Testing the Usability of Serious Game for Low Vision Children

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***Abstract*—Serious games are prodigious tools for building language, science and math knowledge and skills. Despite a growing number of studies on using serious games for learning, children with visual impairment have obstacles when playing the games. Low vision children have a visual balance that can be assisted with assistive technology. A 2D serious game for learning Mathematics is developed using Unity for low vision children. In order to enhance the game's accessibility for low vision children, accessibility elements have been implemented in the serious game prototype. Those elements are screen design (buttons, menus, and navigation), multimedia (text, graphics, audio, and animation), object motion, and language. Upon completion of the serious game, usability testing was done to identify the accessibility of the serious game to low vision children based on the usability level. The observation technique is used for analysing the serious game. The overall usability score is good based on aspects of effectiveness, efficiency and user satisfaction tested.**

Keywords*—Serious game; learning; low vision; usability; accessibility

I. Introduction

Nowadays, information and communication technologies (ICT) are used in education. We can find a lot of educational applications that can help young learners learn. Several ICT applications are on the market, such as e-books, multimedia courseware, and games [1] [2]. Gaming is a very popular activity enjoyed by children. Thus, a serious game is the most promising tool for helping children learn. A serious game is used beyond entertainment [3][4]. Serious games are prodigious tools for building language, science, and math knowledge and skills. Despite a growing number of studies on using serious games for learning, children with visual impairments have obstacles when playing the games. There are two categories of visual impairment: blindness and low vision. Low vision children have a visual balance that can be assisted with assistive technology. The World Health Organisation defines low vision as visual acuity between 20/70 and 20/400 with a possible correction of 20 degrees or less [5]. Low vision children have obstacles accessing graphical elements in games. A preliminary study conducted by [6] indicates that low vision has several accessibility issues, such as visual, animation, audio, and navigation. They need to look at the graphical elements from a very close distance because the size of the text and graphics is small. The colour contrast between the graphics and background is low. The choice of dark colour is unsuitable for the children. They also have difficulties navigating the menus and buttons in games. They also focus on one sound at a time. Besides, fast animation movements affect their vision when playing games. Thus, to ensure they can play the game, a 2D serious game for learning Mathematics is developed using Unity for low vision children. This serious game runs on mobile devices using the Android operating system. This game's storyline is about a rabbit named "Bunny" trying to save his friends who a tiger kidnaped. Bunny needs to complete the Mathematical tasks provided for each game level to obtain the instructions and tools used in the next challenge. Hints and tools will help Bunny save his friends from the tiger. This game consists of three levels of Mathematical tasks, which are based on the Mathematics Syllabus for Year 1. The game's content consists of an introduction to numbers, shapes, addition, and subtraction.

Serious games should be easily accessible to low vision children. The game design should be flexible, with an interface adapted to the accessibility requirements of low vision children. In order to enhance the game's accessibility for low vision children, accessibility elements have been implemented in the serious game prototype. Those elements are screen design (buttons, menus, and navigation), multimedia (text, graphics, audio, and animation), object motion, and language. The children can set the appropriate background colour and contrast level to see menus and buttons more clearly based on their vision level. The game's navigation is designed to be consistent throughout the game. The text size is large and adapted to the children's vision. The background colour has a high colour contrast. The use of bright colours and large graphics are implemented in the game. Children can adjust the background colour. Thus, children can easily identify and move objects in the game. The background audio must be clear and adjustable based on the needs of children with low vision. Important objects in the game include background sounds to help the children identify the position of the object. The game's task instructions are accompanied by background audio so children can easily understand the game's storyline. Besides, the language used in the game should be easy to understand. For the proposed serious game, the Malay Language is used because it is used in learning Mathematics in primary school. The movement of objects in the game can also be adjusted according to the child's vision so that it is not too fast. The movement of objects in the game is also minimal so that children can control the game based on their needs. Upon completion of the serious game, usability testing was done to identify the accessibility of the serious game to low vision children based on the usability level. Usability testing is conducted to ensure the serious game fulfills the children's accessibility requirements. The serious game user interface is depicted in Fig. 1.

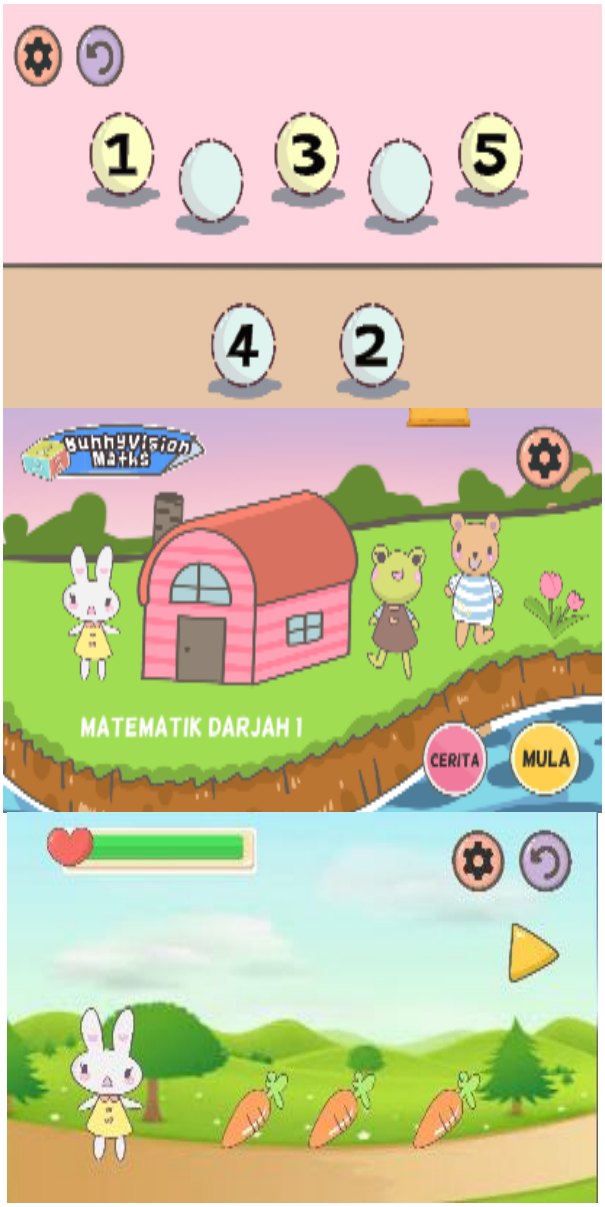

Fig. 1. Serious game user interface.

Thus, this paper presents the usability testing of Math Game, a serious game prototype that was developed specifically for low vision children aged seven years old. The serious game is developed based on the accessibility requirements of low vision children. The effectiveness, efficiency, and user satisfaction of the serious game are tested in the usability testing. The observation technique is used for analysing the serious game. The usability testing aims to identify the serious game's usability level for low vision children.

This paper is organised as follows: Section I discusses introduction, while Section II describes the related work. Section III describes the methodology and Section IV and Section V discusses the results and discussion, respectively, while Section VI presents the conclusion and plan for future work.

II. Related Work

The International Organization for Standardization (ISO) 9241-11 (1998) defines usability as the ability of a product to be used by users to accomplish certain goals effectively, efficiently, and with user satisfaction [1]. Usability also refers to whether a product is easy to use. Usability testing allows a product to be usable by target users to meet accessibility requirements. Based on the ISO 9241-11 definition, usability consists of the following components:

Effectiveness: The accuracy and completeness with which a user can achieve a certain goal in a certain environment.

Efficiency: The effort the user gives to complete a task and achieve the objective of using an application or system.

User Satisfaction: User comfort and acceptance of the system.

Usability testing is conducted to identify usability problems before releasing the serious game in its real context. The usability testing ensures the serious game fulfills the children's accessibility requirements. It is because both usability and accessibility should be considered good design practices and involved in system and application development stages. There is some overlap between the concepts of usability and accessibility. Accessibility enables particular users to access ICT applications independently without accounting for their disability. At the same time, usability refers to the ability of the ICT application to carry out the intended function effectively, efficiently, and with satisfaction when used by users. Therefore, accessibility specifically refers to disabled users, while usability refers to the general population. According to [7], usability testing is also suitable for assessing ICT applications for accessibility.

In human-computer interaction (HCI), usability is one of the focus areas where specified users can use a product to achieve goals effectively, efficiently, and satisfactorily [8]. When designing for usability and accessibility, a usability study should be conducted on the ICT application. Usability is defined as how efficiently user requirements are fulfilled [9]. It has developed usability criteria for accessible websites based on their effectiveness, where the user carries out tasks without experiencing barriers such as clear link texts. For efficiency, the user obtains the desired information quickly, and the system is usable. In contrast, for satisfaction, the user feels joy when navigating the website because the screen design facilitates navigation by the disabled user and avoids the accessibility barrier.

Several evaluation factors in usability testing include screen appearance, consistency, accessibility, navigation, interactivity, and content [8]. The literature comprises many usability testing types, methods, measurements, and respondents. Besides, usability research could be done in many forms based on the scope and goal of the ICT application. There are activities for usability research, such as focus groups, task analysis, user observation, interviews, and surveys. The activities provide insights into how users interact with the ICT application [10]. For example, from the observation and interview, the respondent's reaction when using the product will help the researcher understand the user's satisfaction with the ICT

application [11]. A summative usability evaluation has been done using observation and questionnaires to measure the usability of the Mudah.my mobile application's efficiency, effectiveness, and satisfaction [12]. Ten respondents are involved in the study and will perform five application tasks. Based on the study, the results show that the Mudah.my mobile application is easy to use and consistent. A usability study was also done using the Technology Acceptance Model to evaluate the usability of virtual game-based simulation to help nursing students improve their pediatric nursing skills [13]. The methods involved heuristic evaluation with experts, think-aloud activities while playing the game, and interviews. The study shows high user satisfaction, and they learned about pediatrics care easily. Observation has also been conducted to evaluate the usability of the TVET m-learning application for 30 Multimedia Software Technology course students. A questionnaire was used to measure the usability elements such as system usefulness, ease of use, ease of learning, and user satisfaction. A special room and tools, such as a video camera, notebooks, mobile devices and task lists, are prepared for this usability testing. This study's results showed that students accepted the TVET m-learning application, and the usability score value was at a high level [14].

In addition, usability metrics have been implemented to evaluate the quality of the ICT applications. However, the metrics used for usability testing always change due to new inventions in ICT applications [15]. There are numerous usability measurement tools for usability testing. Website Analysis and Measurement Inventory (WAMMI) is a usability measurement tool that assesses website usability. WAMMI is a questionnaire developed by the Human Factors Research Group (HFRG). WAMMI comprises usability factors such as attractiveness, controllability, efficiency, and helpfulness [16]. WAMMI is used to evaluate the usability level of the Ministry of Education Malaysia (MOE) web portal and provide usability enhancement based on the testing results. There are two stages of usability testing, such as pre-usability testing to evaluate the current web portal and post-usability testing for the web portal that has been enhanced. The pre-usability testing result showed that the usability of the current web portal was at a moderate level. In contrast, the post-usability testing result showed that usability improved significantly [16].

Besides, the Software Usability Measurement Inventory (SUMI) was used as a usability measurement tool to measure system usability. SUMI was used to evaluate user experience when it was introduced in the 1990s. SUMI consists of usability criteria such as effectiveness, efficiency, satisfaction, error management, consistency, adaptability, and compatibility. This evaluation tool assesses a semantic image retrieval application, WebSIR. The results showed that 85% of respondents were satisfied with this application, which is easy to use [16]. Another study by [17] evaluated the usability of South Tangerang E-Government using SUMI. Based on the study, the usability scores of the e-government website are taken as a benchmark for the system's usability. The system usability scores are 85 for effectiveness, 81.5 for efficiency, and 72.5 for satisfaction. Thus, the usability of the e-government website is good.

A representative sample of users must conduct usability testing because users are different and have different problems [18]. Suitable usability testing methods and measurement should be considered when planning the testing with users, especially children. Usability testing with children consists of introspection, direct observation, thinking aloud, and interaction. Simple observation is used to observe users as they perform their tasks. Thus, this technique has been recognised as one of the best techniques for usability testing [19]. The usability testing should be planned before it is conducted on a real user.

III. Methodology

The usability testing method used in this study is direct observation. The observation method is conducted to evaluate the user experience of the product. This method involved evaluating users by observing them carrying out the tasks provided. Observations are conducted based on effectiveness, efficiency, and user satisfaction. User satisfaction is subjective. Thus, interviews were also conducted with low vision children to get feedback regarding their satisfaction level with the tested serious game. During the interview, emoticons (like, normal, dislike) are prepared to observe the user's reaction to the game. Observations will be recorded on the user satisfaction checklist. Users are required to perform tasks using the provided prototypes.

This usability testing used a selected study sample conducted at Sekolah Kebangsaan Pendidikan Khas Jalan Batu, Kuala Lumpur, and Sekolah Kebangsaan Pendidikan Khas Muar. This testing involves fifteen to seven-year-old low vision children (nine boys and six girls). In order to conduct usability testing, there are ethics that the researcher must follow. Since the testing was conducted during the COVID-19 pandemic, it complied with the Standard Operating Procedures (SOP) set by the Ministry of Education. Before conducting the usability test, consent from parents or guardians is required to ensure that the study meets research guidelines and ethics. The purpose of this research is also explained to the teachers involved.

A. Usability Testing Procedures

The activities involved in usability testing include determining the testing objective, preparing the instruments and testing tools, identifying the task scenario, preparing the testing checklist, and measuring usability testing. The testing procedure begins with the preparation of the testing instruments and tools. The testing procedure is further explained in the following sections.

1) Determination of testing objective: This usability testing was conducted to verify the accessibility of serious games to low vision children. Evaluation is important to ensure serious games accomplish development objectives. The evaluation is conducted based on the ISO 9241-11 definition, which covers effectiveness, efficiency, and user satisfaction concerning serious games.

2) Testing instruments and testing tools preparation: The testing instruments are prepared before the test is conducted. The testing instruments are reviewed by lecturers who are

experts in multimedia and games. The testing instruments consist of a serious game prototype, a usability testing task list, an observation checklist, a video recording, and a screen recording. Testing tools, such as tablets, a video camera, and a screen recorder, are prepared to support the usability test.

3) Identify task scenarios: Usability testing is conducted by giving the user a task scenario while the user plays the game. Researchers help users play the game when needed. The task scenario is an action that needs to be performed by the user during interface testing. The task scenario is based on the game task instructions. The task scenario is prepared according to the game screen and the game's design, such as the start screen, the narration screen, and the game task screen. Researchers use these task scenarios to ensure that all testing activities are going as planned.

4) Testing checklist preparation: A checklist is prepared based on the usability construct [1], [19], which consists of effectiveness, efficiency, and user satisfaction. The usability checklist consists of sixty-three items. Checklists are provided based on game functions and actions that players need to perform while playing the game. Table I shows the contents of the usability checklist.

TABLE I. THE CONTENTS OF THE USABILITY CHECKLIST

Accessibility Elements	Effectiveness	Efficiency	User Satisfaction
Menu and Button Screen Design) and Navigation	Children can click the menu and button functions.	Children easily click on menus and buttons. Children click on the right menu and button.	Children's reactions when they click the menu and button.
Multimedia (Graphics, Animation, Text, and Audio)	The multimedia on the screen are interesting for children. The audio used appeals to children.	Children click objects in the game easily. Children do not confuse while playing.	Children's reactions to multimedia in the game.
Object Movement	Adjustable speed of objects helps children to play.	Object movement makes it easier for children to click on the correct object in the game.	Children's reactions to the object's movement.
Language	The language used in the game is understandable and suitable for the children's ability.	The language used does not confuse or cause children to make mistakes while playing.	Children's reactions to the language used.

5) Measurement of usability testing: The measurement of effectiveness, efficiency, and user satisfaction are measured using the usability score [15], [20]. There are three observation options, effectiveness, efficiency, and user satisfaction, for the checklist, with the score represented for each option. Scores are awarded based on completing each task. Scores are then accumulated based on the three observation options. The usability measurements are as follows:

a) Effectiveness Measurement: Effectiveness measures is the ability of the user to complete a task within the game. If a task is completed successfully, a score of 5.0 will be marked on the effectiveness checklist item. Half of the task is completed or fails to complete; a score of 2.5 and 0 will be marked on the checklist item, respectively. Table II shows the scoring guide for the effectiveness checklist item during the observation.

TABLE II. EFFECTIVENESS SCORING GUIDELINES

Score	5.0	2.5	0
Details	When the children manage to complete the task successfully, the accessibility elements on-screen help children playing the game as below: -Children have no problem navigating the button and menu display on the screen. -Children understand the instructions of the game.	Children completed half of the task but had several issues, as below: -Children have difficulty navigating certain buttons and menu displays on the game screen, but they can still proceed with the game. -Multimedia elements do not consistently attract children's attention.	Children do not complete the task below: -Children have a problem finding all the menus and button displays on the game screen. -Children do not understand the game instructions.

Thus, the usability score for the effectiveness, X, is formulated as:

$$X = (\sum \text{Score for each effectiveness checklist item}) / \text{Total effectiveness checklist item} \quad (1)$$

b) Efficiency measurement: Efficiency is measured based on the duration of task completion time, which is the average task completion time. The average task completion time is a reference in efficiency testing [21]. The efficiency aspect is better when the user completes the task faster. The efficiency checklist has three observation options, with the score represented for each option. If the time is taken by the child to complete the task is equal to or faster than the average task completion time, then a score of 5.0 will be marked on the efficiency checklist item. Whereas, if the time the child takes to complete the task exceeds the average task completion time, a score of 2.5 will be marked on the efficiency checklist items. However, if the task fails, a score of 0 will be marked on the checklist items. Table III shows the scoring guide for the efficiency checklist item during the observation.

TABLE III. EFFICIENCY SCORING GUIDELINES

Score	5.0	2.5	0
Details	Children choose the right menu and button based on the game function The assistance provided when children play the game is minimal.	Some menus and buttons in the game are not selected correctly. However, they still could proceed to play the game. Some of the tasks require help.	Children are difficult to choose the right menu and button. Children play the entire game with assistance from the researcher

Thus, the usability scores for the efficiency, X, formulated as:

$$X = (\sum \text{Score for each item of efficiency checklist}) / \text{Total Efficiency Checklist item} \quad (2)$$

c) User satisfaction measurement: User satisfaction measurement consists of like, neutral, and disliked. A 5.0 score will be marked on the user's satisfaction checklist items if a child likes the serious game. If the child's reaction is neutral, a score of 2.5 will be marked on the checklist items, and if the child does not like the game, a score of 0 will be marked on the checklist items. Table IV shows the scoring guide for the user satisfaction checklist item during the observation.

TABLE IV. USER SATISFACTION SCORING GUIDELINES

Score	5.0	2.5	0
Details	Children show emoticons provided with "happy" signs. Children can focus on playing the game. Children finish the game successfully.	Children show emoticons provided with "neutral" signs. Children can focus on some of the games. Children stop playing in the middle of the game	Children show emoticons provided with signs "dislike". Children are not focused while playing the game. Children are unable to finish the game.

Thus, usability scores for the user satisfaction category, x, can be formulated as:

$$X = (\sum \text{ Score for each item of user satisfaction checklist}) / (\text{Total User Satisfaction Checklist item}) \quad (3)$$

The average value of each usability category is considered the use score for that category. The overall usability score is the average value of usability scores for three usability categories. Thus, the overall usability score, X, can be formulated at Table V:

TABLE V. USABILITY SCORE

Weak	Moderately Good	Good
$.0 \leq x \leq 2.49$	$2.5 \leq x \leq 3.49$	$3.5 \leq x \leq 5.0$

6) Implementation of usability test: A pilot study is conducted on the instrument to test its reliability before it is used in the actual testing. The pilot study involved a sample of five to seven-year-old low vision children. The pilot study was conducted to ensure that the assessment faced no problems. Through a pilot study, children's reactions, behaviours, and play tasks can be recorded. During the usability testing, children played the game with minimal assistance. The camera is used to record testing sessions. Screen recorder software records children's activities on the screen when playing the game. During the observation, researchers must observe the child's actions and reactions to the game tested. Children's actions in the game are recorded on the provided task scenario checklist and transferred to the usability checklist. Scores are given on the user's achievement in the task, which is recorded on the usability checklist based on the effectiveness, efficiency, and user satisfaction constructs. The data collected was analyzed with a descriptive analysis method. Fig. 2 shows the usability testing preparation.

Fig. 2. Usability testing preparation.

IV. RESULTS

The usability measurement is done by analysing the user's success in completing tasks. Usability data is collected as a usability score and determines whether the game design goals

are achieved and the need to improve the serious game. A user's success score indicates how successful the user is at completing a task. Scores are then accumulated based on three categories of usability: measurement of effectiveness, efficiency, and user satisfaction.

Based on the analysis, the effectiveness score for the game screen is 4.74. The children complete the tasks successfully on the game screen. Children begin to adapt in the early stages of the game. They make mistakes when selecting objects in the game and choosing the wrong answer. However, they can still reselect the correct button and complete the task. When the children can play at a higher level in the game, the user can adapt to the game interface. Fig. 3 shows the graph of the effectiveness score for each screen.

Fig. 3. The graph of effectiveness score.

Efficiency scores are given based on the time it takes to complete the task and efficiency measurement metrics. For the level 1 task, the average time the children took to complete the task was seven minutes. Children need more time to complete games because they begin to explore the game interface and begin to adapt to the game environment. The average time the children complete the level 2 and level 3 tasks is five minutes. At level 2 and 3 game tasks, children become more efficient at playing games because they can already adapt to the game interface and environment. They already understand how to play the game. The efficiency score is 4.55. Based on the usability score, the efficiency level is good. The game task can be executed smoothly and easily. Serious game efficiency analysis shows children click on the right buttons and menus to play the game. The assistance given to children is minimal, and they easily correct mistakes. Therefore, children can play the game easily and smoothly. Fig. 4 shows the graph of the efficiency score for each screen.

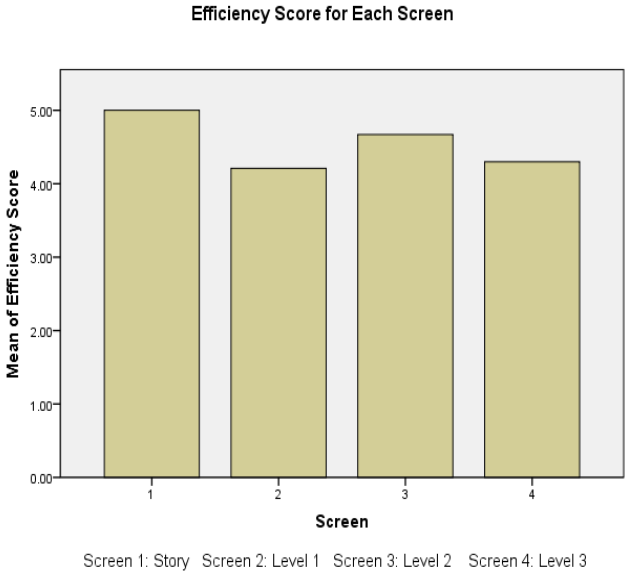

Fig. 4. The graph of efficiency score.

User satisfaction is measured based on the user's feelings when playing serious games, such as their reactions to screen design, buttons, menus, and games. For user satisfaction constructs, the user satisfaction score is 4.92. Based on usability scores, the level of user satisfaction is good. This shows that the children react positively to playing the game. Children react positively to the game interface, such as buttons, menus, graphics, and animations. Multimedia elements such as audio and in-game animations also attract users to play games. Fig. 5 shows the user the graph of the user satisfaction score.

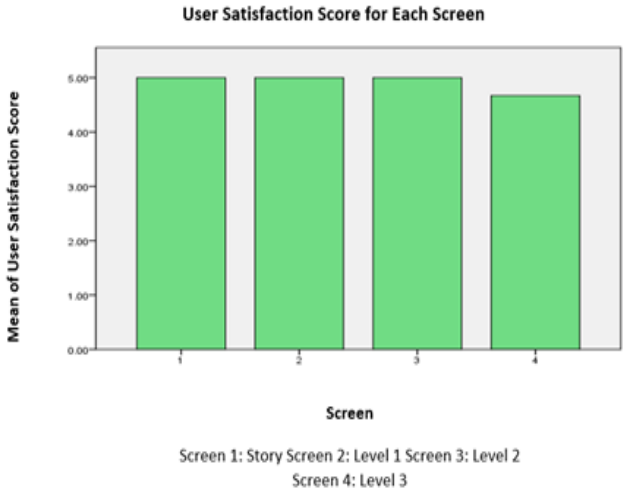

Fig. 5. The graph of user satisfaction score.

Based on aspects of effectiveness, efficiency, and user satisfaction tested, the overall usability score is 4.76, which is good. Based on descriptive usability analysis, elements of accessibility such as screen design (buttons, menus, and navigation), multimedia, language, and object motion are important in increasing the usability of serious games for low vision children.

V. Discussion

In the context of the usability of serious games, accessibility elements such as screen design, multimedia, language, and object motion help children complete the game successfully. The game interface features a simple screen design with larger buttons, menus, and icons to prevent accidental clicks, enabling children to interact with the game easily. This is consistent with a previous study by Allah et al. [22], which found that screen design elements such as menus and buttons were considered for improving the usability of the user interface.

Animations provide visual and auditory feedback when objects are selected or actions are performed, aiding children to choose the correct answers during gameplay. This finding aligns with the results of Ghanouni et al. [23], who emphasized the important role of animations in game design for children. The game also includes audio to assist children with low vision in understanding the content. The option to adjust audio volume ensures that children can set it to a comfortable level or mute it if needed. This outcome demonstrates that background audio associated with objects in the game assists users in selecting the correct object or answer, as reported by Najjar et al. [24].

Brighter colors are used for important in-game objects. A good contrast between text, graphics, and background colors enhances readability, allowing children to easily identify important object. Concise language helps children understand and follow the game's tasks, and these findings are in line with previous research conducted by Benaida [25]. However, this study goes further by demonstrating that object speed can be adjusted based on children's preferences to help children control the game.

Furthermore, when children navigate the game interface without confusion, they enjoy the gameplay and feel satisfied with the experience [26]. Multimedia elements make the game more enjoyable for children [14]. When children can easily understand the gameplay and objectives, they experience a sense of accomplishment and satisfaction. Positive reinforcement through sounds or animations can keep users engaged and motivated [27]. Therefore, the use of accessibility elements on each screen is important for helping low vision children play games.

VI. Conclusion

In this study, usability testing on a serious game was done successfully, involving low-vision children playing the game. The testing has been done through observation. The results of usability testing show that the effectiveness aspect achieved a good average score of 4.74, while the efficiency aspect obtained an average score of 4.55. Moreover, the user satisfaction aspect received a high average score of 4.92. Thus, the overall level of usability is rated as good, with an average usability score of 4.76. Accessibility elements such as multimedia, screen design, language, and object motion enhance the usability of serious games. With this testing, the prototype will be more usable. Therefore, this serious game meets the usability aspects of serious games for low vision children. In conclusion, this study shows that this serious game is useful for children with low vision. The design of this game helps children play and learn more comfortably and improves their play experience. Future research could be done on designing an accessibility design for serious games for other disabilities, and new technology, such as artificial intelligence, could be implemented into the game design.

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References

[1] S. Z. Mohid, “Model Reka Bentuk Ketercapaian Perisian Kursus Multimedia Untuk Kanak-Kanak Oku Pendengaran,” Universiti Kebangsaan Malaysia, 2017.

[2] R. R. Z. Ramli, N. Sahari, S.F Mat Noor, M. M. Noor, N. A. Abd Majid, H. A. Dahlan, and A. N. Abd Wahab, “Assessing Usability of Learning Experience Prototype,” Int. J. Emerg. Technol. Learn., vol. 17, no. 9, pp. 20–36, 2022, doi: 10.3991/ijet.v17i09.29955.

[3] S. R. Z. Abidin, S. F. M. Noor, and N. S. Ashaari, “Guidelines of brain-based learning through serious game for slow reader students,” Proc. 2017 6th Int. Conf. Electr. Eng. Informatics Sustain. Soc. Through Digit. Innov. ICEEI 2017, vol. 2017-Novem, pp. 1–6, 2018, doi: 10.1109/ICEEI.2017.8312461.

[4] Z. Cheng, F. Hao, and Z. Jianyou, “04. Research on Design of Serious Game Based on GIS Serious Game Engine Structure Based on GIS Serious game engine based on GIS is the combination of Access GIS to call required terrain data by OpenGIS,” Lect. Notes Comput. Sci., pp. 231–233, 2010.

[5] World Health Organization, “Visual Impairment and Blindness,” 2016.

[6] N. I. Othman, N. A. M. Zin, and H. Mohamed, “Accessibility Requirements in Serious Games for Low Vision Children,” Proc. Int. Conf. Electr. Eng. Informatics, vol. 2019-July, no. July, pp. 624–630, 2019, doi: 10.1109/ICEEI47359.2019.8988791.

[7] M. M. Ali-Shahid and S. Sulaiman, “A case study on reliability and usability testing of a Web portal,” 2015 9th Malaysian Softw. Eng. Conf. MySEC 2015, pp. 31–36, 2016, doi: 10.1109/MySEC.2015.7475191.

[8] N. A. A. Zaki, T. S. M. T. Wook, and K. Ahmad, “A usability testing of ASAH-/ for children with speech and language delay,” Proc. 2017 6th Int. Conf. Electr. Eng. Informatics Sustain. Soc. Through Digit. Innov. ICEEI 2017, vol. 2017-Novem, pp. 1–6, 2018, doi: 10.1109/ICEEI.2017.8312392.

[9] M. A. Hersh and B. Leporini, An overview of accessibility and usability of educational games, no. April 2016. 2013. doi: 10.4018/978-1-4666-4422-9.ch005.

[10] B. Lange, S. Flynn, and A. Rizzo, “Initial usability assessment of off-the-shelf video game consoles for clinical game-based motor rehabilitation,” Phys. Ther. Rev., vol. 14, no. 5, pp. 355–363, 2009, doi: 10.1179/108331909X12488667117258.

[11] D. I. Rosli and M. Moharnad, “A usability testing on aa-ba-ta Arabic learning tool,” ICDLE 2010 - 2010 4th Int. Conf. Distance Learn. Educ. Proc., pp. 218–221, 2010, doi: 10.1109/ICDLE.2010.5606000.

[12] A. Hussain, E. O. C. Mkpojiogu, H. Abubakar, and H. M. Hassan, “The usability evaluation of Mudah.my on mobile device,” AIP Conf. Proc., vol. 1891, no. October, 2017, doi: 10.1063/1.5005391.

[13] M. Verkuyl, L. Atack, P. Mastrilli, and D. Romaniuk, “Virtual gaming to develop students’ pediatric nursing skills: A usability test,” Nurse Educ. Today, vol. 46, pp. 81–85, 2016, doi: 10.1016/j.nedt.2016.08.024.

[14] A. Syazwani, M. N. Siti Fadzilah, and M. Hazura, “SkillsMalaysia Journal Kebolehgunaan Aplikasi M-Pembelajaran TVET,” Ski. J., vol. 4, no. 1, 2018, [Online]. Available: http://www.ciast.gov.my/journal%7C34-46

[15] N. B. N. Rozali and M. Y. B. Said, “Usability testing on government agencies web portal: A study on Ministry of Education Malaysia (MOE)

web portal," 2015 9th Malaysian Softw. Eng. Conf. MySEC 2015, pp. 37–42, 2016, doi: 10.1109/MySEC.2015.7475192.

[16] M. S. Sulaiman and A. Azmi, "Interactive WebSIR Using Software Usability Measurement Inventory (SUMI)," Adv. Electr. Comput. Sci. Electron. Eng. Comput. Sci, 2021.

[17] T. T and A. T. Muharram, "The Analysis Knowledge Management System Of Electronic Government South Tangerang Based On Usability Evaluation Using SUMI (Software Usability Measurement Inventory)," Data Sci. J. Comput. Appl. Informatics, vol. 4, no. 1, pp. 47–58, 2020, doi: 10.32734/jocai.v4.i1-3203.

[18] A. Donker and P. Reitsma, "Usability testing with young children," Proc. 2004 Conf. Interact. Des. Child. Build. a Community, IDC 2004, pp. 43–48, 2004, doi: 10.1145/1017833.1017839.

[19] M. Ismail, N. M. Diah, S. Ahmad, N. A. M. Kamal, and M. K. M. Dahari, "Measuring usability of educational computer games based on the user success rate," SHUSER 2011 - 2011 Int. Symp. Humanit. Sci. Eng. Res., pp. 56–60, 2011, doi: 10.1109/SHUSER.2011.6008500.

[20] T. K. Chiew and S. S. Salim, "Webuse: Website usability evaluation tool," Malaysian J. Comput. Sci., vol. 16, no. 1, pp. 47–57, 2003.

[21] T. Tullis and B. Albert, Measuring the User Experience. Elsevier, 2013. doi: 10.1016/C2011-0-00016-9.

[22] K. K. Allah, N. A. Ismail, L. Hasan, and W. Y. Leng, "Usability Evaluation of Web Search User Interfaces from the Elderly Perspective," Int. J. Adv. Comput. Sci. Appl., vol. 12, no. 12, pp. 647–657, 2021, doi: 10.14569/IJACSA.2021.0121281.

[23] P. Ghanouni, T. Jarus, J. G. Zwicker, and J. Lucyshyn, "An interactive serious game to Target perspective taking skills among children with ASD: A usability testing," Behav. Inf. Technol., vol. 40, no. 16, pp. 1716–1726, 2021, doi: 10.1080/0144929X.2020.1776770.

[24] A. B. Najjar, A. Alhussayen, and R. Jafri, "Usability Engineering of a Tangible User Interface Application for Visually Impaired Children," Human-centric Comput. Inf. Sci., vol. 11, no. March, 2021, doi: 10.22967/HCIS.2021.11.014.

[25] M. Benaida, "e-Government Usability Evaluation: A Comparison between Algeria and the UK," Int. J. Adv. Comput. Sci. Appl., vol. 14, no. 1, pp. 680–690, 2023, doi: 10.14569/IJACSA.2023.0140175.

[26] G. P. Tolentino, C. Battaglini, A. C. V. Pereira, R. J. De Oliveria, and M. G. M. De Paula, "Usability of serious games for health," Proc. - 2011 3rd Int. Conf. Games Virtual Worlds Serious Appl. VS-Games 2011, pp. 172–175, 2011, doi: 10.1109/VS-GAMES.2011.33.

[27] Tan Wee Hoe, Gamifikasi dalam Pendidikan, 1st ed. Tanjung Malim: Universiti Pendidikan Sultan Idris, 2015.