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Mixed Reality Sandbox Game Development for Improving Disability Children Fine Motor Skill

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Abstract— One of the categories of disabled children is a double disability with two or more barriers, such as blind and deaf (Multiple Disabilities with Visual Impairments / MDVI). MDVI children with vision lower or less than Normal vision (low vision) tends to experience motor problems due to a lack of received external stimuli. From previous research, the three learning areas of MDVI children with low vision improved gradually, but the motor skills that support these activities are not optimal. This is because motor movement exercises are not enough just to be presented in visual form but require natural movement from body movements. Therapeutic use playing with sand is effective in stimulating motor movements in children. But its application to MDVI children with low vision has not been tested. In addition, loop repetitive motor training reduces motivation to practice because the training environment is monotonous. Provides an interactive training environment and supports the stimulus aspect visuals such as lighting, contrast, object size, and visualization distance can increase motivation and exercise compliance. The use of a virtual environment (virtual environments / VE) such as mixed reality (MR) can provide a training environment adaptive and produces deeper sensations in the brain (immersion) for exercise extremity motor movements. However the use of interventions is Unprecedented interactive and dynamic practice environment sand-based games applied to help exercise motor skills in MDVI children with low vision. The development of serious games is proposed using a mixed reality-based sandbox game device (MR-Sandbox) for motion therapy upper limb motor skills for MDVI children with low vision by combining reinforcement of visual stimuli to stimulate the activation of the corticospinal nervous system through combining real and virtual activities (mixed reality) and creative visualization using sand media (virtual topography) in promoting fine motor movements. This study uses a quasi-experimental design research method, pre-test, and post-test. The sampling technique uses purposive sampling of 12 MDVI respondents with low vision (eight men, eight women) in the sand-type educational game intervention group. The Assessment uses sheets Denver II instrument, which is taken from the aspect of acceptable motor measurement. Data analysis is the t-test of 2 dependent samples and the t-test of 2 independent models for bivariate.

Keywords—MDVI, Virtual Reality, Fine Motor Skill

I. Introduction

One of the categories of children with special needs is double-blind, who has two or more disabilities, for example, blind and deaf (Multiple Disabilities with Visual Impairments / MDVI or deaf-blind). MDVI children with vision lower or less than usual vision (low vision) tend to experience motor disorders due to the lack of received external stimuli (Argyropoulos & Thymakis, 2014). External stimuli motivate the development of motion or motor and become the basis for the development of social communication, cognition, self-development and work (Miles, 2008). Due to the lack of visual stimulation, MDVI children with low vision lose motivation to move and experience physical skills barriers, especially in using their bodies, such as hand coordination and fine motor skills, to get to know the environment.

MDVI children with low vision need help to learn to move in their environment. Without sight or impaired vision, they will not only have difficulty moving but may also have no motivation to move. Therefore, MDVI children need a learning environment that attracts attention to train motor movements. So far, the learning environment for MDVI children with low vision has focused on developing social areas of communication, self-development, and work (Sunanto, 2010; Rini et al, 2017). The learning concepts taught are from the real to the abstract. From the results of previous studies, although the social areas of communication, self-development, and work of MDVI children with low vision are increasing gradually, the motor skills that support these activities are not trained optimally. It requires natural movement from body movements. The use of sand play therapy has proven to be effective in stimulating motor development in children (Fuad et al, 2016; Yuniati, 2018). However, its application to MDVI children with low vision has not been tested. It requires a game environment that is not monotonous and meets the aspects of light, contrast, size and visualisation distance. Generation of visual stimuli can be done through mixed reality (MR) technology to produce deeper sensations in the brain (immersion) to train upper extremity motor movements (Lesmana et al, 2018; Budury et al, 2020). Therefore, in supporting the development of assistive technology for disabled children, an innovation is proposed in the development of mixed reality-based sand game devices (MR-Sandbox) to train and improve motor skills in MDVI children with low vision.

This study proposed new innovations in the development of serious games using mixed reality (mixed) sand game device reality sandbox / MR-Sandbox) for upper limb motor movement therapy for children with MDVI with low vision by combining visual stimulus reinforcement to stimulate the activation of the corticospinal nervous system through the combination of real and virtual (mixed reality) and creative visualization using sand media (virtual topography) in stimulating fine motor movements. This study uses research methods quasi-experimental design with pre-test and post-test designs. The sample retrieval technique uses purposive sampling of 12 respondents in the intervention group sand-type educational game. The way to collect data using a questionnaire and by observation. The assessment uses the Denver II instrument sheet, which takes aspects of fine motor measurement. Data analysis used is the t-test of 2 dependent samples and the t-test of 2 independent samples for bivariate.

II. LITERATURE REVIEW

Multi Disable Visual Impaired (MDVI) can be interpreted as a child with needs specifically for the category of blind children who are accompanied by other disabilities. In terms of another with the same meaning, namely VIMD (Visually Impaired Multiple disabled). In Subsequent developments in the United States, known the term multiply disabled with visual impairments (MDVI). The term refers to someone who is experiencing obstacles in vision accompanied by other obstacles, so MDVI is those who have visual impairment accompanied by other obstacles, both hearing, intellectual, physical, emotional, and so on. The combination of these obstacles can be graded very diverse, and many of these children can still hear or see something (Argyropoulos & Thymakis, 2014). Children with blindness at once Deaf-blind is one of the children with the MDVI category. This child experience loss of the main senses, namely sight and hearing plays a role in carrying information in human life. To get information about the environment, deafblind children are very dependent on other people who are willing to provide information. The impact of the loss of these two senses causes a person experiences many challenges in learning, development, and skills communicate. Such children need special education services, incorporating the applicable criteria that follow.

MDVI children with low vision tend to experience motor problems due to the lack of received external stimulus (Miles, 2008). External stimuli play a role motivate the development of motion or motor and become the basis for the development of social communication, cognition, self-development, and work (Sunanto, 2010). Due to a lack of visual stimulation, MDVI children with low vision lose motivation to move and experience physical skill barriers, especially in using their body, such as hand coordination and fine motor skills to recognize the (Rini et al., 2017)MDVI children with low vision need help to learn to move around the environment. Without sight or with impaired vision, he will not only have difficulty moving but also may not have the motivation to move. Therefore, MDVI children need an interesting learning environment and attention to train motor movements. So far, the learning environment for MDVI children with a low vision focused on developing the social areas of communication, self-building, and work (Fuad et al., 2016)

The learning concepts taught are from the real to the abstract. An example is introducing watermelon. MDVI children with low vision will not be introduced to watermelon images if they have never felt the whole watermelon, split it, know the smell, know the taste and understand the structure of watermelon. Abstract learning is carried out with printed images for students to remember practice. This learning model can help MDVI children with low vision remembers what has been learned previously. However, the learning concept of real to abstract is not suitable to be applied to train motor movements in children MDVI with low vision because it requires real movement exercises from body movements continuously. The use of sand play therapy is proven to be effective in stimulating motor movement in children (Yuniati, 2018). But its application to MDVI children with low vision has not been tested. In addition, loop repeated motor training can reduce motivation to practice because of the monotonous training environment. Providing an interactive training environment that supports aspects of visual stimuli such as lighting, contrast, object size, and visualization distance for MDVI children with low vision can increase motivation and compliance with exercise. The use of a virtual environment (virtual environments / VE) such as mixed reality (MR) can provide a training environment adaptive and produces deeper sensations in the brain (immersion) for training upper extremity motor movements (I. P.D. Lesmana et al., 2020; I Putu Dody Lesmana et al., 2018). However, until now, the use of environmental-based sand game interventions and interactive and dynamic exercises have never been applied to help with movement exercises and motor skills in MDVI children with low vision.

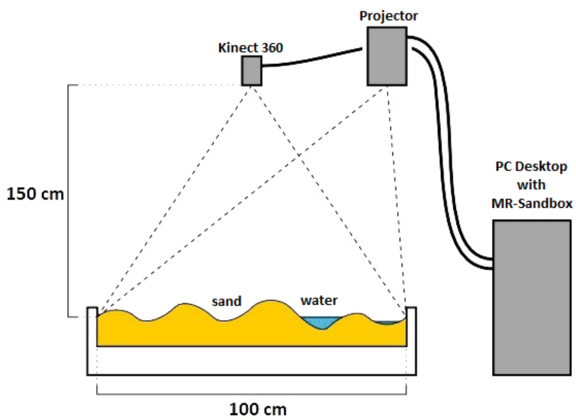
There are several studies related to improving fine motor skills in children. A study has been conducted to see the Effect of Chewing Activities on Fine Motor Skills in Kindergarten students. The results showed that weaving banana leaves affected fine motor skills. The conclusion is that weaving banana leaves has a positive effect on the fine motor development of kindergarten students. The effectiveness of weaving banana leaves contributes to fine motor skills by 74% (Irmawati & Ichsan, 2021). The application of embroidery activities can improve fine motor skills in children with disabilities. Children gradually hone their fine motor skills as they learn to respond to the stimulus. The intervention condition also applies to using scissors, grabbing, writing, and coloring (Budury et al., 2020). Puzzle play therapy can also improve children's fine motor skills (Da'i & Maulidaty, 2021). The collaborative method involves class teachers, with 20 preschool-age children participating. After the play therapy activities were completed, awards were given as appreciation. The results of this activity show that all participants during the activity actively participated in playing using puzzle media. The children were very enthusiastic and had fun doing the play therapy activities. Their fine motor skills also develop after the activity ends. An arcade controller and video games had been developed for children with intellectual disabilities to improve their fine motor skills. The result of the study shows that it can effectively improve children fine motor skills in short time(Merchan-Garcia et al., 2020). A Serious game has been tried to improve fine motor skills using leap motion, but most of the children in this research need more time to adapt to a virtual environment(Cabrera Hidalgo et al., 2018). Another serious game platform based on virtual reality has been proposed for the fine motor skills and cognitive development of children with special needs(Ashwini et al., 2021). The proposed game is developed in such a way as to improve children's pincer grasp, intellectual reasoning, and hand-eye coordination. The proposed virtual reality game can also be an assistive device and traditional rehabilitation method. Augmented Reality technology had been applied to drawing activities to improve fine motor skill, but it can work properly juts in some category of children(Kurniawan et al., 2019). The results of an evaluation of the effect of gadgets on the development of fine motor skills in children show that the more often children use gadgets, the more developed their fine motor skills(Moon et al., 2019). The same thing applies to the ability of social development. However, the length of time using gadgets hurts children's speaking abilities.

III. Methodology

A. Requirements Analysis

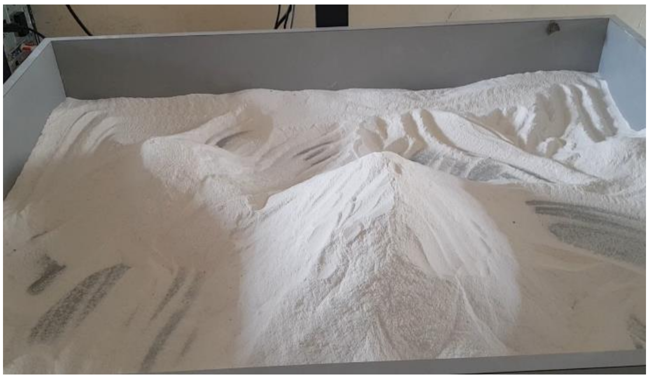
At this stage, an analysis of the hardware and software requirements is carried out to assemble an MR-Sandbox. Based on the results of the analysis, here are the requirements for making MR-Sandbox.

1. Computer Graphics
   The computer graphics used in this study to be able to process and run 3D virtual environment applications in the form of mixed reality have Linux Mint 19.3 Tricia 64 Bit operating system, Processor Intel Core i7 3GHz, VGA Nvidia GeForce GTX 1060,8GB of RAM and Minimum hard disk capacity of 20 GB
2. Kinect 360. 3D CameraCamera
   The 3D CameraCamera used to read the contours of the sand surface uses Microsoft Kinect 360 with Kinect driver conPictureuration version 2.8 for Linux.
3. Projector
   Ideally, the projector used is a short-throw projector with an aspect ratio of 4:3, which can be used at short distances and is compatible with the field-of-view (FoV) of Kinect cameras. Short-throw type projectors generally project the image through the midline position of the horizontal plane, which is in accordance with the optimal FoV of the Kinect CameraCamera placed in the center of an observation plane. However, because the short-throw projector is expensive and the required projector resolution is 1024x768 pixels, which is larger than the Kinect Camera'sCamera's 640 x 480-pixel resolution, in this study, a normal projector type is used which is placed at the height of 2 m above the sandbox and is positioned vertically parallel to the edge of the sandbox, then the Kinect CameraCamera is placed in the center of the sandbox and side by side with a normal projector as shown in the design in Picture 1. The projector to VGA interface of the graphics computer is connected using an HDMI digital cable.



Picture 1. Design of the placement of the Kinect projector and CameraCamera on top of the sandbox

4. Sandbox and Sand Material
   The size of the sandbox used is 100 cm x 75 cm x 20 cm, with the height of the projector and Kinect camera 150 cm above the sandbox, as shown in Picture 1. While the type of sand used is Sandtastic polymer sand which is safe from dust, non-toxic, and can reflect the projection results well, as shown in Picture 2. Another type of sand that can be used is Kinetic polymer sand.



Picture. 2. Sandtastic polymer sand for MR-Sandbox

B. MR-Sandbox Device Assembly

The MR-Sandbox device, as shown in Picture 3, has a sandbox table component, a depth camera sensor measuring the height of the sand surface contour, a projector as a three-dimensional virtual environment viewer on the sand surface, and a graphics computer to reconstruct the virtual environment from the contour height data where the rendered results are displayed. Returned by the projector in the form of a three-dimensional virtual environment on the sand surface as a visualization of the post-stroke patient's ability to move the hemiparetic hand to form a miniature contour of the island environment. The volume of the sandbox made is 100 cm x 75 cm x 20 cm, which is filled with Sandtastic polymer sand ± 25 kg. The contour height meter is used by a Kinect 360 camera which is connected to a graphics computer via a USB port. While the projector to the computer graphics connection using HDMI. The height of the Kinect 360 and the projector is placed at least 150 cm above the sand surface to produce a pixel density that, when projected by the projector, can fill the entire designed sandbox area. While the graphics computer used uses an Nvidia graphics card.

Picture. 3. MR-Sandbox Device Components

C. MR-Sandbox Application Requirements Installation Software

The basic installation of the MR-Sandbox application is to install the Vrui toolkit to support mixed reality processing, Kinect drivers, and sandbox. The initial stages of the MR-Sandbox support toolkit requirements are described as follows:

1. Install Linux Mint 64 Bit
2. Installing Nvidia Drivers
3. Installing Vrui
   Vrui is a toolkit to facilitate the development of low-cost virtual environments aimed at low-spec devices. Vrui provides display abstraction that functions as an OpenGL-based rendering interface, distribution abstraction that functions whether rendering is performed on a single node or involves multiple nodes over the network and input abstraction, which provides an interface for connecting various input devices.
4. Installing Kinect 3D Camera Driver
5. Installing Augmented Reality Sandbox Toolkit

RawKinectViewer has a built-in calibration utility to correct this Kinect camera distortion. To perform depth-per-pixel correction, the Kinect camera is positioned so that it faces a flat, non-glossy surface, such as a blank wall. Then run RawKinectViewer utility as administrator to write calibration conPictureuration file to system location /usr/local/etc/Vrui-8.0/Kinect-

D. MR-Sandbox Test on Children with Physical Disabilities

Participants in the MR-Sandbox test involved four physically challenged children with disorders of the upper extremities (4 boys aged between 10-13 years). In this test, participants were asked to perform activities that train fine motor skills in daily activities, such as grasping sand, moving sand, and releasing sand using both hands to create a simple miniature island in a sand game set.

IV. Result and Discussion

Participants involved in the MR-Sandbox test were selected and participated in the study after obtaining permission from the class teacher at SLB Negeri 1 Jember. Safety is measured by the presence or absence of side effects that arise due to respiratory disorders such as coughing, asthma, or triggering allergic effects. Meanwhile, eligibility was measured from the total attendance for nine days, the total training time for nine days, the ability of participants to use both hands in completing the activities instructed by the teacher using the MR-Sandbox media, and the extent to which the participants' interest or motivation in using the MR-Sanbox was measured. once on the seventh day of practice. Participants' interest (user engagement) in using the MR-Sandbox was measured using the Witmer–Singer presence questionnaire (PQ) observation sheet. The full version of the PQ consists of thirty-two questions to measure the level of user interest in the range of one (lowest score) to seven (highest score) according to a Likert scale. However, in this study, only questions numbered 5, 10, 18, 23, and 32 were selected which indicate user involvement in the media used (involvement). The number of participants' attendance and training time were calculated for each training session, while the PQ was taken on the last day of training. While effectiveness is measured by the extent to which the fine motor development of the participants in completing activities using the MR-Sandbox media for nine days. The effectiveness assessment is carried out using an observation sheet that records the activities of both hands with the assessment divided into three aspects, namely:

1. none (score 0), indicating that participants have not been able to carry out the activities instructed by the teacher
2. partial (worth 1), indicating that the participants have been able to do the activities instructed by the teacher, although they are still limited
3. full (worth 2), indicating that participants can complete the activities instructed by the teacher as a whole.

Fine motor development in each training session was assessed using four categories including:

1. BB (Not yet Developed), the assessment range of aspects 0 to d. 8
2. MB (Starting to Develop) aspect assessment range from 9 to d. 17
3. BSH (Developing According to Expectations), the assessment range of aspects is 18 to d. 26
4. BSB (Very Good Development), the range of aspect assessment is 27 to d. 36. The participant activity observation sheet using the MR-Sandbox was taken at the end of the training session every day for nine consecutive days.

Fine motor skills training was carried out for nine days, where in one day there was only one training session which was limited to 15 minutes per participant. This training session utilizes acceptable motor development subjects at SLB Negeri 1 Jember, which starts every 09.00 WIB from Monday to Friday. Thursday. Each training session will be terminated if the participant experiences fatigue or the training time exceeds 15 minutes. Observations and recordings of adverse side effects are carried out during the training session.

From the results of the MR-Sandbox test for nine days, it was found that the safety level of using MR-Sandbox was 100%, which was indicated by the absence of side effects that occurred during the test period. Meanwhile, from the results of measuring the level of user involvement / user interest (involvement) from the use of MR-Sandbox for nine days of testing using the PQ instrument, the average PQ value was 32 (with a standard deviation of 0.6), from the total PQ value of 35. Then the total time the training obtained during the nine days of testing shows a minimum exercise time of 6 minutes and a maximum training time of 12 minutes as shown in Picture 4, with a total training time of 54 minutes to 108 minutes. Although the trainees showed interest in using the MR-Sandbox media as indicated by their good PQ scores, none of the participants had exceeded the 15 minute training time limit. This is due to several factors:

1. the MR-Sandbox device is still too high so that participants have to stand to use it where their physical abilities are limited
2. the presence of pain that sometimes arises in both hands due to nerve disorders in the upper extremities so that strong motivation is not fully supported by physical abilities.

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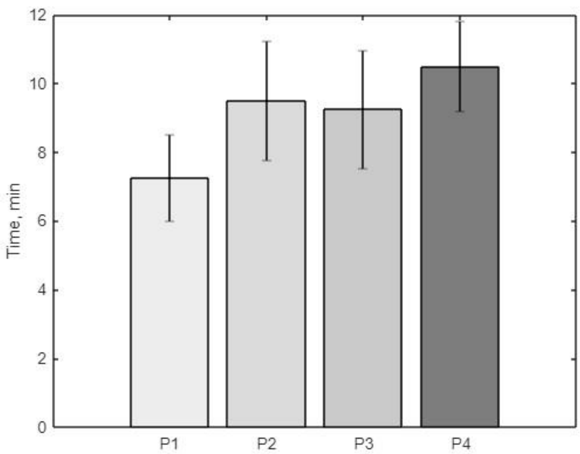
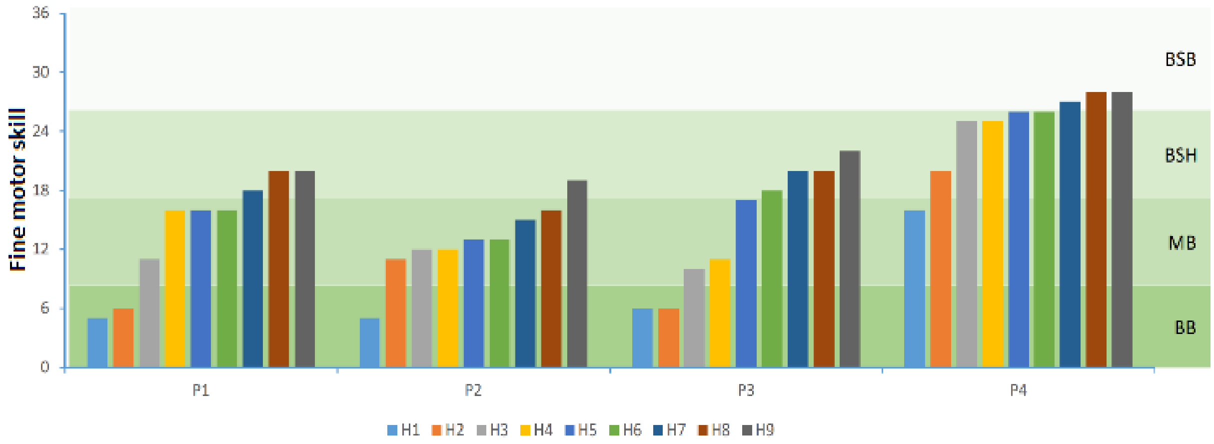


Picture. 4. Average training time for each participant

The level of effectiveness of using MR-Sandbox for nine days of testing on children with disabilities is shown in Picture 5. The instrument for assessing the level of effectiveness of the MR-Sandbox can be seen in Appendix 1. Based on Picture 4, it can be explained that Participant 1 (P1) and Participant 3 (P3) for up to two days of testing are still in the Undeveloped (BB) criteria, while the other two participants, Participant 2 (P2) and Participant 4 (P4) experienced an increase in fine motor skills on the MB and BSH criteria. Until the end of the exercise (day 9), P1, P2, P3 showed significant fine motor development from the BB criteria on the first day of training to BSH criteria on the ninth day of training, and P4 showed fine motor development from the MB criteria on the first day of training to BSH criteria on the ninth day of training. BSB criteria on the ninth day of training. This shows that the effectiveness of MR-Sandbox in training fine motor skills in children with disabilities gives good results for physical development in the upper extremities.



Picture. 5. Comparison of exercise results from fine motor development in children with disabilities during nine days of testing using MR-Sandbox

V. Conclusion

In this research, the design and development of a sandbox based on a mixed reality (MR-Sandbox) prototype was carried out for hand therapy due to hemiparesis in the upper extremities after stroke. A form of game therapy that can be made using the MR-Sandbox prototype is creating a small island by forming sand using sweeping hand movements that experience hemiparesis. The results are immediately projected back onto the surface of the sand in the form of a 3D virtual environment. MR-Sandbox prototype components consist of a graphics computer, a depth camera, a standard projector, and a sandbox filled with non-toxic white sand. The MR-Sandbox prototype has been successfully demonstrated by generating a topographical miniature of an island containing contour lines, rivers or seas, mountains, highlands, and lowlands to provide various challenges to patients using the sand play experience.

From the results of the nine-day MR-Sandbox test, it was found that the safety level of using the MR-Sandbox was 100%, which was shown by the absence of side effects that occurred during the test period. Meanwhile, from the results of measuring the level of user involvement/user interest (involvement) from using the MR-Sandbox during the nine days of testing using the PQ instrument, an average PQ value of 32 out of a total of 36 showed good user involvement during the use of the MR-Sandbox. The total training time totaled 54 to 108 minutes for each participant during the nine training days. The effectiveness level of using the MR-Sandbox for nine days of practice can improve fine motor skills from BB criteria to the average BSH and BSB criteria.

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