Technology-Assisted Intervention for Children with Autism Spectrum Disorder using Augmented Reality

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Abstract: ***Technology-assisted intervention has potentials in improving the social, communication and behavior impairments in of children with autism spectrum disorder (ASD). Augmented reality (AR) offers multitude of possibilities and opportunities for the intervention of children with ASD. Therefore, this study identifies 13 researches from 2012 to 2018 that documented the efficacy of augmented reality applications in supporting the intervention of children with ASD. This study reviews the applications of augmented reality that nhanced the intervention for children with autism in (i) social skills, (ii) communication skills, and (iii) behavior skills. The conclusion reports the significant roles of augmented reality as technology-assisted intervention for children with ASD.***

Keywords: Aaugmented Reality, AR, Technology-Assisted Intervention, Children with ASD.

I. INTRODUCTION

The increasing in awareness among public on Autism Spectrum Disorder (ASD) has led to the growing interests in the related research. The research focus in autism ranged from the medical field to the education related autism intervention. Autism spectrum disorder is one of the larger spectrum of complex brain disorders which known as Pervasive Developmental Disorders (PDDs)[1]. Leo Kanner described autism as a syndrome of autistic disturbance. A triad of severe impairment symptom is found in most of the person diagnosed with ASD. The impairments are mostly in reciprocal socialization, language and communication, and stereotypical or unusual behavior [2]. Person with ASD regularly exhibits unique characters with different cognitive styles, having emotional and physical health issues, memory and intellectual disabilities, motor coordination difficulties and joint attention problem. Therefore, a person with ASD is different from a normal person in thinking, feeling, hearing, speaking, social interaction and at how they are facing with the daily life skills [3]. Some of them manage to live independently and socialize with the society, but others might require assistance and guidance [4]. In other cases, they tend to be alone and living in their own world of interest. In order to increase the ability to learn new skills and knowledge among the children with ASD, a special or specific training have to be conducted for them. As a result, the children with ASD might be able to adapt with the changing environment and people.

A study by Baglama et.al. [5], has shown an increase in the research interests towards the technology application as intervention for autism between 2015 and 2016. The current trend of research studies mostly focus on video modeling, virtual and augmented reality and robotic technologies. Many researchers have also works on the ways of how augmented reality could benefits in educational settings and intervention for autism. Augmented reality technology has the promising functionalities and capabilities to attract attention and increase the focus of children with ASD towards learning materials during training [6], encourage their self-regulation [7] and self-facial expression [8], improve enjoyment, involvement and develop imagination skills [3][9]. Augmented reality is very effective as an educational and therapeutic method [10].

This paper aims to explore the application of augmented reality as the technology-assisted intervention for children with ASD. The review of the previous study in augmented reality applications for ASD was conducted from the year of 2012 to 2018. This research also tries to identify the augmented reality applications that focus on different impairments in autism.

II. RELATED WORK

A. Technology-Assisted Intervention for Children with ASD

There are broad development of software and products for educational program and intervention focusing on children with ASD. The implementation of technology-assisted intervention will benefit the families, teachers or the professionals by lessening the distress when dealing with children with autism [10],[11]. Technology-assisted intervention has wide possibilities to assist in improving the impairments and skills that the children with ASD may suffered or not well-developed [13]. Technology-assisted intervention offers functional supports for users to exercise their strengths and weaknesses repetitively while enjoying themselves, support social interactions and help motivation within activities [14],[15]. Furthermore, technology-assisted intervention could expand the accessibility spectrum and reduce the costs of providing effective interventions for autism [16].

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In addition, technology-assisted intervention can be personalized according to autism needs, preferences or interests [17]. Previous studies had shown numerous technology-assisted interventions that has been adopted and adapted for generic and specific autism education and therapy. According to Cafiero [18], most researchers and practitioners tend to classify the technology tools used for autism into two categories. The augmentative and alternative communication devices includes speech generating devices, computer generated graphic system and Internet communication. Computer learning software and virtual learning are classified as the other technology and media devices for autism intervention.

Odom et al. [19] detailed the previous work by classifying seven areas where technologies are utilized for the intervention of people with ASD through video modeling, visually prompt supports, specific training for social and academic skills, covert audio coaching, speech generating devices, performance feedback and self-management. Extending the previous study, Barton et al.[20] coded technology-based intervention for ASD into three categories: (a) Augmentative and Alternative Communication (AAC), (b) Computer Aided Instruction (CAI) and (c) Virtual Reality (VR). They emphasized that the utilization of technology-based intervention has to be expanded into a broad scope of its component and characteristic to address the diverse needs of autism. Although, Knight et al. [21] suggests to embed individual basis and systematic instructional procedures with reinforcement and regular monitoring when applying technology for autism intervention. Aljameel et al. [22] extend a review which focuses on technology that enhances on cognitive domain: (1) language and communication, (2) social skill, and (3) facial and emotion recognition. Their finding shows the application of various technologies intervention for ASD from year 2005 to 2015. The range of technology-assisted intervention includes power point slides with visual and audio component, movie clips, animated tutor text-based software, interactive agents [23], computer [24][25][26], serious game [27]–[29], tablet-based system [30], collaborative system [31], virtual reality (VR) [32]–[34] and augmented reality (AR) system [35]–[37] .

B. Augmented Reality

Augmented Reality (AR) is a computer technology that has many advantages in sustaining domain areas such as engineering, entertainment, medical and surgical operation, education and other fields where information are essentials. This technology can enhance our perception towards our real world experience in a new and enriched way, with the assistance of computational models and elements. The idea of augmented reality was first initiated by a cinematographer known as Morton Heileg, back in 1950s [38]. However, the first augmented reality prototype has been realized by a research group lead by Ivan Sutherland [39]. The term "Augmented Reality" was originally coined by scientists working at Boeing Corporation [17],[40]. Since then, augmented reality has become research interests in many areas.

In augmented reality applications, physical objects are overlaid and blended with computer generated images or virtual information in a real-time world in a non-immersive way [41]–[43]. Thus, it can enhance the experience or understanding of the users. Azuma et al. [44] has defined the most accepted requirements of augmented reality, where it combines real and virtual elements (or content; imagery) that are able to perform interactively in real-time environment and calibrates with each other. There are different context and perspectives about augmented reality:

- Augmented reality as the emergent technology to create a "next generation, reality-based interface" [39].
- Augmented reality challenges the human perception through visual telepresence, may possibly affect the human life and cultures [45].
- Augmented reality is a wide spectrum of technologies that may incorporate multiple computer-generated sensory input technologies [46].
- Augmented reality "bridge the gap between the real and virtual objects" [47].
- Augmented reality might have capabilities in augmenting smell, touch and hearing for person with or without disabilities [39].
- Augmented reality is known as "mediated or diminished reality" [39].

In an augmented reality system, user may partially or fully immersed in the environment but still co-exist in the real world. It is slightly different from virtual reality where users are completely immersed in virtual world. Both augmented reality and virtual reality provide different kind of visual feedback although rely on similar technology [48]. However, the reality-virtuality (RV) continuum concept introduced by Milgram and Kishino, has highlighted augmented reality as a form of mixed reality [47]. Within this theory, augmented reality sets between real environment and virtual environment. The wide interpretation of the theory includes the "reality of augmented reality" and the "virtually of augmented reality" [45], " the range of realness between the fully real and the fully virtual" [49] and the " substitution from direct interaction to smarts environments to digitally enhanced physical worlds and to virtual worlds" [50].

Vyas et al. [46] categorized three types of interaction in augmented reality system:

- GPS and compass-based AR system uses onboard GPS and compass to detect user's current location, thus facilitating user's navigation by aligning virtual objects with camera screen.
- Marker-based AR system displays 3D related objects or photo by tracking on the visual marker.
- Marker-less AR system rely on natural features to perform the object tracking and display the required outputs.

As an addition, Tobar-muñoz et al. [51] identified spatial augmented reality where interaction occurs when players facing the marker towards camera or using controlled based device. Kim et al. [52] in their review on major survey papers which were published since 1997, had discovered three categories of core augmented reality technologies. According to them, the research scope and trends on augmented reality implementations have changed from virtual information to the tracking types and focus on display device.

III. METHOD

A comprehensive review of the current augmented reality application for children with ASD was conducted. In the literature review, 13 articles published in journals and conference proceedings which met the criteria were analyzed. The review was carried out by covering research articles published between years 2012 to 2018.

Three stages of filtering and analysis were used in finding the related articles. The first stage includes with finding the articles published in indexed journal, non-indexed journal and conference proceedings. The articles were identified throughout the searching in (a) Google Scholar; (b) IEEE Explore; (c) ACM Digital Library; (d) Science Direct; (e) SAGE; and (f) SpringerLink. The search terms 'augmented reality','autism', 'autism intervention', 'technology-based intervention', 'technology-aided intervention' and 'technology-assisted intervention' were used in finding the relevant articles prior to the research scope. Searches were restricted to articles written in English. The combination of Boolean term used in the keyword search. Articles which enclosed title with the application of 'augmented reality' and focus on 'autism children' or 'children with autism' or 'autistic children' or 'children with special disabilities' were searched interchangeably. Focus on autism impairments were also considered in the article search process. In the first search, about 110 articles were discovered and downloaded in electronic format.

In the second stage, the abstract in the articles which appears in the searching processing were skimmed to find the related contents. The purpose of this stage was to identify articles which met the following criteria:

(1) The study propose technology-assisted intervention for autism.
(2) The study using augmented reality as the technology-assisted intervention
(3) The study focus on particular impairments in ASD.
(4) The study must have included at least one participant with ASD.

The third stage involves analyzing the content of the remained articles in depth. An article is excluded if the article only discusses reviews, systematic review or proposed design. In total, about 13 articles were made into a result table.

IV. RESULT AND DISCUSSION

A total of thirteen articles met the criteria on presenting augmented reality as the technology-assisted intervention for children with ASD. Table I summarized findings from the studies.

A. Augmented Reality Applications for Autism Intervention in Social Skills

There are five (5) studies focused on the application of augmented reality to improve the social skills of children with ASD. Bhatt et al. [36] develop two (2) augmented reality-based educational games to assist children with ASD in social skills. The selected children were monitored to play with *Happy minion* and *Emotion* games to help them in recognizing human emotion and facial expression. The Happy minion game utilized a motion tracking technology with the use of a web camera to capture a user's facial expression. While that, the feedback gained from the *Emotion* game provides a result on the level of understanding of human emotion. The effectiveness of the proposed augmented reality games was measured by conducting a usability study with four children with ASD from the age of 10 to 15 years old. The study indicates that the augmented reality games help to increase the skills of socializing with peers among the children with ASD.

Bai et al.[35] develop an augmented reality application that implements a pretend play concept to nurture the lack of imagination in children with ASD. A marker-based tracking was used with the augmented reality objects. The augmented reality system allows users to interact with the augmented reality objects that reflect as the imaginative toys through physical blocks that represent mirroring metaphors. A pilot study with twelve participants between 4 to 6 years old was conducted. The result showed a positive impact of augmented reality in eliciting the pretend play among the children with ASD.

Chen et al.[6] conduct a study with six children with ASD between 11 to 13 years old to test the effectiveness of a developed augmented reality-based video modeling storybook of nonverbal facial cues. The experiment was conducted with the assistance of an experienced occupational therapist in three sessions which involved a baseline phase, an intervention phase and a maintenance phase. The effectiveness of the augmented reality story book system was observed before and after the intervention. The augmented reality system works by allowing participants to interact with the video in a given storybook. When user used handheld tablet pc, the system augmented the virtual video showed while a social stimuli will appears. The participants will be asked to select the appropriate emotion for six facial expressions. The result showed that the augmented reality system had attracted the children's attention and improved their social and emotional awareness.

Hosseini & Foutohi-Ghazvini [10] develop an augmented reality application by embedding *Picture Exchange Communication System (PECS)* method. They conducted a quasi-experimental study on children with ASD between the age of 6 and 11 years old. The result showed that augmented reality system can enhance the communication ability of the children with ASD.

Sahin et al.[54] investigate the effectiveness of using augmented reality intervention in improving the social communication among children with ASD in a school setting. The 'Empowered Brain Face2Face' tool with augmented reality smart glass was used in the 16 intervention sessions with a 13 years old autistic student. A single subject experimental design was conducted in the study, within a subject control. The intervention was conducted for twice-daily times during three weeks of school day, facilitated by school teachers. The 'Empowered Brain' contains module that focusing on improving attention to social cues and recognizing facial emotion. Outcome from the study was measured using a validated social communication measurement for children with ASD known as *Social Responsiveness Scale 2 (SRS2)*. Observation notes recorded the difficulties occurred during intervention sessions. The intervention resulted with an improvement in social communication.

Furthermore, the result also showed an improvement in social motivation and behavior skills. It was also found out that the augmented reality system is applicable to be used in the school setting with the facilitation of school professionals.

B. Augmented Reality Applications for Autism Intervention in Communication Skills

Casas et al. [55] proposed a prototype using pictogram in natural interaction environment through augmented reality application.

Table- I: Research on Augmented Reality Applications for Autism between Years 2012 to 2018

Author	Participants/	Autism Impairments	Methodology	Outcomes
Syahputra et al., (2018) [56]	Unidentified	Cognitive skills	User testing	AR helps to train the focus and concentration ability
Nazaruddin & Effendi (2018) [57]	Four students	Cognitive skills	Descriptive procedural design	The design of AR is important in increasing the focus and attention to object recognition.
Sahin et al., (2018)[54]	13 years old	Social and communication skills	Single subject experimental design	AR improves the social communication of participants.
Taryadi & Kurniawan (2016) [9]	5-12 years old	Behavior skills	Experimental session PECS	AR works effectively for discrete trial autistic children training
Hosseini & Foutohi-Ghazvini (2016)[10]	6-11 years old	Social and communication skills	Quasi-experimental PECS	
Cihak et al., (2016)[7]	Three elementary students	Daily living skills	Experimental session Multiple probe design across participants	AR is effective in motivating elementary students with ASD
Chen, Lee, & Lin, (2016) [59]	10-13 years old	Emotional and social skills	Experimental session	AR system motivates participants in recognizing social signals
Nubia et al.,(2015)[60]	6 children	Communication skills	Tests Interviews	AR increase the use of verbal language and speech
Bai et al.,(2015)[61]	4-6 years old	Social and communication skills	Pilot study Experiment design	AR helps to engage children with ASD during intervention
da Silva, Fernandes, & Grohmann (2015)[62]	6-10 years old	Communication skills	Tests	AR has benefits in speech-language therapy for children with ASD
Bhatt, De Leon, & Al-Jumaily (2014) [36]	10-15 years old	Social and communication skills	Usability study	AR games increase the enjoyable feelings
Escobedo & Favela (2014) [63]	12 children	Cognitive skills	Single-subject design	AR has an effect on the engagement of children with ASD
Casas et. al.,(2012)[55]	Unidentified	Communication skills	User testing	Pictogram is used with AR for training of children with ASD

The purpose of the prototype was as a medium to foster the motivation of the children with ASD in the intervention aspect. Communication skill was addressed in the prototype by encouraging self-recognition and self-awareness.

Nubia et al.[60]developed an augmented reality application with the representative of pictogram and related images. They tested the application with six children with ASD at Neurorehabilitar Clinic. A speech therapist and an auditor also involved in the intervention session. The test resulted in the increased of verbal language as of 9% compared to traditional method.

C. Augmented Reality Applications for Autism Intervention in Behavioral Skills

A study focused on improving the behavioral skills of children with ASD has been conducted by Taryadi & Kurniawan [9] They had developed an augmented system with the implementation of PEC system. They followed the common practice in discrete trial training in implementing the system. The system used camera to track the children with autism action. Reinforcement or reward point will be given for accomplishment for every correct answer given. The behavior of the children with ASD was tracked especially the hand movement using hand detection technique.

D. Augmented Reality Applications as Technology-Assisted Intervention

Seven types of technology-assisted intervention includes video modelling, visual prompt or visual cues, specific training for academic content, audio coaching, speech generating devices, performance feedback and reinforcement and self-management [19]. Our intention was to determine the potential implementation of augmented reality as the technology-assisted intervention for children with ASD. However, most of the developed augmented reality application discovered in the literature used video modeling, visual prompt or visual cues, includes specific training and performance feedback and reinforcement.

Video modeling. We identified two researchers that utilized video modeling to enhance the communication skills of children with ASD, conducted by Chen et al. [6]. The researchers created video fragments that portray daily life scenarios at different places. An augmented reality-based storybook is used to train the given social cues to participants. Bhatt et al. [36] used real time video feed to establish augmented reality features in the proposed game and to capture immediate user feedback.

Visual prompt/visual cues. The most frequent strategy used in current augmented reality application. Two applications had embedded this strategy in increasing the social skills of autism children. Bhatt et al. [36] and Sahin et al. [54] proposed the used of visual face to support imagination and pretend play of autism children. Bai et al. [61] proposed virtual objects of interests overlaying on physical props to encourage imaginative pretend play among the autism children. While that, the other researchers used PECS and pictogram to support their augmented reality intervention in communication skill and behavior skill. Casas et al. [55] implemented virtual avatar to encourage the children with ASD to identify their self- image and body parts.

Specific training. Discrete Trial Training (DTT) was used by Taryadi & Kurniawan [9] in their augmented reality application. The purpose is to improve the learning methods among the autism children by instructing the task, monitoring the feedback and strengthen their understanding.

Performance feedback/reinforcement. Audio and visual reinforcement were used in the application proposed by da Silva et al. [62]. The reinforcement helps to guide and engage the children during the intervention activity. Taryadi & Kurniawan [9] again used continuous positive reinforcement in encouraging the autism children to respond correctly. Their proposed system detected any delayed or incorrect action performed during intervention. Hosseini & Foutohi-Ghazvini [10] implemented repetition and practice as the reinforcement strategy in the intervention.

V. CONCLUSION

It was found that most of the developed augmented reality applications were focused to assist the autism impairments in social and communication impairments. In future, more research which focus on using augmented reality to enhance the other autism impairments need to be increased. This review found out that most of the existing augmented reality applications developed between years of 2012 to 2018 implements four types of technology-assisted intervention tools/strategies. The augmented reality applications contain of video modelling, visual prompt/cues, specific training and performance feedback/ reinforcement components which are important parts of technology-assisted intervention. In future, further development of augmented reality that incorporates audio and speech generating devices and self-management tool for intervention shall be conducted.

In conclusion, augmented reality offers promising technological supports for autism intervention in education and therapy. Augmented reality technology that has capability to combine virtual and real objects in real settings could attract the attention of children with ASD who are identified as visual learner.

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