Journal of Information System and Technology Management
EISSN: 0128-1666
JISTM
Volume 6 Issue 22 (September 2021) PP. 158-170
DOI: 10.35631/JISTM.622013

JOURNAL OF INFORMATION SYSTEM AND TECHNOLOGY MANAGEMENT (JISTM)
www.jistm.com

A FRAMEWORK FOR DESIGNING AN AUGMENTED REALITY APPLICATION FOCUSING ON OBJECT FUNCTION FOR CHILDREN WITH AUTISM

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Article Info:

Article history:
Received date: 10.06.2021
Revised date: 15.07.2021
Accepted date: 20.08.2021
Published date: 01.09.2021

To cite this document:

Hakim, I. N. A., Mohamad, U. H., & Ahmad, A. (2021). A Framework For Designing An Augmented Reality Application Focusing On Object Function For Children With Autism. *Journal of Information System and Technology Management*, *6* (22), 158-170.

DOI: 10.35631/JISTM.622013

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Abstract:

Augmented Reality (AR) is the evolution of the concept of Virtual Reality (VR). Its goal is to enhance a person's perception of the surrounding world. Augmented reality techniques are often applied to facilitate understanding and create attractive educational and health tools. As such, augmented reality is deemed suitable to be implemented as one of the potential intervention methods as the treatment of autism in a fun environment. Hence, this study is aimed to develop a conceptual framework to design augmented reality applications based on object function to help in the communication of children with autism. The study framework will be developed based on vision-based object recognition. Object recognition has been used in many applications, especially in bio-imaging, industrial inspection, and robotic vision. The findings of this study will benefit autistic children in visual communication and indirectly help them to effectively link objects with their functions. This framework will then help designers to develop augmented reality applications suited to be an intervention tool that fits the need of autistic children.

Keywords:

Autism, Autism Spectrum Disorder, Pecs, Augmented Reality, User-Centred Design, Object Recognition

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Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
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Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that typically affects the function of the brain; it appears in the first three years of a human's life. Autism is four times more prevalent in boys than girls. Autism affects the normal development of the brain in the areas of social interaction and communication skills. It contributes to difficulty in verbal or non-verbal communication and play activities with others. According to the Centre for Disease Control (CDC) in the United States, approximately 1 in 68 have been diagnosed with ASD (Baio et al., 2018). That would mean that approximately 9000 children in Malaysia are born with ASD in a year.

Early intervention approach for children with ASD is very effective to help them overcome the potential future problems that they may face. It is important to provide early intervention to ASD children as early as 2 years old. The early intervention approach consists of educational efforts, nutrition, motor skill development, self-care, social interaction, and family support. In short, early intervention aims to reduce the impact of the disability in the lives of these children, by making it less pronounced as the child grows older.

One of the interventions is the use of the "Picture Exchange Communication System" (PECS) as a communication method to interact with others. PECS is a method used to train ASD children to communicate with others using picture cards (Hosseini, Foutohi-Ghazvini, & Hosseini Emial, 2016). It is designed for training or intervention of early non-verbal symbolic communication.

Some previous studies found that the use of PECS concepts in AR had some issue where a card would be incorrectly recognized, triggering an inappropriate action (Almeida da Silva, Ramires Fernandes, & Grohnmann, 2015). The card recognition subsystem also needs to be fine-tuned to increase robustness, hence suppressing unintentional card misclassification. The system errors, due to the way children reacted to them, raised an interesting question. It is shown that the usage of information technologies, in particular, AR-based systems, in the interventions, complementing and supporting the traditional approaches, is an option that must be further explored. Hence, this study is of importance to develop a conceptual framework for designing object function based on augmented reality applications that focus on user-centered design.

Literature Review

Autism Spectrum Disorder

Eugen Bleuler (1857-1939), a Swiss psychiatrist, coined the term autism. It is derived from the Greek "autos" (meaning "self") which describes the patient with autism as having a fantasy life that has an incomprehensible perception or external image and "ism" gives the meaning of flow (Kuhn, 2004). Autism is a disorder (nerve formation) that has a variety of symptoms that are different in each person (Park et al., 2016) that can cause communication, social, and behavioral problems. There are three levels of Autism, namely, low, moderate, and high functionality, and all of them are known as 'Autism Spectrum Disorder'.

Past studies have also shown that there are autistic children who have communication problems and the ability to pronounce words well (Chenausky, 2015). This should be practiced from the beginning and is closely related to the expression of a given image to describe a visual function

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Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 6 Issue 22 (September 2021) PP. 158-170
DOI: 10.35631/JISTM.622013
(Field, Allen, & Lewis, 2016). There are also related factors to help build the ability to interpret visuals that have levels of perception, emotions, as well as the environment that greatly influence autistic children in interpreting something. The lack of imagination to interpret the function of objects is a deficiency in communication problems because autistic children do not understand the objects seen (Field et al., 2016).

Based on a study conducted by Field 2016, there is reason to believe that children with ASD may show differences compared to Typical Development (TD), concerning understanding the function of objects. For example, evidence suggests that children with ASD often exhibit idiosyncratic, stereotypical, and limited social use. Early intervention should be implemented to help the weaknesses faced by these children.

Intervention

Intervention is doing something or acting to restore or help to alleviate a problem encountered. The primary goal of treatment is to optimize functional outcomes, including communication skills, social skills, quality of life, and independent living, while reducing or eliminating increasingly serious behaviors (Will et al., 2018). The application of good behavioral principles will improve communication, social, play, cognitive, and other skills, as well as reduce some of the serious behaviors of autistic children, and good treatment can help self-improvement (Schreibman & Anderson, 2001). Six months of intervention will help to reduce communication and social problems and show that autistic children would do better with follow-up/rehabilitation methods (Kaku et al., 2017). Overcoming this condition can improve attention, learning, and related behaviors. Approaches with Behavioral Treatments and Interventions have been identified, among them are Applied Behavior Analysis, Speech Therapy, and Occupational Therapy (OT).

Intervention Method of "Picture Exchange Communication System" (PECS)

Interventions implemented in the Autism Teaching Laboratory are using the Picture Exchange Communication System (PECS) method. PECS is an augmentative communication system designed to help individuals acquire one way or another to communicate with others. This method uses picture cards to convey a message about something that one wants to do. The PECS method has six consecutive and systematic phases. Each phase is presented in an orderly manner. As autistic children master each phase, they will move on to the next phase. Based on the implementation model done by Kauffman 2003, the phases are:

Phase 1: How to Communicate;
Phase 2: Distance and Persistence;
Phase 3: Image Discrimination;
Phase 4: Word Structure;
Phase 5: Answering Question; and
Phase 6: Comment.

Technology as An Intervention - Visual as A Communication Tool

Prior to the rapid development of digital media, much research had been done on human-computer interaction (HCI) for autistic children. Computer applications and mobile applications have been well developed by researchers to aid the learning and development process of autistic children (Chien et al., 2015) (Hourcade, Bullock-Rest, & Hansen, 2012) (Pavlov, 2014). Past studies state that visual support is one of the effective tools to enable

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autistic children to communicate and learn more easily. Children with autism are often referred to as visual thinkers (Frauenberger et al., 2012). Researchers have found that autistic children respond better through visuals than other senses (Hayes et al., 2010; McKone et al., 2010; Milley & Machalicek, 2012). Children with autism can improve their ability to communicate through visuals as well as reduce their dependence on adults. In addition, much research proves that interactive visuals in mobile technology are useful for the learning of autistic children. Mobile technology is very well known for using self-direction (Ayres, Mechling, & Sansosti, 2013).

AR Technology

The use of Augmented Reality (AR) application technology has increased recently in various fields to enhance engagement, motivation, and learning for people with ASD. AR overlays, like 3D videos, figures, and information, can be added to anything, and multiple studies have shown that AR experiences result in increased engagement, enjoyment, motivation, and attention. A study designed to teach object discrimination revealed a 62% increase in on-task participation and happier, more determined students (Escobedo & Favela, 2014).

Many past studies had shown the potential of using augmented reality towards ASD children, as shown in Table 1.

Table 1: Previous Research Involving the Application of Augmented Reality for Autism Intervention

No	Application of AR	Research details	Reference
1.	Augmented Reality interfaces for symbolic play in early childhood	Develops augmented reality as a symbolic play medium that allows children to see and manipulate their imagination. The use of AR provides an alternative approach to clarify and reinforce unclear cognitive mechanisms in symbolic play to children with ASD.	(Bai, 2014)
2.	Using Augmented Reality to help children with autism stay focused	Developed an augmented reality application (Mobile Object Identification System-MOBIS) using the Mobile Object Identification System, which allows teachers to insert digital content on physical objects. Researchers studied how augmented reality can increase the ongoing attention of autistic children during object-discriminating therapy and elicit more positive emotions.	(Escobedo & Favela, 2014)
3.	Augmented Reality-based video-modeling storybook of non-verbal facial cues for children with autism spectrum disorder to improve their perceptions and	This study focused on problems that help improve the social interactions of children with ASD. This was done by using augmented reality (AR) combined with a video modeling strategy (VM) that has story content with a video duration of fewer than 45 seconds by focusing on specific social cues.	(Chen, Lee, & Lin, 2016)

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	judgments of facial expressions and emotions		
4.	Play therapy in Augmented Reality children with autism	This study develops augmented reality by using the PECS method as a digital implementation by selecting each image. Children with ASD will see three-dimensional (3D) images that are related to the relevance of a given picture.	(Hosseini et al., 2016)
5.	Augmented Reality for teaching science vocabulary to post-secondary education for students with intellectual disabilities and autism	The purpose of this study was to examine the use of a new technology called augmented reality to teach science vocabulary words to college students with intellectual disabilities and autism.	(McMahon, Cihak, Wright, & Bell, 2016)
6.	An Augmented Reality-based framework for assisting individuals with autism and cognitive disorders	This study focused on the development of a framework to help children with autism and those with cognitive impairment. The framework was based on common mobile devices and Augmented Reality (AR) applications used in a marker approach that uses cameras and visual markers to view media content on the screen of a mobile device. The developed framework allows parents and teachers to easily create additional learning environments for children with autism and cognitive impairment by filling real-world spaces with visual markers where favorite cartoons can be seen in AR content in real-world environments.	(Abou El-Seoud, Halabi, & Geroimenko, 2019)

Object Recognition

Artificial Intelligence (AI) is a field of computer science that emphasizes the creation of intelligent machines that function and respond like humans (Nils J Nilsson, Morgan Kauffman, 2014). Object recognition is part of the technique of computer vision. The main thing to achieve realism when creating a virtual object recognition (mixing) composition with real content is that the virtual object must share the same characteristics with the real world (Lalonde, 2019).

There are a variety of past studies that use object recognition in augmented reality for autistic children. Many past studies have used object recognition from 2D visuals to 3D, but autistic children are still lacking in imagining the actual function of an object seen to be interpreted (Field et al., 2016). To achieve realistic results will involve solving tasks on challenging computer vision such as obtaining real 3D objects and estimating camera position, object detection, and even illumination of those objects (Lalonde, 2019).

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Research Methodology

The methodology of this study is to describe the research process and the methodology that will be implemented to achieve the objectives of the study. The research methodology implemented in this study is adapted from the study of Kuechler, & Vaishnavi (2008). This methodology is suitable for the study conducted because the result of the study is in the form of models, methodologies, and prototypes (Purao, 2002). This research uses qualitative methods that use interviews, observations, and User-Centered-Design (UCD) at all levels of research phases as a reference to improve the usability of applications. Figure 1 depicts the whole process of framework development for this study. However, for this study, we are only focusing on the first phase of the study.

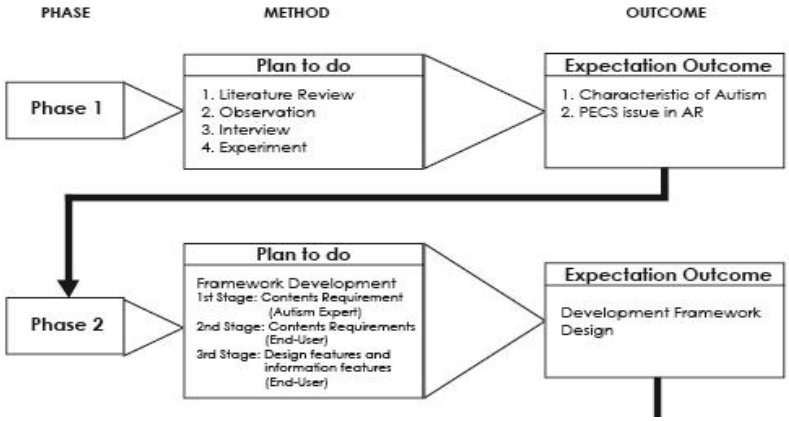

Figure 1: Framework Development

The first phase began with identifying communication problems faced by autistic children through a literature review study. Then, observation was conducted on the targeted participants, who are the autistic children from the Autism Learning Laboratory, UKM.

The first stage of content requirements was identified to determine the requirements of the framework to be developed for the use of autistic children. Few studies have been conducted involving the use of augmented reality in the classroom or instructional settings for teaching content (e.g., vocabulary) and tasks. Among those studies, the use of augmented reality reported positive outcomes in content mastery (Liu, 2009; McMahon et al., 2016).

This study focused on the Applied Behavioral Analysis (ABA) method because it is recognized as the most effective evidence-based intervention method for autistic children (Fein et al., 2013). The ABA approach has evolved and expanded to include a comprehensive behavioral package designed to address all developmental requirements, and applied to all (or advanced parts of) children, as well as behavioral strategies that focus on deficient response patterns or skills; both of which will result in good treatment (Vismara & Rogers, 2010). ABA is a systematic approach that aims to improve social behaviors such as communication, social, educational skills, and environmental adaptation (Scagnelli, Copelli, Presti, & Moderato, 2017), including Language (or behavior during eating).

Past researchers have also said that Applied Behavioral Analysis (ABA) used Indirect Learning teaching as a form of teaching, in which a teacher provides guidance from 'incidents' or situations that occur naturally, to provide learning opportunities for students (Childress, Meyer, & Meadan, 2015; Neely et al., 2018). Indirect teaching is based on the ideas of students,

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including autistic children. This is because they are more willing to learn if the teaching is based on their desires (Neely et al., 2018). In indirect teaching, teachers organize learning based on the surrounding situation as a learning objective but by considering the individual preferences of the students. When students show interest in an item or activity, the teacher encourages that interest by questioning or encouraging students. For example, the teacher may put something more out of the student's mind, so that the student needs to communicate with the teacher in response or in response to getting it. As such, this can be used in augmented reality technology by using indirect learning methods, by scanning the surrounding objects and giving imagination to the function of the object.

Result

Analysis of First Observation

Observations on the autistic children were done twice and were conducted via video recording in a natural setting with a group of 12 children that were formally diagnosed with ASD. The children were between 4-7 years old in class 1. However, only 4 children fully participated in the study with a ratio of 3 male and 1 female.

From the first observation on these children in the Autism Learning Laboratory, UKM, it was found that ASD children preferred to play alone, showed difficulty interacting with others, and depicted a short attention span when an activity was performed. Due to that, ASD children often require repeated learning interventions before a positive outcome can be seen.

Figure 2: Observation of How the Communication Process Happens in A Classroom Setting

Analysis of Second Observation

The objective of the second observation is to identify the communication problems faced by children with autism. Table 2 lists some questions asked by the teachers during the intervention program while the observation was conducted.

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Table 2: Questions Asked During the Intervention Program

Contents	Implementation
a. Understanding the instructions	1) Children were asked questions such as: i. Count the numbers 1-10 ii. Match the same picture
b. Understanding the function of the object	1) Children were given picture cards. Questions asked: i. What is the picture on this card? ii. What is this object for? 2) Children were given real objects. Questions asked: i. What is the name of this object? ii. What is this object for?
c. Communicate using the PECS method	Children were trained to communicate using PECS methods for going to the toilet, eating, and doing an activity.
d. Word pronunciation	Children were given picture cards and were required to say the word. i. Picture of a chair
e. Answering easy questions	Children were asked simple questions such as: i. What is your name? ii. How old are you? iii. What is your mother's name? iv. What is your father's name?
e. Paying attention	Paying attention within 5 minutes

Table 3 reveals some of the communication problems persisting among the children with autism such as not understanding instructions, not understanding the functions of objects, unclear word pronunciation such as **"kerusi"** will be ***"erusi"*** and "**makan"** will be ***"akan"***, as well as the inability to answer easy questions. Some of the children with ASD also have difficulty paying attention for more than 5 minutes when communicating and performing an activity. Yet, one of the most prominent communication problems observed is not understanding the function of an object.

Table 3: Identifying Prominent Communication Problems Among Children With ASD

Communication problem	Understand instructions	**Understand the function of the object**	Communicate using the PECS method	Clear word pronunciation	Answering easy questions
Children A	/	/	/	**X**	/
Children B	**X**	**X**	/	/	**X**
Children C	/	**X**	/	/	**X**
Children D	**X**	**X**	/	/	/

Note: (/) observed, (X) not observed

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EISSN: 0128-1666
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Communication problems are the sharing of information and opinions between individuals. It involves delivery coding and message code evaluation. In agreement to past research, autistic children find it difficult to communicate and interact with people from an early age (Dawson, Osterling, Meltzoff, & Kuhl, 2000). Observations also highlighted that autistic children were taught to communicate using the PECS method as a communication method. The PECS method is implemented as an early intervention to help autistic children. Autistic children will use the PECS method which is a picture card to express their wants or desires for something in exchange for verbal communication. This process has been rehearsed repeatedly to make it easier for these children to understand the picture or symbol to express a wish. This is because the PECS process has six different phases that need to be done according to those phases.

Several studies have found that individuals with ASD have deficiencies in visual processing (Funabiki & Shiwa, 2018). Observations on some autistic children found that these children could not interpret the function of an object from a given picture as long as it was not assisted by the teacher to pronounce and understand the function of the object. Autistic children cannot imagine the function of an object based on pictures on a given paper without the help of a teacher. This may be due to the thinking limitations of autistic children in processing the information given. Additionally, previous studies have reported that autistic children show impairment with visual learning acquisition (Erdödi, Lajiness-O'Neill, & Schmitt, 2013).

Autistic children may have problems with visual perception to interpret a given symbol or object. One sample was found to be able to recognize objects well. This is because interventions performed repeatedly can help these children recognize a given object. Visual perception depends on the brain's ability to identify objects seen. When the study was conducted, one sample from the autistic children could not remember or missed words that were read or written. It was also found that the child missed the number when writing on the book to make the count in the exercise book. Some children can answer some simple questions like their parents' name, age, and their name. However, from the observation, it was also found that each pronunciation was less clear and quite difficult to understand.

The results of the initial analysis found that these autistic children have different problems in behavior as well as in communication. Early intervention done before entering the age of 7 years is very important to help improve self-management and thinking. This is because the improvement of self-efficacy and way of thinking will help these children to be independent in the day-to-day activities. Early intervention in improving the ability to think and understand the perception of a point of view about something is very important to help the ability to communicate. The ability of the imagination greatly influences autistic children in communication problems.

Discussion

The findings from the observations will be used to identify the content requirements as shown in the framework design in Figure 3. The development of the AR prototype will be based on the UCD design approach which acts as a proof-of-concept to highlight the framework's effectiveness. UCD is an iterative design process in which designers can focus on the users' needs in each phase of the design process. The process involves identifying the intended users, their capabilities, needs, and expectations (Lubas, Mitchell, & De Leo, 2014).

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EISSN: 0128-1666
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The user-centered design process is a linear and iterative process. Each iteration of the UCD approach involves four distinct phases. First, designers need to understand the context in which users may use a system. Then, they need to identify and specify the users' requirements. A design phase follows, in which the designer develops solutions. Designers then proceed to an evaluation phase. The outcomes of the evaluation are compared against the users' context and requirements, to check how well a design is performing. More specifically, designers can see how close it is to a level that matches the users' specific context and satisfies all of their relevant needs. From here, it can make further iterations of these four phases, and continue until the evaluation results are satisfactory.

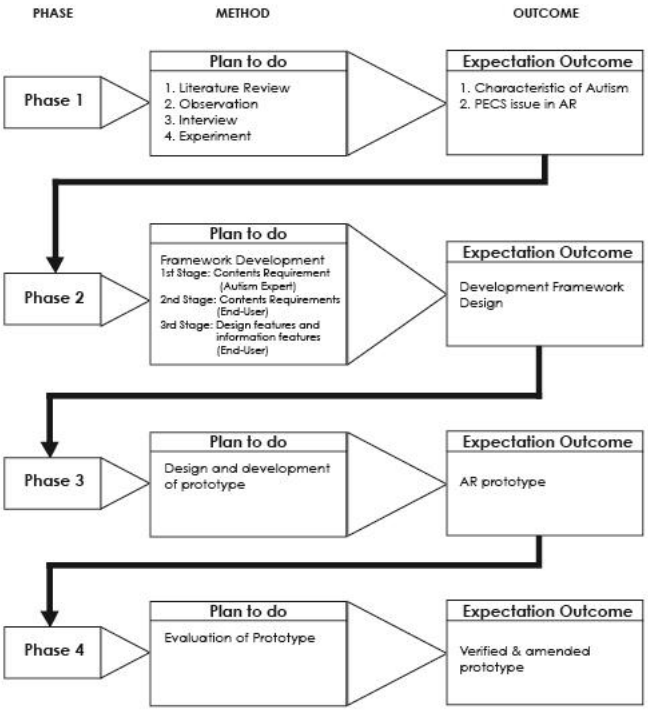

Figure 3: Framework to Design AR Application

Object recognition has been used in many applications, especially in bio-imaging, industrial inspection, and robotic vision. The findings of this study provide benefits to autistic children in visual communication, and indirectly help enhance the imagination of an object and linking it to its function. The main feature included in the AR mode is scanning of the object (recognize object) in the surrounding environment, where 3D models appear and will translate the function of the object. The translation will appear using video, audio, and textual instructions that can be adapted to the needs of autistic children to understand the object's function (see Figure 4). The practice of augmented reality is better reflective of ABA theory and practice, as it provides multiple means of engagement, representation, and action/expression.

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EISSN: 0128-1666
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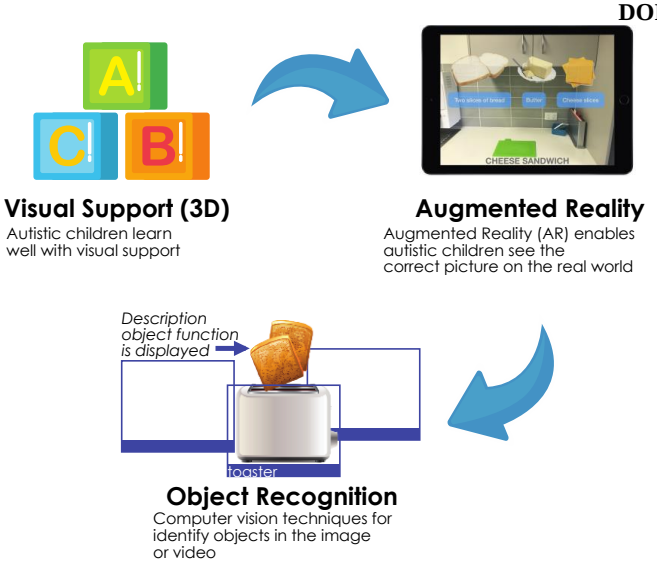

Figure 4: Main Features in Augmented Reality Prototype

The use of mobile devices as a medium to run augmented reality (AR) applications is the latest method because it does not require a marker to be carried anywhere. This makes it easier for autistic children to explore and recognize the useful function of an object in their daily lives and helps them overcome communication problems.

The fourth stage will be implemented where experts in augmented reality will evaluate the effectiveness of the developed prototype. In the final stage, the prototype will be used by ASD children, and the effectiveness and usability of the prototype will be evaluated. In the end, the framework will be improved to produce more meaningful prototypes to help address communication problems with autistic children.

Conclusion

In this paper, the initial framework is developed on designing AR applications. Future work will involve improving the framework to focus on object function for children with ASD. The final framework will later be implemented in tablets or smartphones which can be a powerful tool of intervention for autistic children, regardless of the severity of their autism spectrum. Findings from this initial study have revealed the most prominent communication problem, which is understanding object function. From here, the relevant requirements can be identified and assessed further to ensure that the framework is also able to address the issue of using PECS when using AR as a tool.

Acknowledgement

This study was supported by the Geran Universiti Penyelidikan (GUP), Universiti Kebangsaan Malaysia, Grant No. GGP-2020-020.

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Journal of Information System and Technology Management
EISSN: 0128-1666
JISTM
Volume 6 Issue 22 (September 2021) PP. 158-170
DOI: 10.35631/JISTM.622013

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