Double measurement on cognitive learning apps for children with mentally retardation

A G Persada\(^1\) and O R L Ati\(^2\)

\(^{1,2}\)Teknik Informatika, Universitas Islam Indonesia, Jalan Kaliurang KM 14.5, Umbulmartani, Ngemplak, Sleman, Yogyakarta

\(^1\)e-mail: andhika.giri@uii.ac.id

Abstract. There are four cognitive aspects revealed aim to develop learning application (apps) for children with mentally retardation (MR), namely perception, association, memory, and motoric. However, motoric aspects is less noticed in apps which had been being developed. In this study, we aim to design the interaction of the apps which accommodate motoric aspect. Apps may be used as companion tool aside with formal learning. Apps is focused on motoric aspect, while another four aspects are adopted from existing apps. In order to reach high level of usability, interaction design (IxD) is measured iteratively using double measurements, cognitive walkthrough (CW) and heuristic evaluation (HE). Both method is covering each other. This way is suitable to verify previous measurement and strengthen usability. Result of the study stated that apps can properly used by students and teacher and relevant with user research. There is no major usability problems found either in CW or HE measurement. Moreover, HE method ensures end-user’s satisfaction is good design principles also.

1. Introduction

Based on the definition set by American Association on Intellectual and Developmental Disabilities (AAIDD), mental retardation (MR) refers to intellectual abilities of someone who is below average, followed by lack of behavioral adaptability during the development [1]. Intellectual ability of people who has MR become the main cause of their learning difficulty. Learning difficulty, according to National Institute of Health, USA is a gap which occurs significantly between intelligence abilities in their academic study [2]. In children who has MR, difficulty in learning both academically and self-development is characterized into perceptual disturbances (perception), association, motoric, and memory. Learning difficulty can be helped utilizing formal learning which apps is used to deliver content. Recently, some apps had been developed, but not yet accommodating all those four aspects.

Observation on previous apps reveals that some apps is not yet accommodating motoric aspects. In line with the discussion to psychologist which has speciality in children development, stated that motoric-based learning focuses on the ability which need movement of the muscles of body. It is required to practice directly on specific object. For example, fine motoric disorders causes children with MR have difficulty in reading and writing. It is important to discover this problem and attempt this into apps. In this study, we aim to develop the IxD of motoric learning apps which is designed specifically for children with MR. Another three aspects, they are perception, association, and memory are adopted from existing apps. One of suitable ways to improve psychomotor ability is game [3]. Game is designed utilizing IxD and guided by UX approach, which aims to achieve user satisfaction during interaction.
To reach ideal condition, double measurement is applied. CW had been applied first then followed by HE measurement. Briefly, this methodology is used to strengthen usability result by accommodating end-user’s experiences and improve design quality that guided by UX expert’s knowledge bases.

CW focuses on exploratory learning aims to produce better first experience [4]. It is important to produce good experience for children with MR, which has frustrating tendency when game they are playing is confusing. The methodology focuses on task-based measurement obtain to achieve goals [5] [4]. This method prefer to focus on how user explore and experience the apps, than formal training [4]. Teacher and six MR children are selected to be involved in user research and then being referred as personas. CW can be applied on any phase of development process to describe how system do and what user need [4]. On other hand, HE is a measurement method which based on brief list of usability or UX principles [6]. Involving experts in measuring design is compiles with standard is necessarily need to decrease major usability problems. Based on Nielsen and Molich, HE explained as a group of evaluators which are measuring based on usability heuristics [6]. So far, this method is the most popular being used [7]. However, each method has weakness, there is no measurement method can cover all usability problems [8]. So, idea to combine those methods in this study aims to identify usability problems comprehensively.

In the rest of paper, we divide discussion into several sections. First section is introduction. Second, discussion about children with MR. Section three discusses about user-reseach, while section four provide the result of the study. Finally, section five provides conclusion and future work.

2. Children with Mentally Retardation

2.1. Current Condition and Goal
This research is focusing on designing the IxD. As IxD, concept is more urge than the apps itself. So, measurement methods in this research is led to assess the children-apps interaction during playing. Meanwhile, impact on children is still assessing by teacher. It is required to explore and conduct further research in order to assess the impact of applying apps on mentally retarded children. Based on discussion with psychologist, it is relevant to apply this apps only as companion tool. Goal of this research is developing IxD which is applied as companion tool, but dismiss the impact on children with mentally retardation. Personas are mentioned as group of distinguish characteristic. Personas is different with sample. Those Six personas is chosen and classified based on group of characteristic. Each personas represents certain character of mentally retarded children. Personas selection and classification is conducted based on discussion with teachers and psychologists.

2.2. Difficulty Understanding
According to the American Association on Mental Deficiency (AAMD), children with MR is someone who has low ability to adapt their behavior into environment. Moreover, MR children requires support from outside parties to help them adjusting in condition [9]. According to the NJCLD (National Joint Committee of Learning Disabilities), learning difficulty includes several types namely reading, speaking, writing, counting, and listening. Someone with this characteristic is difficult to perceive certain objects they are observing. According to ACCALD (Association Committee for Children and Adult Learning Disabilities), learning difficulties are condition of development disorders, both verbal and nonverbal and inability to integrate something due to a neurological problem [1]. Generally, their symptoms are recognized when observation is performed before they are 18 [10]. There are some definition regard to MR, but they have minor differences among all the definitions. There are three basic elements which are similar in all definition, they are significantly subaverage IQ, significantly subaverage adaptive behavior, and manifestation before adulthood [1] [11]. Briefly, difficulty in learning can be classified into perception, association, memory, and motoric [12] on [13].

Perceptual (perception) disorders which is experienced by children with MR causes them have a lack ability to interpret a sentence or instruction, and less understand about the meaning of symbols, or even images both visually and auditory. visual perception can also make them unable to distinguish
similar forms of letters. Association disorders cause a children with MR have lack ability to understand ideas or concepts. Lack of memory and understanding which is experienced by MR causes them difficult to communicate [12]. Their short-term memory is weak, and this affects their long-term memory too. Last, children with MR experiences impaired motoric ability. This causes them less able to move with their gross and fine motoric movements. Example of gross motoric movement are walking and running, while fine motoric examples are writing, holding objects, and painting.

2.3. Motoric Aspect

Motoric learning focuses on the ability to move the body muscles. This learning concept requires MR children to practice interaction directly with certain objects aim to stimulate their motion. Based on interview to expert and lecturer on the field of children with special needs, children with MR has experienced impaired abilities in his motoric. Unfortunately, there is no apps was found that thoroughly accommodates four aspects that must be included on apps which accommodate children with MR. Motoric aspect is divided into gross motoric and fine motoric. Gross motoric system is a process of body movement that tends to use large muscles, consisting of movement manipulative (such as kicking, throwing, catching, etc.), locomotor (moving on), and non-locomotor (such as bending, turning, etc.) [14]. Fine motoric system is a process of body movement using smooth muscles such as finger movements while holding, writing, drawing, etc. Motoric disorders experienced by children with MR also influence their ability to learn [14]. Review on similar apps based on four aspects is presented on Table 1.

| Aspect   | Pal | The Idiot Test | Mental! | Skillz | MentalUp |
|----------|-----|----------------|---------|--------|----------|
| Perception | √   | √              | √       | √      | √        |
| Association | -   | -              | √       | -      | √        |
| Memory    | √   | -              | √       | √      | √        |
| Motoric   | -   | -              | -       | -      | -        |

As presented on Table 1, five apps were observed dividing by four aspects. We can see that all apps not yet accommodating motoric aspect. In this study, we develop IxD which is aiming to accommodate motoric aspect. Apps which is developed focuses on motoric aspect, although still accommodating another aspects by adopting from another five apps. It is challenging to accommodate motoric aspect. Motoric aspect requires user's body movement which is the weakness of children with MR.

3. User Research

Case study is taken place in SLB Negeri 1 Sleman. There are six students who are chosen as personas. They originated from same school and have different age range between 9 to 13 years old. In this study, six personas are accompanied by psychologist and teacher. Observation process states that, in fact children with MR have motivation to learn. However, they are easily to be bored. In this case, they want to be involved in the process of learning which is interactive. Interactive learning process make them excited and focus on problem they are facing. Briefly, goal of activating the interactive learning processes aim to exercise their cognitive ability.

Based on observation, we can summarize some problems regard to be settled in the apps. First, they need to be motivated and supervised in order to ignite their desire. Second, they are easily to be bored. Third, their motoric ability is still rigid. It needs to ignite them to launch physical effort during communication. It was relevant with the study conducted by Kirk et. al. stated that MR children has difficulty in communication [12]. Fourth, they have weaker understanding and memory ability. Fifth, they have not yet fluent in reading and has limitations to memorize vocabularies. Moreover, they are easily to be distracted by their external environment.
Next step, we confirm the result of our observation to their teacher. Teachers agree with some statements, such as obstacles that students are potentially facing to have maintained focus. Moreover, they agree about the importance of motivate them sustainably during learning process. Sometimes they need to teach same thing repeatedly. Regard to the apps, there are some recommendations. Apps is used as complementary tool while main learning process is led by teacher. In this study, game is suitable to support their psychomotor ability [3]. Multimedia elements on game able to attract children’s attention [3]. So, teacher is still act as center in learning process, while apps is used to help them deliver the contents. Hopefully apps can ignite student's motivation so they can actively involved in learning process. Following points are briefly summarized the need of the learning process for apps.

- In order to exercise the movement of fingers, writing may useful. Trigger by utilizing vibration can be applied when an error is occurring, so children is easier to identify their error and recognize what is correct during writing process.
- Daily motoric activities, such as cutting, tearing paper, and holding objects can be applied to improve skills and familiarize their motoric movements.
- New knowledge may be given to children by adding new vocabulary and understanding the instruction.
- Children need a game which accommodate them to improve concentration and memorizing ability.
- Instructions given in game are provided as minimum as possible. So it is easy to be understood. Specifically, moderate MR is given one simple instruction, whereas mild MR is given two simple instructions. The level of difficulty is adjusted to their ability, because children with MR difficult to capture and understand more than one instruction.
- Instruction is provided as clear as possible to prevent them from misunderstanding. For example, instruction "Take the apple and put it in the basket", should be clear who has the apple belongs to. This aim to anticipate the misunderstanding because teachers have already teach them that apples belonging to others should not be taken.
- Use interesting sound effect and character which are familiar to them.

4. Result

4.1. Double Measurement

Iteration in designing IxD is a repeatedly processes to achieve harmony between developers and user needs. Each page will be measured to achieve two main goals, user satisfaction and design standardization. This methodology is proposed aim to reach high level of usability. In this study, we aim to reach user satisfaction during interaction, while usability standardization is keep maintained. In this study, end-user satisfaction is attempted by applying CW method. Instead of end-user which tend to focus on satisfaction during interaction, HE focuses on usability achievement.

CW method is task-based measurement. While major usability can be identified by involving expertise field, minor usability can be identified using task-based measurement. This is the goal of CW measurement where minor usability problem is necessarily becoming major problem experienced by end-user. There are two perspectives in order to identify user problem, namely physiology and psychology. Physiological emphasizes on the form of design, color, layout, etc., while psychological emphasizes on the user’s emotion such as difficulty, and comfortable. Design principles is relevant to be achieved in order to reach high quality usability. Reaching in user satisfaction is not necessarily alignment with high quality of usability. Ease of useness of the apps potentially becoming trap to the usability. This is caused by the tendency of each user in assesing product. Each user potentially has tendency to love certain product and hate certain product even before have measuring new apps. Ideally, personas which is proposed new ideas then they compare with previous ideas and objectively evaluate which one is the most ideal. However, shifting user’s cognitive mind is not necessarily going to be predictable.
So, it needs design principles to overcome human-cognitive obstacles by providing design standards. Bligård and Osvalder revealed that CW had deficient high-level perspective in the analysis, insufficient information in the motivation for success or failure in measurement, and the difficulty in obtaining an overview of the results for a given interface or when comparing interfaces [15]. Moreover, CW is more narrow in identifying usability problems than HW. CW focuses on how user learning apps than efficiency or other usability attributes [4]. In case of measuring apps with heterogeneous feature, it will be difficult to identify usability problems comprehensively.

HE measurement conducted by involving two experts in UX which have expertise in design principles. Collaborate two experts with specific expertise perform better result [16]. Nielsen heuristic principles are conducted in this study. However, different evaluator may produce different usability problems found on same product [17]. Moreover, evaluators may not be the actual user of the apps [17]. HE evaluator has not experienced similar basic problems as end-user experienced [17], while CW has focused on ease of learning than solution to design problems [4]. Both measurement method have its advantages and weaknesses. It could be suitable to collaborate those methods aims to recover weaknesses possessed by each method. In HE, major usability problems may being found with higher probability than minor usability [16]. Even though, end-users has been experienced more often minor usability problems, such as button, background colour, and link which does not work.

There are two interation produced in CW measurement process. Table 2 present result of CW measurement. After CW, HE is conducted by involving two experts which have different background. First expert has capability on academic/theoretical-based UX. Second expert has capability on practical-based UX. In HE, evaluators assess design based on experiences and knowledges they have. The problem is, they are not the actual end-user of apps. In order to harmonize the results between two experts, we provide a standard for measurement those are ten principles from Nielsen.

| Task | Psy* | Phy** | Task | Psy | Phy | Task | Psy | Phy |
|-------|------|-------|-------|-----|-----|-------|-----|-----|
| It.1  | 1    | 0     | It.1  | 0   | 1   | It.1  | 0   | 1   |
| It.2  | 1    | 1     | It.2  | 1   | 1   | It.2  | 1   | 1   |

Table 2. Cognitive walkthrough measurement

* Psychological-based task
** Physiological-based task
Table 2 presents result of CW measurement in detail. Value “1” means each task is worked properly by personas properly. Value “0” means each task is failed worked properly by personas. There are 33 tasks worked by personas and identified four usability problems. Second iteration is conducted by recovering problems first. Second measurement show that all tasks are already worked properly by personas. Next, HE is conducted to confirm result against CW measurement. Nielsen heuristic principles has been implemented. There are ten heuristic principles which are used to measure IxD of the apps. On Table 3, result has generated from expert measurement. Each principle has been confirmed and analyzed by experts. Result of each principles then to be documented into numerical value. Then, result being converted into numerical value to make it easier to be classified. Value generated from both experts then be calculated its average value.

| Principle                                      | Value |
|------------------------------------------------|-------|
| Visibility of System Status                    | 3.5   |
| Match between System and The Real World         | 4.5   |
| User Control and Freedom                       | 4     |
| Consistency and Standard                       | 4.5   |
| Error Prevention                               | 3.5   |
| Recognition Rather then Recall                 | 4     |
| Flexibility and Efficiency of Use              | 3.5   |
| Aesthetic and Minimalistic Design              | 4     |
| Help User Recognize, Diagnose, and Recover from Error | 4 |
| Help and Documentation                         | 4.5   |

On Table 3, average point is 4 (scale 1-5). This value is good but not excellent, because of there are three principles having value below 4. There is no iteration aim to recover three principles with lowest value. Changing design which aim to adjust to result of measurement will also affect previous result obtained in CW measurement. It is too much time spending. Three principles which have lowest value are Visibility of System Status, Error Prevention, and Flexibility and Efficiency of Use.

- Many pages requires clear sitemap and system status. In this apps, there are categories to be choosen, whether fine or gross motoric. Moreover, there are a lot of level, where each level has instruction to be applied before playing game. This condition generates too many system status in each category and level which may confuse children.
- Error prevention is mandatory to be implemented because of potentially error revealed by children with MR. Although it seems accommodated in CW, experts may have appraisal more in this scope.
- There are too many ‘click’ in order to transmigrate over pages. Moreover, there are too many instruction to play in each level, such as activity of capturing picture aims determine object environment. It requires to shift interaction into less effort in apps, so children could easier to understand the IxD. Although, the role of the teacher as a companion will help children to understand instruction given.
4.2. Interaction Design
Discussion is focused on motoric learning activity. There are two kind of motoric activity which are being accommodated in apps, namely fine and gross motoric. Pre-exam and actual exam are conducted in each activity. Pre-exam accommodates children to practice activity before they are going to actual exam. The concept and technical activity of pre-exam and actual exam approximately similar. It is useful to exercise children to memorize previous activity which expected aim to improve result. Each activity held by children should be supervised by teacher. Children tends to feel anxiety when first time they interacting with the game, but by supervising and motivating them, children will start enjoying the game [3]. There are some level in each activity. Upper level will unlock when previous level has been passed. IxD is produced by following user research.

Augmented reality (AR) as a tool is used to accommodate motoric learning activity. In this study, IxD concept is precedence, while technical implementation of AR has not been discussed too detail. Next, wireframe has produced to visualize the concept into visual medium. Wireframe has not been measured against personas in this phase. Iteration in each interaction is being confirmed utilizing CW method. CW is relevant to be used in this study because it concentrate on the ease of learning by exploring IxD [18]. Psychological and Physiological aspects are two aspect used to measure interaction. Psychological aspect means question asked to personas is measured based on psychology theory, for example is level of anxiety during interaction with apps. Physiological aspect means question asked to personas is measured based on physiology theory which is regard to physical human senses. After confirmed by personas, interaction is being recovered and then generated as prototypes. While wireframes are designed using hand drawing, prototypes are designed using prototyping tools.

4.2.1. Fine Motoric
Overall, there are five activities in fine motoric learning. They are writing, coloring, scissor, throwing, and swiping. First activity is writing. MR children are asked to rewrite alphabet letter following virtual objects that appeared in screen. They are asked to rewrite by following sequence number and arrow as instruction. Vibration warning will perceived when personas makes a mistake, for example a line that should be drawn straight but be drawn curvely. Hopefully, MR children is easier to understand and remember correct form of the alphabet letter. Second activity is coloring the visualized forms. Similar to first test, if personas makes a mistake during coloring, there will be a vibrating to warn that the action given is wrong. This is useful to train the flexibility of the fingers and the accuracy. In third activity, personas will be introduced how to scissors through two adjacent poles. A rope between the two poles used as object. Then, personas will make a cutting motion to break the rope. This activity Exercise fingers movement. Moreover, this activity provides a simple understanding about how scissors is work.

Fourth activity displays garbage and trash as virtual object. Children will be asked to make a gesture of pinching, holding, and sliding on the screen to pick up scattered garbage and put it on the trash according to its type. Garbage bin is grouped based on the garbage types. Green bins for organic waste, yellow for non-organic, and red for toxic materials. The purpose of fourth activity is exercise personas to understand moral values regard to throw garbage on its place. The focus of the fifth activity is to train finger's reflections. Flexibility of the fingers is trained by swiping screen to insert the ball into the ring. The location of ball and ring are made in such position to facilitate children directing the ball into the ring. Those five activities during fine motoric learning presented in Figure 1.
Both psychological and physiological measurement has conducted using CW method. Result show that both measurement are successfully generating good interaction and reach user’s satisfaction. Psychologist also confirms the improvement effectivity and goal achievement gained from these activities. First activity has fullfilled the goal of motoric learning activity. In second test, MR children are indeed having difficulty coloring neatly. This can be seen from the irregular finger’s movements while coloring. It was irregular at first time, but later the hand movements start being trained well and able to color more neatly. There is no suggestion given by teacher in third activity. Suggestions from the teacher on fourth activity is utilization of simple instruction so it is easy to be understood by personas. Children are interested in this fifth activity, although in practice, some children have not being flexible while playing it, especially when doing swipe movements.

4.2.2. Gross Motoric
In first gross motoric learning activity, MR children are trained to be able to move agile by passing the cones sign in a zigzag manner. Each couple of virtual cones sign are arranged with a approximately distance one meter. It requires broad place so children free in moving. However, more broader location is taken place, more cones sign that children should pass through. This may affects children's psychological state which too many cones can mess up their mind. Children potentially feel bored, while there are still many cones that should be passed. However, if this goal is completed, expected they already have trained in agility and balancing their body, strengthening leg muscles, coordinating nerves and muscles, eye coordinating, and leg moving.

Second gross motoric learning activity is similar to the fifth fine motoric learning activity. The difference is that the activity on the fifth fine motoric uses finger, while second gross motoric uses feet. Both activities purpose to train children’s focus in projecting direction. Projecting directions can be formulated by calculating or estimating towards the goal position. Beside strength of the legs and body, this activity is useful to measure level of concentration and understanding. In this third activity, hall has captured as gameplay. This location was choosen because there are many poles standing here. MR children must follow a virtual blue track object among poles. In gameplay, track is called as ribbon so instruction can easier to be understood by children. The shape of the ribbon is winding between the poles, which have different distance between couple of poles. This activity trains the concentration, body balancing, and legs strengthening. If children cannot coordinate blue track properly, they potentially confused to perceive between ribbon and support pole. Those three gross motoric learning process are presented in Figure 2.
Figure 2. Gross motoric learning activity (zig-zag walking, shooting, and tracking)

MR children has little difficulty in practicing second motoric gross activity. This is not caused by bad interaction presented, but the children innate weakness causes them difficult to project the ball into the goal.

5. Conclusion
Double measurement purposes to improve level of usability. Moreover, double measurement is suitable to minimize subjectivity in design, by including expert’s base knowledge. Good IxD is produced by reaching user satisfaction and design principles. Briefly, HE can recover interaction that have been produced iteratively in CW. HE measurement revealed good enough result but not excellent. There are three principles which have value below 3. It is proven that good result obtained in CW not necessarily guarantees good result in HE. As personas, MR children should be accompanied by teacher as a supervisor. Supervising can be carried out during measurement and decision making. Therefore, each produced interaction has already confirmed against the teacher and psychologist. The role of psychologist is ensuring each interaction is appropriate to the learning process. Apps is used as companion tool aside with formal learning. It is recommended to measure children’s impact after using this apps in future works. Moreover, technical aspect, such as VR is important to be discussed more.

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