$, $p < 0.001$. It can be assumed that through the sequential perception of the details of the pictograms, an interpretation of semantic connections occurs, which expresses the procedural component of thinking (Zashchirinskaia O.V., 2016).

The fixation duration factor provides an idea of the cognitive processing of what was seen. The average duration of the first fixation on all pictograms and the average duration of the remaining fixations are positively interrelated at a high level of significance, Spearman's correlation coefficient $r_s(98) = 0.676$, $p < 0.001$. In linguistic studies, the average duration of fixations is an indicator of the activation of lexical processing (Juhasz B.J., Rayner K., 2003). According to the hypothesis of direct cognitive control, the duration of gaze fixation is controlled by cognitive processes associated with the processing of lexical and linguistic properties of the perceived word. In this case, the duration of the first fixation is of particular importance (Rayner K., Reingold E.M., 2015).

The time parameter Fix_time (time of viewing a separate picogram) is strongly correlated with the factor of quantitative parameters, Spearman $r_s (98) = 0.923$, $p < 0.001$, and was less strongly correlated with the fixation duration factor, Spearman $r_s (98) = 0.804$, $p < 0.001$. It seems obvious that viewing time is a consequence of the duration and number of oculomotor activity parameters. This parameter can be considered as integrating, since all oculomotor activity parameters are directly related to the time spent on visual perception.

At the same time, it is possible to note the average strength of the relationship between the parameter First_Fix (the average duration of the first fixation) and the total number of fixations, Spearman $r_s (98) = 0.631$, $p < 0.001$ and total number of returns, Spearman $r_s (98) = 0.555$, $p < 0.001$. This finding is interesting because it indicates that a higher cognitive load at first glance at a pictogram results in a more detailed examination. Factor statistics for the oculomotor activity parameters are presented in Appendix F.

The relationship between the quantitative factor and the duration of fixations factor is of average strength, but at a high level of significance: Spearman $r_s (98) = 0.572$, $p < 0.001$. The graphs of correlations of the parameters of oculomotor activity for all tasks are presented in Appendix H.

Thus, it became possible to construct a correlation matrix of the interrelations of the parameters of oculomotor activity during the perception of pictograms of various alternative communication systems (Fig. 13).

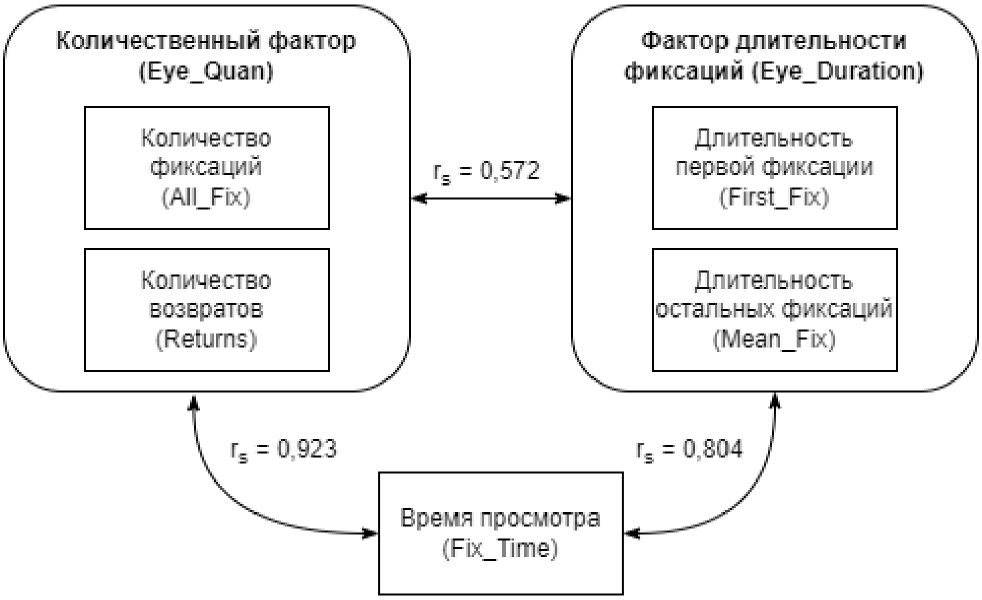


Figure 13. The structure of the relationships between the parameters of oculomotor activity in a group with intellectual disorder when viewing pictograms of various AAC systems

Note: r_s – Spearman's rank correlation coefficient.

Next, based on factorization, an analysis of the relationships between the oculomotor activity parameters was conducted during the perception of pictograms of various AAC systems in the context of different cognitive tasks and under the influence of additional factors. It is worth noting that since pictograms are a semantic form different from text, the analysis of oculomotor activity parameters in relation to them can reveal qualitatively new patterns. In addition, each individual oculomotor activity parameter in the composition of factors (in particular, the number of returns and the number of fixations) has a special research value, therefore, in this study, quantitative parameters and parameters of fixation duration were analyzed both in combination, in the form of the above-described factors, and separately.

3.8. Features of oculomotor activity in adolescents with intellectual disorder when perceiving alternative communication pictograms

Comparative analysis of oculomotor activity during viewing of pictograms of all tasks of stimulus material by adolescents with intellectual disorder with the control group revealed reliable differences in the parameters of fixation duration. The average duration of the first fixation on pictograms is statistically significantly shorter in the group of adolescents with intellectual disorder (M=0.2439, SD=0.0724) than in the group of adolescents with normo- typical development (M=0.3490, SD=0.119), U =1953, p <0.001, ES =0.5933. The average duration of subsequent fixations is also statistically significantly shorter in the group of adolescents with intellectual disorder (M=0.3756, SD=0.0856) than in the group of adolescents with typical development (M=0.4659, SD=0.145), U =2734, p <0.001, ES =0.4307. Considering the fact that the complexity of lexical processing can modulate the duration of the first fixation, delaying new saccadic programs and providing additional time for vocabulary processing (Rayner K., Reingold E.M., 2015), it can be assumed that the mechanism of direct cognitive control in the perception of pictograms is less pronounced in the experimental group due to the specificity of the implementation of cognitive processes. The same fact explains the smaller number of "correct" responses to the stimuli of the author's technique in the group of adolescents with intellectual disorder compared to the group of adolescents with typical development.

Regular differences in the parameters of fixation duration were found for individual tasks of the stimulus material, i.e. in the context of solving various cognitive problems. All differences were found at a high or medium level of statistical significance and with a sufficient effect size (Table 6).

Table 6. Statistical differences in the parameters of fixation duration between groups of adolescents with intellectual disorder and those with typical development

Parameter	**Group**	**M ± SD**	**U Mann-Whitney**	**p**	**Effect size (ES)**
Task 1. Selecting the "extra" icon					
First Fix Duration (First_Fix)	Intellectual disorder	0.249 ± 0.0455	92	< 0.001	0,6806
	Normal	0.349 ± 0.115			
Duration of remaining fixations (Mean_Fix)	Intellectual disorder	0.336 ± 0.0457	90	< 0.001	0.6875
	Normal	0.435 ± 0.110			

Task 2. Translation of a sentence from pictograms					
First Fix Duration (First_Fix)	Intellectual disorder	0.208 ± 0.0811	108	< 0.001	0.7037
	Normal	0.297 ± 0.0644			
Duration of remaining fixations (Mean_Fix)	Intellectual disorder	0.326 ± 0.0355	143	< 0.001	0.6077
	Normal	0.381 ± 0.0508			
Task 3. Translation of the pictogram in context					
First Fix Duration (First_Fix)	Intellectual disorder	0.283 ± 0.0655	247	< 0.001	0.6188
	Normal	0.413 ± 0.136			
Duration of remaining fixations (Mean_Fix)	Intellectual disorder	0.459 ± 0.0776	271	< 0.001	0.5818
	Normal	0.578 ± 0.150			
Task 4. Decoding public signs					
First Fix Duration (First_Fix)	Intellectual disorder	0.193 ± 0.0454	16	0.002	0.736
	Normal	0.268 ± 0.0494			
Duration of remaining fixations (Mean_Fix)	Intellectual disorder	0.309 ± 0.0355	28	0.034	0.537
	Normalal	0.345 ± 0.0387			

No statistically significant differences were found regarding the number of fixations, U = 4218, p = 0.142, average number of returns per pictogram, U = 4429, p = 0.348, time spent viewing pictograms, U = 4484, p = 0.424. Descriptive statistics of the subjects' eye movement activity data for all tasks as a whole and for individual tasks are presented in Appendix G.

3.9. The relationship between quantitative and qualitative parameters of oculomotor activity and the process of decoding pictograms

Correlations between individual parameters of oculomotor activity of subjects with intellectual disorder were analyzed within the four tasks separately, i.e. in the context of different cognitive tasks. In each of the four tasks, direct relationships were found between the average viewing time and the quantitative parameters of oculomotor activity

Eye_Quan at the level of statistical significance $p < 0.001$, which corresponds to the factor model of oculomotor activity identified for all tasks taken together. This relationship reflects cognitive load in the context of different cognitive tasks, where the perception process is associated with the time spent on detailed review and rechecking of lexical hypotheses.

The relationship between the parameters of the fixation duration factor Eye _ Duration differs in individual tasks; in some of them, the relationship between these parameters is weak or is at a low level of statistical significance (Table 7).

Table 7. Relationship between the parameters of the average duration of the first and subsequent fixations in the group with intellectual disorder depending on the cognitive task

Exercise	**Spearman r** $_s$	**df**	**p**
Selecting an "extra" icon	0.416	22	0.044
Translation of a sentence from pictograms	0.512	25	0,007
Translation of a pictogram in a verbal context	0.375	34	0.025
Decoding public signs	0.891	9	< 0.001

A pattern was found in the relationship between the average duration of the first fixation (First_Fix) and the average viewing time (All_Fix) in relation to all tasks, while the strength of the relationship between these parameters and the level of statistical significance differed for individual tasks (Table 8).

Table 8. Relationship between the parameters of the average duration of the first fixation and the average viewing time in the group with intellectual disorder depending on the cognitive task

Exercise	**Spearman r** $_s$	**df**	**p**
Selecting an "extra" icon	0.578	22	0.004
Translation of a sentence from pictograms	0.833	25	< 0.001
Translation of a pictogram in a verbal context	0.533	34	< 0.001
Decoding public signs	0.755	9	0,010

It can be assumed that the time spent on perceiving and analyzing pictograms is related to the cognitive difficulty of the task due to the activation of the lexical processing process. In this way, the tasks were identified that activated the lexical processing process to the greatest extent in the group of subjects with intellectual disorder. In these tasks, subjects were asked to express the meaning of pictograms in verbal form, in other words, to “name” the pictogram: a task to translate a sentence from pictograms and a task to translate a pictogram in a verbal context.

In the task of translating a sentence from pictograms, a strong direct relationship was found between the parameter of the average duration of the first fixation (First_Fix) and the average number of fixations (All_Fix), Spearman r_s (25) = 0.798, $p < 0.001$. In addition, in this task, the average duration of the first fixation is strongly positively correlated at a high level of significance with the average number of returns (Returns), Spearman r_s (25) = 0.797, $p < 0.001$. Weak relationships at a medium level of significance were found between the mean duration of all fixations (Mean_Fix) and the mean viewing time (Fix_Time), Spearman r_s (25) = 0.522, $p = 0.006$, and the number of returns (Returns), Spearman r_s (25) = 0.470, $p = 0.013$.

In the task of translating a pictogram in a verbal context, a correlation was also found between the parameters of the duration of the first fixation (First_Fix) and the number of fixations (All_Fix). It was smaller than in the task of translating a sentence from pictograms, at a lower level of significance and amounted to r_s (34) = 0.451, $p = 0.006$. The parameter of the duration of the remaining fixations (Mean_Fix) weakly positively correlated at a low level of significance with the time spent viewing pictograms (Fix_Time), Spearman r_s (34) = 0.438, $p = 0.008$.

Thus, when performing tasks that most activate the process of lexical processing, the following patterns were discovered:

1. Activation of the lexical processing process is associated with more detailed viewing and a greater number of returns for matching links and rechecking;
2. Activation of the lexical processing process is associated with time spent on revision and cognitive processing.

Correlations between the eye tracker parameters and the number of correct answers to individual tasks were analyzed only in Tasks 3 and 4 due to the fact that only in these tasks the stimuli contained one pictogram and could be correlated with the number of correct answers.

In the pictogram translation task in a verbal context, the number of responses close to the system-prescribed meaning of the pictograms negatively correlates at a high level of significance with three of the four oculomotor activity parameters: the average total time spent viewing the pictograms (Fix_Time), Spearman's correlation coefficient r_s (34) = -0.773, $p < 0.001$; the average number of returns to the pictograms (Returns), Spearman 's correlation coefficient r_s (34) = -0.690, $p < 0.001$; the average number of fixations on the pictograms (All_Fix), Spearman's correlation coefficient r_s (34) = -0.734, $p < 0.001$. A weak negative relationship at a low level of significance exists between the number of "correct" responses and the average duration of the first fixation (First_Fix), Spearman's correlation coefficient r_s (34) = -0.773, $p < 0.001$. r_s (34) = -0.405, $p = 0.014$. Presumably, longer viewing, a greater number of returns to the pictogram, a greater number of fixations on the pictogram are associated with the difficulty of some adolescents with intellectual disorder in reading (Isaev D.N., 2003). In the case when the text is additionally burdened with a symbol of a different property, i.e. a pictogram, the process of perception and decoding of the symbol itself is complicated. If it is impossible to “on the fly” (intuitively and quickly) grasp the meaning of a sentence with one word replaced by a pictogram, further attempts to guess the meaning of the pictogram are more likely to entail an answer different from the meaning prescribed by the pictographic system. Difficulties can be associated either with the graphic features of specific pictograms, the perception of which increases the cognitive load and which in some cases cannot be quickly interpreted, or with the fact of an error in reading the verbal context. Some adolescents with intellectual disorder read the verbal context incorrectly, making it even more difficult for them to decode the pictogram. The experimenters did not correct the inaccuracies or prompt the subjects while reading the text.

The number of correct interpretations of public signs is negatively correlated at a low level of significance with three parameters of oculomotor activity: the average total time of looking at signs (Fix_Time) , Spearman correlation coefficient r_s (9) = -0.653, p = 0.029; the average number of returns to pictograms (Returns), Spearman correlation coefficient r_s (9) = -0.699, p = 0.017; the average number of fixations (All_Fix), Spearman correlation coefficient r_s (9) = -0.680, p = 0.021. It can be assumed that in this case, symbol recognition plays a role: if a symbol is familiar to a child, he or she selects its interpretation faster and more purposefully. In the opposite case, an analysis takes place, coupled with a long detailed viewing and correlation of what is seen with textual variants of the designation, which entails an answer that does not correspond to the generally accepted meaning (probably based on the details of the sign and their free interpretation). Graphs of correlations of the parameters of oculomotor activity for individual tasks are presented in Appendix H.

3.10. The influence of controlled factors on the processes of decoding and perception of pictograms of various alternative communication systems

3.10.1. The influence of controlled factors on the decoding of pictograms of various alternative communication systems

Of particular interest to the study was the degree of influence of the following factors on the decoding of pictograms by students with intellectual disorder:

1. Belonging of pictograms to one or another AAC system;
2. Repeating a series of pictograms from Task 1 in Task 3;
3. The part of speech to which the verbal referent of the pictograms belongs (noun or verb);
4. The presence of a human figure on the pictograms.

Since one of the hypotheses of the study was to test the assumption that the alternative communication system affects the efficiency of decoding pictograms, for the factor analysis of the influence of the AAC on the number of correct answers, the data from Tasks 1–3 were used, which involved pictograms of three AAC systems (LoCoS, Pictogram, Bliss). Task 4 on decoding public signs was not considered in the analysis due to the fact that interpretation in this case strongly depended on the fact of familiarity with the signs. The data on the number of correct answers of subjects with intellectual disorder turned out to be normally distributed, the homogeneity of variances is confirmed by the Levene criterion ($F(2.48) = 0.420$; $p > 0.1$. Accordingly, one-way analysis of variance and the Tukey post-hoc test were used . The statistics of normal distribution, homogeneity of variances, as well as descriptive statistics and the result of the post-hoc test are presented in Appendix I.

The factor of the pictogram belonging to one or another AAC system influences the number of correct answers of subjects with intellectual disorder, Fisher criterion $F(2.48) = 5.36$; $p = 0.008$; $R^2 = 0.109$. Average value for conditions: $M_{LoCoS} = 58.1 \pm 19.5$; $M_{Pictogram} = 65.6 \pm 23.4$; $M_{Bliss} = 41.8 \pm 21.7$ (Fig. 14).

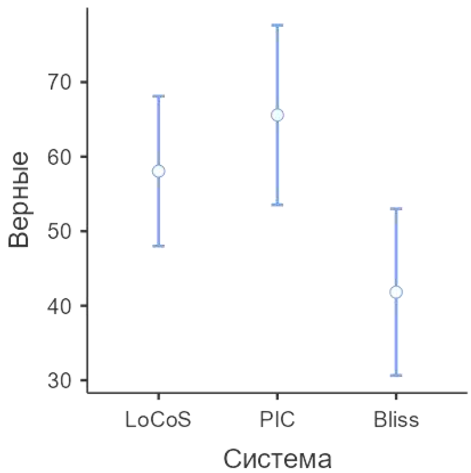


Figure 14. The influence of the factor of pictograms belonging to different AAC systems on the number of correct answers of students with intellectual disorder

Note: "Система" – AAC system; "Верные" – the number of correct answers.

The post-hoc test showed that the number of correct answers in the perception of pictograms of the Pictogram system was statistically significantly higher than in the perception of pictograms of the Bliss system, $t(48) = 3.20$; $p = 0.007$. No statistically significant differences were found in the number of correct answers in the perception of pictograms of the Pictogram and LoCoS systems ($t(48) = -1.01$; $p = 0.571$), as well as LoSoS and Bliss ($t(48) = 2.19$; $p = 0.083$).

Due to the fact that in two of the four tasks the correlation analysis of the oculomotor activity parameters revealed a more active involvement of the lexical processing process, the factor analysis of the influence of the AAC system on the number of correct answers was carried out separately for Tasks 2 and 3 (translation of a sentence from pictograms and translation of a pictogram in a verbal context). The influence of the factor of pictograms belonging to one or another AAC system on the number of correct answers was insignificant, Fisher's criterion F(2.42) = 4.05; p = 0.025; R^2 = 0.0975. Average value for conditions: M_{LoCoS} = 58.9±19.9; $M_{Pictogram}$ = 64.7±24.8; M_{Bliss} = 42.0±23.2. In this case, the pattern of the results of the factor analysis for all three tasks is repeated: the greatest difference at a low level of significance was found in the number of correct answers in the perception of pictograms of the Pictogram system, which is statistically significantly greater than in the perception of pictograms of the Bliss system, t(42) = 2.74; p = 0.024. No statistically significant differences were found in the number of correct answers in the perception of pictograms of the Pictogram and LoCoS systems (t(42) = -0.699; p = 0.766), as well as LoSoS and Bliss (t(42) = 2.04; p = 0.115).

Next, the effect of repetition of the pictograms from Task 1 in the stimulus material of Task 3 was analyzed. It was assumed that the first acquaintance with the pictogram in the context of the task of choosing the odd one out would influence the number of correct responses to stimuli in which the pictograms already seen figured. It turned out that the effect of the influence of repetition with a very high degree of statistical probability was absent in the group of adolescents with intellectual disorder, F(1.33) = 0.001; p = 0.974. The same result was found for the entire sample (both the control and experimental groups combined), F(1,68) = 0.234; p = 0.630, and for the group with typical development separately, F (1,33) = 0.580; p = 0.452.

To detect the influence of the repetition factor of the pictograms in Task 3, which appeared in Task 1 as targets and non-targets (“extra” and distractors corresponding to the verbal referent), the multiple linear regression method was used. The results showed that the repetition factor, taking into account the factor of whether the pictogram in Task 1 was a target, does not affect the number of correct answers in the group with intellectual disorder: adjusted R^2 = -0.0480, F(2,33) = 0.198, p = 0.821. Similar results were found for the overall sample, adjusted R2 = -0.0209, F(2,69) = 0.275, p = 0.761, and the typical development group , adjusted R2 = -0.0425, F(2,33) = 0.287, p = 0.753. Apparently, the choice of the odd pictogram, coupled with the identification of distractor pictograms, does not activate the lexical processing process, and therefore does not influence more efficient naming of pictograms in the context of the cognitive task of translating a pictogram in a verbal context. The fit indices and model coefficients are presented in Appendix J.

The next step was to study the influence of the part of speech (noun or verb) to which the verbal referent of individual pictograms belonged on the number of correct answers of the subjects with intellectual disorder. The effect was studied in relation to the target pictograms of Task 1 and Task 3, since in relation to the task of decoding social signs, the analysis of specific parts of speech seemed incorrect due to the multi-syllabic and conceptual load of the signs, and in Task 2 both parts of speech were involved and, therefore, could not be correlated with the number of correct answers. It was found that the factor of pictogram belonging to nouns or verbs did not affect the number of correct answers of adolescents with intellectual disorder with a high degree of statistical significance, F(1.40) = 1.67; p = 0.990. No statistically significant differences were found in the number of correct answers when perceiving noun pictograms and verb pictograms (t(40) = -0.013; p = 0.990). Also, no effect of part of speech on the number of correct answers was found for the entire sample, F(1.82) = 0.04; p = 0.844.

The influence of the pictograms belonging to a particular system on the number of correct answers of subjects with intellectual disorder, taking into account the honor of speech, was analyzed using the multiple linear regression method. The model did not reveal a sufficient effect size, adjusted R^2 = 0.221, F(3, 38) = 4.88, p = 0.006. At the same time, the contribution of the predictor "part of speech" turned out to be the least significant (t = -0.0148, p = 0.988). The fit indices and model coefficients are presented in Appendix J.

The influence of the AAC pictographic system on the decoding of verbs by students with intellectual disorder was not found (F(2,18) = 2.14; p = 0.146), while the influence of the system on the decoding of nouns was at a low level of statistical significance, F(2,18) = 5.19; p = 0.017; R^2 = 0.366. Students with intellectual disorder gave a greater number of correct answers when perceiving pictograms-nouns of the Pictogram system (M = 78.1±20.6) compared to the Bliss system (M = 78.1 ± 20.6), t(18) = 3.22; p =0.013.

Of additional interest was the study of the influence of the human figure on the pictograms Pictogram, since the concreteness and high detail of these pictograms could both simplify the perception of the pictogram meaning by the subjects and complicate it. The influence was studied in relation to the pictogram-verbs of Task 3 on the translation of the pictogram in the verbal context, since it was in this task that pictograms from different AAC systems with the same meaning and in the same verbal context appeared (taking into account the rearrangement of the pictogram's place in the sentence). The influence of the human figure on the number of correct answers of subjects with intellectual disorder was not detected, F(1,16) = 0,0597; p = 0,810. To detect the influence of the AAC system on the number of correct answers to Task 3, taking into account the presence of the human figure on the stimulus pictograms, the multiple linear regression method was used. The results showed that the model was unreliable: adjusted R2 = 0.181, F(3,14) = 1.03, p = 0.409. The contribution of the predictor "person" turned out to be the one with the lowest weight (t = 0.0390, p = 0.969). The fit indices and model coefficients are presented in Appendix J.

Thus, multiple testing of the assumptions about the influence of the AAC system, part of speech and human figure on the number of correct answers of subjects with intellectual disorder was carried out. Hypotheses confirmed at a sufficient level of statistical significance are presented in Table 9.

Table 9. The influence of the AAC system on the decoding of pictograms by adolescents with intellectual disorder

Hypothesis	**F**	**R^2**	**p**	**p_{corr}**
The influence of AAC on the number of correct answers	5.36	0.109	0.008	0,017
The influence of AAC on decoding of nouns	5.19	0.366	0,017	0.025
The influence of AAC on the number of correct answers in lexical tasks	4.05	0.0975	0.025	0,050

Note: Results are presented using the Holm-Bonferroni multiple hypothesis testing correction at α = 0.05.

3.10.2. The influence of controlled factors on the parameters of oculomotor activity during the perception of various alternative communication systems

At the final stage, the influence of the factors of pictograms belonging to the AAC systems, repetition, part of speech and human figure on the characteristics of oculomotor activity of subjects with intellectual disorder was analyzed.

Since the assumptions of equality of variances and normal distribution in relation to eye-tracking data were not confirmed, a nonparametric one-way analysis of variance was performed using the Kruskal-Wallis test and the Dwass-Steele-Critchlow-Flinger (DSCF) pairwise comparison method, which provides pairwise comparison of groups with correction for multiple comparisons based on W (Wilcoxon test). Homogeneity and normality testing tables, as well as descriptive statistics, are presented in Appendix I.

The study of the influence of the pictographic system (including public signs) on the parameters of oculomotor activity yielded statistically significant results for all parameters. Since in Task 3 individual pictogram sentences were written with symbols from one AAC system, the eye tracker indicators for the three sentence symbols were averaged. The highest degree of significance of the results and the largest effect size relate to the quantitative parameters and viewing time (Table 10).

Table 10. The influence of the factor of belonging of the pictogram to one of the four AAC systems on the parameters of oculomotor activity of subjects with intellectual disorder

Parameter	χ^2	**df**	**p**	ε^2	**p_{corr}**
Viewing time	26.2	3	< .001	0.332	0,007
Number of returns	22.6	3	< .001	0.286	0.008
Number of fixations	23.2	3	< .001	0.293	0,010
Quantitative factor	18.9	3	< .001	0.240	0,013
Duration of the first fixation	14.5	3	0.002	0.183	0,017

Average fixation time	13.3	3	0.004	0.168	0.025
Fixation duration factor	12.3	3	0.007	0.155	0,050

Note: Results are presented using the Holm-Bonferroni multiple hypothesis testing correction at α = 0.05.

Quantitative parameters of oculomotor activity, including the average number of returns and the average number of fixations on pictograms, are more pronounced at a statistically significant level in relation to the Bliss system pictograms (Fig. 15).

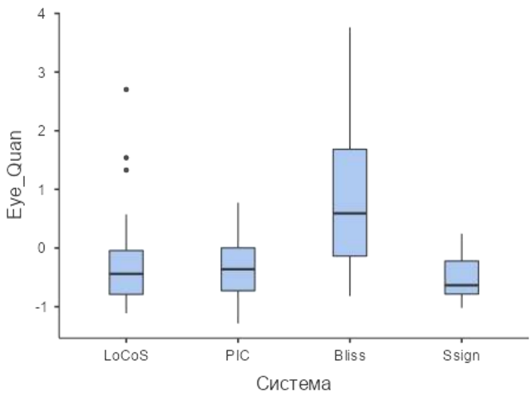


Figure 15. Differences in quantitative parameters of oculomotor activity in the group with intellectual disorder when perceiving pictograms of various AAC systems

Note: "Eye_Quan" is a factor of quantitative parameters of oculomotor activity.

The average number of returns to the Bliss system icons is significantly higher than to the LoCoS system icons (W = 4.623; p = 0.006), Pictogram system icons (W = 5.467; p < 0.001) and public signs (W = -5.389; p < 0.001). The average number of fixations on the Bliss system pictograms is also significantly higher than on the LoCoS system pictograms (W = 4.614; p = 0.006), Pictogram system pictograms (W = 5.562; p < 0.001) and public signs (W = -5.493; p < 0.001).

The average viewing time of the Bliss system icons was significantly longer than that of the LoCoS system icons (W = 4.086; p = 0.020), Pictogram system icons (W = 5.546; p < 0.001) and public signs (W = -5.961; p < 0.001).

The parameters of fixation duration, including the average duration of the first fixation and the average duration of subsequent fixations, are lower at a statistically significant level for public signs (Fig. 16).

The average duration of the first fixation on public signs is significantly shorter than on LoCoS pictograms (W = -4.035; p = 0.022) and Bliss pictograms (W = -5.076; p = 0.002). The average duration of subsequent fixations on public signs is also significantly shorter than on LoCoS pictograms (W = -4.607; p = 0.006), Pictograms (W = -3.826; p = 0.034), and Bliss pictograms (W = -4.555; p = 0.00 7). Presumably, graphic representations of public signs activate the lexical processing process in adolescents with intellectual disorder to the least extent, and are therefore perceived as a “gestalt” with a conditional specific meaning.

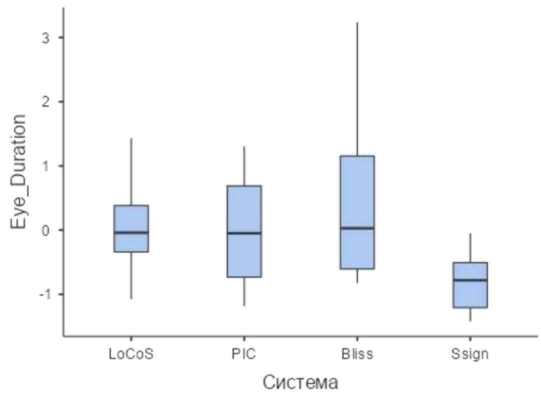


Figure 16. Differences in the parameters of fixation duration in the group with intellectual disorder when perceiving pictograms of various AAC systems

Note: " Eye _ Duration " is a factor of the duration of fixations.

Due to the fact that in two of the four tasks the correlation analysis of the oculomotor activity parameters revealed the activation of lexical processing based on the relationship between the duration of the first fixation on the pictogram and the average viewing duration, the factor analysis of the influence of the AAC system on the number of correct answers was conducted separately for Tasks 2 and 3 (translation of a sentence from pictograms and translation of a pictogram in a verbal context). In these tasks, no influence of the AAC system on the parameters of fixation duration was found: $\chi^2(2) = 3.90$; $p = 0.142$; $\varepsilon^2 = 0.0887$. It can be assumed that the graphical representation of pictograms in one or another AAC system does not directly affect the mechanism of direct cognitive control.

The influence of the part of speech to which the verbal equivalent of the pictograms of various AAC systems belongs on the parameters of oculomotor activity of subjects with intellectual disorder was studied. Only Tasks 1 and 3 were taken for analysis. One-way ANOVA did not reveal a reliable influence of the part of speech on any parameter of oculomotor activity.

In conclusion, the influence of the presence of a human figure in the graphic representation of pictograms, as well as repetitions from Task 1, on the parameters of oculomotor activity during the interaction of subjects with intellectual disorder with Task 3 was investigated. No statistically significant influence of these factors was found.

Chapter 4. Basic recommendations for developing alternative communication skills in cases of intellectual disorder

Based on the results of the study, recommendations were formulated for the use of pictographic AACs in working with students with mild intellectual disorder. Teachers-psychologists of general education correctional schools and psychological and pedagogical centers for correction and rehabilitation are recommended to use alternative and additional communication technologies in everyday navigation and communication to compensate for speech disorders.

Educational psychologists and parents of individuals with intellectual disorder are advised to use an individual approach when choosing alternative communication tools for a child. Individual characteristics that must be taken into account when using pictographic alternative communication include the level of intellectual development, preferences in perceiving visual information, and the presence of additional secondary disorder.

Regular assessment of the progress of students with intellectual disorder in the use of pictographic communication allows for the adjustment of teaching methods and materials, as well as the identification of successes and difficulties, which is important for optimizing the development of communication skills. To improve the effectiveness of correctional interventions using graphic alternative means of communication, special attention should be paid to the graphic representativeness of pictograms.

In the process of selecting symbols for pictographic alternative communication, it is recommended to take into account the phenomenology of psychological concepts of perception of alternative communication in cases of intellectual disorder (Fig. 17).

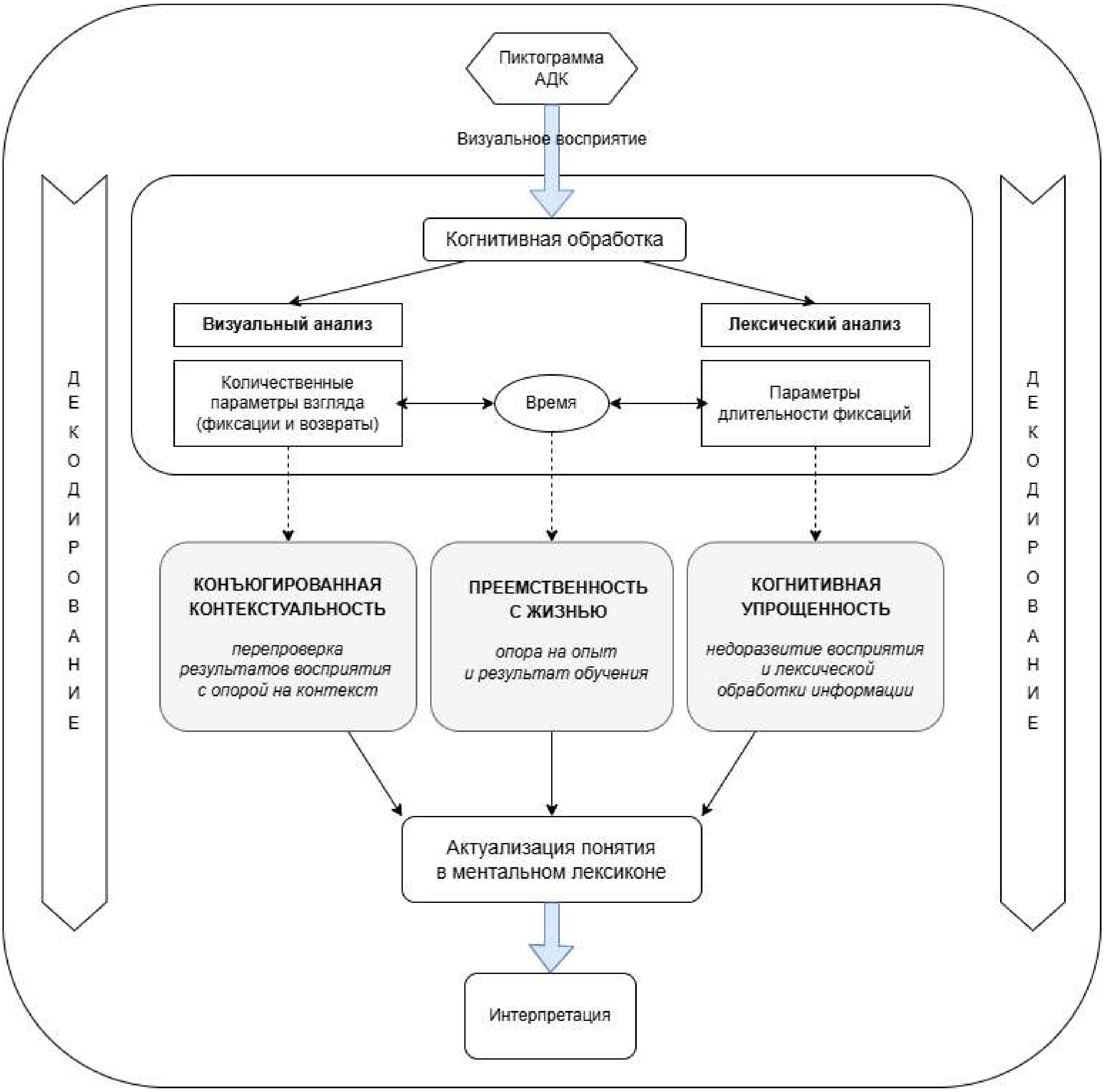


Figure 17. Prognostic model of the phenomenology of psychological concepts of perception of the AAC in intellectual disorder

Note: "Когнитивная упрощенность" – Cognitive simplification; "Конъюгированная контекстуальность" – Conjugated contextuality; "Преемственность с жизнью" – Continuity with life.

In the prognostic model, three psychological concepts of perception of the AAC pictograms in the process of their decoding in intellectual disorder can be distinguished. *Cognitive simplification* is associated with the peculiarities of the cognitive sphere in intellectual disorder and is expressed in the reduced duration of gaze fixations on pictograms, which reflects the reduced time of activation of lexical processing and actualization of the verbal referent in the mental lexicon in the perception of AAC pictograms. Impaired pictogram decoding in adolescents with intellectual disorder is associated with underdevelopment of lexical activity. Pictograms visually close to the referent reduce the cognitive complexity of processing visual stimuli. Taking into account intellectual disorder, it is not recommended to use visually overloaded symbols, especially in the representation of noun concepts, since a complex graphic representation can complicate visual perception and cognitive processing.

Conjugated contextuality is based on a greater number of fixations and gaze returns during the process of decoding pictograms. This effect is associated with rechecking the decoding results depending on the context. When decoding pictograms in a verbal context, a longer viewing, a greater number of returns to the pictogram, a greater number of fixations on the pictogram may be associated with reading difficulties in some adolescents with intellectual disorder. In the case where the text is additionally burdened with a symbol of a different property, i.e. a pictogram, the process of perception and decoding of the symbol itself is complicated. If it is impossible to intuitively grasp the meaning of a sentence with one word replaced by a pictogram, further attempts to guess the meaning of the pictogram are more likely to entail an answer different from the meaning prescribed by the pictographic system. Difficulties may be caused either by the graphic features of specific pictograms, the perception of which increases the cognitive load and which in some cases are not subject to rapid cognitive processing, or by the fact of an error in reading the verbal context. Thus, the violation of pictogram decoding in adolescents with intellectual disorder is associated with the underdevelopment of voluntary regulation of mental processes.

Continuity with life helps to reduce the time of cognitive processing of familiar visual symbols of public spaces. Graphic representation of public signs activates the process of lexical processing in adolescents with intellectual disorder to the least extent, therefore, it is perceived as a "gestalt" with a conditional specific meaning. In the framework of adapted basic educational programs for adolescents with intellectual disorder, it is recommended to pay special attention to the study of prohibitory, warning and other public safety signs.

Psychological and pedagogical correction of communication in cases of intellectual disorder using AAC can include the integration of pictographic communication into the daily activities of students, including games, educational and social interactions, thereby promoting the natural use of alternative communication and helping to develop communication skills in real situations.

FINDINGS

In the empirical part of the study, one main and three partial hypotheses were tested. Based on the results of the study, the following conclusions were formulated:

1. The developed associative technique allows us to conduct studies of the perception of pictograms as components of the AAC using the oculography method and to make statistically significant conclusions about the ability of individuals with intellectual disorder to decode pictograms in a verbal context, which is confirmed by a sufficient degree of internal consistency of the stimulus material.

2. The specificity of decoding pictograms as a component of the AAC in the context of various cognitive tasks by adolescents with intellectual disorder is characterized by a violation of interpretations compared to normally developing adolescents.

3. The parameters of oculomotor activity differ significantly in adolescents with different levels of intelligence development. The process of lexical processing during the perception of pictograms is less pronounced in the experimental group due to the specificity of the implementation of cognitive processes, which is expressed in the reduced duration of fixations.

4. Activation of lexical processing in intellectual disorder is associated with time spent on cognitive processing, more detailed scanning, and more backtracking to match connections and recheck perceptual results.

5. The decoding result of pictograms by adolescents with intellectual disorder is interconnected with the parameters of oculomotor activity. When perceiving pictograms in a verbal context, a greater number of fixations and returns, longer viewing, and a longer duration of the first fixation are interconnected with incorrect interpretation of pictograms. If it is impossible to intuitively and quickly grasp the meaning of a pictogram, further attempts are more likely to result in an incorrect answer.

6. Graphic representativeness of the AAC pictograms influences the success of their decoding. The success of decoding of pictograms of the iconic Pictogram system by

adolescents with intellectual disorder is significantly higher than that of pictograms of the simplified schematic Blissymbols system.

7. Graphic representativeness of the AAC pictograms influences the parameters of oculomotor activity in perception by persons with intellectual disorder. Viewing time, average number of returns and average number of fixations on pictograms are more pronounced in relation to the pictograms of the simplified schematic Blissymbols system, which indicates the cognitive complexity of this AAC system.

8. The number of erroneous interpretations of public signs is associated with a large number of fixations and returns, and longer viewing. When perceiving a familiar symbol, a teenager selects its interpretation more quickly and purposefully. Difficulties in decoding are associated with long detailed viewing, which most likely entails a distortion of the generally accepted meanings of pictograms.

9. In case of intellectual disorder, the duration of fixations is shorter when perceiving signs of public spaces. Their graphic representation activates the process of lexical processing in adolescents with intellectual disorder to the least extent.

10. The factor of belonging of a specific pictogram to nouns or verbs, graphic representation of a human figure, as well as repetition of unfamiliar pictograms during the implementation of various cognitive tasks does not affect the success of decoding and the parameters of oculomotor activity of adolescents with intellectual disorder.

11. Psychological concepts in the perception of pictograms by adolescents with intellectual disorder are characterized by cognitive simplification, conjugated contextuality and the significance of continuity with life.

12. Cognitive simplification is associated with the characteristics of the cognitive sphere in cases of intellectual disorder and is expressed in the reduced duration of gaze fixations on pictograms.

13. Conjugated contextuality is based on a greater number of fixations and gaze returns during the decoding of icons. This effect is associated with rechecking the decoding results depending on the context.

14. Continuity with life helps to reduce the time it takes to cognitively process familiar visual symbols of public spaces.

15. Psychological concepts of perception of pictograms in adolescents with intellectual disorder are determined by the underdevelopment of lexical activity and voluntary regulation of mental processes.

16. In correctional and pedagogical practice, it is recommended to base the selection of communicative symbols for persons with intellectual disorder on an individual approach. Preference should be given to simpler and more iconic pictograms, taking into account their interconnection with everyday life.

CONCLUSION

The results obtained in the study reflect the specifics of the perception of pictograms as elements of alternative and additional communication by persons with intellectual disorder.

A theoretical review of Russian and foreign studies points to the relevance of AAC interventions in correctional and psychological work with children and adolescents with intellectual disorder and highlights the cognitive characteristics of intellectual disorder that affect the perception and decoding of pictograms.

The cognitive sphere in cases of intellectual disorder is characterized by a decrease volume of perception and reduced speed of information processing, which in combination with speech disorders affects communicative competence. A necessary condition for socialization is the creation of an inclusive environment that takes into account the special needs of people with different health capabilities. With regard to intellectual disorder, pictographic means of communication that replace or supplement oral or written speech are considered a correctional and pedagogical technology that requires a scientifically based approach.

Experimental methods that allow assessing cognitive load during visual perception, such as oculography, can serve as an effective research tool. In this study, existing scientific concepts of lexical processing activation in response to visual stimuli contributed to complementing scientific concepts of cognitive processes during perception of graphic systems of the AAC by individuals with intellectual disorder.

Graphic symbols as elements of alternative and additional communication are the subject of special attention when choosing communicative signs in individual correctional and pedagogical work with people with reduced intellectual abilities, as well as in organizing the social and educational environment (Belimova P.A., 2023; Belimova P.A., Zashchirinskaia O.V., Shcheglova N.A., 2022; Belimova P.A., Zashchirinskaia O.V., 2022; Belimova P.A., 2022; Shcheglova N., Belimova P., 2021 (1, 2, 3); Belimova P.A., Shcheglova N.A., 2020; Zashchirinskaia O.V., Belimova P.A., 2020). Communicative sign systems can be implemented in the everyday life of students with intellectual disorder, including in digital format, which makes them more accessible and convenient to use (Belimova P.A., Zhalimova S.B., Dzhumagulova A.F., 2020; Belimova P.A., Miklyaeva A.V., 2024). The decisive role is played by the graphic representation of the symbol, expressed in such parameters as recognition, clarity, schematicity and semantics. Studying the sign effects that influence the perception and decoding of symbols in intellectual disorder will contribute to the creation of an inclusive environment that matches the cognitive abilities of all members of society, in particular those with intellectual disorder.

The diversity in the representation of concepts in different communication systems and navigation systems of public spaces can cause difficulties in their decoding by persons with intellectual disorder. There is a need for pictographic systems based on the principles of iconicity and obviousness and, on this basis, optimally represented graphically (Zashchirinskaia O.V., Belimova P.A. 2024). The role of understanding (in addition to memorization) in the correct interpretation of pictograms by persons with intellectual disorder is fundamental for the assimilation of unfamiliar symbols encountered in the modern social and digital environment. Training in the recognition of socially significant symbols for orientation and communication is important in the practical activities of specialists to improve the quality of life of persons with intellectual disorder. At the same time, the role of the social environment and cultural education is extremely important for the development of a person with intellectual disorder: they can either contribute to its compensation or lead to a further decrease in the indicators of the development of social intelligence and cultural skills (Zashchirinskaia O.V., Belimova P.A., 2022).

Comparison of the results of the associative technique for decoding pictograms in the control and experimental groups allowed us to obtain reliable differences in the parameters of the duration of gaze fixations and in the number of "correct" answers. The concept of "correct" answers here and below refers to the meanings that are assigned to pictograms by the authors of a particular alternative communication system. However, the interpretation of the meanings of pictograms by the subjects cannot be interpreted according to absolutely objective indicators of correctness, since the pictographic sign itself does not have a strictly determined meaning, but only reflects individual subjective experience (Khersonsky B.G., 2003).

The results of the study confirm the assertion about a certain degree of passivity of thinking of persons with intellectual disorder when presented with visual stimuli (Zashchirinskaia O.V., 2020), which is evidence of a violation of the cognitive component of thinking in this group of subjects (Zashchirinskaia O.V., Gorbunov I.A. 2009).

Considering the fact that the duration of the first fixation can modulate the complexity of lexical processing, delaying new saccadic programs and providing additional time for vocabulary processing (Rayner K., Reingold E.M., 2015), it can be assumed that the mechanism of direct cognitive control in the perception of pictograms is less pronounced in the experimental group due to the specificity of the implementation of cognitive processes. Lexical processing takes less time due to the difficulty of activating the mental dictionary. The same fact explains the smaller number of correct responses to the stimuli of the associative technique in the group of adolescents with intellectual disorder compared to the group of normo- typical adolescents (Belimova P.A., 2024).

Further research results on this issue will contribute to understanding the features of logical-figurative thinking of adolescents with mild mental retardation in order to develop social rehabilitation programs. A promising direction for further research in this area is the study of mnemonic activity and other mental processes associated with the perception of graphic symbols, as well as the features of the perception of digital content containing graphic symbols, to comply with the conditions of safety and accessibility of digital services and services for people with intellectual disorder.

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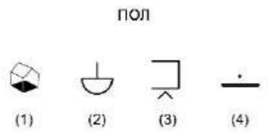
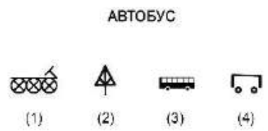
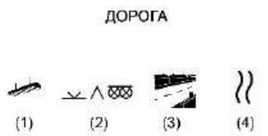
APPENDIX A

Stimulus material for the author's tasks on decoding pictograms as a component of the AAC.

Table A.1. Stimuli for Task 1 (selecting an extra pictogram that does not correspond to the verbal referent).

Incentive code	Stimulus content	Description of the stimulus
Training stimulus		(1) - "Girl", Bliss (2) - "Girl", Pictogram (3) *– “Read”, Pictogram (4) - "Girl", LoCoS
1 Q1 "Floor"		(1) - "Paul", Pictogram (repeat in Task 3) (2) *– "Ship", Bliss (repeat in Task 3) (3) - "Paul", Bliss (repeat in Task 3) (4) – “Paul”, LoCoS (variation “here+place”, repeat in Task 3)
1Q2 "Bus"		(1) - "Bus", Bliss (repeat in Task 3) (2) *– “Coniferous tree”, LoCoS (3) - "Bus", Pictogram (repeat in Task 3) (4) - "Bus", LoCoS (repeat in Task 3)
1Q3 "Road"		(1) *– “Lamp”, Pictogram (repeat in Task 3) (2) - "The Road", Bliss (3) – “Road”, Pictogram (4) - "Road", LoCoS
1Q4 "Carry"		(1) - "Carry", Pictogram (2) - "Carry", Bliss (3) *– “Family”, Bliss (4) - "Carry", LoCoS
1Q5 "Hear"		(1) - "Hear", LoCoS (repeat in Task 3) (2) – “Hear”, Pictogram (repeat in Task 3) (3) - "Hear", Bliss (repeat in Task 3) (4) *– “Sit”, LoCoS (repeat in Task 3)
1Q6 "See"		(1) - "See", Pictogram (repeat in Task 3) (2) *– “Fall”, Pictogram (repeat in Task 3) (3) - "See", Bliss (repeat in Task 3) (4) - "See", Pictogram (repeat in Task 3)

Note: * – “extra” pictogram, correct answer to the task

Table A.2. Stimuli for Task 2 (translation of a sentence from pictograms).

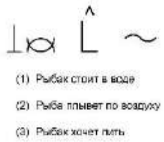
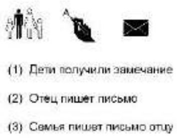
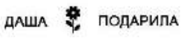
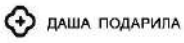
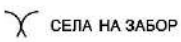
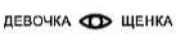
Incentive code	Stimulus content	Description of the stimulus
Training stimulus		LoCoS "correct answer" - (1) variation "place"
2 Q1		Bliss "correct answer" - (1)
2Q2		LoCoS "correct answer" - (2) variation "place"
2Q3		Pictogram "correct answer" - (2)
2Q4		LoCoS "correct answer" - (1)
2Q5		Pictogram "correct answer" - (2)
2Q6		Bliss "correct answer" - (3)
2Q7		Bliss "correct answer" - (3)
2Q8		Pictogram "correct answer" - (3)
2Q9		LoCoS "correct answer" - (2)

Table A.3. Stimuli for Task 3 (translation of a pictogram in a verbal context).

Incentive code	Stimulus content	Description of the stimulus
Training stimulus	 КАПАЕТ ИЗ КРАНА	LoCoS – «Water» "Water dripping from the tap"
Nouns		
3Q1	 ЕДЕТ ПО ДОРОГЕ	Bliss – «Bus» "The bus is driving along the road" Repeat in Task 1
3Q2	ЕДЕТ  ПО ДОРОГЕ	Pictogram – "Bus" "A bus is driving along the road" Repeat in Task 1
3Q3	ЕДЕТ ПО ДОРОГЕ 	LoCoS – «Bus» "A bus is driving along the road" Repeat in Task 1
3Q4	НА  ЛЕЖИТ КНИГА	Pictogram – «Gender» "There is a book on the floor" Repeat in Task 1
3Q5	ЛЕЖИТ НА  КНИГА	Bliss – «Paul» "There is a book on the floor" Repeat in Task 1
3Q6	ЛЕЖИТ КНИГА НА 	LoCoS – "Paul" "There is a book on the floor" Repeat in Task 1
3Q7	 ПЛЫВЕТ ПО МОРЮ	Bliss – «Boat» "The boat is sailing on the sea" Repeat in Task 1
3Q8	ПЛЫВЕТ  ПО МОРЮ	LoCoS – "Boat" "A boat is sailing on the sea"
3Q9	ПЛЫВЕТ ПО МОРЮ	Pictogram – «Boat» "A boat is sailing on the sea"
3Q10	ВИСИТ  НАД ДВЕРЬЮ	Pictogram – «Lamp» "There is a lamp hanging above the door" Repeat in Task 1
3Q11	 ВИСИТ НАД ДВЕРЬЮ	Bliss – «Lamp» "The lamp hangs above the door"

3Q12		LoCoS – «Lamp» "There is a lamp hanging above the door"
3Q13		Pictogram – «Flower» "Dasha gave me a flower"
3Q14		Bliss – «Flower» "Dasha gave me a flower"
3Q15		LoCoS – "Flower" "Dasha gave me a flower"
3Q16		Pictogram – «Bird» "A bird sat on the fence"
3Q17		Bliss – «Bird» "The bird sat on the fence"
3Q18		LoCoS – «Bird» "A bird sat on the fence"
Verbs		
3Q19		LoCoS – "Listen" "Petya listens to music" Repeat in Task 1
3Q20		Bliss – «Listen» "Petya listens to music" Repeat in Task 1
3Q21		Pictogram – "Listen" "Petya is listening to music" Repeat in Task 1
3Q22		Bliss – «See» "The girl sees the puppy" Repeat in Task 1
3Q23		LoCoS – «See» "Girl sees a puppy" Repeat in Task 1

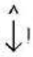
3Q24	 ДЕВОЧКА ЩЕНКА	Pictogram – “See” "The girl sees a puppy" Repeat in Task 1
3Q25	ЛИСТОК НА ВОДУ 	Pictogram – «Fall» "A leaf fell on the water" Repeat in Task 1
3Q26	 ЛИСТОК НА ВОДУ	LoCoS – «Fall» "A leaf fell on the water"
3Q27	ЛИСТОК  НА ВОДУ	Bliss – «Fall» "A leaf fell on the water"
3Q28	БЕЛКА  НА ДЕРЕВЕ	LoCoS – «Sit» "A squirrel sits on a tree" Repeat in Task 1
3Q29	БЕЛКА НА ДЕРЕВЕ 	Bliss – «Sit» "A squirrel sits on a tree"
3Q30	 БЕЛКА НА ДЕРЕВЕ	Pictogram – “Sit” "A squirrel is sitting on a tree"
3Q31	МАША  ЕДУ	Pictogram – “Cooking” "Masha is cooking"
3Q32	МАША ЕДУ 	Bliss – «Cooking» "Masha is cooking"
3Q33	 МАША ЕДУ	LoCoS – “Cook” "Masha is cooking food"
3Q34	 КОЛЯ КЛЮЧИ	Pictogram – «Search» "Kolya is looking for the keys"
3Q35	КОЛЯ  КЛЮЧИ	Bliss – «Search» "Kolya is looking for the keys"
3Q36	КОЛЯ КЛЮЧИ 	LoCoS – «Search» "Kolya is looking for the keys"

Table A.4. Stimuli for Task 4 (decoding of public signs).

Incentive code	Stimulus content	Description of the stimulus
Training stimulus	 (1) Выход (2) Убегать (3) Дверь	"Exit" The correct answer is (1)
4Q 1	 (1) Мальчик и девочка (2) Туалет (3) Друзья	"Toilet" The correct answer is (2)
4Q 2	 (1) Велосипед (2) Мальчик сидит (3) Места для инвалидов	"Places for the disabled" The correct answer is (3)
4Q 3	 (1) Выход (2) Человек бежит (3) Лестница вниз	"Stairs Down" The correct answer is (3)
4Q 4	 (1) Скользкий пол (2) Мальчик упал (3) Катание с горки	"Slippery Floor" The correct answer is (1)
4Q 5	 (1) Ходить нельзя (2) Пешеходный переход (3) Людей нет	"You can't walk" The correct answer is (1)
4Q 6	 (1) Бегать нельзя (2) Опасный выход (3) Нет выхода	"No way out" The correct answer is (3)
4Q 7	 (1) Велосипедная парковка (2) Прокат велосипедов (3) Осторожно, велосипед	"Bike" Does not comply with GOST, The conditionally "correct" answer is (3)

4Q 8	 (1) Пожар (2) Огнетушитель (3) Жидкость для розжига	"Fire extinguisher" The correct answer is (2)
4Q9	 (1) Часто бывают молнии (2) Осторожно, электричество (3) Яркий свет	"Beware of electricity" The correct answer is (2)
4Q10	 (1) Перекресток (2) Церковь (3) Медпункт	"First aid station" The correct answer is (3)
4Q11	 (1) Нужна помощь (2) Быстрый вызов (3) Звонок	"Need help" The correct answer is (1)

Задание 1

Ты прочтешь на экране одно слово.

Ниже появятся 4 картинки:
три из них соответствуют слову, а одна — **лишняя.**
Найди **лишнюю** картинку и назови ее номер вслух.

На каждый слайд дано 30 секунд. После этого слайд переключится сам.
Нажми "*пробел*" для того, чтобы увидеть **пример**.

a)

Задание 2

Ты увидишь предложение, которое написано с помощью картинок.

Ниже будут три варианта перевода этого предложения.
Выбери **правильный** перевод и назови его номер вслух.

На каждый слайд дано 25 секунд.
После этого слайд переключится сам.

Нажми "*пробел*" для того, чтобы увидеть **пример**.

b)

Задание 3

Ты прочтешь предложение, где одно слово заменили на картинку.

Отгадай слово и правильно **прочитай** предложение вслух.

На каждый слайд дано 20 секунд.
После этого слайд переключится сам.

Нажми "*пробел*" для того, чтобы увидеть **пример**.

c)

Задание 4

Ты увидишь серию цветных картинок.
Некоторые из них могут быть тебе знакомы.

К каждой картинке подбери **правильное** обозначение и назови его номер вслух.

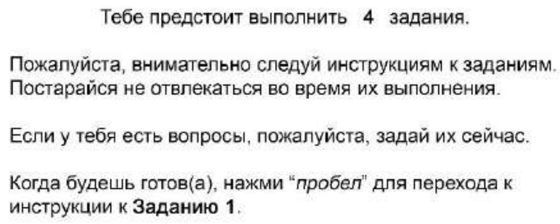
На каждый слайд дано 20 секунд.
После этого слайд переключится сам.

Нажми "*пробел*" для того, чтобы увидеть **пример**.

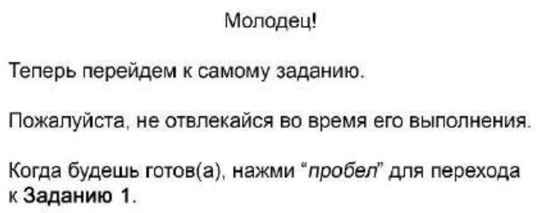
d)

Figure A.1. Instructions for participants for Task 1 (a), Task 2 (b), Task 3 (c), Task 4 (d).

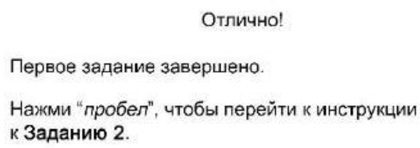
a)



b)



c)



d)

Figure A.2. General instructions for participants: a) – first testing screen, b) – second testing screen, c) – screen after working with the test stimuli, d) – screen after finishing working with all task stimuli.

APPENDIX B

Table B.1. Descriptive statistics for the number of total "correct" answers in the control and experimental groups

	Group	Task_1	Task_2	Task_3	Task_4	Overall score
N	INT. DIS.	92	92	92	92	92
	Norm	92	92	89	92	88
Missed	INT. DIS.	0	0	0	0	0
	Norm	0	0	3	0	0
Average	INT. DIS.	3.57	3.82	22.8	8.17	38.4
	Norm	4.47	4.63	27.2	8.90	45.1
Standard Error of the Mean	INT. DIS.	0.176	0.164	0.466	0.187	0.669
	Normal	0.114	0.183	0.327	0.130	0.479
Median	INT. DIS.	4.00	4.00	23.0	8.00	39.0
	Normal	5.00	4.00	27.0	9.00 a.m	45.0
Fashion	INT. DIS.	4.00	4.00	21.0	8.00	39.0
	Normal	5.00	4.00	27.0	10.0	44.0
Standard removal	INT. DIS.	1.69	1.57	4.47	1.80	6.42
	Normal	1.09	1.75	3.09	1.25	4.49
Dispersion	INT. DIS.	2.86	2.46	20.0	3.22	41.2
	Normal	1.20	3.07	9.54	1.56	20.2
Range	INT. DIS.	6	7	24.0	9	42
	Normal	6	9	17.0	5	25
The minimum	INT. DIS.	0	1	8.00	2	15
	Normal	0	0	17.0	6	30
The maximum	INT. DIS.	6	8	32.0	11	57
	Normal	6	9	34.0	11	55
Asymmetry	INT. DIS.	-0.469	0.313	-0.554	-1.11	-0.676
	Normal	-0.867	-0.0158	-0.637	-0.433	-0.645
Standard Error of Skewness	INT. DIS.	0.251	0.251	0.251	0.251	0.251
	Normal	0.251	0.251	0.255	0.251	0.257
Excess	INT. DIS.	-0.493	-0.222	1.01	1.64	2.20
	Normal	1.94	-0.410	1.31	-0.400	1.56
Standard Error of Kurtosis	INT. DIS.	0.498	0.498	0.498	0.498	0.498
	Normal	0.498	0.498	0.506	0.498	0.508
Shapiro- Wilk W	INT. DIS.	0.929	0.951	0.969	0.897	0.956

	Group	Task_1	Task_2	Task_3	Task_4	Overall score
	Normal	0.884	0.963	0.959	0.917	0.960
Shapiro- Wilk p	INT. DIS.	< .001	0.002	0.026	< .001	0.003
	Normal	< .001	0.011	0.006	< .001	0.008

Table B.2. Descriptive statistics for the number of "correct" answers to Task 3 (translation of a pictogram in a verbal context) in the control and experimental groups.

	Group	N	Medium	SD	SE
3Q1	INT. DIS.	91	0.725	0.449	0.0471
	Normal	89	0.697	0.462	0.0490
3Q2	INT. DIS.	93	0.989	0.104	0.0108
	Normal	89	1,000	0.000	0.0000
3Q3	INT. DIS.	93	0.860	0.349	0.0362
	Normal	88	0.852	0.357	0.0380
3Q4	INT. DIS.	92	0.402	0.493	0.0514
	Normal	89	0.809	0.395	0.0419
3Q5	INT. DIS.	91	0.165	0.373	0.0391
	Normal	89	0.315	0.467	0.0495
3Q6	INT. DIS.	91	0.132	0.340	0.0357
	Normal	89	0.258	0.440	0.0467
3Q7	INT. DIS.	93	0.796	0.405	0.0420
	Normal	89	0.910	0.288	0.0305
3 Q8	INT. DIS.	91	0.835	0.373	0.0391
	Normal	88	0.943	0.233	0.0248
Q9	INT. DIS.	93	0.989	0.104	0.0108
	Normal	87	0.989	0.107	0.0115
3Q10	INT. DIS.	90	0.744	0.439	0.0462
	Normal	89	0.876	0.331	0.0351
3Q11	INT. DIS.	89	0.135	0.343	0.0364
	Normal	89	0.157	0.366	0.0388
3Q12	INT. DIS.	92	0.826	0.381	0.0397
	Normal	89	0.820	0.386	0.0409
3Q13	INT. DIS.	93	0.968	0.178	0.0184
	Normal	89	0.989	0.106	0.0112
3Q14	INT. DIS.	91	0.198	0.401	0.0420
	Normal	88	0.239	0.429	0.0457

	Group	N	Medium	SD	SE
3Q15	INT. DIS.	90	0.544	0.501	0.0528
	Normal	89	0.674	0.471	0.0500
3Q16	INT. DIS.	93	0.989	0.104	0.0108
	Normal	89	1,000	0.000	0.0000
3Q17	INT. DIS.	81	0.481	0.503	0.0559
	Normal	88	0.727	0.448	0.0477
3Q18	INT. DIS.	87	0.655	0.478	0.0513
	Normal	89	0.809	0.395	0.0419
3Q19	INT. DIS.	90	0.933	0.251	0.0264
	Normal	89	0.989	0.106	0.0112
3Q20	INT. DIS.	91	0.912	0.285	0.0298
	Normal	88	0.966	0.183	0.0195
3Q21	INT. DIS.	93	0.957	0.204	0.0212
	Normal	89	1,000	0.000	0.0000
3Q22	INT. DIS.	90	0.367	0.485	0.0511
	Normal	89	0.472	0.502	0.0532
3Q23	INT. DIS.	93	0.720	0.451	0.0468
	Normal	88	0.670	0.473	0.0504
3Q24	INT. DIS.	91	0.516	0.502	0.0527
	Normal	88	0.443	0.500	0.0533
3Q25	INT. DIS.	91	0.791	0.409	0.0428
	Normal	89	0.978	0.149	0.0158
3Q26	INT. DIS.	90	0.744	0.439	0.0462
	Normal	89	0.966	0.181	0.0192
3Q27	INT. DIS.	93	0.774	0.420	0.0436
	Normal	89	0.989	0.106	0.0112
3Q28	INT. DIS.	92	0.761	0.429	0.0447
	Normal	88	0.920	0.272	0.0290
3Q29	INT. DIS.	89	0.517	0.503	0.0533
	Normal	87	0.770	0.423	0.0454
3Q30	INT. DIS.	90	0.833	0.375	0.0395
	Normal	89	0.989	0.106	0.0112
3Q31	INT. DIS.	92	0.793	0.407	0.0424
	Normal	89	0.888	0.318	0.0337
3Q32	INT. DIS.	89	0.393	0.491	0.0521
	Normal	88	0.568	0.498	0.0531
3Q33	INT. DIS.	93	0.731	0.446	0.0462

	Group	N	Medium	SD	SE
	Normal	89	0.899	0.303	0.0321
3Q34	INT. DIS.	92	0.565	0.498	0.0520
	Normal	89	0.798	0.404	0.0428
3Q35	INT. DIS.	91	0.286	0.454	0.0476
	Normal	89	0.337	0.475	0.0504
3Q36	INT. DIS.	92	0.337	0.475	0.0495
	Normal	88	0.591	0.494	0.0527

APPENDIX C

Table C.1. Comparative analysis of the responses of subjects from the control and experimental groups to Task 1 (selecting the “extra” pictogram).

Stimulus	Student t	df	p	Difference in averages	Standard Error Difference (SE)	Effect size
"Floor"	-2.17	181	0.032	-0.1578	0.0728	-0.320
"Bus"	-4.12	181	< .001 *	-0.2168	0.0526	-0.609
"Road"	-2.38	182	0.018	-0.1739	0.0730	-0.351
"Carry"	-1.19	182	0.236	-0.0870	0.0732	-0.175
"Hear"	-3.39	182	< .001 *	-0.1413	0.0416	-0.500
"See"	-2.20	182	0.029	-0.1304	0.0592	-0.325

Table C.2. Comparative analysis of the responses of subjects from the control and experimental groups to Task 2 (translation of a sentence from pictograms)

Stimulus	Student t	df	p	Difference in averages	Standard Error Difference (SE)	Effect size
2Q1	-1.4880	182	0.138	-0.10870	0.0730	-0.2194
2Q2	-3.3172	182	0.001 *	-0.22826	0.0688	-0.4891
2Q3	-1.2940	182	0.197	-0.08696	0.0672	-0.1908
2Q4	-0.2136	181	0.831	-0.01577	0.0738	-0.0316
2Q5	-3.5653	182	< .001 *	-0.25000	0.0701	-0.5257
2Q6	0.0708	181	0.944	0.00526	0.0743	0.0105
2Q7	0.0000	182	1.000	0.00000	0.0562	0.0000
2Q8	-2.0955	182	0.038	-0.15217	0.0726	-0.3090
2 Q9	0.1515	182	0.880	0.01087	0.0718	0.0223

Table C.3. Comparative analysis of the responses of subjects from the control and experimental groups to Task 3 (translation of a pictogram in a verbal context).

Stimulus	Student t	df	p		Difference in averages	Standard Error Difference (SE)	Effect size
3Q1	0.4218	178	0.674		0.02865	0.0679	0.06288
3Q2	-0.9781	180	0.329		-0.01075	0.0110	-0.14504
3Q3	0.1514	179	0.880		0.00794	0.0524	0.02252
3Q4	-6.1121	179	< .001	*	-0.40681	0.0666	-0.90875
3Q5	-2.3799	178	0.018		-0.14977	0.0629	-0.35480
3Q6	-2.1608	178	0.032		-0.12656	0.0586	-0.32214
3Q7	-2.1872	180	0.030		-0.11441	0.0523	-0.32434
3Q8	-2.3147	177	0.022		-0.10802	0.0467	-0.34607
3Q9	0.0472	178	0.962		7.42e-4	0.0157	0.00704
3Q10	-2.2701	177	0.024		-0.13196	0.0581	-0.33936
3Q11	-0.4223	176	0.673		-0.02247	0.0532	-0.06330
3Q12	0.1028	179	0.918		0.00586	0.0570	0.01528
3Q13	-0.9641	180	0.336		-0.02102	0.0218	-0.14296
3Q14	-0.6587	177	0.511		-0.04083	0.0620	-0.09849
3Q15	-1.7840	177	0.076		-0.12971	0.0727	-0.26669
3Q16	-0.9781	180	0.329		-0.01075	0.0110	-0.14504
3Q17	-3.3607	167	< .001	*	-0.24579	0.0731	-0.51747
3Q18	-2.3284	174	0.021		-0.15382	0.0661	-0.35104
3Q19	-1.9219	177	0.056		-0.05543	0.0288	-0.28730
3Q20	-1.5000	177	0.135		-0.05382	0.0359	-0.22426
3Q21	-1.9890	180	0.048		-0.04301	0.0216	-0.29494
3Q22	-1.4270	177	0.155		-0.10524	0.0737	-0.21333
3Q23	0.7277	179	0.468		0.04998	0.0687	0.10822
3Q24	0.9785	177	0.329		0.07330	0.0749	0.14629
3Q25	-4.0455	178	< .001	*	-0.18632	0.0461	-0.60311
3Q26	-4.4125	177	< .001	*	-0.22185	0.0503	-0.65963
3Q27	-4.6747	180	< .001	*	-0.21457	0.0459	-0.69319
3Q28	-2.9657	178	0.003		-0.15958	0.0538	-0.44220
3Q29	-3.6124	174	< .001	*	-0.25326	0.0701	-0.54462
3Q30	-3.7664	177	< .001		-0.15543	0.0413	-0.56304
3Q31	-1.7313	179	0.085		-0.09416	0.0544	-0.25741
3Q32	-2.3521	175	0.020		-0.17492	0.0744	-0.35360
3Q33	-2.9546	180	0.004		-0.16769	0.0568	-0.43813
3Q34	-3.4415	179	< .001	*	-0.23254	0.0676	-0.51168
3Q35	-0.7412	178	0.460		-0.05136	0.0693	-0.11050
3Q36	-3.5134	178	< .001	*	-0.25395	0.0723	-0.52388

Table C.4. Comparative analysis of the responses of subjects from the control and experimental groups to Task 4 (decoding public signs).

Stimulus	Student t	df	p		Difference in averages	Standard Error Difference (SE)	Effect size
Q2	-2.521	180	0.013		-0.06593	0.0262	-0.3737
Q3	-2.570	182	0.011		-0.17391	0.0677	-0.3790
Q4	-2.417	182	0.017		-0.07609	0.0315	-0.3564
Q5	-2.100	182	0.037		-0.09783	0.0466	-0.3097
Q6	-3.763	182	< .001	*	-0.26087	0.0693	-0.5548
Q7	0.987	181	0.325		0.06928	0.0702	0.1460
Q8	0.194	181	0.846		0.00956	0.0493	0.0287
Q9	-1.921	181	0.056		-0.05423	0.0282	-0.2840
Q10	-1.023	182	0.308		-0.03261	0.0319	-0.1508
Q11	1.645	180	0.102		0.12150	0.0739	0.2438

APPENDIX D

Frequency analysis of Task 1 (choosing the odd pictogram) for a group with intellectual disorder. "Correct" answers are marked*.

Frequencies "Floor"

"Floor"	Counters	% of total	Accumulated %
1	14	15.4%	15.4%
2*	44	48.4%	63.7%
3	24	26.4%	90.1%
4	9	9.9%	100.0%

Frequencies "Bus"

"Bus"	Counters	% of total	Accumulated %
1	12	13.0%	13.0%
2*	67	72.8%	85.9%
3	10	10.9%	96.7%
4	3	3.3%	100.0%

Frequencies "Road"

"Road"	Counters	% of total	Accumulated %
1*	37	40.2%	40.2%
2	39	42.4%	82.6%
3	9	9.8%	92.4%
4	7	7.6%	100.0%

Frequencies of "Carry"

"Carry"	Counters	% of total	Accumulated %
1	11	12.0%	12.0%
2	18	19.6%	31.5%
3*	36	39.1%	70.7%
4	27	29.3%	100.0%

Frequencies "Hear"

"Hear"	Counters	% of total	Accumulated %
1	5	5.4%	5.4%
2	10	10.9%	16.3%
4*	77	83.7%	100.0%

Frequencies "See"

"See"	Counters	% of total	Accumulated %
1	6	6.5%	6.5%
2*	67	72.8%	79.3%
3	14	15.2%	94.6%
4	5	5.4%	100.0%

Frequency analysis of Task 2 (translation of a sentence from pictograms) for a group with intellectual disorder. "Correct" answers are marked*

2Q1	Counters	% of total	Accumulated %
1*	47	51.1%	51.1%
2	25	27.2%	78.3%
3	20	21.7%	100.0%

2Q2	Counters	% of total	Accumulated %
1	19	20.7%	20.7%
2*	49	53.3%	73.9%
3	24	26.1%	100.0%

2Q3	Counters	% of total	Accumulated %
1	10	10.9%	10.9%
2*	23	25.0%	35.9%
3	59	64.1%	100.0%

2Q4	Counters	% of total	Accumulated %
1*	40	43.5%	43.5%
2	38	41.3%	84.8%
3	12	13.0%	97.8%

2Q5	Counters	% of total	Accumulated %
1	12	13.0%	13.0%
2*	25	27.2%	40.2%
3	55	59.8%	100.0%

2Q6	Counters	% of total	Accumulated %
1	17	18.5%	18.5%
2	27	29.3%	47.8%
3*	48	52.2%	100.0%

2Q7	Counters	% of total	Accumulated %
1	63	68.5%	68.5%
2	13	14.1%	82.6%
3*	16	17.4%	100.0%

2Q8	Counters	% of total	Accumulated %
1	20	21.7%	21.7%
2	27	29.3%	51.1%
3*	45	48.9%	100.0%

2Q9	Counters	% of total	Accumulated %
1	17	18.5%	18.5%
2*	58	63.0%	81.5%
3	17	18.5%	100.0%

Frequency analysis of Task 4 (decoding social signs) for a group with intellectual disorder. "Correct" answers are marked*

4Q1	Counters	% of total	Accumulated %
1	21	22.8%	22.8%
2 *	69	75.0%	97.8%
3	2	2.2%	100.0%

4Q2	Counters	% of total	Accumulated %
1	2	2.2%	2.2%
2	4	4.4%	6.6%
3 *	85	93.4%	100.0%

4Q3	Counters	% of total	Accumulated %
1	27	29.3%	29.3%
2	10	10.9%	40.2%
3 *	55	59.8%	100.0%

4Q4	Counters	% of total	Accumulated %
1 *	84	91.3%	91.3%
2	7	7.6%	98.9%
3	1	1.1%	100.0%

4Q5	Counters	% of total	Accumulated %
1 *	77	83.7%	83.7%
2	9	9.8%	93.5%
3	6	6.5%	100.0%

4Q6	Counters	% of total	Accumulated %
1	25	27.2%	27.2%
2	22	23.9%	51.1%
3 *	45	48.9%	100.0%

4Q7	Counters	% of total	Accumulated %
1	39	42.9%	42.9%
2	18	19.8%	62.6%
3 *	34	37.4%	100.0%

4Q8	Counters	% of total	Accumulated %
1	10	11.0%	11.0%
2 *	80	87.9%	98.9%
3	1	1.1%	100.0%

4Q9	Counters	% of total	Accumulated %
1	4	4.3%	4.3%
2 *	86	93.5%	97.8%
3	2	2.2%	100.0%

4Q10	Counters	% of total	Accumulated %
1	3	3.3%	3.3%
2	3	3.3%	6.5%
3 *	86	93.5%	100.0%

4Q11	Counters	% of total	Accumulated %
1	53	58.9%	58.9%
2	23	25.6%	84.4%
3	14	15.6%	100.0%

APPENDIX E

Frequency analysis of Task 3 (translation of a pictogram in a verbal context) for a group with intellectual disorder, taking into account the gradation of interpretation levels

Frequencies 3Q4

3 Q4	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	37	40.2%	40.2%
Rep_2		31	33.7%	73.9%
Rep_3		23	25.0%	98.9%
Rep_0		1	1.1%	100.0%

3 Q4. Interpretation level	Students' Answers
Rep_1	On half
Rep_2	On the table, on the closet, on the desk, on the chest of drawers, on the bed, on the sofa
Rep_3	On the house, in the house, on the booth, on the greenhouse, in the attic, on the roof
Rep_0	On the tree

Frequencies 3 Q5

3 Q5	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	15	16.5%	16.5%
Rep_2		71	78.0%	94.5%
Rep_3		3	3.3%	97.8%
Rep_0		2	2.2%	100.0%

3Q5. Interpretation level	Students' Answers
Rep_1	On half
Rep_2	On the table, on the closet, on the desk, on the chest of drawers, on the bed, on the sofa, on the shelf, on the TV, on the nightstand
Rep_3	Under the table, on the surface, on the book, on the side, on the house
Rep_0	Boy, on a piece of paper

Frequencies 3 Q6

3 Q6	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	12	13.2%	13.2%
Rep_2		75	82.4%	95.6%
Rep_3		3	3.3%	98.9%
Rep_0		1	1.1%	100.0%

3 Q6 . Interpretation level	Students' Answers
Rep_1	On half
Rep_2	On the table, on the closet, on the desk, on the chest of drawers, on the bed, on the sofa, on the shelf, on the TV, on the nightstand, on the refrigerator
Rep_3	On the door, on the whale, on the house
Rep_0	Book

Frequencies 3 Q11

3 Q11	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	12	13.5%	13.5%
Rep_2		41	46.1%	59.6%
Rep_3		32	36.0%	95.5%
Rep_0		4	4.5%	100.0%

3 Q11, Interpretation level	Students' Answers
Rep_1	Chandelier, lamp, lantern
Rep_2	Bell, fire safety system, socket, alarm, electrical panel, current, microphone, camera, meter, wires, switch, voltage, intercom
Rep_3	Darts, castle, camera, squirrel, lightning, clock, photograph, decoration, wheel, toy, target, t-shirt, ring, thunder, plate, drawing, dot, lightning, flower, loop, antenna, apple, picture, peephole, circle, feeder, alarm clock
Rep_0	Hanging, dangerous

Frequencies 3Q14

3Q14	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	18	19.8%	19.8%
Rep_2		72	79.1%	98.9%
Rep_0		1	1.1%	100.0%

3Q14. Interpretation level	Students' Answers
Rep_1	Flower, dandelion, rose
Rep_2	Chupa Chups, lollipop, candy, poem, book, person, bird, keys, glasses, doll, ball, gift, song, magnifying glass, friend, picture, rattle, soap bubbles, camera, fish, headphones, ball, net, photo, boy, brush, toy, charger, first aid kit, racket, hook, girlfriend, voice, bee
Rep_0	No answer

Frequencies 3Q17

3Q17	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	39	51.3%	51.3%
Rep_2		3	3.9%	55.3%
Rep_0		34	44.7%	100.0%

3Q17. Interpretation level	Students' Answers
Rep_1	Bird (seagull, crow, chicken, sparrow, swallow, jackdaw, pigeon, tit)
Rep_2	Butterfly, fly
Rep_0	Girl, dog, knees, boy, butt, legs, she, person, nail, Masha, cat, different directions, sat, tree, towel, crooked, me, mouse, fence, sea, girl, squirrel, on high

Frequencies 3Q22

3Q22	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	33	36.7%	36.7%
Rep_2		19	21.1%	57.8%
Rep_3		34	37.8%	95.6%
Rep_0		4	4.4%	100.0%

3Q22. Interpretation level	Students' Answers
Rep_1	She sees, looks, noticed
Rep_2	Searching, found, lost
Rep_3	Raises, took, walks, holds, fed, caught, lifted, strokes, called, walks, surprised, saved, brought, hides, loves, plays, took, gave, hugged, heard
Rep_0	Circle, chicken, puppy, and puppy

Frequencies 3Q25

3Q25	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	72	80.0%	80.0%
Rep_3		5	5.6%	85.6%
Rep_0		13	14.4%	100.0%

3Q25. Interpretation level	Students' Answers
Rep_1	Fell, falls
Rep_3	Floats, lies
Rep_0	Man, boy, spilled

Frequencies 3Q26

3Q26	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	67	74.4%	74.4%
Rep_2		6	6.7%	81.1%
Rep_3		13	14.4%	95.6%
Rep_0		4	4.4%	100.0%

3Q26. Interpretation level	Students' Answers
Rep_1	Fell, falls, landed, dropped, put, landed, throw, flies down, drips, from a height, put
Rep_2	Drowned, drowned, dived
Rep_3	Floats, lies
Rep_0	Paper, inverted, leaf, boat

Frequencies 3Q27

	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	72	78.3%	78.3%
Rep_2		3	3.3%	81.5%
Rep_3		10	10.9%	92.4%
Rep_0		7	7.6%	100.0%

3Q27. Interpretation level	Students' Answers
Rep_1	Fell, falls, dropped, descends, landed, laid, lies, flies, down, threw, dropped, from a height
Rep_2	Dived, drowned
Rep_3	Floats
Rep_0	Turned over, shows, leaf, rose, ship, notebooks, back

Frequencies 3Q29

3Q29	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	46	51.7%	51.7%
Rep_2		28	31.5%	83.1%
Rep_0		15	16.9%	100.0%

3Q29. Interpretation level	Students' Answers
Rep_1	Sits, sat down , sat
Rep_2	Jumps, climbs on top, rises, crawls, jumps, climbs, on top, climbed, crawls
Rep_0	Lives, dances, builds a house, sleeps, disappeared, eats, broke, red, looks for nuts, squirrel, gnaws, on a branch, a person stands, ran, on the roof, left, fell on the road, stands

Frequencies 3Q30

3Q30	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	75	83.3%	83.3%
Rep_3		3	3.3%	86.7%
Rep_0		12	13.3%	100.0%

3Q30. Interpretation level	Students' Answers
Rep_1	Sits, sat down , sat
Rep_3	Jumps, climbs, runs
Rep_0	Man, boy, looking, searching, eating, on chair

Frequencies 3Q32

3Q32	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	35	39.3%	39.3%
Rep_2		22	24.7%	64.0%
Rep_3		10	11.2%	75.3%
Rep_0		22	24.7%	100.0%

3Q32. Interpretation level	Students' Answers
Rep_1	Cooks, boils, fries, prepared, heated up
Rep_2	Eats, eats, feels, applies, tastes, cools
Rep_3	Carries, dropped, drowned, carries, hid, looks at, searches, ordered
Rep_0	Rides along the road, up, to you, in a taxi, straight, to the sun, to school, for a walk

Frequencies 3Q34

3Q34	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	52	56.5%	56.5%
Rep_2		18	19.6%	76.1%
Rep_3		7	7.6%	83.7%
Rep_0		15	16.3%	100.0%

3Q34. Interpretation level	Students' Answers
Rep_1	Looking for, found, find
Rep_2	Saw, sees, looks
Rep_3	Lost, Forgotten, Studying, Noticed, Bloodhound
Rep_0	Magnifying glass, took, put, opened, takes out, hung, bought, holds

Frequencies 3Q35

3Q35	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	26	28.6%	28.6%
Rep_2		17	18.7%	47.3%
Rep_3		16	17.6%	64.8%
Rep_0		32	35.2%	100.0%

3Q35. Interpretation level	Students' Answers
Rep_1	Looking for, found, can't find, doesn't know where, find, discovered
Rep_2	Saw, sees
Rep_3	Lost, Forgot, Don't Forget, Studying, Researching
Rep_0	Took, washing machine, left, holds, dropped, hid, measures, hangs, washed, suddenly, got out, hung, take away, broke, removes, inserts, threw, put, opened, lies, hid, squiggles, asks, heard, wrapped

Frequencies 3Q36

3Q36	Group	Counters	% of total	Accumulated %
Rep_1	INT. DIS.	31	33.7%	33.7%
Rep_2		30	32.6%	66.3%
Rep_3		14	15.2%	81.5%
Rep_0		17	18.5%	100.0%

3Q36. Interpretation level	**Students' Answers**
Rep_1	Searching, found, find, searched, can't find
Rep_2	Saw, sees, saw, look, opened eyes
Rep_3	Lost, Forgot, Noticed
Rep_0	Fish, remembers, hid, put, conspiracy, hung, opens, gave, put, inserts, triangle, lock, opened, turned on the alchemist, holds, inserted, raised, lamp

APPENDIX F

Factor statistics of oculomotor activity data analysis

KMO measure of sampling adequacy

	MSA
Comprehensive	0.591
Number of returns	0.565
Number of fixations	0.549
FIRST_FIX	0.720
MEAN_FIX	0.587

Bartlett's Test of Sphericity

χ^2	df (degrees of freedom)	p
332	6	< .001

Resume

Factor	Sum of squared loads (SS)	% of variance	Accumulated %
Eye_Quan	1.98	49.4	49.4
Eye_Duration	1.28	32.0	81.4

APPENDIX G

Table G.1. Descriptive statistics of the oculomotor activity data of the subjects for all pictograms of the stimulus material

	Group	N	Average	Median	SD	SE
FIX_TIME	INT. DIS.	98	1.3643	1.113	0.9374	0.09469
	Norm	98	1.5265	1.1242	1.088	0.1099
FIRST_FIX	INT. DIS.	98	0.2439	0.241	0.0724	0.00731
	Normal	98	0.3490	0.3197	0.119	0.0120
RETURNS	INT. DIS.	98	1.6277	1,418	0.8751	0.08840
	Normal	98	1.4846	1.3370	0.761	0.0769
MEAN_FIX	INT. DIS.	98	0.3756	0.352	0.0856	0.00864
	Normal	98	0.4659	0.4315	0.145	0.0147
ALL_FIX	INT. DIS.	98	3.4917	2,995	1.9098	0.19292
	Normal	98	3.0548	2.7065	1,427	0.1442
Eye_Quan	INT. DIS.	98	0.0833	-0.155	1.0694	0.10803
	Normal	98	-0.0833	-0.2806	0.907	0.0916
Eye_Duration	INT. DIS.	98	-0.3575	-0.554	0.6522	0.06588
	Normal	98	0.3575	0.0676	1.116	0.1128

Table G.2. Descriptive statistics of the oculomotor activity data of the subjects for all pictograms of Task 1 (choosing the extra pictogram)

	Group	N	Average	Median	SD	SE
FIX_TIME	INT. DIS.	24	1.293	1.1976	0.5554	0.11336
	Normal	24	1.331	1.076	0.747	0.1524
FIRST_FIX	INT. DIS.	24	0.249	0.2453	0.0455	0.00929
	Normal	24	0.349	0.316	0.115	0.0235
RETURNS	INT. DIS.	24	1.827	1.6154	0.8710	0.17780
	Normal	24	1,355	1.141	0.817	0.1667
MEAN_FIX	INT. DIS.	24	0.336	0.3261	0.0457	0.00932
	Normal	24	0.435	0.421	0.110	0.0224
ALL_FIX	INT. DIS.	24	3,851	3.4505	1.5740	0.32129
	Normal	24	2,943	2,685	1.333	0.2720
Eye_Quan	INT. DIS.	24	0.265	0.0291	1.0088	0.20591

	Group	N	Average	Median	SD	SE
	Normal	24	-0.265	-0.481	0.933	0.1905
Eye_Duration	INT. DIS.	24	-0.490	-0.5591	0.4591	0.09371
	Normal	24	0.490	0.185	1,150	0.2347

Table G.3. Descriptive statistics of the oculomotor activity data of the subjects for all pictograms of Task 2 (translation of a sentence from pictograms)

	Group	N	Average	Median	SD	SE
FIX_TIME	INT. DIS.	27	0.8938	0.704	0.5651	0.10875
	Normal	27	1.0325	0.905	0.6436	0.12387
FIRST_FIX	INT. DIS.	27	0.2077	0.185	0.0811	0.01560
	Normal	27	0.2975	0.310	0.0644	0.01239
RETURNS	INT. DIS.	27	1.3284	1.088	0.8118	0.15622
	Normal	27	1.4223	1.196	0.8906	0.17140
MEAN_FIX	INT. DIS.	27	0.3258	0.316	0.0355	0.00682
	Normal	27	0.3814	0.384	0.0508	0.00978
ALL_FIX	INT. DIS.	27	2.6842	2.165	1.5412	0.29660
	Normal	27	2.6188	2.217	1.4096	0.27128
Eye_Quan	INT. DIS.	27	-0.0131	-0.333	1.0319	0.19859
	Normal	27	0.0131	-0.251	0.9822	0.18902
Eye_Duration	INT. DIS.	27	-0.5102	-0.698	0.6980	0.13434
	Normal	27	0.5102	0.597	0.9459	0.18205

Table G.4. Descriptive statistics of the oculomotor activity data of the subjects for all pictograms of Task 3 (translation of the pictogram in a verbal context)

	Group	N	Average	Median	SD	SE
FIX_TIME	INT. DIS.	36	1.944	1.504	1.1593	0.1932
	Normal	36	2.201	1.607	1.345	0.2241
FIRST_FIX	INT. DIS.	36	0.283	0.282	0.0655	0.0109
	Normal	36	0.413	0.400	0.136	0.0226
RETURNS	INT. DIS.	36	1.867	1,560	0.9265	0.1544
	Normal	36	1,625	1.533	0.697	0.1162
MEAN_FIX	INT. DIS.	36	0.459	0.445	0.0776	0.0129

	Group	N	Average	Median	SD	SE
	Normal	36	0.587	0.552	0.150	0.0250
ALL_FIX	INT. DIS.	36	4.171	3.258	2.2693	0.3782
	Normal	36	3,547	3.185	1.577	0.2628
Eye_Quan	INT. DIS.	36	0.128	-0.249	1.1267	0.1878
	Normal	36	-0.128	-0.235	0.847	0.1412
Eye_Duration	INT. DIS.	36	-0.522	-0.539	0.5229	0.0872
	Normal	36	0.522	0.390	1.089	0.1816

Table G.5. Descriptive statistics of the oculomotor activity data of the subjects for all pictograms of Task 4 (decoding public signs)

	Group	N	Average	Median	SD	SE
FIX_TIME	INT. DIS.	11	0.779	0.805	0.2901	0.0875
	Normal	11	0.958	0.951	0.2375	0.07162
FIRST_FIX	INT. DIS.	11	0.193	0.195	0.0454	0.0137
	Normal	11	0.268	0.250	0.0494	0.01489
RETURNS	INT. DIS.	11	1.145	1.110	0.4081	0.1231
	Normal	11	1,459	1,413	0.4520	0.13629
MEAN_FIX	INT. DIS.	11	0.309	0.302	0.0355	0.0107
	Normal	11	0.345	0.347	0.0287	0.00865
ALL_FIX	INT. DIS.	11	2,468	2,297	0.7732	0.2331
	Normal	11	2,757	2,652	0.5460	0.16464
Eye_Quan	INT. DIS.	11	-0.347	-0.484	0.9018	0.2719
	Normal	11	0.347	0.228	1.0088	0.30417
Eye_Duration	INT. DIS.	11	-0.527	-0.663	0.8933	0.2693
	Normal	11	0.527	0.465	0.7126	0.21486

APPENDIX H

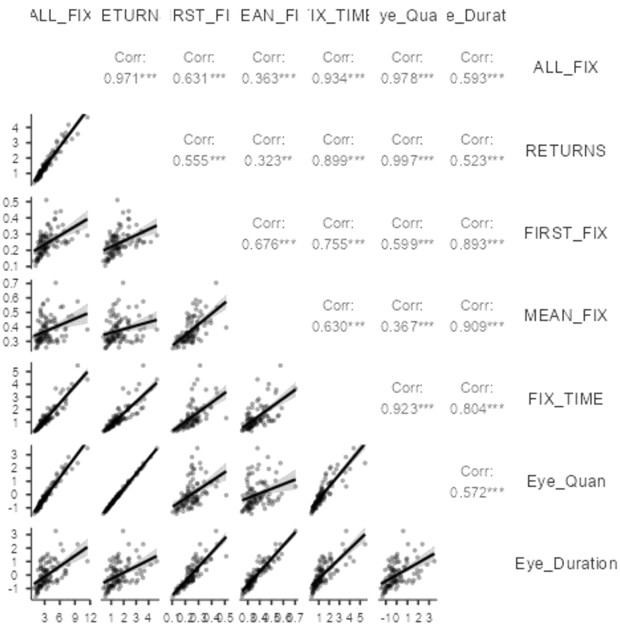


Fig. H.1. Graphs of correlations of oculomotor activity parameters in the group with intellectual disorder for all tasks

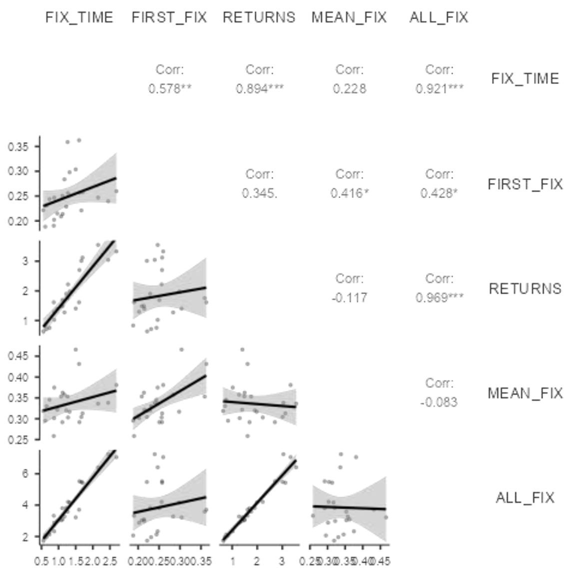


Fig. H.2. Graphs of correlations of oculomotor activity parameters in the group with intellectual disorder when completing Task 1 (selecting the “extra” pictogram)

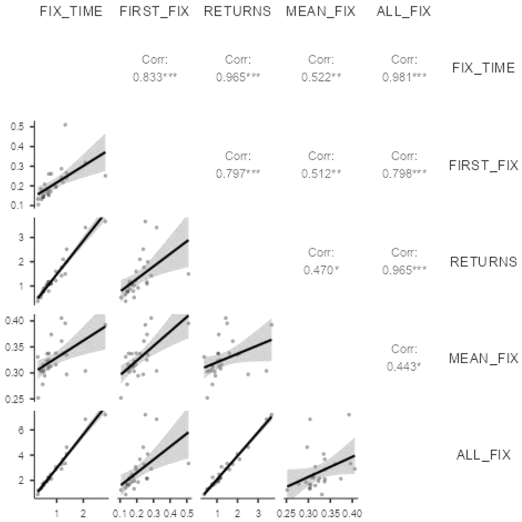


Fig. H.3. Graphs of correlations of oculomotor activity parameters in the group with intellectual disorder when completing Task 2 (translation of sentences from pictograms)

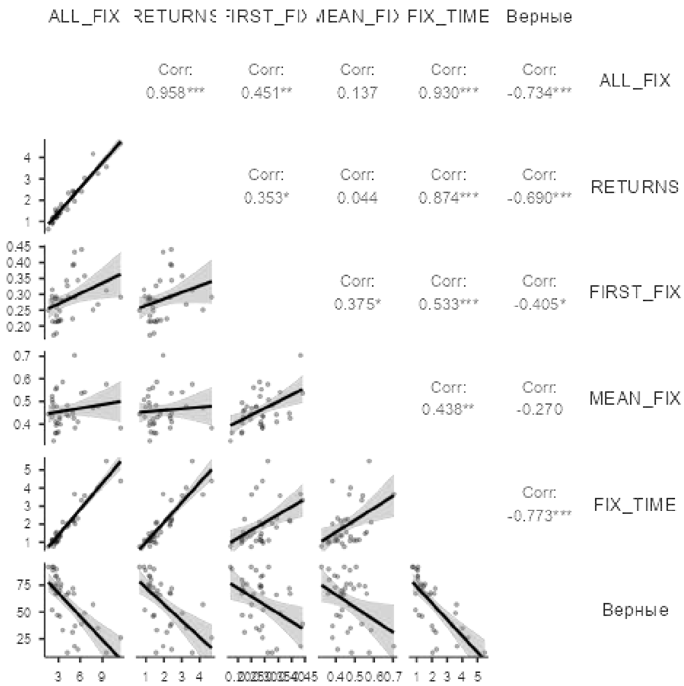


Fig. H.4. Graphs of correlations of oculomotor activity parameters in the group with intellectual disorder when completing Task 3 (translation of pictograms in a verbal context)

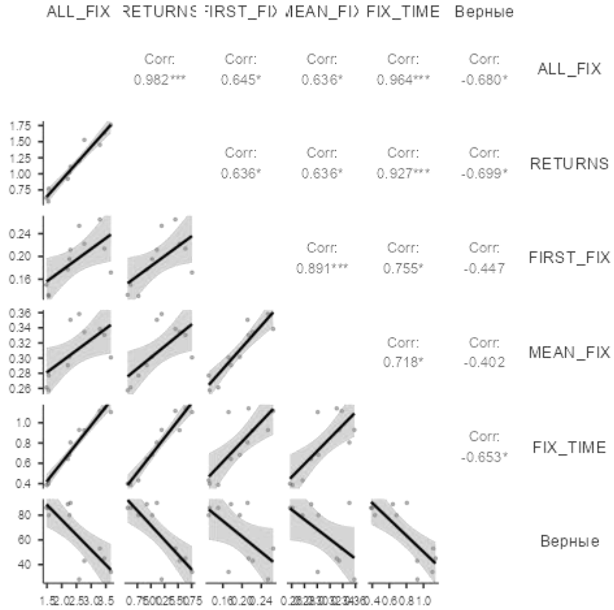


Fig. H.5. Graphs of correlations of oculomotor activity parameters in the group with intellectual disorder when completing Task 4 (decoding public signs)

APPENDIX I

Testing the assumptions about the normality of distribution and homogeneity of variances of data on the number of correct answers in subjects with intellectual disorder to tasks 1–3.

Homogeneity of Variances Test (Levene)

	F	df1	df2	p
Faithful	0.420	2	48	0.659

Normality test (Shapiro- Wilk)

Statistics	p
0.974	0.321

Descriptive statistics of the group

	System	N	Average	SD	SE
Faithful	LoCoS	17	58.1	19.5	4.74
	Pictogram	17	65.6	23.4	5.68
	Bliss	17	41.8	21.7	5.27

Testing the assumptions about the normality of distribution and homogeneity of variances of oculomotor activity data of subjects with intellectual disorder.

Normality test (Shapiro- Wilk)

	W	p
FIX_TIME	0.883	< .001
FIRST_FIX	0.958	0.003
RETURNS	0.954	0.002
MEAN_FIX	0.921	< .001
ALL_FIX	0.934	< .001
Eye_Quan	0.957	0.003
Eye_Duration	0.957	0.003

Note: A small p-value suggests a violation of the normality assumption.

Homogeneity of Variances Test (Levene)

	F	df1	df2	p
FIX_TIME	7.773	3	94	< .001
FIRST_FIX	0.612	3	94	0.609
RETURNS	5.494	3	94	0.002
MEAN_FIX	3.165	3	94	0.028
ALL_FIX	7.042	3	94	< .001
Eye_Quan	5.371	3	94	0.002
Eye_Duration	2.825	3	94	0.043

Descriptive statistics of the group

	System	N	Average	SD	SE
FIX_TIME	LoCoS	29	1.2432	0.8283	0.1538
	PICTOGRAPH	29	1.0389	0.4297	0.0798
	Bliss	29	2.0330	1.1919	0.2213
	Sign	11	0.7786	0.2901	0.0875
FIRST_FIX	LoCoS	29	0.2450	0.0761	0.0141
	PICTOGRAM	29	0.2368	0.0699	0.0130
	Bliss	29	0.2691	0.0709	0.0132
	Ssign	11	0.1930	0.0454	0.0137
RETURNS	LoCoS	29	1.4452	0.8262	0.1534
	PICTOGRAM	29	1.3448	0.5253	0.0975
	Bliss	29	2.2762	0.9953	0.1848
	Ssign	11	1.1449	0.4081	0.1231
MEAN_FIX	LoCoS	29	0.3851	0.0753	0.0140
	PICTOGRAM	29	0.3679	0.0769	0.0143
	Bliss	29	0.3989	0.1043	0.0194
	Ssign	11	0.3092	0.0355	0.0107
ALL_FIX	LoCoS	29	3.0477	1.5497	0.2878
	PICTOGRAM	29	2.8257	1.0754	0.1997
	Bliss	29	4.9901	2.3373	0.4340
	Ssign	11	2.4675	0.7732	0.2331
Eye_Quan	LoCoS	29	-0.2030	0.9354	0.1737
	PICTOGRAM	29	-0.3249	0.5970	0.1109
	Bliss	29	0.7484	1.1279	0.2094
	Ssign	11	-0.5812	0.4688	0.1414
Eye_Duration	LoCoS	29	0.0286	0.8071	0.1499
	PICTOGRAM	29	-0.1374	0.7687	0.1428
	Bliss	29	0.3887	1.0547	0.1959
	Sign	11	-0.7380	0.4597	0.1386

APPENDIX J

Testing the hypothesis about the influence of repetition of pictograms in Task 3 on the number of correct answers of subjects with intellectual disorder, taking into account whether the repeated pictogram of Task 1 was “superfluous” or a distractor.

Model fit indices

					Test of the comprehensive model			
Model	R	R^2	Adjusted R^2	SKO	F	df1	df2	p
1	0.109	0.0119	-0.0480	24.2	0.198	2	33	0.821

Model Coefficients - Number of Correct

Predictor	Weight	SE	t	p
Constant [a]	58.97	5.69	10.363	< .001
Repeat:				
yes - no	-1.46	8.68	-0.168	0.867
Extra in 1	8.63	13.73	0.629	0.534

[a] Represents the reference level

Collinearity statistics

	VIF	Tolerance
Repeat	1.05	0.953
Extra in 1	1.05	0.953

Testing the hypothesis about the influence of the belonging of pictograms to a particular AAC system on the number of correct answers of subjects with intellectual disorder, taking into account the accuracy of speech.

Model fit indices

					Test of the comprehensive model			
Model	R	R^2	Adjusted R^2	SKO	F	df1	df2	p
1	0.528	0.278	0.221	19.9	4.88	3	38	0.006

Model Coefficients - Number of Correct

Predictor	Weight	SE	t	p
Constant [a]	60.1429	11.17	5.3835	< .001
System:				
PICTOGRAM – LoCoS	13.0000	7.90	1.6456	0.108
Bliss – LoCoS	-17.1429	7.90	-2.1701	0.036
CR	-0.0952	6.45	-0.0148	0.988

[a] Represents the reference level

Collinearity statistics

	VIF	Tolerance
System	1.00	1.00
CR	1.00	1.00

Testing the hypothesis about the influence of the AAC system on the number of correct answers of subjects with intellectual disorder to task 3, taking into account the presence of a human figure on the pictograms.

Model fit indices

					Test of the comprehensive model			
Model	R	R^2	Adjusted R^2	SKO	F	df1	df2	p
1	0.425	0.181	0.00522	17.4	1.03	3	14	0.409

Collinearity statistics

	VIF	Tolerance
System	1.01	0.991
Human	1.02	0.982

Model Coefficients - Number of Correct

Predictor	Weight	SE	t	p
Constant [a]	64.426	8.28	7.7781	< .001
System:				
PICTOGRAM – LoCoS	3.426	11.56	0.2964	0.771
Bliss – LoCoS	-15.333	11.40	-1.3449	0.200
Human	0.444	11.40	0.0390	0.969

[a] Represents the reference level