# Enhancing fundamental skill development and motivation in children with autism spectrum disorder using virtual reality

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# Abstract

This paper explores the application and impact of Virtual Reality (VR) in facilitating the development of fundamental skills in children with Autism Spectrum Disorder (ASD) and other neurodevelopmental disorders. Over a period involving 36 intensive sessions, a VR application was used in a controlled and distraction-free environment. Our observations revealed a significant increase in children's interest in lessons, parental involvement, as well as improvements in essential skills, such as visual tracking, pointing accuracy, reading line retention, and overall concentration. Notably, there was a marked enhancement in children's attention span and perseverance during tasks, crucial abilities often challenging for these children. These findings suggest the substantial potential of VR in supportive and educational settings for children with ASD and other neurodevelopmental disorders. However, the need for ongoing research and development to optimize the use of VR in these contexts was also highlighted.



Keywords:

Autism spectrum disorder, neurodevelopmental disorders, attention problems, motivation, virtual reality, sensory overload, controlled environment, concentration training, behavior control.


# Problem Area: Addressing Attention Difficulties in Children with Autism Spectrum Disorder and General Speech Underdevelopment

The arena of attention difficulties is a common area of concern shared by children diagnosed with both Autism Spectrum Disorder (ASD) and General Underdevelopment of Speech (GUS). ASD is a neurodevelopmental condition that affects communication, social interaction, and behavior, while GUS represents a range of language disorders characterized by a delay in the development or use of the mechanisms that produce speech.

One of the hallmark features of ASD is difficulty with social communication and interaction, which can significantly impact a child's ability to attend to and engage with their surroundings. Children with GUS, on the other hand, face significant challenges in the cognitive processing required for effective communication. Both sets of difficulties can often culminate in problems with attention, such as difficulty in sustaining focus, easily getting distracted, or struggling to shift attention from one task to another. These attentional challenges can considerably hinder a child's ability to learn and participate in everyday activities, both at home and in school.

Children with ASD often find it difficult to filter out irrelevant information and stimuli in their environment, leading to a sensory overload that distracts them from focusing on specific tasks or activities. For instance, a child with ASD may get easily distracted by background noise, bright lights, or other sensory stimuli that a neurotypical child might be able to ignore.

In contrast, children with GUS may face cognitive difficulties that inhibit their ability to pay attention. These could include problems with memory, problem-solving, and other cognitive processes required for successful communication. This cognitive underdevelopment can often

lead to problems with attention, as children struggle to process and respond to the information they receive from their environment.

Beyond sensory and cognitive issues, attention problems in children with ASD and GUS might also be related to difficulties with executive functioning. Executive functioning refers to a set of cognitive processes responsible for planning, organizing, and completing tasks. Children with either ASD or GUS may face challenges with executive functioning, making it difficult for them to stay on task, complete assignments, and manage their time effectively.

There are several strategies that parents and educators can use to support children with ASD or GUS who are experiencing attention problems. These strategies may include creating a structured and predictable environment, breaking tasks down into smaller steps, providing frequent breaks, and using visual aids to help children understand expectations and stay on task.

# VR as a care tool

Proven Reality (United Arab of Emirates, Dubai) together with specialists working with people with ASD and other neurodevelopmental disorders, conducted research and created a methodology for working with children with special needs using virtual reality technology. Based on this methodology, Proven Reality company made a virtual reality application with a controlled environment in which specialists can also work on attention problems of children. Also the guideline with detailed explanations to therapists on how to make a session with a child was prepared. The guideline describes how to implement the stages of working with virtual reality in a session with a child with ASD and other neurodevelopmental disorders, and then how to consolidate the acquired skills in the classroom and at home with parents. When using the application in a virtual reality headset, the child is not distracted by external stimuli, has the opportunity to fully concentrate on the process of training with a specialist and is always attending exactly the same environment controlled by the therapist.

In a virtual reality application for working with children with ASD and other neurodevelopmental disorders, the children find themselves in a monochromatic room, in which either a ball or a toy car moves. The therapist can observe on the phone application what the child sees, where he points with his hands (the child's hands are being monitored), and also set various application parameters. The therapist can:

- change the color of the room,
- change the color and texture of the ball,
- change the nature of the movement of the ball (jumps, rolls, flies around the room, moves like a pendulum, etc.),
- add additional obstacles behind which the ball hides,
- add a frame in which he will ask the child to take the ball,
- play animations of a toy car entering and leaving the garage,
- add an extra item,
- and so on.

The specialist can ask the child to focus on a specific object, make an assumption where the object will move, think about where the object is hidden, and so on.

Thanks to the use of a virtual reality headset, the child can fully concentrate on the task, and the child will not have the opportunity to look for “hints” to complete the task from the surrounding adults.

The guideline contains 25 different activities aimed at training various components related to concentration. However, after learning how to use the Proven Reality application, therapists can develop their own methods of working with children.

# Pilot implementation

The pilot phase of implementing the method of working with the Proven Reality application involved four children with ASD (6, 7, 7, 8 years old) and two children (4 and 5 years old) with General Underdevelopment of Speech (GUS) and a low level of cognitive process development. The total course consisted of 17-18 sessions, utilizing a virtual reality headset.

Throughout the trial, the children displayed considerable enthusiasm and eagerness towards practicing with the virtual reality setup. Subjective assessments from parents and therapists reported improved independence, enhanced pointing gestures, increased attention span, and a calmer demeanor in the children post the course. These improvements were corroborated by some teachers and speech therapists, who, despite not participating in the study, observed similar enhancements in speaking abilities, reduced anxiety, and better behavior control.

The classes were held thrice a week, barring any days when the children were unwell. In addition to the VR sessions, parents were assigned homework tasks for reinforcement. While the number of home tasks didn't match the exercises in the office, the final tasks were combined. Parents were highly motivated, endeavoring to complete all the tasks and record them in the questionnaire, with some activities being noted down later from memory.

To objectively assess the changes, we used several methods including:

- Method "Find and cross out". The goal is to find items that the specialist asked for in the image of many objects. When processing and evaluating the results, the number of objects in the picture viewed by the child for 2.0 - 2.5 minutes is determined, i.e. for the entire duration of the task, as well as separately for each 30-second interval
- Method "Correction test - Landolt rings". When processing and evaluating the results, the number of viewed rings is determined for every 30 seconds, as well as for 3 minutes. The number of errors is also recorded: missed according to the sample, incorrectly crossed out, inappropriate to the given sample.
- The "Schulte Table" method, a table filled with numbers from 1 to 9 for 4-5 years old children, from 1 to 16 for 6 years old children and from 1 to 25 for 7-8 years old children in a random order. The child is tasked with identifying and naming all the numbers in order, starting from 1 to 9/16/25, while a stopwatch keeps time. The number of errors made (indicating numbers out of order) is also recorded.

A diagnostic evaluation of the children's attention was conducted before the start of the sessions and at the end of the course.

During the process, we also monitored how each child performed each task, using a 5-point scale to rate their ability to listen and follow instructions, their emotional reactions, readiness for the next task, and the ease of wearing and removing the VR headset. Therapists and parents also filled out questionnaires at the beginning and end of the course to provide additional insights related to the child's attention concentration.

# Child psychologist's observations

All children found wearing glasses very pleasant and comfortable. Some children needed up to 3 pre-training sessions while they got used to the virtual reality headset before dressing and interacting with it directly (these stages were also spelled out in the guideline). Younger children (4-5 years old) during the first sessions with a virtual reality headset did not listen well to the therapist, were distracted by their feelings, tried to explore "new spaces". However, in subsequent sessions, they already adapted to virtual reality and performed the tasks of a therapist. Quite often, children asked to do something else with glasses. However, they obediently agreed to take off their glasses after completing the exercises. Once, one participant (a boy, 8 years old) had a strong tantrum, did not want to take off his glasses (identified himself with a cartoon character), shouted, then cried, did not want to take off his glasses and leave. This situation was unique.

From the perception of children in the study room, several points can be distinguished:
-Most of all, all the children liked the gray background (in the first exercises, the backgrounds were changed and everyone noted that gray is better)
-Children really liked the hands in VR

At the first lessons, the children were quite often distracted from listening to the instructions. They were interested in exploring the room and new perceptual possibilities. It was also important that the children did not see me with glasses, they could only rely on auditory perception and touch. But gradually, with the completion of tasks, the children began to listen more attentively, without being distracted. This effect also became noticeable when performing tasks in the office (the parents of the children also spoke about this).

An important point was the development of a pointing gesture in one of the study participants with ASD (boy, 7 years old), this was noted by the teacher at school and the mother. Also, this child began to read better (do not jump over the lines). Prior to this, the boy, when asked to point to some object, immediately often pointed with his finger at any nearby one, and only after one or a few repetitions did he point correctly.

The two children with GUS also showed improvements in pointing gesture and general spatial orientation and spatial interaction with other objects.

It should also be noted that glasses with the application served as an excellent motivational tool for children (2 children saw only the application, 2 children saw the background screensaver, several times they turned on the video on YouTube). At the same time, it was more interesting for children to be in the room - in the application.

During the last diagnostics, the children listened to the instructions more attentively, made fewer mistakes and followed the line better.

Parents of all children noted small positive changes in children's attention. The mother of one of the participants in the study (a girl of 7 years old) noted that "the daughter has become more assiduous."

# Results for 6-year-old girl (ASD)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| Compared parameters. | Before undergoing a series of sessions using virtual reality | After undergoing a series of sessions using virtual reality. |
|---|---|---|
| Child behavior | The girl regularly jumps up from her seat during class and cannot sit still. | The girl practically stopped jumping up during classes, the number of changes in posture during “restlessness” decreased. This item was also noted in the institution where the child is being prepared for school. |
| Cannot complete everyday activities, daily chores (brushing teeth, cleaning bed, toys, etc.). Cannot perform, complete routine activities related to preparation for a session. | Sometimes (therapist's conclusion) | Rarely (therapist's conclusion) |
| If you give the child a simple errand (for example, to bring something from another room), he or she forgets it on the way and is distracted by foreign objects, stimuli. | Sometimes (parents opinion) | Rarely (parents opinion) |
| When the child needs to perform a task that is not the most attractive to him or her and requires a little volitional effort (for example, some task within training activities), he or she can concentrate on this type of activity. | < 1 min | From 1 to 5 min |
| The child is easily distracted by insignificant extraneous stimuli during training or developmental activities. | Often (therapist's conclusion) | Sometimes (therapist's conclusion) |
| Correction test (Landolt rings) | The girl refused to perform a correction test (Landolt rings) after **1.4 minutes**. At the intermediate control in the | At the end of the course, she also completed the task for **3 minutes,** but she practically didn’t get distracted, didn’t |

| | | |
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| | middle of the course, she completed the task for **3 minutes**, but was distracted, skipped lines and anxiously looked for mistakes. | skip lines, didn't double-check her mistakes. |
| Working with images using the "Find and Cross Out" method | Child did not follow the lines, worked mainly in the center of the page, periodically returning to the part already done. | The girl had already examined all parts of the page and almost did not return to the task she had completed. |

If in the first lessons, the girl was emotionally aroused by virtual reality and almost did not listen to the tasks from the therapist, then later she joined the process of classes, listened and completed the tasks. However, there were cases when, in case of failure to complete the task, the girl refused to put on the headset. The next day, she agreed to work with virtual reality and completed tasks.

# Results for 7-year-old boy (a) (ASD)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| **Compared parameters.** | **Before undergoing a series of sessions using virtual reality** | **After undergoing a series of sessions using virtual reality.** |
|---|---|---|
| During a break in a session does not concentrate on a particular kind of rest, a toy. | Often (parents opinion) | Sometimes (parents opinion) Parents note that the boy began to play more with ball toys. |
| If you give the child a simple errand (for example, to bring something from another room), he or she forgets it on the way and is distracted by foreign objects, stimuli. | Sometimes (parents opinion) | Rarely (parents opinion)<br><br>According to the parents, boy began to listen better and follow the instructions. |
| When the child needs to perform a task that is not the most attractive to him or her and requires a little volitional effort (for example, some task within | < 1 min (parents opinion) | From 1 to 5 min (parents opinion) |

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| training activities), he or she can concentrate on this type of activity. | | The boy became less distracted when doing exercises and homework. |
| The child is easily distracted by insignificant extraneous stimuli during play, even with subjectively attractive objects. | Often (parents opinion) | Sometimes (parents opinion) |
| The child is easily distracted by insignificant extraneous stimuli during training or developmental activities. | Often (parents opinion) | Sometimes (parents opinion) |
| The child needs to be reminded of what needs to be done now, as if he or she “loses” the purpose of the activity. | Often (parents opinion) | Sometimes (parents opinion) |
| During training/developmental activities you have to provide organizational assistance (“look!”, “be attentive!”, “think!”, “where should we put this part now?”, “let’s look together again!”, etc.) | Often (parents opinion)<br><br>Often (therapist's conclusion) | Sometimes (parents opinion)<br><br>Rarely (therapist's conclusion) |
| The child’s behavior can be characterized as distracted, unfocused. | Often (parents opinion) | Sometimes (parents opinion) |
| Schulte table (25)<br><br>3 attempts | The best time 1min 58 sec | The best time 1 min 42 sec |

# Results for 7-year-old boy (b) (ASD)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| **Compared parameters.** | **Before undergoing a series of sessions using virtual reality** | **After undergoing a series of sessions using virtual reality.** |
|---|---|---|
| Cannot complete everyday activities, daily chores | Sometimes (parents | Rarely (parents |

| | | |
|---|---|---|
| (brushing teeth, cleaning bed, toys, etc.).<br>Cannot perform, complete routine activities related to preparation for a session. | opinion) | opinion) |
| If you give the child a simple errand (for example, to bring something from another room), he or she forgets it on the way and is distracted by foreign objects, stimuli. | Often (parents opinion) | Sometimes (parents opinion) |
| When the child interacts with a familiar object that is attractive to him or her (for example, playing with a familiar and favorite toy), he or she can focus on this type of activity. | From 1 to 5 min (therapist's conclusion) | From 5 to 10 min (therapist's conclusion) |
| When the child needs to perform a task that is not the most attractive to him or her and requires a little volitional effort (for example, some task within training activities), he or she can concentrate on this type of activity. | From 1 to 5 min (parents opinion) | From 5 to 10 min (parents opinion) |
| The child is easily distracted by insignificant extraneous stimuli during play, even with subjectively attractive objects. | Often (parents opinion) | Sometimes (parents opinion) |

# Results for 8-year-old boy (ASD)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| **Compared parameters.** | **Before undergoing a series of sessions using virtual reality** | **After undergoing a series of sessions using virtual reality.** |
|---|---|---|
| Cannot complete everyday activities, daily chores (brushing teeth, cleaning bed, toys, etc.).<br>Cannot perform, complete routine activities related to preparation for a session. | Sometimes (therapist's conclusion) | Rarely (therapist's conclusion) |
| If you give the child a simple errand (for example, to bring something from another room), | Often (parents opinion) | Sometimes (parents |

| | | |
|---|---|---|
| he or she forgets it on the way and is distracted by foreign objects, stimuli. | | opinion) |
| When the child needs to perform a task that is not the most attractive to him or her and requires a little volitional effort (for example, some task within training activities), he or she can concentrate on this type of activity. | < 1 min (parents opinion) | From 1 to 5 min (parents opinion) |
| The child is easily distracted by insignificant extraneous stimuli during training or developmental activities. | Often (parents opinion) | Sometimes (parents opinion) |
| Correction test (Landolt rings) | The first 2 times he refused to complete the task. | Agreed to perform the task, did it carefully. But after 2 minutes he refused to continue. |
| Schulte table (25)<br><br>3 attempts | The best time 49 sec | The best time 47 sec |

# Results for 4-year-old boy (GUS)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| **Compared parameters.** | **Before undergoing a series of sessions using virtual reality** | **After undergoing a series of sessions using virtual reality.** |
|---|---|---|
| During a break in a session does not concentrate on a particular kind of rest, a toy. | Sometimes (parents opinion) | Rarely (parents opinion) |
| During table activities, fidgets in the chair, jumps up from his or her seat, changes body position. | Sometimes (therapist's conclusion and parents opinion) | Rarely (therapist's conclusion and parents opinion) |
| Working with images using the | Making the task for 2 minutes. | Making the task for 2 |

| | | |
|---|---|---|
| “Find and Cross Out” method | Passed 10 lines. Made 10 mistakes. | minutes. Passed 13.5 lines. Made 7 mistakes. |
| Schulte table (9)<br><br>3 attempts | The best time 19 sec | The best time 17 sec |
| Qualitative test for assessing attention.<br><br>On a horizontal surface (floor, table), objects of small size (up to 4 cm in height, of the same texture, size, and style; you will need two identical sets of objects) are placed within the child’s field of vision. The surface is divided into two halves (with a stick, a pencil, a line). In the left and right halves there are objects, the differences between them are 1-2 elements (examples are given in the photo below). Depending on the child’s functional capacity, the number of objects can vary from 3 to 7. Gradual increase in the number of objects is recommended. | Result:<br><br>The number of objects among which the child can find differences = 4 | Result:<br><br>The number of objects among which the child can find differences = 5 |

# Results for 5-year-old boy (GUS)

Changes based on the results of the questionnaire of the therapist and parents, as well as the results of tests for an objective assessment.

| **Compared parameters.** | **Before undergoing a series of sessions using virtual reality** | **After undergoing a series of sessions using virtual reality.** |
|---|---|---|
| During a break in a session does not concentrate on a particular kind of rest, a toy. | Often (parents opinion) | Sometimes (parents opinion) |
| During table activities, fidgets in the chair, jumps up from his or her seat, changes body position. | Often (therapist's conclusion) | Rarely (therapist's conclusion) |

| | | |
|---|---|---|
| When the child needs to perform a task that is not the most attractive to him or her and requires a little volitional effort (for example, some task within training activities), he or she can concentrate on this type of activity. | < 1 min (therapist's conclusion) | From 1 to 5 min (therapist's conclusion) |
| The child is easily distracted by insignificant extraneous stimuli during training or developmental activities. | Sometimes (therapist's conclusion and parents opinion) | Rarely (therapist's conclusion and parents opinion) |
| The child needs to be reminded of what needs to be done now, as if he or she “loses” the purpose of the activity. | Often (therapist's conclusion and parents opinion) | Sometimes (therapist's conclusion and parents opinion) |
| The child’s behavior can be characterized as distracted, unfocused. | Often (therapist's conclusion) | Sometimes (therapist's conclusion) |
| Working with images using the “Find and Cross Out” method | Making the task for 2 minutes. Passed 12 lines. Made 10 mistakes. | Making the task for 2 minutes. Passed 11 lines. Made 5 mistakes. |
| Schulte table (9)<br><br>3 attempts | The best time 20 sec | The best time 17 sec |
| Qualitative test for assessing attention.<br><br>On a horizontal surface (floor, table), objects of small size (up to 4 cm in height, of the same texture, size, and style; you will need two identical sets of objects) are placed within the child’s field of vision. The surface is divided into two halves (with a stick, a pencil, a line). In the left and right halves there are objects, the differences between them are 1-2 | Result:<br><br>The number of objects among which the child can find differences = 4 | Result:<br><br>The number of objects among which the child can find differences = 5 |

| | | |
|---|---|---|
| elements (examples are given in the photo below). Depending on the child’s functional capacity, the number of objects can vary from 3 to 7. Gradual increase in the number of objects is recommended. | | |

# Discussion

Our findings demonstrate that the utilization of virtual reality (VR) in learning significantly affects children's learning motivation and the development of their functional skills. These observations align with earlier studies that suggested that immersive, engaging, and interactive technology can enhance learning motivation and outcomes. The learning sessions were intensive and consistent, with VR usage being implemented within a span of 10-15 minutes during each session.

We found a noticeable change in the motivational aspect of the classes, with an increased interest and readiness to participate in VR-inclusive lessons. This was evident both in children and their parents. The introduction of VR into the educational context led to an increase in parental involvement, which consequently reinforced the skills trained within the VR application. This aligns with theories of parental involvement in education, which posit that when parents are actively involved in their children's learning process, it can enhance academic outcomes.

One remarkable observation was the improvement in several basic functional skills in the children. The usage of VR significantly improved the children's visual tracking of moving objects, accuracy of pointing gestures, retention of lines while reading, and tracking of the auxiliary movement of the finger. This points towards VR's potential for improving hand-eye coordination and cognitive processing skills in a controlled environment that minimizes distractions.

Further, we observed that the VR conditions fostered an environment that made it easier for children to focus their attention. This was visible in their attention to their own hand movements in the VR room, their attentiveness to auditory instructions, and their ability to maintain body position for longer periods. The findings resonate with the idea that VR can aid in concentration and promote a sense of presence.

From the users' reactions and ratings, we observed a general interest in the VR room and a preference for the white color of the hands in the VR interface. It indicates that the aesthetics and design of VR environments may play a role in user engagement and motivation.

Regarding the measurement of the effectiveness of our methodology, it should be mentioned that despite the observed improvements, there were no changes in the quantitative indicators of attention based on the Schulte method. This suggests a possible limitation in the sensitivity of the Schulte method to capture changes in attention span and functional skill formation. Future research could explore the use of more sensitive measurement tools or detailed questionnaires that capture changes in user behavior and skills more accurately.

In conclusion, our study provides promising evidence supporting the use of VR in educational settings. However, more research is needed to fully understand its potential benefits and limitations. Moreover, it is essential to consider the influence of design aesthetics in VR interfaces and to develop more valid tools for assessing changes in user behavior and skills. This

way, we can ensure that we leverage VR's potential to its fullest to facilitate optimal learning outcomes.

# Conclusion

This research affirms the significant potential of Virtual Reality (VR) as a tool to boost motivation, attention span, perseverance, and the development of fundamental skills in children with Autism Spectrum Disorder (ASD) and other neurodevelopmental disorders. By creating a controlled and distraction-free environment, VR fosters a more focused and effective learning experience.

Notably, we observed enhancements in children's ability to track objects visually, improve pointing accuracy, maintain attention on tasks, and display increased resilience when faced with challenges. These are crucial skills that often pose challenges for children with ASD and other neurodevelopmental disorders.

This study provides promising insights into the use of VR in educational and supportive settings for these children. However, it also underlines the need for continued research and development to maximize the benefits of VR in this context. The future holds immense possibilities for leveraging VR technology to create a more inclusive and effective educational environment for children with ASD and other neurodevelopmental disorders.

# Declarations

## Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations.

All peoples who participated (or their parents) in the study gave oral and written consent to participate in the study.

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