SYSTEMATIC LITERATURE REVIEW

**Patterns and Connections in Children with ASD: Understanding Preferences for Avatar Interaction in Augmented Reality**

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**ABSTRACT**

Innovative mobile health (mHealth) solutions have proliferated over the past ten years due to improved computer capabilities and mobile technologies, and there have been numerous new research initiatives in the field of technology-based treatments (TBI) for children autism spectrum disorders (ASD). AR systems that make use of portable like smartphones, tablets, or smart glasses, are referred to as augmented reality (AR). The findings of a systematic study conducted in 2010 on the application of AR for acquiring skills relevant to ASD are presented in this article. In addition to offering direction to pertinent designers and researchers, it seeks to shed light on the present status of AR intervention research. Our initial search yielded 625 items from two databases. Over the last decade, advancements in computer and mobile technologies have led to a proliferation of innovative mobile health (mHealth) solutions, and a plethora of new research projects have emerged in the field of technology-based therapies (TBI) for children autism spectrum disorders (ASD). This article presents the results of a comprehensive study on the use of AR for learning abilities related to ASD that was carried out in 2010. Sixty-five entries from two databases were found in our first search.

***Keywords:*** *Children with ASD, Augmented Reality, Avatar*

**INTRODUCTION**

Due to their innate lack of social skills, children with autism, who are influenced by specific linguistic abilities and cognitive limitations, frequently address significant problems (APA, 2013). These social skills impairments are diverse and sophisticated (Baron-Cohen, 1998). Numerous individuals with autism encounter different circumstances and struggle with various kinds and severity of symptoms that mostly impact their interpersonal interaction, speech communication, nonverbal body language, and social reciprocity (Baron-Cohen, 2009). Some of them are intrigued to meet others' perspectives, control their emotions, and have obstacles to responding appropriately to social situations (Fletcher-Watson, 2020). These impairments indirectly bond to challenging children with ASD to establish social relationships. All of them are more likely to experience isolation, bullying, and consequently, social situations precisely, these social circumstances could accentuate the anxiety and helplessness they already feel in their everyday lives (Chen et al, 2015).

The public might discover it easier to access devices like computers, tablets, and smartphones according to the advised technology. Children with impairments are helped by a number of them. Throughout the past ten years, increasing research and studies have focused on technology-based therapy for autism spectrum disorder (ASD). Research shows that children with ASD who use technology and augmented reality (AR) are more likely to develop certain behavioral and social abilities. Because of this, AR-based evaluations and intervention tools are particularly fascinating (Dechsling et al., 2022). Children with autism spectrum disorder (ASD) occasionally experience issue expressing themselves and reacting correctly in social situations through body language and facial expressions. This has a negative impact on the quality of their daily lives. However, through recognizing the body language and facial expressions of 3D virtual characters, children with ASD can acquire knowledge how to interact with other people through AR-enhanced video games (Lee, 2021). The sense of presence that augmented reality (AR) provides is described as "a mental state through which objects that are virtual are experienced as actual object regardless of sensory or nonsensory ways" in addition to a state of consciousness that relies upon the perception of being there in an AR environment. A feature known as an avatar, which appears in a AR environment and functions nearly identically to a human, is a further instance of a sense of presence. Riches et al. (2019) reported that when the AR produced real cognitive, emotional, and behavioral reactions, and additionally when participants constructed their own accounts about events or placed themselves in a sociocultural network connected with memories, it facilitated a sense of presence. When participants experienced physical barriers including cybersickness and awareness of bodily movement and equipment, as well as diminished agency, present declined. According to Ren (2024), a sense of presence in an online environment is insufficient to keep children interested and reduce social anxiety during the learning process. The avatar feature of augmented reality aids children with ASD strengthen their social skills in typical circumstances, but it doesn't completely solve their anxiety and anxiety. Since the avatar has been designed to be the same age as children with ASD, it will primarily concentrate on basic needs and everyday communication in order to establish equity in connection and engagement. Because it puts a greater priority on functional communication than on the intricacy and adaptability of interaction, it is failing in enhancing social skills. Feedback mostly consists of static graphics and straightforward answers; it does not fully replicate actual social settings and does not include real-time dynamic interaction.

AI-generated interfaces, on the reverse hand, enable a unique interactive and guided environment while remaining safe and supervised, allowing children with ASD to practice skills while reducing social stress (Xiong, 2021). Virtual human technology provides a safe and regulated setting with its special interactivity and assistance, enabling children with ASD to practice skills while decreasing social demands (Ren, 2024). This technology greatly lessens children's nervousness when they encounter real-world human interactions by providing them with virtual interactive partners and interesting social circumstances, which encourages them to engage more fully in training. The system translates user speech commands into processable text and use natural language processing (NLP) to comprehend user intent by combining multimodal interaction technologies, such as voice input and adaptive controllers. Children with autism who difficulty with verbal communication can effectively use the system due to to this enrichment of the natural interaction experience and visual support. despite this they express a great deal of interest in communicating with virtual persons, those who possess ASD frequently overlook important aspects of virtual humans while interacting with them.

**METHOD**

*Research Design*

A systematic literature review (SLR) is a procedure for discovering, assessing, and deconstructing all of the research that is significant to a topic area or specific research question, according to Kitchenham, B. (2004). We follow Kitchenham's recommended methodology and the PRISMA criteria (Liberati et al., 2009) for conducting this study.

*Defining the Research Questions*

To accomplish a comprehensive examination of this topic, ten questions have been created using the PICO framework (Chandler et al., 2019). The population (P) in this study encompasses autistic people who are participating in the intervention process; the intervention (I) under account is the use of AR applications for ASD; the comparison (C) is pointless because the purpose of this study is to describe the use of Augmented Reality (AR); and the outcomes (O) are the primary results attained. Therefore, as indicated below, we developed ten research questions that serve as a guide for the study. Sub-research questions are also presented.

|  |  |  |
| --- | --- | --- |
| **No.** | **R|es|earch Qu|estions** | **Data |extraction Proc|ess** |
| RQ1 | What chann|els ar|e us|ed to publish r|es|earch articl|es on childr|en with ASD int|erv|entions |exploiting AR t|echnology? | V|enu|e and y|ears of publication ar|e r|equir|ed |
| RQ2 | What d|evic|es w|er|e us|ed? | Th|e us|ed t|echnological d|evic|es ar|e r|equir|ed |
| RQ3 | What ar|e targ|et|ed population? | Charact|eristics of participants should b|e d|efin|ed |
| RQ4 | For what propos|es has b|e|en appli|ed that th|e propos|ed solution? | Th|e targ|et|ed skills of s|el|ect|ed studi|es should b|e |extract|ed |
| RQ5 | What r|es|earch d|esigns ar|e us|ed in th|e studi|es? | Th|e r|es|earch d|esign of s|el|ect|ed studi|es should b|e d|efin|ed |
| RQ6 | What m|ethods ar|e us|ed to |evaluat|e th|e p|erformanc|e of participants with provid|ed AR t|echnology int|erv|ention? | Th|e ass|essm|ent m|ethodology should b|e pr|es|ent|ed |
| RQ7 | What ar|e th|e outcom|es obtain|ed by th|e application of th|e propos|ed solutions | Th|e major outcom|es of th|e study should b|e pr|es|ent|ed |
| RQ8 | Which s|ettings ar|e us|ed in th|e primary studi|es? | D|etails in th|e s|etting (classroom, hom|e, controll|ed r|es|earch |environm|ent, |etc) ar|e r|equir|ed. |
| RQ9 | How sustainabl|e th|e outcom|e of th|e int|erv|entions is? | D|etails information about maint|enanc|e |
| RQ10 | How g|en|eraliz|ed th|e int|erv|ention r|esult is? | D|etail|ed information about g|en|eralization |

Th|e d|emographic data of th|e primary r|es|earch, such as th|e publish|ed y|ears, articl|e g|enr|es, and th|e quality we evaluated, are referred to as the channel in RQ1. The situation in which the intervention is carried out is referred to as the setting in RQ8. RQ9 defines sustainable as maintaining acquired skills over time, whereas RQ10 defines generalization as applying acquired skills to a new setting.

*Search Strategy*

To gather primary information for this analysis, two internet databases relating to scientific disciplines related to both technologies and ASD therapy were selected. Among these databases are Web of Science and Scopus. The steps involved in the search and selection process are described below:

* Verify each reference independently and remove any that are incorrect (abstracts, contents, etc.) from the EndNote;
* Analyze the online databases independently, and manually input the search results into EndNote for further screening;
* To eliminate all duplicate studies;
* To examine th|e r|es|earch titl|e, abstract, introduction, and conclusion; to |eliminat|e publications that do not m|e|et th|e inclusion crit|eria;
* Conduct a full-text review to eliminate non-mobile AR research (e.g., those that require a PC or Kinect);
* Add the studies from other review papers that we skipped.

Since we only examined papers r|el|evant to comput|er-r|elat|ed cat|egori|es, such as t|echnology, |engin|e|ering, and comput|er sci|enc|e, we did not include publications from the medical or chemical disciplines in our analysis of these resources. Additionally, we chose articles that were released throughout a thirteen-year period, from January 2014 to November 2024.

### *Search Strings*

Based on the subjects of our systematic review, we generated the search terms. Those that follow are the outcomes of combining our topic-related keywords with Boolean operators during the search process : (“Autism\*” OR “Autism Sp|ectrum Disord|er” OR “ASD”) AND (“Mobil|e augm|ent|ed r|eality” OR “AR” OR “Augm|ent|ed r|eality”) AND (“Mobil|e” OR “Tabl|et” OR “Smartphon|e” OR “Phon|e.

### *Inclusion and |Exclusion Crit|eria*

To compr|eh|end compl|et|ely th|e d|esigns w|e ar|e working with and answ|er th|e r|es|earch qu|estions bas|ed on th|e s|el|ect|ed pap|ers. In ord|er to choos|e th|e p|ertin|ent r|es|earch issu|e for th|e s|el|ection crit|eria, th|e id|entifi|ed pap|ers w|er|e includ|ed using th|e PICO mod|el (Higgins, 2008): P: Childr|en in th|e population had to b|e diagnos|ed with autism sp|ectrum disord|er (ASD); I: int|erv|ention (th|e study had to r|eport an AR-bas|ed tr|eatm|ent or an AR-bas|ed int|erv|ention); C: control group (as oppos|ed to non-AR or non-AR-bas|ed tr|eatm|ent, childr|en's condition prior to AR or AR-bas|ed tr|eatm|ent, and without tr|eatm|ent); and O: outcom|e (th|e primary outcom|es attain|ed).

Additionally, th|e authors mandat|ed that th|e Int|ernational Classification of Dis|eas|es (ICD) (WHO, 2004) or th|e Diagnostic and Statistical Manual of M|ental Disord|ers (DSM) (APA, 2013) b|e us|ed to diagnos|e autism. Singl|e-cas|e studi|es or group study d|esigns should hav|e b|e|en tak|en into account in th|e int|erv|ention d|esign, and th|e studi|es should pr|ef|erably hav|e b|e|en approv|ed for publication in p|e|er-r|evi|ew|ed journals or in |English.   
  
Th|e following crit|eria w|er|e us|ed to |exclud|e studi|es: (1) did not includ|e childr|en or adol|esc|ents with autism sp|ectrum disord|er (ASD); (2) did not us|e AR t|echnology-bas|ed th|erapi|es as int|erv|entions; (3) w|er|e not primary r|es|earch r|eports (such as abstracts, not|es, protocols, l|ett|ers, and |editorials); or (4) did not r|eport pati|ent outcom|es.

### *Data Extraction*

The following standards for inclusion were applied:

* R|es|earch from p|e|er-r|evi|ew|ed journals or conf|er|enc|es, books, and l|ectur|e not|es;
* Articl|es concentrating on AR applications for children with ASD;
* Studies published in English;
* Articles published after January 2014;
* Article must be fully open access

*Search Process*

A thorough search of the chosen bibliographic databases according to the topic of discussion is necessary for the systematic literature review. The search procedure is processing according to the standard steps, which are detailed below:

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| --- | --- | --- |
| ***Databas|e*** | ***Qu|ery*** | ***Not|es (if any)*** |
| Web of science | Advanced search :  ("Children with Autism\*" OR "Children with Autism Spectrum Disorder" AND ("Augmented Reality") AND DOCUMENT TYPES (Article OR Open Access) | Year : 2014-2024  Language : English |
| Scopus | Advanced search :  ("Children with Autism\*" OR "Children with Autism Spectrum Disorder" AND ("Augmented Reality") AND DOCUMENT TYPES (Article OR Open Access) | Year : 2014-2024  Language : English |

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### *Methodological Quality Evaluation*

Th|e studi|es includ|ed in this syst|ematic r|evi|ew w|er|e ass|ess|ed for quality using Reichow's evaluative technique (Reichow, 2011). This m|ethod is |eff|ectiv|e wh|en |evaluating |empirical r|es|earch on sp|ecific tr|eatm|ents for individuals with autism sp|ectrum disord|ers. Additionally, this m|ethod works just as w|ell for |evaluating studi|es that us|e singl|e-subj|ect or group comparison d|esigns. According to R|eichow's conc|ept, th|e |evaluation approach follow|ed a compr|eh|ensiv|e proc|ess that was compl|et|ed in thr|e|e stag|es. Th|e following primary quality indicators ar|e us|ed in th|e first st|ep to |evaluat|e th|e quality of |each study: (1) participant charact|eristics; (2) d|efinitions of ind|ep|end|ent and d|ep|end|ent variabl|es; (3) bas|elin|e conditions; and (4) data visualizations. S|econdary quality m|easur|es includ|e blind rat|ers, th|e Kappa statistic, fid|elity, g|en|eralization or maint|enanc|e, social validity, and int|erobs|erv|er agr|e|em|ent. Although s|econdary indicators ar|e important, it is not b|eli|ev|ed that th|ey ar|e n|ec|essary to |evaluat|e th|e validity of a study. |Each indicator r|ec|eiv|ed on|e of thr|e|e ratings: "high quality" (H), "acc|eptabl|e quality" (A), or "unacc|eptabl|e quality" (U). Lastly, the research was summarized using a grading system, and it was categorized as "strong," "adequate," or "weak." The final criterion used to aggregate the research was the number of participants in single-subject study designs and the number of studies in group comparison designs that were successfully treated in studies categorized as "strong" or "adequate". Every possible combination of evidence was found for each intervention using the previously outlined evidence-based practice (EBP) methodology :

Records identified through Scopus & Web of Science

(n = 625)

Identification

Records included after incorrect removal   
(n=413)

Studies added   
(n=9)

Inclusion and exclusion criteria met  
(n=92)

Duplicates removed  
(n=279)

Included

Screening

Records included after full-text review  
(n=36)

Add studies from other SLR   
(n=56)

Records included based on keywords and abstract   
(n=47)

Records screened after duplicates removed   
(n=134)

**Figure 1.** Literature search and selection process.

**RESULT**

*R1 : WHAT CHANNELS ARE USED TO PUBLISH RESEARCH ARTICLE ON CHILDREN WITH ASD INTERVENTIONS EXPLOITING AUGMENTED REALITY TECHNOLOGY?*

The review's findings indicate that studies are released through a variety of ways. The quantity and kind of papers produced annually are displayed in Figure 2. 61.1% (n = 22) of the examined publications were published after 2018, with the majority (n = 22) having been published since 2011. Just 2.7% were published in books, but 38.8% w|er|e publish|ed in conf|er|enc|e proc|e|edings and mor|e than half (58.3%) w|er|e r|eport|ed in journals. N|early half (47.2%) of the materials are found in conference proceedings or periodicals devoted to technology. The remaining studies were published in publications and in conferences for education and medicine. The remaining publications are dispersed throughout 19 journals, 14 conf|er|enc|es, and 1 book, with th|e Journal of R|es|earch on T|echnology in |Education app|earing twic|e [59, 60]. 21.4% (n = 3) of conf|er|enc|es m|ention|ed in COR|E rankings and 37.5% (n = 9) of articl|es pr|es|ent|ed in th|e JCR ranking. R|egarding th|e curr|ent r|es|earch|ers, it was discov|er|ed that McMahon, Chung, L|e|e, Vahabzad|eh, and |Escob|edo |each hav|e two studi|es as th|e first author, whil|e K|eshav and Sahin |each hav|e thr|e|e studi|es as th|e first author.

*R2 : WHAT DEVICES WERE USED?*

Mobile telephones, laptops, iPads, smart glasses, and iPod touch are among the technology and equipment that researchers have employed in the intervention. Smart glasses (n = 10) and mobile cellphones (n = 10) are used in mor|e than half (55.6%) of research intervention programs. iPad and tablet usage rates are 19.4% (n = 7) and 13.9% (n = 5) respectively. According to reports, they were able to utilize any mobile device—laptop, tablet, or smartphone—in three tests, and the iPod was mentioned once.

*R3 : WHAT ARE TARGETED POPULATION?*

The majority of the studies had less than five participants (55.6%, n = 20), but 13.9% had six to nine subjects and 25% (n = 9) recruited ten to twenty. In the studies by Keshav et al. [51] and Antao et al. [53], there were over 20 individuals. Four publications provide a quick summary of the number of participants, whereas 36.1% of th|e studi|es (n=13) |eith|er did not provid|e th|e d|emographic charact|eristics of th|e participants participants in detail or did not even recruit people. For example, Intelligence quotient (IQ) ratings were utilized by Lee et al. [58] to assess individuals' suitability for project study participation. The most recent research (n = 19) provided a detailed description of the demographics and inclusion criteria for the participants. Male participants made up 81% of the total 77 individuals in 14 studies that reported the proportion of male and female participants. Parental involvement was only mentioned in one study.

*R4 : FOR WHAT PROPOSES HAS BEEN APPLIED THAT THE PROPOSES SOLUTION?*

Nubia et al (2015) hav|e alr|eady r|eport|ed th|e application of AR to improv|e th|e ar|eas of communication in childr|en with autism. Th|e purpos|e was to |examin|e wh|eth|er an AR int|erv|ention would improv|e att|ention proc|ess|es and sp|e|ech |expr|ession. . Taryadi |et al (2018) hav|e int|egrat|ed th|e us|e of AR with th|e P|ECS (Pictur|e |Exchang|e Communication Syst|em) t|echniqu|e in training th|e communication skills of childr|en with autism. Th|e prototyp|e b|eing d|ev|elop|ed by th|e authors t|erm|ed Multim|edia AR us|es imag|es, vid|eos, and sounds that |enabl|e on|e to work with P|ECS by simply scanning a QR cod|e, r|eplacing th|e traditional P|ECS with s|el|ecting an imag|e. L|e|e (2019) r|eport|ed on an augm|ent|ed r|eality coloring book (ARCB) to train ASD childr|en how to acknowl|edg|e and int|erpr|et som|e c|ertain social signals. Rath|er, this is th|e just singl|e study that has b|e|en discov|er|ed on augm|ent|ed r|eality coloring books. ARCB sustain|ed th|e participants' |engag|em|ent and maintain|ed positiv|e int|erv|ention outcom|es until th|e maint|enanc|e stag|e. Lor|enzo |et al (2019) have carried out a research to evaluate the efficacy of an AR training program called Quicker Vision app to enhance social skills with autism.

Abou et al (2019) proposed a framework to help childr|en with ASD and ID l|earn in an improv|ed |educational |environm|ent to incr|eas|e social communication and b|ehavior, while the users of the d|esign|ed syst|em ar|e par|ents and t|each|ers, which might r|educ|e th|e |engag|em|ent of autistic childr|en. Conc|erning b|ehavioral skills. Vahabzad|eh |et al (2018) mainly pr|es|ent|ed th|e b|ehavioral and social-|emotional impacts of using |Empow|er|ed Brain on stud|ents with ASD to |examin|e its f|easibility and its |efficacy. Th|ey carri|ed out a study to furth|er inv|estigat|e wh|eth|er |EBS r|educ|es us|ers' irritability and hyp|eractivity. Wang |et al (2019) hav|e don|e r|es|earch to improving th|e |eff|ectivn|ess of autistic childr|en's assistanc|e r|equ|est and |expr|ession functions. Th|e authors hav|e d|ev|elop|ed an Auto Organizational M|enu (AOM), which pairs augm|ent|ed r|eality (AR) with k|ey-part vid|eos with actions (KPV) and ass|ess|ed it through obs|ervational m|ethods. Liu |et al (2017) did on|e s|ession of th|e int|erv|ention in schools and th|en r|eport|ed low|er ABC scor|es on th|e post-t|est, which improv|ed nonv|erbal communication, |ey|e contact, and social participation. Vahabzad|eh |et al (2018) conduct|ed an inv|estigation into chang|es in ADHD-r|elat|ed symptoms in childr|en, adol|esc|ents, and young adults with ASD following th|e us|e of th|e |Empow|er|ed Brain syst|em. Th|e authors us|ed th|e ABC-H scal|e to t|est th|e participants and clust|er|ed th|em according to th|eir scor|es

*R5 : WHAT RESEARCH DESIGNS ARE USED IN THE STUDIES?*

A quarter (25%) of the published publications had no-experimental designs, which are defined by the absence of a control group, multiple measurements, and random assignment design. Eight percent (n = 3) reported a quasi-experimental design including a control group, while two-thirds of the research was carried out using a single-case experimental methodology. In their pre-posttest control group design, Lorenzo et al (2019) divided 11 participants (10 men and 1 woman) into two groups: the experimental group (n = 6) and the control group (n = 5). Because they employed a non-probabilistic purposeful sampling technique, it is not a random assignment experiment. A posttest control group design was introduced by Antao et al (2020) which contrasted the evaluations of several participant groups at the conclusion of the assessment. Along with the most basic pretest-posttest single-case experimental design, there are additional withdrawal single-case designs, alternating treatment single-subject designs, and multiple baseline single-case designs that improve internal validity.

*R6 : WHAT METHODS ARE USED TO EVALUATE THE PERFORMANCE OF PARTICIPANTS WITH PROVICED AR TECHNOLOGY INTERVENTION?*

The results of the mobile AR intervention are recorded using the outcome measurement approach. Survey research, scaling, qualitative research, and non-intrusive measures are the four primary categories of measuring, according to William M.K. Trochim (2007). An interview, questionnaire, observation, and scaling are the four primary outcome measurement techniques that have been employed in the primary studies. Of the studies, 36.1% employed a variety of methods for measurement, 16.7% did not r|eport it, and th|e r|emaining studi|es us|ed only on|e m|easuring m|ethod. Mor|e sp|ecifically, 17 studi|es us|ed surv|ey r|es|earch (8 for questionnaires and 9 for interviews) along or with other measurement methods, 11 studies applied qualitative observation research, and 14 applied scaling. Scaling entails taking into account the primary techniques for creating and implementing scales, while survey research encompasses the design and execution of questionnaires and interviews. A variety of non-numerical measurement techniques are described in qualitative research.

*R7 : WHAT ARE THE OUTCOMES OBTAINED BY THE APPLICATION OF THE PROPOSED SOLUTIONS?*

The main findings of the primary investigations did not carry out user studies but instead reported the outcomes of developing an app, prototype framework, and concept. The majority of studies (42%, n = 15) demonstrated that participants' performance and abilities improved. The qualitative analysis of the study in [51,56,73] demonstrates that participants improved their communication and social interaction abilities. Continuous attention and engagement have improved, according to 16.7% of the investigations (Wang, 2019). The authors of the research by McMahon et al (2015) and Cihak et al (2016) discovered that all participants had increased their level of independence following the AR training. According to the statistical analysis in Vahabzad|eh |et al (2018), childr|en with ASD ar|e l|ess irritabl|e Th|er|e w|er|e no statistically significant diff|er|enc|es between the control and experimental groups, with or without the use of AR-based intervention, according to the results of [68]. However, the researchers' qualitative feedback indicated that AR improved children's motivation and attentional focus, which can help children with ASD develop their skills.

*R8 : WHICH SETTING ARE USED IN THE PRIMARY STUDIES?*

Three types of primary research environments were identified from the primary studies: school, community, and laboratory. Most research was conducted in a school setting (50 percent, n = 18), with the lab coming in second (22.2 percent). The community setting was used in the study conducted in Lorenzo et al (2019), and Nubia et al (2015) conducted their research in a clinic. Two studies did not specify the setting environment.

*R9 : HOW SUSTAINABLE THE OUTCOME OF THE INTERVENTIONS IS?*

There are only six research evaluating near/far effects, and the durability effects of AR have seldom been studied. The results of the immediate and delayed post-tests were comparable, suggesting that the increased correct rate was sustained. Escobedo et al (2014) started the maintenance phase one week following the intervention, while Cihak et al (2016) carried it out nine weeks later. The maintenance phase was addressed but not fully described by Taryadi and Kurniawan (2018).

*R10 : HOW GENERALIZED THE INTERVENTION RESULT IS?*

From th|e primary studi|es, only on|e study by L|e|e |et al (2019) conduct|ed g|en|eralization prob|es at various instanc|es (bas|elin|e, int|erv|ention and maint|enanc|e) of th|eir r|es|earch, but th|ey did not pr|es|ent th|e g|en|eralization r|esults.

**CONCLUSIONS**

According to preliminary research, smartphone augmented reality has a beneficial impact on ASD and has tremendous promise for assisting parents and educators in more successful early intervention. Even though practically every well-conducted study has shown encouraging outcomes, we nevertheless need to be aware of the problems that still present. Future study in this developing multidisciplinary field should, if at all possible, adhere to rigorous evaluation procedures and methodical experimental research methods. For example, the validity of the measurements can be increased by using physiological evaluation techniques like eye-tracking. Additionally, when choosing volunteers, gender bias must be kept to a minimum. Additionally, we should be aware that the more participants in int|erv|ention studi|es that conc|entrat|e on th|e growth of a singl|e p|erson, th|e wors|e. In ord|er to |enhanc|e th|e l|earning outcom|es attain|ed during th|e int|erv|ention and to boost us|er satisfaction, it is also critical to cr|eat|e AR syst|ems using a us|er-c|ent|er|ed approach, incorporating mor|e family m|emb|ers and d|esigning products that match th|eir n|e|eds. Lastly, to furth|er |evid|enc|e-bas|ed practic|e r|es|earch on mobil|e augm|ent|ed r|eality, studi|es on th|e long-t|erm impacts and diss|emination of AR should b|e carri|ed out. Th|e us|e of mobil|e AR t|echnology in autism sp|ectrum disord|er int|erv|entions is pr|es|ent|ed ov|erall in this syst|ematic r|evi|ew, which also addr|ess|es t|en r|es|earch qu|estions to off|er AR-bas|ed solutions for skill l|earning for p|eopl|e with ASD and provid|es guidanc|e for futur|e r|es|earch to improv|e AR for p|eopl|e with autism. It is intended that this review would help researchers, educators, and anyone who are interested in ASD by offering helpful advice and insights. Future researchers are suggested to research the role of symbolic person features in the learning process of children with ASD, this is related to capacity building so that in the future they can produce avatar features that are more than just tools for intervention and researchers so far have not found research articles related to this field.

**DECLARATION OF POTENTIAL CONFLICT OF INTEREST**

Aulia Widi mangesti is not involved in work or receiving funding from any company or organization that may benefit from the publication of this manuscript.

**REFERENCES:**

1. Almurashi, H., Bouaziz, R., Alharthi, W., Al-Sarem, M., Hadwan, M., & Kammoun, S. (2022). Augmented reality, serious games and picture exchange communication system for people with ASD: systematic literature review and future directions. *Sensors*, *22*(3), 1250.
2. American Psychiatric Association, D. S. M. T. F., & American Psychiatric Association, D. S. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (Vol. 5, No. 5). Washington, DC: American Psychiatric Association.
3. Antão, J. Y. F. D. L., Abreu, L. C. D., Barbosa, R. T. D. A., Crocetta, T. B., Guarnieri, R., Massetti, T., ... & Monteiro, C. B. D. M. (2020). Use of augmented reality with a motion-controlled game utilizing alphabet letters and numbers to improve performance and reaction time skills for people with autism spectrum disorder. *Cyberpsychology, Behavior, and Social Networking*, *23*(1), 16-22.
4. Atzil, S., Hendler, T., & Feldman, R. (2011). Specifying the neurobiological basis of human attachment: brain, hormones, and behavior in synchronous and intrusive mothers. *Neuropsychopharmacology*, *36*(13), 2603-2615.
5. Baron‐Cohen, S. (2009). Autism: the empathizing–systemizing (E‐S) theory. Annals of the New York Academy of Sciences, 1156(1), 68-80.
6. Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: Cognitive or affective?. Journal of autism and developmental disorders, 18(3), 379-402.
7. Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. J. H. W. (2019). Cochrane handbook for systematic reviews of interventions. *Hoboken: Wiley*.
8. Chen, C. H., Lee, I. J., & Lin, L. Y. (2015). Augmented reality-based self-facial modeling to promote the emotional expression and social skills of adolescents with autism spectrum disorders. Research in developmental disabilities, 36, 396-403.
9. Cihak, D. F., Moore, E. J., Wright, R. E., McMahon, D. D., Gibbons, M. M., & Smith, C. (2016). Evaluating augmented reality to complete a chain task for elementary students with autism. *Journal of Special Education Technology*, *31*(2), 99-108.
10. Dechsling, A., Orm, S., Kalandadze, T., Sütterlin, S., Øien, R. A., Shic, F., & Nordahl-Hansen, A. (2021). Virtual and augmented reality in social skills interventions for individuals with autism spectrum disorder: A scoping review. *Journal of autism and developmental disorders*, 1-16.
11. Delaherche, E., Chetouani, M., Mahdhaoui, A., Saint-Georges, C., Viaux, S., & Cohen, D. (2012). Interpersonal synchrony: A survey of evaluation methods across disciplines. *IEEE Transactions on Affective Computing*, *3*(3), 349-365.
12. Dumas, G., Nadel, J., Soussignan, R., Martinerie, J., & Garnero, L. (2010). Inter-brain synchronization during social interaction. *PloS one*, *5*(8), e12166.
13. El-Seoud, A., Halabi, O., & Geroimenko, V. (2019). Assisting individuals with autism and cognitive disorders: an augmented reality based framework.
14. Escobedo, L., Tentori, M., Quintana, E., Favela, J., & Garcia-Rosas, D. (2014). Using augmented reality to help children with autism stay focused. *IEEE Pervasive Computing*, *13*(1), 38-46.
15. Fletcher-Watson, S., & Bird, G. (2020). Autism and empathy: What are the real links?. Autism, 24(1), 3-6.
16. Higgins, J. P. (2008). Cochrane handbook for systematic reviews of interventions version 5.0. 1. The Cochrane Collaboration. *http://www. cochrane-handbook. org*.
17. Lee, I. J., Chen, C. H., Wang, C. P., & Chung, C. H. (2018). Augmented reality plus concept map technique to teach children with ASD to use social cues when meeting and greeting. *The Asia-Pacific Education Researcher*, *27*, 227-243.
18. Lee, I. J. (2019). Augmented reality coloring book: An interactive strategy for teaching children with autism to focus on specific nonverbal social cues to promote their social skills. *Interaction Studies*, *20*(2), 256-274.
19. Lee, I. J. (2021). Kinect-for-windows with augmented reality in an interactive roleplay system for children with an autism spectrum disorder. *Interactive Learning Environments*, *29*(4), 688-704.
20. Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*, *151*(4), W-65.
21. Liu, R., Salisbury, J. P., Vahabzadeh, A., & Sahin, N. T. (2017). Feasibility of an autism-focused augmented reality smartglasses system for social communication and behavioral coaching. *Frontiers in pediatrics*, *5*, 145.
22. Lorenzo, G., Gómez-Puerta, M., Arráez-Vera, G., & Lorenzo-Lledó, A. (2019). Preliminary study of augmented reality as an instrument for improvement of social skills in children with autism spectrum disorder. *Education and Information Technologies*, *24*, 181-204.
23. Keshav, N. U., Vogt-Lowell, K., Vahabzadeh, A., & Sahin, N. T. (2019). Digital attention-related augmented-reality game: significant correlation between student game performance and validated clinical measures of attention-deficit/hyperactivity disorder (ADHD). *Children*, *6*(6), 72.
24. Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, *33*(2004), 1-26.
25. First, M. B., France, A., & Pincus, H. A. (2004). *DSM-IV-TR guidebook*. American Psychiatric Publishing, Inc..
26. O’Nions, E., Happé, F., Evers, K., Boonen, H., & Noens, I. (2018). How do parents manage irritability, challenging behaviour, non-compliance and anxiety in children with autism spectrum disorders? A meta-synthesis. *Journal of autism and developmental disorders*, *48*, 1272-1286.
27. Marsh, K. L., Isenhower, R. W., Richardson, M. J., Helt, M., Verbalis, A. D., Schmidt, R. C., & Fein, D. (2013). Autism and social disconnection in interpersonal rocking. *Frontiers in integrative neuroscience*, *7*, 4.
28. McMahon, D., Cihak, D. F., & Wright, R. (2015). Augmented reality as a navigation tool to employment opportunities for postsecondary education students with intellectual disabilities and autism. *Journal of Research on Technology in Education*, *47*(3), 157-172.
29. Mogan, R., Fischer, R., & Bulbulia, J. A. (2017). To be in synchrony or not? A meta-analysis of synchrony's effects on behavior, perception, cognition and affect. *Journal of Experimental Social Psychology*, *72*, 13-20.
30. Nebel, M. B., Eloyan, A., Nettles, C. A., Sweeney, K. L., Ament, K., Ward, R. E., ... & Mostofsky, S. H. (2016). Intrinsic visual-motor synchrony correlates with social deficits in autism. *Biological psychiatry*, *79*(8), 633-641.
31. Nubia, R. M., Fabian, G. R., Wilson, R. A., & Wilmer, P. B. (2015, October). Development of a mobile application in augmented reality to improve the communication field of autistic children at a Neurorehabilitar Clinic. In *2015 Workshop on Engineering Applications-International Congress on Engineering (WEA)* (pp. 1-6). IEEE.
32. Ren, Y., Liu, R., Sang, H., & Yu, X. (2024). Avatar-Based Picture Exchange Communication System Enhancing Joint Attention Training for Children With Autism. *IEEE Journal of Biomedical and Health Informatics*.
33. Riches, S., Elghany, S., Garety, P., Rus-Calafell, M., & Valmaggia, L. (2019). Factors affecting sense of presence in a virtual reality social environment: A qualitative study. *Cyberpsychology, Behavior, and Social Networking*, *22*(4), 288-292.
34. Reichow, B. (2011). Development, procedures, and application of the evaluative method for determining evidence-based practices in autism. Evidence-based practices and treatments for children with autism, 25-39.
35. Romero, V., Fitzpatrick, P., Roulier, S., Duncan, A., Richardson, M. J., & Schmidt, E. R. (2018). Evidence of embodied social competence during conversation in high functioning children with autism spectrum disorder. *Plos one*, *13*(3), e0193906.
36. Taryadi, & Kurniawan, I. (2018, January). The improvement of autism spectrum disorders on children communication ability with PECS method Multimedia Augmented Reality-Based. In *Journal of Physics: Conference Series* (Vol. 947, p. 012009). IOP Publishing.
37. Trochim, W., & Donnelly, J. P. (2007). The research methods knowledge base 3rd Ed: Mason. *OH: Thompson Publishing Group*.
38. Uzuegbunam, N., Wong, W. H., Cheung, S. C. S., & Ruble, L. (2017). MEBook: multimedia social greetings intervention for children with autism spectrum disorders. *IEEE Transactions on Learning Technologies*, *11*(4), 520-535.
39. Vahabzadeh, A., Keshav, N. U., Abdus-Sabur, R., Huey, K., Liu, R., & Sahin, N. T. (2018). Improved socio-emotional and behavioral functioning in students with autism following school-based smartglasses intervention: Multi-stage feasibility and controlled efficacy study. *Behavioral Sciences*, *8*(10), 85.
40. Vahabzadeh, A., Keshav, N. U., Salisbury, J. P., & Sahin, N. T. (2018). Improvement of attention-deficit/hyperactivity disorder symptoms in school-aged children, adolescents, and young adults with autism via a digital smartglasses-based socioemotional coaching aid: short-term, uncontrolled pilot study. *JMIR mental health*, *5*(2), e9631.
41. Van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. *International journal of virtual reality*, *9*(2), 1-20.
42. Wang, C. P., & Tsai, C. H. (2019). Requesting Help Module Interface Design on Speech-Generating Device and Augmented Reality for Children with Autism Spectrum Disorder. *Educ. Innov. Appl*, 395-398.
43. World Health Organization (Ed.). (2004). *International Statistical Classification of Diseases and related health problems: Alphabetical index* (Vol. 3). World Health Organization.
44. Xavier, J., Gauthier, S., Cohen, D., Zahoui, M., Chetouani, M., Villa, F., ... & Anzalone, S. (2018). Interpersonal synchronization, motor coordination, and control are impaired during a dynamic imitation task in children with autism spectrum disorder. *Frontiers in psychology*, *9*, 1467.
45. Xiong, H., Jin, C., Alazab, M., Yeh, K. H., Wang, H., Gadekallu, T. R., ... & Su, C. (2021). On the design of blockchain-based ECDSA with fault-tolerant batch verification protocol for blockchain-enabled IoMT. *IEEE journal of biomedical and health informatics*, *26*(5), 1977-1986.