Usability Evaluation: User Experience Evaluation using Visual Based Augmented Reality for Dyscalculia Learners in Mathematics (V-ARA-Dculia)

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Abstract. Augmented technologies have found to be an effective approach for special needs learners in enhancing their learning skills. On the other hand, these applications must be designed in such a way that they are usable and intuitive for individuals with special needs specially dyscalculia learners. Usability evaluation on user interface is an informal method of usability analysis evaluation which presented within an interface design and required experts to commented on it. Usability evaluation principles applied focused to improve the efficiency and learnability of the applications The usability evaluation involved summative evaluation which was conducted on the use of the application by fifteen (15) elementary dyscalculia learners. Finding of the research indicated that the important for early intervention through embedded in Visual-based Augmented Reality (MV-ARA-Dculia) application was positively significant in assisting dyscalculia learners learn mathematics. The result outcome shows that usability evaluation on user interface has evidence a break in the field of special needs learners.

Keywords: Dyscalculia, Augmented Reality, Mathematical Difficulty, Usability evaluation, Visual Based, Cognitive walkthrough, Informal Walkthrough

1 Introduction

Diverse technologies were used to evaluate Visual-Based Augmented Reality for Dyscalculia Learners (V-ARA-Dculia) application testing was vital to ensure the efficiency and learnability of the working prototype for elementary dyscalculia learners. There is a major difference between Augmented Reality (AR), and traditional interfaces due to their differences in physical environment. AR has a complicated environment in which users mainly move freely as well as moving parts of their physical body to interact with the application. The various strategies used to collect data were employed such as informal walkthrough and cognitive walkthrough embedding questionnaire and expert evaluation. The diverse techniques used in date collection uncovered various aspects of how learning for dyscalculia learners can take is various form apart from the traditional conventional approach.

Usability evaluation emphatically was introduced by Shackel (1981) in order to substitute the phase of user-friendly of an application (Bevan, Kirakowski & Maissel 1991). In Shackel (1990) referred to four (4) aspects of interest in usability evaluation: learnability (easy to learning), throughout, flexibility and attitude. Rubin (1994) accepted that usability includes one or more of the four (4) factors outlined by Shackel (1990) and Booth (1989): usefulness, effectiveness (ease of use), learnability, and attitude (likeability). Usability testing generally, focused on three (3) aspects: easy to learn, easy to use and user satisfaction in using the system (Stone, Jarrett & Minocho 2005; Smith, & Mayes 1996). Based on international standards, usability refers to effectiveness and efficiency to achieve specified goals and users satisfaction. ISO 9241 (1998) define usability standard as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified content use*".

On the other hand, usability evaluation has significant implications on learning application for dyscalculia learners. Furthermore, AR learning application able to assist dyscalculia learners in enhancing learning mathematics which needs to undergo usability testing to ensure that it meets its learnability and efficiency (Gresse von Wangenheim et al. 2016).

2 Objective

The objective of summative usability evaluation is to evaluate dyscalculia learners towards the end of an instructional lesson by comparing it against a standard. The end does not refer to the finish of a whole course or module of study. Summative evaluation may be distributed throughout a lesson after a particular lesson that is taught, and there are advantages to doing so. The technique of summative evaluation employed in AR learning application prototype was aimed to summarise overall learning after the intervention was through ‘informal walkthrough’ and ‘cognitive walkthrough’.

3 Methodology

Usability evaluation composed of summative evaluation is a process which focuses on how well users can learn and use the application to achieve their goals. It refers to how satisfied users are with AR application developed (Nayebi, Desharnais & Abran 2012). Summative evaluation was also adopted to access the goal of the V-ARA-Dculia application had met the stated intended goal.

Summative evaluation involved usability evaluation that was carried on by testing with a relatively large number of representative users and aimed at finding the strengths and weaknesses as well as comparing alternative design solutions or similar applications. The summative evaluation involved assessing the impact of efficiency and learnability of the application. Summative evaluation refers to the assessment for the learning of participants where the focus is on the outcome of a learning application. These contrasts with formative evaluation, which summarises the participants' development at a particular time.

The methodology based on Table 1 can be used to collect information from the target users. The informal walkthrough technique was a fundamental method for gathering data about the application's intended usage, embedded cultural meanings and indicated ideal users use. The informal walkthrough technique indicates that the user allows to explore the use of the application at their own pace and in the order that they see fit without the researcher getting in the way. This method can be used to assess how user-friendly and intuitive the application is. Usability evaluation instrument used during the summative evaluation for the V-ARA-Dculia learning application as working prototype was developed to collect data on usability evaluation of the prototype. Once the elementary dyscalculia learners were comfortable using the AR learning application, the "informal walkthrough" technique was utilized to collect information from them, as shown in Table 1. The cognitive walkthrough technique was used to identify usability issues in an interactive application. It focuses on how easy for a new user to accomplish tasks with the application.

Table 1. Summary of Usability Evaluation Methods for V-ARA-Dculia

Type of evaluation	Evaluation Method	Implemented
Summative Evaluation	Informal Walkthrough	Does not prepare detailed test task in advance but let the participants explore the system.
	Cognitive Walkthrough	Primarily focus on ease of use and confidence as first time users.

3.1 Usability Test Sampling

As many as 35 students from an elementary school who were found to have dyscalculia symptoms made up the sample size. In all, fifteen (15) samples were used in the usability test. These students had dyscalculia, according to a screening. through a specially built screening tool (DYScrin), using a random sample technique. These students were identified as dyscalculia students during screening using a specially designed screening tool (DYScrin) using a random sample method. One of the state's national schools in Selangor hosted the study. Purposive sampling, a non-probability sampling technique used in this study, selects respondents based on a set of criteria, such as similarity in academic background, learning style, and attitude to the learning environment. According to Nielsen (2000), a sample size of three (3) to five (5) persons is adequate for usability testing because only three users are needed to identify 80% of all usability issues.

4 Finding and Discussion

Data was gathered by observation, informal walks, and cognitive walks. The efficiency and learnability of dyscalculia students were the two (2) constructs on which the usability testing was based. Additionally, information was gathered by observation, informal walks, and cognitive walks. The efficiency and learnability of dyscalculia learners were the two (2) constructs used to guide the usability assessment.

4.1 Findings on Learnability Construct

The learnability construct was divided into two (2) parts of application usage that involves: interactive environment in the real world environment and interactive AR environment. instrument which assesses on learnability construct used to collect and measure data on the said construct. Table 2 shows the sections used to evaluate the learnability attributes. The rubric for learnability attributes have been adapted from the previous study of Nielsen (2001) and used to measure the learnability construct of V-ARA-Dculia.

Table 2. Rubric for Construct on Learnability

Scale	Explanations
F	Fail: cannot perform the task even though it is assist
PS	Partial success: able to perform the task after being assist
S	Success: able to perform tasks without assist

Figure 1 shows the Usability Testing Analysis Model I: Learnability construct (UTCMI: Learnability construct) used to evaluate the usability testing based on the learnability construct.

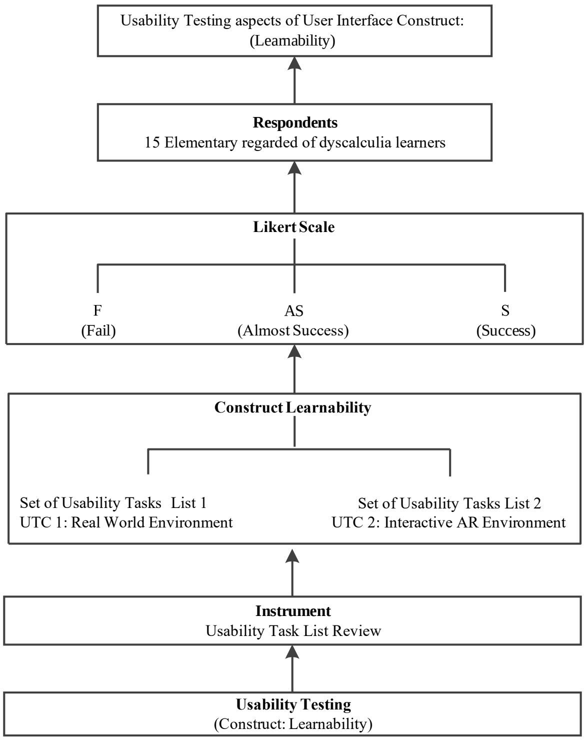

Figure 1. Usability Testing Analysis Model 1: Learnability Construct (UTAM1: Learnability)

The following completion of the assigned task by the dyscalculia learners using the set instrument Usability Tasks List 1: Learnability construct (UTC 1), Table 3 displays task success data from the study. The parts in Table 3 constitute the foundation for the values in Table 2.

Table 3 Usability Task 1: Learnability construct

Learner	Task List																			
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20
L1	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L2	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L3	S	S	AS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L4	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L5	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L6	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L7	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L8	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L9	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L10	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L11	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L12	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L13	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L14	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
L15	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
(%)	100	100	93.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean	2.00	2.00	1.93	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Standard Deviation	.000	.000	.258	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

The success rate score in Table 3 implemented using UTC 1 is based on the formula created by Nielsen (2001b). In total, there were 300 (learners x task list) attempts performed by the learners. Of those attempts, 299 were successful and one (1) was partially successful. For each partial success given half a point (50%) was given. The success rate of Task 1 (UTC 1) as follows:

Success rate = (Success + (Almost Success x 0.5) / attempts perform x 100
= 299 + (1 x 0.5) / 300 x 100
= 99.8%

Based on the results of the Usability Task I (UTC I), the learnability based on real-world environment of the Visual-based Augmented Reality (AR) learning application of dyscalculia learners (V-ARA-Dculia) was very positive, at the rate of 'Success', which means, the learners were able to perform the tasks without assistance. The dyscalculia learners also went through another test: Task 2 (UTC 2) on the interactive AR environment of the learning application prototype as shown in Table 5. The success rate of Task 2 (UTC 2) as follows:

Success rate = (Success + (Almost Success x 0.5) / attempt perform x 100
= 101 + (4 x 0.5) / 105 x 100
= 98%

The test was conducted to get the success rates of dyscalculia learners to provide a general picture of how the application supports them and how much improvement is needed to make the application more suitable for dyscalculia learners. The learners findings on the learnability construct conducted on an informal walkthrough observation concluded that the score for the construct in real world environment based on the task (UTC1) is slightly higher compared to that based on in the interactive AR environment (UTC 2). This could be due to the new exposure on AR learning environment by the dyscalculia learners. However, the success rate obtained in task UTC 1 and UTC 2 was not much difference. Therefore, it can be concluded that the learnability based on the AR interactive learning environment of the V-ARA-Dculia was very positive, at the rate of 'success', which means the learners were able to perform the tasks without assistance.

4.2 Findings on Efficiency Construct

The efficiency construct was evaluated based on the Usability Testing Analysis Model 2: Efficiency construct (UTAM 2: Efficiency). Efficiency is used to measure the time taken to finish a task. It is usually the time taken by the participants to complete a task set in any on the modules performed. Efficiency can be measured using two methods: Overall Relative Efficiency and Time based Efficiency. The Overall Relative Efficiency referred to test conducted on end-users (dyscalculia learner) who successfully completed the task in relation to the total time taken, whilst Time based Efficiency referred to the measurement of the time spent by the end-users (dyscalculia learners) to complete the task or speed of work. Table 4 shows the efficiency construct measured based on time take to complete the task by dyscalculia learners. The usability metrics rubric for efficiency attributes have been adapted from the previous study of (Nielsen 2001b) and used to measure the efficiency construct of V-ARA-Dculia.

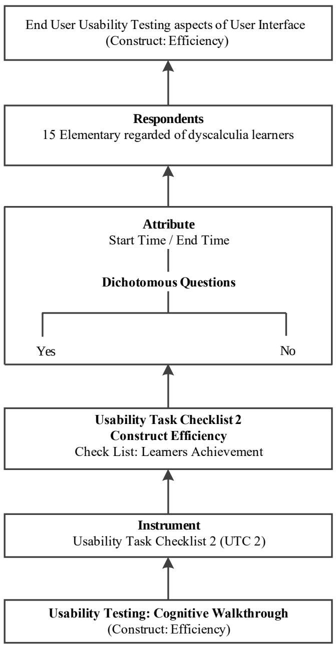

Figure 2. Usability Testing Analysis Model 2: Efficiency Construct (UTAM 2: Efficiency)

Table 4. Efficiency Construct: Time Taken to complete Task

Learner	Time taken to complete the Task (minutes)	Time taken to complete the Task (seconds)
L1	15 minutes	900
L2	10 minutes	600
L3	15 minutes	900
L4	10 minutes	600
L5	10 minutes	600
L6	15 minutes	900
L7	20 minutes	1200
L8	15 minutes	900
L9	15 minutes	900
L10	15 minutes	900
L11	15 minutes	900
L12	15 minutes	900
L13	15 minutes	900
L14	25 minutes	1500
L15	20 minutes	1200

Overall Relative Efficiency is calculated as follows:
Where :

$$Overall\ Relative\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N} n_{ij}t_{ij}}{\sum_{j=1}^{R}\sum_{i=1}^{N} t_{ij}} \times 100\%$$

Where :
N: number of tasks (N=1)
R: number of users (N=15)
nij result for the task (i) by the user (j) If the task is completed successfully, then
nij=1 otherwise nij=0

tij time spent the user 'j' to complete the task 'i'. If the user does not complete the task successfully, then the time will be measured until the moment the user gave up from the task. Table 5 shows the efficiency construct measure based on the overall Relative efficiency. The Overall Efficiency calculated as follows:

=(1*900+1*600+1*900+1*600+1*600+1*900+1*1200+1*900+1*900+1*900+1*900+1*900+1*900+1*1500+1*1200) x 100%
(900+600+900+600+600+900+1200+900+900+900+900+900+900+1500+1200)
= 100%

The Time Based Efficiency is calculated as follows:

$$Time\ Based\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N} \frac{n_{ij}}{t_{ij}}}{NR}$$

Time based Efficiency =
= (1*900+1*600+1*900+1*600+1*600+1*900+1*1200+1*900+1*900+1*900+1*900+1*900+1*900+1*1500+1*1200) (1*15)
= 920 (goals/seconds) / 15.33 (goals/minutes)

Table 5. Efficiency Construct: Overall Relative Efficiency to Complete Task

Learner	Time taken to complete the Task (minutes)	Time taken to complete the Task (seconds)	Time based Efficiency	Overall Relative Efficiency
L1	15 minutes	900	Time<=920s	100%
L2	10 minutes	600	Time<=920s	100%
L3	15 minutes	900	Time<=920s	100%
L4	10 minutes	600	Time<=920s	100%
L5	10 minutes	600	Time<=920s	100%
L6	15 minutes	900	Time<=920s	100%
L7	20 minutes	1200	Time>920s	100%
L8	15 minutes	900	Time<=920s	100%
L9	15 minutes	900	Time<=920s	100%
L10	15 minutes	900	Time<=920s	100%
L11	15 minutes	900	Time<=920s	100%
L12	15 minutes	900	Time<=920s	100%
L13	15 minutes	900	Time<=920s	100%
L14	25 minutes	1500	Time>920s	100%
L15	20 minutes	1200	Time>920s	100%

The findings on the efficiency construct based on the 'cognitive walkthrough observation' concluded that Time Based Efficiency measures 15.3 seconds of the time spent by the dyscalculia learner to complete the task. The Overall Relative Efficiency of the fifteen (15) dyscalculia learners showed 100% successfully completed the task in relation to the total time until the moment they completed the tasks performed. However, as can be observed, three (3) dyscalculia learners (L7, L14, L15) attempted in to complete the task with a longer total time taken compared to the other dyscalculia learners.

Children had higher level of engagement and fun when they were using the tangible system. The children with severe disabilities liked to use their interactive tangible system. In line with these, Fan et al. (2017) found that most of the learners like using the tangible application and they wanted to use it again. Furthermore, the present study revealed that all learners used the application and the tangible objects easily. None of them confronted with any difficulties which resulted a positive score through the informal and cognitive walkthrough. Similarly, Antle et al. (2011) observed that children can easily understand how to use the AR application. In the learning process, they used the AR application easily. Besides, stated that learners with learning disabilities quickly learned how to use the application. In line with these, revealed that the children reported that the AR tangible technology was easy to use.

5. Conclusion

Past literature pertaining to the current study was vital to identify the theoretical gaps that are appropriate for the study. The study covered areas of identification and early detection of dyscalculia learners, approach field of Augmented Reality (AR) in education, the benefits of Augmented Reality technology for learning tangible user interface (TUI), application development principles and usability inspection and usability testing), the approach of behaviourist theory and cognitivist theory underpinning the use Augmented Reality (AR) assistive learning technology for dyscalculia learners. The theoretical gap in terms of cognitivist and cognitive learning theories were investigated to find elements to be suitable for teaching and learning the basic facts of mathematics for dyscalculia learners using AR technology. Crucial aspects such as an integrated design and development LD application model which incorporated with the Iterative-Evolution model and the Human-Computer Interaction (HCI) development model, in order to design and develop an AR learning application that can truly meet the needs of dyscalculia learners taking into consideration their learning difficulties.

The other aspects that need to take into consideration as the suitable for dyscalculia learners; the pedagogical approach in relation to visual materials and visualisation due to the preferred approached of dyscalculia learners in learning mathematics particularly the abstractive aspects of mathematics, where there is need for them to visualise. Therefore, the more attributes of dyscalculia learners are known, the more accurate would be the design of the learning application for them. A cognitive walkthrough is a method devoted to new users by testing usability in which the examiner performs a series of task scenarios to achieve this goals. The usability test components include learnability and efficiency.

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