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Interactive Multi-Sensory Environments for Children with Autism Spectrum Disorders

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Abstract: *The emerging of digital technology not only encourages the development of new tools but also changes traditional approaches to solving emerging problems. The sound, music, art, colors, etc. that prevailed in the 20th-century forms of therapy are being replaced by integrated systems that overcome many of these forms, thanks to digital technology. With the increasing number of people with autism spectrum disorder (ASD) in the world, such systems provide new opportunities for the treatment of these disorders. In this research, the creation of such a system has been chosen as the object of work. The article presents an interactive tool for the education of children with ASD created by audio, video, and computer technologies and assesses its potential impact. The experimental research and its results are presented. This study aims to evaluate an interactive instrument developed for the education of such children. Following the objectives of ensuring the interactivity of the process, provoking all the perceptions of the subject, and developing the subject's ability to respond to the environment, a personalized audiovisual environment was created. For interactivity, the virtual program EyeCon, Webcam and camcorders, video projector, and speaker system were used. The study was conducted with one subject and a case study method was used. The impact of the instrument was established based on a survey of the parents of the child and the findings of childcare experts. The results of the study demonstrated the positive benefits for this child such as increased eye-to-hand coordination, concentration duration, improved communication, and emotional expression. The results obtained show that such interactive multi-sensory environments in special and general education schools can be a supplemental tool for traditional methods.*

Keywords: *interactive audiovisual technologies, ASD, sound.*

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1. Introduction

1.1. Education of autistic persons and interactive audiovisual and visual environment

Despite the better quality of life and medical care, a better understanding of hygiene conditions, and so on. There is a steady increase in the number of children with learning difficulties in the world. According to a study by UNICEF (Lansdown et al., 2013), about 15% of the Earth's population suffers from various forms of special educational needs (SEN). One of the fastest-growing forms of SEN is an autism spectrum disorder (ASD) (Ainscow et al., 2013). In 2000, one in 150 ASDs in the world was diagnosed with 3-21 years of age person and in 2016 one in 88 of them is already counted (Lai et al., 2013; Preece & Howley, 2018). This is characterized as a neurological developmental disorder that most affects the development of language, communication, social skills, and behavior (Frith, 2008; O'Connor, 2012; Powers, 2000; Sokhadze et al., 2016). Many children with ASD have difficulty making social connections, recognizing or expressing emotions, and imitating other people's patterns of behavior (American Psychiatric Association, 2013).

One of the essential features of the subject's in ASD is a complicated ability to recognize one's own and others' emotional language. This is the basis of empathy and the ability to orientate in the social space which is very important in our lives (Gonsalves, 2010; Santomauro et al., 2017). Despite the importance of emotions in social life, they have rarely become the object of research in twentieth-century scientific theories and research. The prevailing view was that emotions are secondary and must obey rational thinking (Zajonc, 2000). It is therefore not surprising that there is not much research in this area. The dominant traits that researchers focus on include the relationship of such individuals to a) the expression of another person and their emotions; (b) visual information; (c) sound and music; d) audio-visual interactivity and e) identification of all the above features in the educational process (Ališauskienė & Milteniene, 2018; Bach et al., 2015; Brockett et al., 2014; Curry et al., 2006; Sokhadze et al., 2016; Nelson, 2012; Stiegler & Davis 2010).

1.2. Emotional expression, sound, and video.

Emotional facial expressions were found to be learned. This can be ascertained by observing the particularly specific emotional expression of the blind at birth. Therefore, we need to teach children experiencing ASD to at least recognize the emotional signs of the other person. A similar problem is now faced by the creators of artificial intelligence, robots, who want their creations to be able not only to recognize but also to represent characters of emotional expression. One of the most important human characteristics is empathy. It requires an understanding of the other entity. It is argued that the experience and expression of emotions can be learned by communicating through music. However, the emotions evoked by music and life situations have one particularly important difference: in real life emotions always have a very specific reason, and it is quite difficult to say why we experience one or another emotion while listening to music although the mood created by music can affect our perception of the world (Jolij & Meurs, 2011). Even more, questions arise when analyzing the relationship between emotions, music, and color that occurs in the case of synesthesia.

Predictability of the surrounding world is especially important for children with ASD. And the fact that we respond differently to those sounds for which we are prepared and for which we are not prepared makes it even more difficult to orientate in the environment (Bach et al., 2015). Unpredictability is also increased by different ear sensitivities to audio information (Jeste & Nelson, 2009; Sokhadze et al., 2016). Children experiencing ASD often exhibit a distorted relationship with audio information. Some children with ASD believe that sound can hurt so try to protect the ears by covering them with their hands. Their reaction to sound depends on the context they may be particularly sensitive to specific sounds but not at all responsive to very loud sounds (Nelson, 2012; Stiegler & Davis, 2010; Whitehouse & Bishop, 2008). This interferes with the feeling of fullness of acoustic space and has a negative effect on language receptivity (Bomba & Pang, 2004). Problems are solved by exploiting the physical properties of sound. The best-known experiments in this field are the

TOMATIS and Berard methods (Berard & Brockett, 2011; Brockett et al., 2014). There are differences between these methods but it is specially modified audio information designed to stimulate certain areas of the brain. Exposure methodologies are also known that attempt to activate the perception of audio information by combining moments of sound and silence (Voisin et al., 2006).

Many children with ASD have a particularly well-developed visual perception, so it is very important to assess how much visual perception contributes to the perception of audio information, and how sound affects what we see. Two hypotheses of the directionality of audio and video perception prevail. One of them, the so-called common space hypothesis states that the perception of audio-visual is a common process that integrates continuous and instantaneous analysis of video and audio material. The second hypothesis states that there are two different processes of audiovisual perception in which the perception of video and audio material takes place independently of each other (Auerbach, 1974). Our relationship with sound and image is fundamentally different. Our vision or observation of the environment around us is always directed to the outside, and the perception of sound information is directed to ourselves, to the inside. In this way listening is afferent, it seems to immerse us in the world of sounds, and seeing is efferent. With his help, we distinguish ourselves from the world around us (Valle, 2011). In the context of these hypotheses, the essential factor determining the ability to understand human actions is the ability to combine into one whole the information obtained by all means of perception. Research has shown that time (sound and music), space (visual space), and semantically similar information facilitate behavior and the development of behavioral patterns (Meyer et al., 2011). This synthesis of video and audio material is especially important when interacting with other people. Emotional facial expression and observation of lip movements greatly facilitate language comprehension. The expression of the speaker's face during communication increases the comprehension of audible language as much as if the interlocutor spoke 15-20 dB louder (Saito et al., 2005).

1.3. Sound, video, movement, and music education

The goal of many education systems is to create equal opportunities for every child to improve. Inclusive education is best suited to this end. It is an educational process in which both traditional development and children with educational difficulties are equally involved. It aims to assess what the child is ready for what it cannot accept, what models are offered to it, how the system is ready, and so on. It provides every learner including those with special educational needs, with the opportunity to acquire a qualification by adapting and personalizing education, taking into account everyone's needs (Ališauskienė & Milteniené, 2018). There are inevitably problems with such a process. One of them (especially in the field of music education) is a traditionally formed model of imitation teaching, the basis of which is the repetition of certain modes (teaching of a song, piece of music, rhythmic structure, etc.). Children in ASD respond differently to simulation than their neurotypical peers (Scott, 2016). Some scholars (Mostofsky et al., 2006; Smith & Bryson, 2007) divide movements into meaningful and meaningless. Meaningful movements have socio-cultural significance, e.g. waving a hand greeting or saying goodbye, making a circle with your fingers, implying that everything is in order, pointing a finger at an object, and so on. It means signs that have an experiential meaning. Meaningless movements are characterized by vague content, they do not mean anything and do not have clear content and purpose (Vivanti et al., 2008). Examples of such movements could be turning hands at shoulder height, waving hands, and so on. To simulate meaningful movements the child must evaluate the movement visually, compare the movement with the movement seen in the past, evaluate its possible meaning, and memorize the tempo and amplitude of the movement (e.g. by remembering the tempo). There is no possibility to rely on the experience gained in performing meaningless movements, there is no clear reason why the movement has to be exactly like that. It uses only visual assessment and motor repetition making it much more difficult for children in ASD to memorize and perform them. It is more difficult to integrate visual and psychomotor information into motor-requiring movements for children in ASD neither their traditional development peers.

Therefore children in ASD are better able to simulate movements that have clear content and meaning.

Another problem with learning in a classroom for a child with ASD is differences in the duration of perception of audiovisual information. ASD children perceive attention from a visual symbol to its associated sound equivalent as quickly as their neurotypical peers. However, the transition from an audible sign to its visual counterpart takes more time (Williams et al., 2013). This feature is very useful when it comes to the educational process that uses virtual computer technologies. Here you can record singing with a microphone. After a few moments, a diagram of the recorded melody is displayed in the computer or special program window. The program compares the curve of the chart with the absolute tones of the tonality in which the melody was performed and identifies places where there were inaccuracies in the singing. Such a teaching model (especially when there is no opportunity to participate equally in the overall music-making process) helps to: a) improve feedback; (b) to facilitate self-directed learning; (c) provide an attractive learning environment; (d) improve learning skills; e) contributes to a better understanding of their voice capabilities. With the rapid development of digital technologies new virtual products for computers and smart devices (AUMI, My Breath My Music, EAMIR, SoundCool, SoundPlant, etc.) are emerging every day to help implement the process of inclusive education.

The advent of computers and research into their use has shown that they have given children in ASD an additional opportunity to interact with peers, these children are more likely to choose programs that integrate animation, sounds, and voices, prefer to play with computers neither with toys (Boucenna et al., 2014). The use of computers: a) increases concentration; (b) prolongs the period of voluntary attention; (c) contributes to a longer stay calm; d) develops the ability to engage in a variety of activities (from computer to regular daily activities); e) suppresses feelings of anxiety (Jordan, 1995). Animated everyday objects displayed on a computer screen help people in ASD to learn to distinguish objects by color, shape, size, etc., and develop the ability to associate visible images with sounds (La´nyi & Tilinger, 2004). A hugely successful cartoon called Transporters for children in ASD was created in 2008, the U.S. Its main characters are trains, cars, tractors, and so on with images of faces of actors modeling certain emotions embedded in their front. The popularity of the film was explained by the attractiveness of virtual toys in 4-8 year age children. Actor's simulated emotions have become an excellent learning tool for emotional expression for children experiencing ASD (Golan et al., 2010).

2. Research questions/Aims of the research

The study aims to answer the question of the importance of interactive audiovisual environments in the education of children where the modeling of audio, video, and process interactivity is integrated, what educational opportunities this process provides to its participants, and what ways of combining audio and visual material are most appropriate for developing children in ASD. The issues raised dictated the aim of the study - to create an interactive acoustic and visual environment that promotes a model for the development of communication and orientation skills in people with Autism Spectrum Disorder.

3. Research methods

3.1. Participants

A boy was selected for the study who was diagnosed with mixed specific developmental disorders at the Child Development Center. Experts assessed the boy's condition as a moderate disability. Delayed psychological development, a tendency to withdraw from peers, impulsive anger when the agenda is not going according to a pre-arranged plan, especially a brief concentration of attention, a tendency to resist or protest against the emergence of new things in a familiar environment were observed. The boy's language was limited to 3-5 word sentences. The consent of the kindergarten administration and the child's parents to participate in the experiment were obtained.

3.2. Materials and instruments

In order to evaluate the possibilities of developing the application of interactive audiovisual technologies in working with a child in 2015 (from September to December) an empirical experimental study was carried out and the case analysis methodology was applied. A questionnaire was prepared for the child's parents, the analysis of the conclusions of the experts assessing the child's health was performed, and 8 interactive animated projections were prepared. All 16 experimental lessons were filmed.

The questionnaire for parents consisted of 18 open-ended questions. The questionnaire starts with demographic questions. The rest were divided into 4 blocks: I) development of cognitive abilities; II) emotional stability after lessons; III) social initiative; IV) fine motor skills and phonetic abilities. The survey was repeated three times: at the beginning of the research - on September 3, 2015, in the course of the research - on October 29, 2015. and at the end of the study - 20/12/2015.

The conclusions and recommendations of the experts (psychologist, speech therapist, occupational therapist, and social worker of the Child Development Center certified in Lithuania) were analyzed.

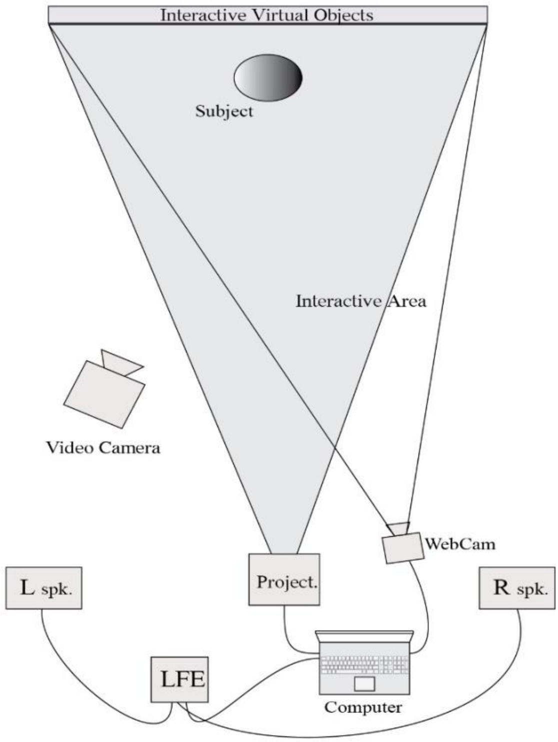
A multi-interactive environment methodology was used to create the experimental research environment (Brooks, 2005), the aim of which was to create an environment in which the visual, auditory, and tactile senses were stimulated. In principle, the movement of a person in such an environment is equivalent to the movement in an electrified environment that responds to every movement of the person, encourages the participant in the process to make quick further decisions. This promotes creativity, independence, the coordination of movements, and the ability to change the environment spontaneously.

Based on different musical tales (Vicente-Yagüe & Guerrero Ruiz, 2015), eight two types of animated video projections were created. The duration of the projection is about 2 minutes. However, because it's interactive (i.e. can be stopped and repeated anywhere) significantly increases the duration of projection. The first type 4 projections were created based on children's Lithuanian folk songs (Šarkele varnele, Gydu gydu katutes; Šiaudų batai, etc.). They supplement the narrator's text with musical inserts made by various musical instruments (violin, kankle, cymbals, sound boxes, etc.). The second type of 4 projections was based on animated images and typical sound examples of various objects that occur in our everyday environment (dog's barking, wheel's rumbling, crow's croaking, tree's soughing, running water, bell's ringing, singing boy and girl, car, etc.). Animated characters were created using giff technology (Bantjes, 2019), which is characterized by movement. This was done to provoke the movements of the subject. All projections were complemented by various colored interactive symbols (circles of various sizes, images of flower blossoms and birds, etc.). Covering any symbol with his hand, a sound or musical insert characteristic of one of the projection characters sounded. In the first type of projections, the symbols mentioned were placed next to the characters assigned to them. In the second type of projections, these symbols are arranged chaotically. Therefore the research participant had to learn to find and associate a sounding symbol with a suitable character.

To accustom the child to various acoustic and visual environments the projections were demonstrated with a video projector on a variety of surfaces (walls, floors, doors, using two planes in the corners of the room, etc.). The computer program EyeCon 1.6 and a webcam were used to create the interactivity of the symbols. The computer program made it possible to activate the areas of the screen in which the symbols were mentioned. The zones were associated with selected audible symbols (the bird was assigned an example of the sound of a sucking bird, the flowing water symbol was the rustling of water, the wheel was given the sound of a wheel, etc.). Closing a character on the screen with your hand activated the screen area for that symbol and activates the sound sample or other projection control operation (pausing or repeating a music track) assigned to that symbol. In some cases, it was possible to activate several characters at once. In other projections, the child was forced to wait for the previously activated symbol to stop sounding and only then could a new one be activated. The faces of the human figures (girl, boy, grandfather) reflected a specific emotional state (joy, sadness, peace, surprise) in harmony with the sounding music. The scheme of creating an interactive environment is presented in Picture 1.

3.3. Procedure

The educational experiment was conducted in a kindergarten, which the boy has been attending since 2015 March. For the group educator was prepared detailed recommendations on how to organize the experimental activities. Educational activities were organized twice a week. A total of 16 weeks. The equipment needed to demonstrate the projections were prepared by the organizers of this experimental study.

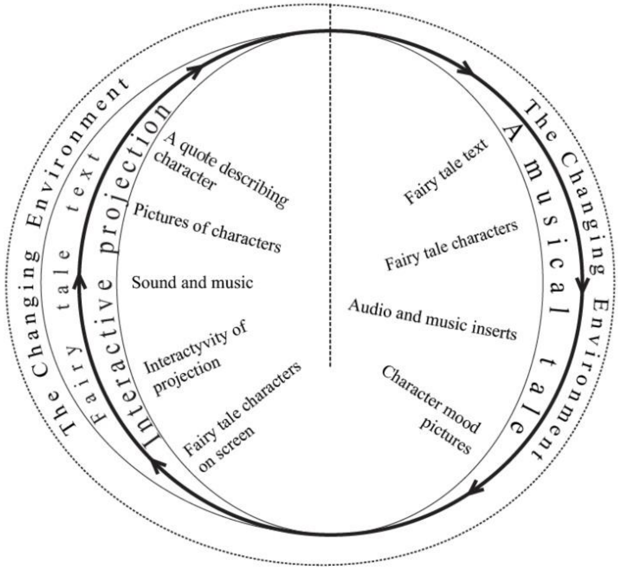


Picture 1. Scheme of creating an interactive environment

Source: Authors own contribution

The recommendations referred to the emphasis on those places of the projections (by repeating them or otherwise drawing the child's attention) where the projection characters were uttered with specific concepts and different variants of the pronunciation of the concepts were presented. The child was asked to choose the character whose facial expression best suited the mood of the sounding music when was working with projections featuring several characters demonstrating different emotional moods. Some of the projections used more than one piece of music to reflect a different mood therefore the boy was trained to perform music and video selection exercises quickly and accurately. By demonstrating projections on different surfaces (especially on the floor) the coordination of the child's movements was developed and the predictability of the sequence of actions was taught. This ability was also taught by allowing the child to choose for themselves when and what audio or video signal should dominate with the help of interactive symbols. It was taught to feel the importance not only of sound but also of moments when no sounds (i.e. silence) (Voisin et al., 2006). Particularly important were the moments when projections were used in which only one character could be activated and to activate the next one had to wait until the sound of the first one finished sounding. Such activities required concentration, voluntary attention, and the ability to remain calm for some time from the subject.

To prepare the child for the projection the educator organized a musical fairy tale at the beginning of the lessons. It was a fairy tale based on an interactive projection shown in the same lesson. At the beginning of the fairy tale, the educator introduced the fairy tale characters, toys depicting pre-prepared characters and the reading-acting of the fairy tale began. For each character, the child was encouraged to come up with an acoustic-musical symbol (it could be imitating a bird’s voice, a song, a gust of wind, etc.). Also from the illustrations of moods prepared in advance by the educator the child had to choose the illustration that best suited their character's mood. A model of the activities and measures used in the experiment is presented in Picture 2.



Picture 2. A model of an interactive projection with musical tale

Source: Authors own contribution

Each lesson begins with a reading of a fairy tale. Gradually the characters are introduced, the main features them is described by imitating computer-broadcast music or the sounds of nature and by analyzing pre-prepared drawings depicting different moods. This creates a musical tale. After reading and partially playing a musical fairy tale we move on to an interactive projection depicting the same fairy tale. During it the characters are re-introduced, their control is evaluated, the audio material related to the characters is tested and the movements of the characters are demonstrated. The whole projection takes place at the sound of a tale text entry. Each element of the projection: the text of the fairy tale being read, the sounds or music associated with the characters, the animation of the characters, and so on. can be stopped and repeated at any time. Each lesson takes place in a different environment (in another room or part of it), the projection is demonstrated on a different surface (side wall of the room, corner of the room on two walls, on the door and floor, etc.).

A questionnaire survey of the parents of the study child was organized three times: at the beginning of the experiment, at the end of the second month, and the end of the experiment.

4. Results

To record the course of the experiment as consistently as possible, 16 lessons were filmed (one each week). This accumulated 320 min. videos (average 20 minutes per lesson). Multimodal transcription methodology (Cowan, 2013) was used for video analysis. 7 most frequently externally monitored behavioral factors and their accounting indicators based on the initial analysis of the video material were identified:

• *process verbalization.* Measured by the number of cases when the subject tries to retell the content of the fairy tale during the projection;

• *voluntary attention and demonstration of a sense of the rhythm of the process.* Measured by the number of positive cases. Each projection was designed to contain 8 cases in which the subject must demonstrate the ability to maintain attention. This is seen when at the end of one projection element and the beginning of another the subject tries to wait for the momentary beginning of the new element;

• *confidence and desire to combine elements of the projection process.* Measured in cases where the subject tries to combine visual and audio symbols of different characters;

• *copying singing of characters.* Measured in cases where the subject is trying to sing.

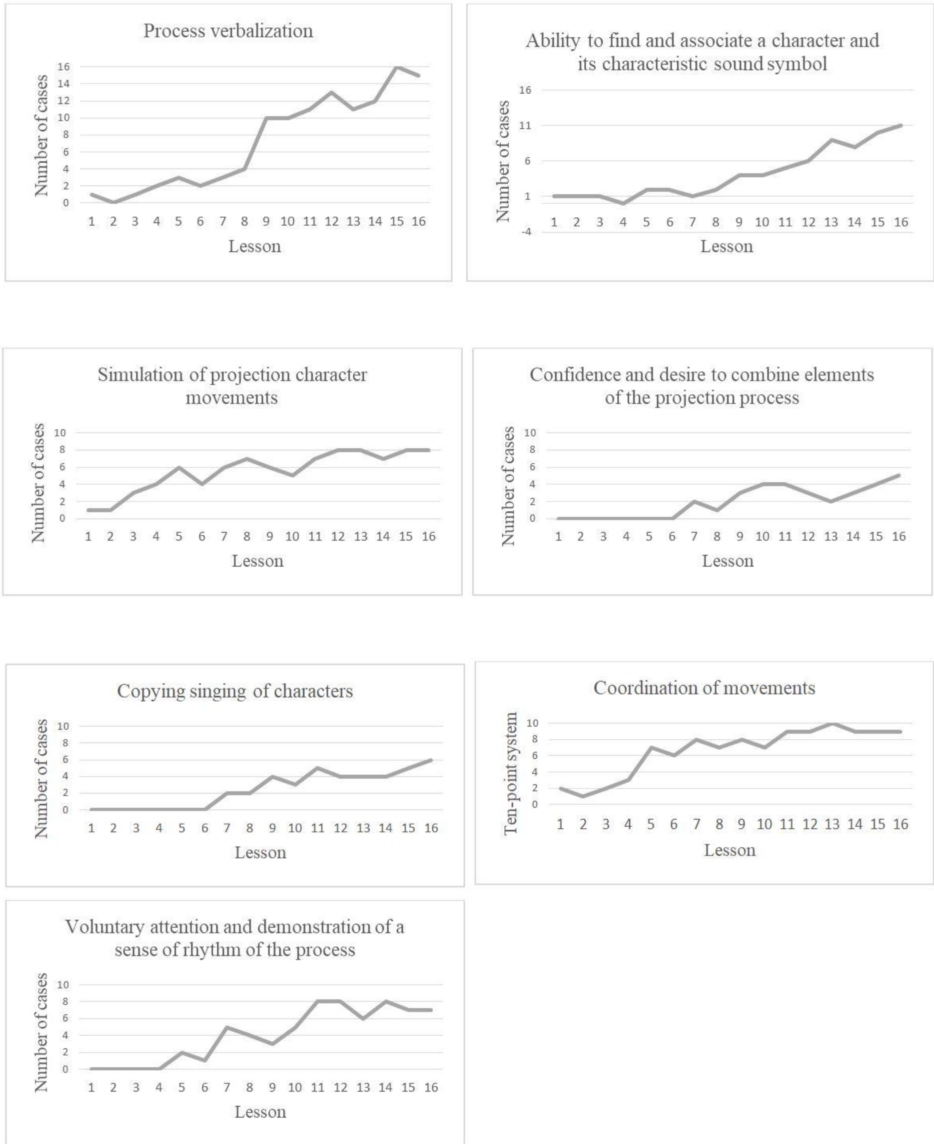
• *coordination of movements.* The ten-point system evaluates the accuracy of the subject's movements in controlling the projection processes;

• *simulation of projection character movements.* Measured by the number of cases.

• *ability to find and associate a character and its characteristic sound symbol.* Measured by the number of cases.

Factors of video material analysis and their change during the study are presented in Tables 1-7.

Tables 1-7. Externally monitored behavioral factors and their accounting indicators (**Source:** Authors own contribution)



The analysis of the videos showed that at the beginning of the study the subject had difficulty connecting to the game. There were frequent cases when he left the playing field trying to engage in other activities. Since the fifth week of the study, the number of such objections has decreased significantly. When participating in a musical fairy tale reading or interactive projection activity, the subject increasingly expressed a desire to re-listen to or review material characterizing some of the characters.

From the eleventh week onwards there was a desire to combine the elements of the projection not as planned. In this way when the story of "Grandfather" (a fairy tale character) sounds, the researcher additionally activated the chirping of the carriage wheel, tried to combine the sounds of the bird's chirping and running water, activating more and more characters by stopping and restarting the projection. By doing so the subject showed a desire to relate the content presented in the projection to certain structures and demonstrated the basics of creative abilities.

Based on the results of the questionnaire survey of the subject's parents it can be stated that the change in the child's mood has stabilized in the home environment. Although the pronunciation of some words remained irregular the vocabulary expanded. The ability to engage in the same activity for longer and the desire to achieve a result is observed. There were signs of self-planning. Frequent activities are accompanied by restrained singing and movements that demonstrate the rhythmic pulsation of music. There was a significant decrease in the number of particularly pronounced emotional reactions.

Positive developments in the field of fine motor control and expanded active and passive vocabulary were noted after repeated expert assessments by a psychologist occupational therapist and speech therapist. Irregular interdental pronunciation of some sounds remained but the phonemic hearing was improved. The ability to tell from a picture or own experience has changed positively. According to the occupational therapist the desire to perform all tasks well and completely was observed, the concentration of attention improved. Improved fine motor tasks that require eye-hand coordination skills and finger strength. The recognition of objects similar in color, shape, and size has improved.

5. Discussions

Often we try to use some kind of technology. However, in our daily activities, we are constantly confronted with the system of all of them. This is how we experience all sorts of effects. For the person in ASD, the most difficult thing is to integrate all those experiences, to combine them into one whole (which is like the norm for neurotypical people). This poses some challenges for the educator. However audiovisual technologies allow the learner to become a process manager choosing both the direction and the level of complexity. Although the combination of different audiovisual technologies is not a typical activity for ASD children, they are inevitably exposed to separate technologies in their daily activities. So the role of educational institutions in creating environments in which the child would gradually find himself combining skills in various fields becomes particularly important. Probably the word is not appropriate here - to combine. Maybe look for new tools to accomplish the task. Because in such activities the audio material confirms or denies the correctness of the choice of visual material and the interactivity of the activity pushes the child into a time frame, urging them to take the next action. It is the development of attention, voluntary attention, ability to think abstractly, etc. It is very different from activities at home or in a lesson when the child receives a specific task and his goal is to find one correct answer. Here the possible outcome of the activity is constantly changing depending on the child's choices.

6. Conclusions

Audiovisual technology was used in the study in such a way that the experimental environment did not differ significantly from the subject's everyday environment. Although the first steps were quite cautious. The solution to the problems that emerged as the investigation accelerated gained signs of play. At the beginning of the study, the experimental process was seen as a phenomenon that must be performed. At the end of the experiment, however, the subject seemed to become part of the game. By trying to combine different visual and aural symbols of different characters he has already demonstrated a desire to create.

The particularly rapid development of computer technology has transformed a computer from a device consisting of a keyboard and screen into a device that makes all our senses responsive - sound, image, interactivity, real-life simulation, and so on. Interactive video projections further highlight the possibilities of combining these media. And managing and participating in opportunities for such interactions becomes (especially for children in ASD) a great opportunity to learn about the world and make personal contact with it.

The combination of audiovisual information (audio, video, and animation) in video projection is a great opportunity for people with ASD to learn to understand the emotional expression of other people, develop phonetic hearing, and enrich vocabulary. The interactivity of the projections provides an opportunity to develop the coordination of movements.

The experiment did not require particularly large material investments or special training from the researchers and can therefore be easily repeated. Given that similar hardware and software are changing very rapidly it can be expected that the newly performed experiments will reveal the possibilities of educating new individuals in ASD with interactive projections.

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