Mobile games interaction design for people with visual impairment using participatory design approach

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Abstract. Mobile games are one of the technologies that can change the way people express and interact with their environment. In certain development, mobile games can also be used as medium to support the learning process. One of the main elements of mobile games is accessibility. Accessibility can be illustrated by the ease of interaction in the mobile games itself. There are not many mobile games developed for players with special needs, such as people with visual impairment. This research was conducted to develop alternative interaction design on mobile device that can be used by people with visual impairment. The development of alternative design was conducted by using participatory design approach. The participatory design approach is considered to be able to create interaction design which is appropriate with the participants wish. This study involved 10 visual impairment people as participants in the participatory design process. The final result showed that the alternative design produced were in accordance with participants desire.

Keywords: mobile games, accessibility, interactions, visual impairment, participatory design

1. Introduction
Computer game is a type of game that is highly developed today [1]. The development of computer games was driven by the development of commercial markets for computer-based games and other multimedia products. This type of game has become something that can change the way people express, learn, and interact with the environment around them [2]. The advantages of gim computer have made this type of game got new challenges where computer-based games are not only made for entertainment purposes. Currently computer game has also been developed for educational purposes, such as mathematics learning [3][4], for medical purposes, such as the introduction of nutritional needs [5] and others. One type of game that is growing rapidly today is a game built on mobile devices or better known as mobile games. Mobile games become popular today because of their ease of being able to be played anytime and anywhere [6].

One of the important elements in mobile game is accessibility that focuses on the ease of users to access all game contents. The accessibility development on computer game is more difficult than the development of accessibility on a general computer application [7], especially in the development of gim computer accessibility for people with special needs. Most computer game were not developed to be played by people with special needs [8], this is because people with special needs cannot access general input device and graphical interface perfectly [9].
On the other hand, the Special Interest Group on Game Accessibility (SIG GA) under the Independent Game Developers Association (IGDA) recommends several guidelines that can be used as a reference for developing the accessibility of computer games [10]. The recommendation is proposed for applications used by visually impaired (blind) and deaf (hearing impaired) users. However, in some cases, the guidelines cannot be applied properly [2]. To anticipate the needs that are not facilitated properly when developing computer game for blind people, the game development process needs to be carried out through collaboration between developers (designers) and users [11]. One of approaches that can be used to realize the collaboration is participatory design.

There are several software design approaches that are commonly used, namely user centered design and participatory design. On the user centered design, the research subjects have a role to provide information on the needs of the system, while on the participatory design the research subjects will contribute to make the system as participant. To get the original results, the participatory design will be used in this study. Participatory design is a software design approach that involves all actors (application developers, application users, etc.) at the design process stage [12]. The main challenge in implementing participatory design is to motivate users (as design actors) so that they are able to express creative and innovative ideas during the design development process [13].

This research was conducted to find out the types of interactions on mobile devices that are suitable for blind people. In this study, the participatory design approach will be carried out using cognitive walkthrough method. In cognitive walkthrough method, the design development will be conducted through several iterations until the final design agreed can be realized [14].

2. Related Works

Efforts to utilize multimedia technology were attempted by Miller through the development of an audio-based computer game or better known as audiogame [8]. The game developed in that study is played by playing a sound on a particular pattern, the player is asked to follow the sound pattern by pressing several characters on the input device. Audiogames make totally blind people possible to access the game.

In other studies, Yuan & Folmer tried to develop an interaction device that can adapt to a particular computer game [15]. The game chosen was "Guitar Hero", one of the instrument simulation type games that was not designed for blind users. In the study, Yuan & Folmer used haptic feedback that was attached to a certain glove. Through this feedback, the players can find out the right time to press the button on the controller device that is used as the interaction media in the game.

This research was conducted to develop an interaction design by utilizing multimedia elements such as sound, text, and color as output media and touch screen as input media. In addition, this research will be developed in accordance with the characteristics of blind people in Indonesia, especially in one of the extraordinary school in the Yogyakarta Special Region province. The challenge is the differences in acceptance related to technology, especially on technology of gim computer with mobile device-based.

3. Method

This research was conducted in 3 main steps. First, identifying the participants habits while using mobile device (Mobile Device Usage). Second, developing a participatory design scenario based on the elements needed in the development of interaction design (Participatory Design Scenario). Third, doing the participatory design process based on the scenario that has been made. The final result of the participatory design is an interaction design recommendation resulting.

3.1. Mobile Device Usage

Based on observation result at one of the extraordinary school in Yogyakarta (Indonesia), there were 10 people who can participate (4 totally blind people and 6 low vision people). The participants age varied between 4 years old and 6 years old.
The use of mobile device technology can be well received by students. About 80% of students can use the device. Students can take action such as press the button (tap), press and hold the button (hold), and move the screen (swipe). The use of Android-based mobile device has been generally used for learning (accessing information) and communicating. The use of mobile device has been more useful because it has various forms of interaction and relatively easy to operate than the use of computer technology such as PCs (personal computers) or laptops that need to keyboards and pointers.

The use of color combinations that are suitable for blind people with low vision category must have high contrast values. The colour combination commonly used are black-white, red-white, or blue-white.

3.2. Participatory Design Scenario
Participatory design in this study will be conducted in several processes (iterations) in accordance with the element that has been developed. Each iteration must be completed in sequence, therefore the completion of an iteration must be done before moving on the next iteration. The term iteration of the participatory design process refers to the workshop action with the participants. The element that developed is output elements (color, text, and sound) and input elements.

3.3. Participatory Design Process
Participatory Design was conducted in accordance with a predetermined scenario. The iteration that has been carried out in the participatory design process consist of color determination, text determination, sound determination, and determination of the form of input action.

3.4. Color Selection
The colors that can be seen clearly by the participants are high contrast colors. The colors used consist of 3 colors (1 basic color, and 2 accent colors). The use of basic colors must be used on each display, while accent colors can be applied either one color or two combination color but cannot overlap. The alternative color combinations used in this study are white-red-blue, yellow-red-blue, and black-white-yellow, with hexadecimal values #FFFFFF (white), #E30000 (red), #002B82 (blue), #FFFF00 (yellow), and #000000 (black). Alternative color design can be seen in Figure 1 (points a, b, and c).

The process of determining the color was conducted in 2 stages. The first stage was done to determine the color combination that has been selected. The second stage was done to determine the clarity level of color that has been used. Color determination was only involved low vision participants (6 people).

From the iteration process, it was found that 4 of the 6 participants had chosen the first design (white-red-blue), while the other 2 have chosen the second design (yellow-red-blue). In addition, there were 2 participants who saw blue as purple in the second design, and 1 participant who saw yellow as green in the third design. From these results it was agreed that the color used was a combination of white-red-blue (first design).

![Figure 1. Screenshot of the color alternative design (a. white-red-blue, b. yellow-red-blue, c. black-white-yellow) and the font combination alternative design (d)](image-url)
3.5. Text Selection
The type of font that has been recommended for blind people in the low vision category is Sans Serif [16]. Sans serif font has good readability, and clear simple form. The font used in this study is called ‘Myriad Pro’, which is one of types of Sans serif font that was commonly used.

The process of determining text is done to determine the combination of text capitalization that can be read easily by participants. The combination of capitalization text that has been used is capitalize each word (Example Word), Capitalize each word bold (Example Word), uppercase (EXAMPLE WORD), and uppercase bold (EXAMPLE WORD). This process only involved low vision participants (6 people). Alternative design for text combination can be seen in Figure 1 (point d).

Iteration result showed that 5 out of 6 participants have chosen the fourth combination (uppercase bold), while one participant did not choose because he cannot read. There was only one participant of 6 participants who can read all types of combinations clearly. Based on this result, the combination of text used is uppercase bold.

3.6. Sound Selection
In the interaction design that has been developed, sound has a function as an output medium that has been used to convey information related to action that must be conducted by the users. The process of selecting the type of sound was focused on determining how fast a sentence must be read. The sentence used for the process of determining the sound is "apakah suara saya terdengar dengan jelas?" (native language of Indonesia), which means "is my voice heard clearly?" There were 3 types of alternative speeds, namely fast (0.15 second/syllable), medium (0.4 second/syllable), and slow (0.7 second/syllable).

Design testing was conducted by make the participate listen to each sound that has been produced using headphone. The participants were then asked to choose one of the three types of sounds that have been played. The process of determining sounds involves all participants (low vision and totally blind participants).

From the process that has been conducted, there were 7 participants choosing medium speed, while 3 other participants have chosen fast speed. There was no participant who has chosen a slow speed, it was because reading at a slow speed can weaken the capture of the meaning of the sentence that has been read. From the results, the speed of sentence reading used is medium speed (0.4 second/syllable).

3.7. Determination of Input Action
Input action has been developed by referring to the action of pressing a button (tap), pressing and holding the button (hold), and shifting the screen (swipe) on the mobile device. The input action that has been developed must be able to accept at least 2 input options.

There were four alternative designs developed for the determination of input action design, namely 2 answers swipe (portrait), 4 answers swipe (portrait), 2 answers hold (landscape), and 3 answers hold (landscape). The action of pressing (tap) button was used as a trigger to activate/repeat commands (questions). To test the suitability of orders and actions, simple mathematical questions were used in alternative design. Alternative design for input action can be seen in Figure 2.

The process of selecting the input action showed that the the input action design that most participant can answer math problems correctly is the hold interaction with both, 2 answers and 3 answers. However, most participants chose 2 answer swipe for the input action design. In selecting the best input action design, weight are given for each choice from the participants (3 points for the first choice, 2 points for the second choice, 1 point for the third choice, and 0 points for the last choice).

4. Results
The final result in the process of determining the input action can be seen in Table 1. Based on the participatory design rules, the alternative mobile game interaction design that has been recommended is 2 answers swipe. The interface in the interaction has been built with a combination of white, red and
blue. The capitalization text used is uppercase bold with a reading speed of medium (0.4 second/syllable).

![Figure 2. Screenshot of the alternative input action (a. 2 answers swipe, b. 4 answers swipe, c. 2 answers hold, d. 4 answers hold)](image)

| No | Input Action         | Results of The Answer Test | Results of The Selected Design |
|----|----------------------|----------------------------|--------------------------------|
|    |                      | Avg of Correct Answers | Avg of Incorrect Answers | Percentage of Correct Answers | Weight of The Selected Design | Percentage of The Selected Design |
| 1  | 2 answers swipe      | 8                        | 2                          | 80%                           | 24                           | 40%                             |
| 2  | 4 answers swipe      | 8.6                      | 1.4                        | 86%                           | 12                           | 20%                             |
| 3  | 2 answers hold       | 9                        | 1                          | 90%                           | 18                           | 30%                             |
| 4  | 3 answers hold       | 9                        | 1                          | 90%                           | 6                            | 10%                             |

5. Conclusions
The process of participatory design in this study was carried out by developing several alternative designs which were then selected and developed by participants. Alternative designs are used to provide stimuli to participants so they can immediately generate their ideas. In this study, alternative designs are submitted to participants in stages through 5 iterations until the desired model can be achieved.

Mobile game interactions design that is suitable for people with visual impairment can built with a combination of white (background), red (foreground), and blue (foreground). Type of font that can be used is ‘sans serif’, with ‘uppcercase bold’ capitalization type. To accommodate users in the totally blind category, the questions/instructions will be read at medium speed (0.4 second / syllable). The interaction model chosen by the participants is the ‘two answers swipe’ model.

6. Discussion
There were limitations of participants to be able to describe the design they expected. To anticipate this, we conducted the process of collecting design based on participants suggestions. From these suggestions, several design alternatives are made so that participants can choose the best design that meets their needs. In this way, we have assumed that the resulting design is the original result of the participants' ideas.

From the result of selecting input action design, the form of interaction with swipe 2 answers has become an alternative form of interaction that has been widely chosen. However, this form of interaction design has also become a form of interaction with the lowest level of answer’s truth. This was probably caused by a type of problem that was not identical question. To get a certain answer, the
two alternatives (swipe 2 answers and hold 2 answers) must be compared with the appropriate method in the next research.

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