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Virtual reality as a tool for children with autism spectrum disorder

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Abstract

Children with an autism spectrum disorder tend to lose focus quickly. The possibility of displaying changeable, three-dimensional environments in virtual reality can increase the user's concentration time due to the stimuli used. Through the use of virtual reality, an individual assistant can be provided for the daily care and encouragement of learning for children with autism spectrum disorders. To investigate the feasibility of a virtual assistant and the acceptability of virtual reality among autistic children, a review of the literature and conducted studies is undertaken. The selection, identification and evaluation of the relevant research results is carried out according to the preferred reporting items of the systemic literature search.

Keywords: Autism spectrum disorder, virtual reality, virtual assistant, systematic review

1. Introduction

Autism Spectrum Disorder is a neurodevelopmental disorder that can be diagnosed as early as eighteen months of age. However, the diagnosis can be made at different ages because of the heterogeneity of symptoms. A prevalence of 0.6%-1% is assumed worldwide [Federal Environment Agency, 2021]. Compared to recent years, the number of autistic people has increased. The current development of diagnostic tools is seen as the cause of this increase [Federal Environment Agency, 2021]. Core deficits for this disorder are social communication, interaction, and repetitive behavioral patterns. Those affected need support for behavior, education, health and leisure ^[1]. In addition, deficits in information processing via sensory modalities, such as vision (gesture) and hearing (speech), can occur. There are screening tools for the diagnosis, with which the behavior of the children can be observed and evaluated. However, these tools are not sufficient for a definitive diagnosis. For this purpose, in the case of conspicuous behavior patterns, both cognitive tests and language tests are carried out. This can be performed and diagnosed by a pediatrician, psychologist, or neurologist. A prerequisite for this is sufficient knowledge of DSM-5 (Diagnostic and Statistical manual of mental disorders) ^[1]. Studies presented in this literature review report that the therapy of these disorders can be supported with the help of Virtual Reality (VR). The virtual world is a 3D environment in which a real world is created for the user. However, the focus is on therapy with the help of VR on emotion recognition ^[14]. With the help of this literature analysis, it is examined whether the use can also serve as support for problems in everyday life of autistic children.

2. Methods

The systematic literature search was carried out in three phases according to Kitchenham's method ^[2]. In order to carry out the investigation in a targeted manner, the research questions and the structure of the analysis were first planned. Next, the studies were checked for quality and selected. This also includes data extraction and data synthesis. Finally, the results were presented. These steps are described in detail in the following chapter.

2.1 Research question

For the systematic literature research, the research questions were first formulated. Since there is already knowledge that VR can be used as therapy for autistic children in emotion recognition, it was necessary to find out whether the use of VR would also be possible for

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support in everyday life. This resulted in the following research questions: "How is the acceptance of the children when using the VR glasses?", "Can the VR glasses provide support in everyday life?" and "Can the learning ability of the children be promoted in a playful way with the help of VR glasses become?"

2.2 Sources and Search Strategy

Pub-Med, ScienceDirect, IEEE and Web of Science databases were searched to find relevant scientific papers. Only sources related to the technology and the related relationship to medicine were considered. In addition, the years 2020 to 2021 were used as a filter for the year of publication. Thus, only the current studies were displayed.

2.2.1 Selection of Articles

The search terms were defined and searched for the search for relevant works that should serve to answer the research questions. In order to cover the fields of medicine and technology, the search terms "autism spectrum disorder" and "virtual reality" were defined. Since these terms are to be searched for in context, the operators AND and OR are used. This resulted in the statement "(Virtual reality OR virtual environment) AND (autism OR autism spectrum disorder) AND (child OR children)" as a search term.

2.2.2 Eligibility Criteria for Studies

Several points were considered as selection criteria. These criteria are based on the fact that the articles listed not only examine medical treatment in terms of content, but also contain a reference to VR. Inclusion criteria considered are shown in Table 1. Criteria were also established for excluded studies, which can be seen in Table 2.

Table 1: Study inclusion criteria

Inclusion Criteria	
E1	Studies which in 2020 and 2021 were published
E2	Journals and conference papers
E3	Studies with a focus on autism spectrum disorder
E4	Studies related to the use of technology (VR)
E5	Studies conducted in the context learning

Table 2: Study exclusion criteria

Exclusion criteria	
A1	Studies that have a pure focus on medical research
A2	Studies that focus on caregivers or parents
A3	Studies with a focus on augmented reality

The inclusion and exclusion procedures are illustrated diagrammatically in Figure 1 to clarify the process of searching and selecting studies.

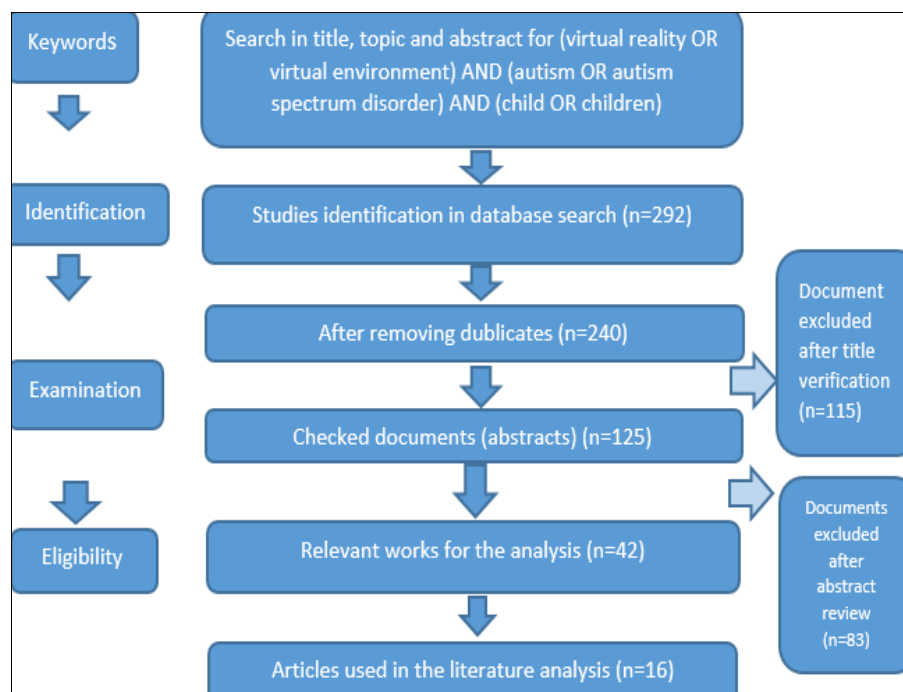


Fig 1: Flow chart: Item selection process

2.3 Data Synthesis

A total of 292 items were found with this search. Several databases were examined and resulting duplicates were removed. 125 articles were also removed based on the title check. This was done using the exclusion criteria. For the examination of the remaining 125 articles, the abstract was read first. Here, too, the inclusion and exclusion criteria were observed and studies were selected. Finally, a total of 42 articles were classified as relevant and retained for the literature analysis. These articles have been studied in more detail to extract important information. After this extraction, the remaining papers were read in their entirety. A new selection was carried out in relation to the relevance of the

research questions and finally a total of 24 articles were selected for the analysis. However, in order to stay within the scope of this scientific work, 16 articles were included in the analysis, in which the use and acceptance of VR glasses was described in detail.

3. Findings of the studies

3.1 Release year and type of items

In order to take the current research into account, a filter for the year of publication of the published work was set during the search. For this purpose, the work published in 2020 and 2021 was taken into account. A distribution is shown in Fig. 2.

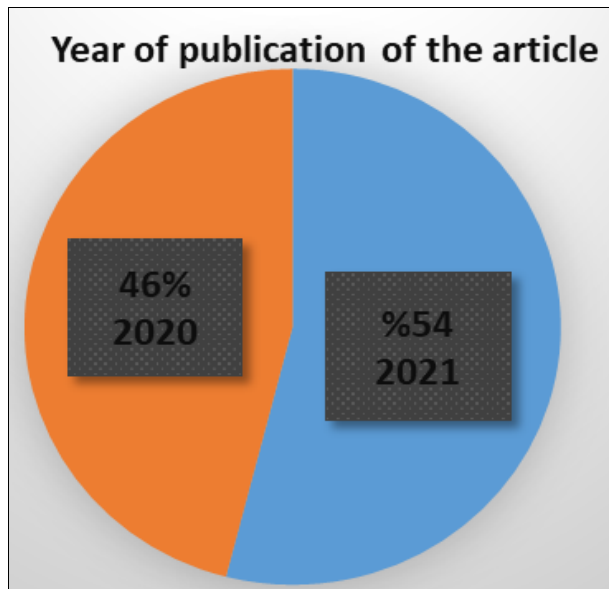


Fig 2: Share of publication years

The species is taken into account for the use of the data and results of the articles. Here it was important to obtain empirical data as well. Figure 3 shows the distribution of article types.

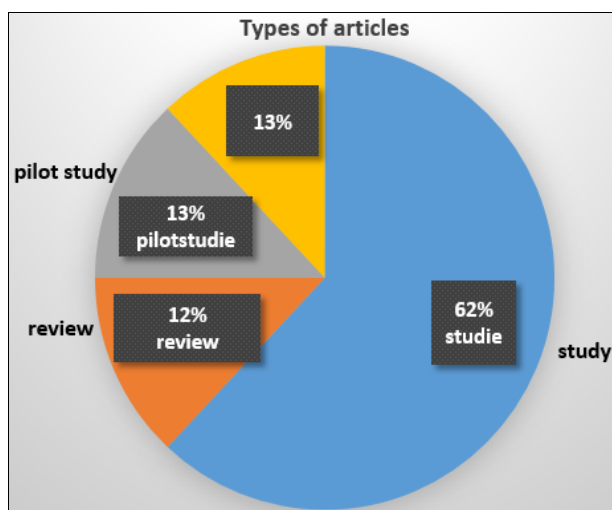


Fig 3: Type of items

3.2 Study design and sample size

The studies are mostly carried out to test the usability and the acceptance of the subjects. Articles found relate to autistic children, although the age group may vary. Studies from Qatar ^[3], Canada ^[4] and the Netherlands ^[5] have the widest sample size and thus achieve a higher information rate (Qatar = 45 children, Netherlands = 22, Canada = 35 children). Further studies are carried out with only three, five or a maximum of 12 children. The intended age for the studies is 10 years on average. However, this average value cannot be generalized as there are also studies that only examine children aged 4-8 years. The design of the studies can be explained with a usability test. The experiments conducted with the children provide information on whether the children are coping with the virtual world and whether they are able to implement the skills they have learned in the real world after the sessions. After the sessions, feedback is obtained from the subjects and from the parents or caregivers. Even after the end of the study, conclusions are

drawn about the behavior of the children. As inclusion criteria for test persons, a medical diagnosis of the disorder and, if present, evidence of additional disorders such as phobias, hyperactivity and the ability for verbal or non-verbal communication of the children are obtained before the experiment.

3.3 Technologies used

In the work by Bilikis ^[3] a virtual classroom is presented to measure children's attention. An eye tracker is used for this purpose, which is intended to follow the eyes of the children. The eye tracker can be used to measure where the children's areas of interest (AOI) are located and how long this interest lasts. Malihi ^[4] also present a virtual environment in which the subjects can see a scenario on the bus with a head-mounted display (HMD). Another work from the USA by Dixon ^[6] reports a scenario with an HMD for learning to cross the street with cars and traffic lights. The study by Johnston ^[7] uses spatial audio and a dark forest scenario in addition to an HMD to match the visual and auditory sensory experiences of the real world. In the pilot report by Miller ^[8] an I phone X is used together with a Google Cardboard to demonstrate the usefulness of a low-cost VR experience. To report a comparison between the virtual environments in terms of the design of the VR learning scenarios, the work by Shing ^[9] used a CAVE (cave automatic virtual environment) and an HDM. CAVE is a three-dimensional space in which the illusion of virtual reality can be projected. Ravindran ^[10] examine a self-developed software called "Floreo", which provides scenes for Google Carboard compatible smartphones, how children's attention can be stimulated with different games. Another work by Rahmadiva ^[11] uses the Leap Motion device in addition to an HMD. The hands of the subjects are read by infrared and transferred to manipulated hands in the virtual world. Leap-Motion can use infrared to capture objects and transfer them into the virtual world. This means that the hands of the subjects can be used as a means of interaction in the virtual world. The choice for an HMD fell on the studies on the Oculus Rift. With these glasses, which are connected to a computer, the experience of an immersive reality and the display of three-dimensional images is possible.

3.4 Objectives of the studies

The aim of these studies is to test the acceptance of the virtual environment in autistic children and thereby strengthen their willingness to learn. Since autistic children often suffer from poor concentration and lose their attention quickly, the use of VR tries to keep the children interested. As soon as the attention disappears, they lose interest in the task and the associated learning effect. For this purpose, the work by Bilikis ^[3] examines how children react to external stimuli and how much they are distracted by them. These stimuli in the virtual environment can be experimented with by exposing the children to more or less stimuli. This examination is extended with the calculation of times such as "Time to fix on AOI", "Duration of first fixation", "Average fixation duration" and "Sum of fixation count". These times give an indication of how the virtual environment can be designed, or what additional elements should be added to retain attention. The use of the "Floeo" software also aims to place elements in the virtual world so that the children's attention is drawn to the desired elements

or areas in the virtual world ^[10]. In addition, this work examines whether a learning scenario in VR can be set up for children with limited verbal skills and needs in relation to social reciprocity ^[10]. In addition to the attention, the focus on relevant information plays an important role in the study objectives. Rahmadiva ^[11] develop a game for this in which the children should learn to shift their attention. Autistic children often have the problem of not knowing which task is more important. It is therefore important to first arouse the children's interest in order to then increase their concentration. Then the training for the focus can be tackled.

In addition to attention, emotion recognition is also a deficit that can occur in autism. In order to provide assistance in this regard, a study is being carried out that is intended to facilitate emotion recognition with the help of avatars ^[5]. Because the avatars can make the emotions more visible, the aim of this study is to develop a learning scenario for children to recognize the emotions of the oncoming avatars when crossing a shopping street. The selection from multiple-choice answers is achieved by clicking on the given answer options. In addition, this study attempts to strengthen the children's ability to understand the interactions of the avatars and to develop a socio-cognitive problem-solving technique through role play ^[5].

Case studies were also examined in the studies and possible solutions sought. Due to the children's quick confusion and lack of concentration, learning in everyday life can lead to difficulties. For this reason, experiments are being carried out in the virtual world to make it possible to learn the rules of the road in a playful way ^[6, 12]. For this purpose, a scenario is created in which the children are supposed to cross a street with cars, stop signs and traffic lights. The aim is to first learn the basic rules of crossing a street in the virtual world and then to implement this knowledge in the real world. Due to the adjustable options of the virtual world, with empty streets or busy streets, the fear of the children is minimized and a safe environment is conveyed ^[6, 12].

Another case study is carried out to promote the ability to travel by air ^[8]. It focuses on social communication and interaction (SCI) and uses simulations to try to alleviate children's anxiety in a new environment or a crowded place. The aim is that after these sessions children can easily cope with a stay at the airport or a trip by plane ^[8]. In addition to the alleviation of the anxiety states, another study is being carried out that aims to train those affected to be alarmed and to be safe. Shree ^[13] is developing a game in the virtual environment that is intended to draw the children's attention when there is a danger. In this scenario, a house is shown, which is located in a forest environment in which a fire breaks out after a few seconds. The child is made aware of the fire with a note such as an erupting alarm signal or the avatars' calls for help. After this clue, the children should go into the house in the virtual world and identify the object that caught fire. After identification, the child must get to safety, run out of the house and wait safely in the forest. It is expressly emphasized that the aim of this study is to develop awareness of alarm situations ^[13]. In this way, the child develops the ability to improvise in order to become sensitive to fire and recognize the danger without panicking. In order to perceive the real world, the brain must decode a constant stream of multimodal information from different sensory channels. This information can be visual, auditory

or textual, for example. In the work by Johnston ^[7] showed that 65% of autistic people have a complication in auditory perception. Therefore, they studied spatial attention and sound localization ability in a multimodal VR environment. The aim is to determine head movements and rotational accuracy in response to auditory stimuli. For this purpose, a scenario in the dark forest was prepared, in which the children should use sounds to find objects. Since the auditory approaches are examined in this study, a dark environment was deliberately chosen so that the attention is not scattered by the bright light.

In the article by Malihi ^[4] is not set as a goal to create a learning effect, but to test the safety and usability of VR environments with autistic children. A scenario was also prepared for this in which the children board a stationary bus and both sensory and social triggers are displayed. For usability, effectiveness, efficiency and satisfaction are tested here, which is examined using questionnaires and self-reports. Safety while using the HDM is also examined based on this feedback and observations during the session ^[4]. Li ^[9] examine how different immersive VR environments affect the design of the learning scenarios. It examines how the learning content can be designed to facilitate experiential learning for autistic children in a virtual environment. Here the concept for experience-based learning by Kolb ^[9] is assumed. This concept involves an iterative learning cycle consisting of four steps:

1. Concrete experience
2. Reflective observation
3. Abstract conceptualization
4. Active experimentation

4. Discussion

After presenting the approach of several works, the collected results are discussed in this section. The research questions can be answered with the findings of the studies and information from various literature searches.

4.1 Results

The results of the work were initially collected through participant or therapist surveys ^[5]. During the test phase, it was recorded how many children, for example the test process with a bus, gave up ^[4]. A negative experience with a bus is given as the reason for this termination. The noise and fidgeting triggered anxiety in the children, which prevented them from continuing the process ^[4]. However, 30% of the users were less nervous when boarding a real bus ^[4]. The children's parents also report a positive change when boarding a real bus ^[4]. Malihi provide preliminary evidence that head-mounted displays have the potential to improve user experience over video displayed on a monitor ^[4]. Dixon ^[6] report that short videos have no after-effect on the real environment. On the other hand, long videos draw attention to irrelevant areas. Therefore, they recommend interaction during the process for a lasting effect of use. According to Nijman ^[5] multiple choice answers are not a helpful method. Instead, open-ended responses are used to reinforce understanding of how and why. It has also turned out that combined tasks can cause problems ^[3]. Looking at letters, saying them out loud and clicking on the correct answer at the same time irritates the children ^[3].

It must be emphasized that the problems of autistic children can be very different. However, the fundamental problems lie in perception, attention, emotion recognition and

awareness. Because of the varying Children's reactions to different stimuli, an individual or customizable user interface is suggested ^[14]. A child with autism spectrum disorder needs a contact person who shares interests and remains consistent even when the child is misbehaving. From a therapeutic point of view, this is unfortunately not possible in the long term. For this, an individual, virtual friend is proposed, which can be adjusted according to preferences and which, based on the collected data, can intelligently decide on the next suitable steps and build up a knowledge base in relation to the interests. This can be provided using autonomous systems ^[14]. Because a virtual environment is predictable and structured, autistic children can maintain their routine and repetitive behavior. It is important not to compromise comfort in children with this disorder as much as possible. In order to maintain attention, it is strongly advised to incorporate necessary elements such as point collection, various levels and rewards. It has been shown that feedback and avatars promote the attention of those affected ^[15].

The virtual world is a safe and supportive environment in which knowledge transfer between the virtual and real world can take place. Because manipulation of the introduction or removal of activities or actions is possible, it provides powerful and customizable learning ^[16]. Thus, obstacles faced by autistic children in finding learning materials in the appropriate format are removed. The benefit of VR is that it offers flexibility, easy and intuitive use, and low physical effort ^[16].

4.2 Answering the research questions

According to Jeffs ^[16] the use of virtual reality can be used to promote reading and writing skills. This makes it easier for children to read and distinguish printed brand names on products or labels, for example. Buying ability, for example when shopping for groceries, can also be strengthened ^[16]. Affected children may learn social skills such as asking for help or safety skills such as learning signs to reduce danger ^[16]. It is thus clear that the area of application of virtual reality can be varied as required.

The aim of this systematic literature review was to answer the following research questions:

- How do children accept using VR glasses?
- Can the glasses provide support in everyday life?
- Can the ability to learn be supported playfully with the help of VR glasses?

With the knowledge gathered, these questions can be answered very satisfactorily. Examined articles have shown that children accept the VR glasses very quickly and also enjoy using them. If difficulties arose during the first use, training courses have helped to eliminate these problems. Case studies have shown that using a VR environment can also provide support for everyday life, such as crossing a street or preparing for a trip by plane. According to the approach of Zhao ^[14] it is reinforced that the use of an individual assistant is helpful. With this point of reference, further difficulties in everyday life can be overcome. Since the children can use the VR glasses flexibly, the training can be individually designed. Feedback received after each session and research after the experiments have been completed have shown that the learning effects are maintained after the testing operations. Also, it is confirmed that humanoid or non-humanoid avatars advance the

educational process and improve social skills ^[17].

Finally, it can be stated that virtual reality is an important part of learning support for autistic children and will also be used as a therapy tool in everyday life in the future. Since each child has individual difficulties, these problems can be eliminated by using a personal VR assistant in everyday life. Further, it would be interesting to investigate whether an autonomous, adaptable system for each child makes the expected achievements in overcoming the problems in everyday life feasible.

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