Designing a Device for Measuring Human Reaction Time

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Abstract. Human reaction time is the time needed for someone to take action shortly after the person receives information. Not many measuring devices that can measure the time or speed of human reactions in detail, which are regarding the cognitive (thinking) and the motoric (action) aspects. Therefore, this research aims to design a reaction time measuring device for a simple activity. The device should calculate the speed of human reactions from the cognitive and motoric aspects. A series of product development phases was conducted, i.e. user requirements identification, concept development, embodiment design, construction, and testing. As a result, the selected concept used stimulus from light to measure reaction time, considering the difference of light color, flash rate, and intensity. A series of trials proved that those characteristics could be used to measure and distinguish reaction time (p-value < 0.05), considering cognitive and motoric time. The device was also proven can differ reaction time normal and fatigue condition.

Keywords: Reaction time, a cognitive, motoric, product development phase

1. Introduction
Humans have 3 aspects of ability, namely: cognitive, affective, and psychomotor abilities [1]. Of the three aspects, psychomotor is an interesting aspect to study because psychomotor is related to the skill (ability) or the ability to act after someone receives certain stimuli or knowledge. Psychomotor represents a person's ability to receive knowledge and then actuate it into the form of movement following the commands received by the brain. According to [2] Psychomotor is the ability that prioritizes physical skills consisting of perception, readiness, guided movements, accustomed movements, complex movements, adjustment of movement patterns, and creativity. Psychomotor skills related to actions that require coordination between nerves and the brain [3] and to the workings of muscles so that they cause body movements [4].

A common method to measure psychomotor ability is by measuring the reaction time. The reaction time comes from the word “reaction” and “time”. Reaction means the activity or action that arises because of an order or an event. Reaction ability can be determined by measuring the time interval between the receipt of stimuli with the answer (response). The Reaction time is the time spent between the appearance of a stimulus or stimulation from the start of the reaction until a certain reaction is done. Reaction time or speed can be identified by measuring the shortest time needed to give a kinetic answer after receiving a stimulus.

Considering the human information system model [5], humans must process the information or stimuli they receive in certain sequences before executing an action, which are perceptual encoding, central processing, and responding. Within the steps, the human process the stimulus received by the sensory, make perception based on long term memory, select response based on working memory, and
finally execute the responses. The processes are measured from the moment stimulus is accepted by the human sensory until the reaction move start. Perception and response selection activity need more thinking skills than physical skills [5]. After the steps, responses will be actuated by executing some motions. The execution time is carried out until the end of the movement or until the task is completely fulfilled, depending on the complexity of the task.

A famous method of psychomotor performance measurement by measuring time reaction is the Psychomotor Vigilance Test (PVT) [6][7]. PVT measures the time needed to give a response for a simple stimulus (dot on a screen). The method usually used to detect fatigue or sleepiness [7]. In this method, the reaction is measured as a total time between stimulus task is given, until the task is responded completely. Considering the human information system model by Wickens [5], there are no established tools or approaches available to measure reaction time, which take into consideration the thinking time and the execution time. Therefore, the problem to be discussed in this research is how to design a tool to measure the ability of human psychomotor to perform a simple task, considering the cognitive time and the execution time.

This study aims to design a device to measure the psychomotor aspects of humans, especially in its relations with reaction time. In this study, the reaction time is defined as the ability of individuals to decide on the time stimulus accepted to the time responses finished in the shortest possible time. A product design methodology [8][9][10] was performed to design the device. The device is planned to be used in the university laboratory; therefore, user requirements were identified to know what aspect of psychomotor ability that interested to be explored further. Based on the requirement, a concept of measurement device was developed and constructed.

2. Methods
At this stage, the researcher developed alternatives to the reaction time measuring device concepts according to the user requirement. The selected concept was built into a real product. The design phase was carried out as follows:

2.1 Identification of Requirement
The collection of user identification was done in two ways, which were literature and interview. The device is intended to be used in a university laboratory. Therefore, interviews with potential users (university students) were done to obtain user needs or wants. By translating the needs or wants of users to clearer sentences, the user requirements list was built. The list consisted of requirements that were organized into several hierarchies, which are primary, secondary needs, and tertiary needs. For each tertiary need, a quantitative technical need was defined. However, the technical needs and target was not presented in this paper. Based on the user requirement list, a functional breakdown was conducted as a basis for morphological charts and concepts generation.

2.2. Design Phase: concept development, embodiment design, detail design
Based on the functional breakdown, a morphological chart is built. The morphological chart is used to generate concepts for each function in the functional breakdown. By elaborating ideas from the morphological chart, some alternatives concepts of the device were generated. The Pugh’s Selection Method [8][9] was used to select and evaluate each concept that most fulfill user requirements. As a result, one concept was selected and continued to further stage. In this manuscript, the morphological chart and the Pugh’s Selection Method is not presented.

The second stage is the embodiment design stage. At this stage, the chosen concept was formed physically. The embodiment design phase was divided into 3 phases, namely: product architecture design, configuration design, and parametric design [9] the final stage was the detailed design phase. In this phase, the finalization of the design before product realization is carried out. In this paper, the second and third stages is not discussed in detail. Only the final product design is displayed.
2.3. Testing
After the device was constructed, it was tested to the potential user. Testing was done to test that all prescribed functions were run well and to test that the tool can differentiate certain user’s conditions. In this research, the prescribed condition was at normal and fatigue condition. Fatigue can cause a decrease in psychomotor abilities [11]. The condition of fatigue can reduce both capacities to work and the efficiency of achievement [12]. Therefore, testing was done two times on the same user, in a normal and fatigue condition. User in normal condition when she/he is in good health, fit and focused. On the other hand, the condition of fatigue in this study was defined as a condition where users are in a state of exhaustion due to lack of sleep. In this condition, the test is carried out when the participant was not sleeping (staying up late). This manuscript only presented the final results. The detailed test was not presented in this manuscript.

3. Result and Discussion

3.1. Identification of Requirements
Based on the user requirement identification phase, 12 tertiary requirements were expected to be carried out by this tool (Table 1). In addition to needs related to features such as easy to operate and ergonomics, there are several performance needs related to the expected function. If the existing speed measurement tool (PVT) can only measure the total reaction time, then this tool is expected to be able to separate thinking time (cognitive time) and execution time. Besides, this tool is also expected to consider several factors that may be related to the reaction time, namely the color of light, flash, and light intensity. For the three factors considered, the division is as follows: color of the light (dark and bright), flash (flashing and steady), light intensity (high and low). Based on these needs, technical needs and target values are determined.

Table 1 User Requirements List

| Primary | Secondary | Tertiary |
|---------|-----------|----------|
| Features | Easy to operate | Can be operated by 1 person |
| | | Easy to carry |
| | | Light |
| | Ergonomics | The display can be read easily |
| | | The size of part fit to human anthropometry |
| Performance | Measure information processing steps | Measure thinking time |
| | | Measure execution time |
| | Considering stimulus movement | Measure reaction in steady light |
| | | Measure reaction to flashing light |
| | Considering stimulus color | Measure reaction to light color |
| | | Measure reaction to bright color |
| | Considering the intensity of light | Measure reaction in high intensity |
| | | Measure reaction in low intensity |

Every need is broken down into functions and sub-functions. The establishment of functional breakdown has the purpose of knowing what functions should appear on the product according to the user's wishes. Table 2 presented examples of functional breakdown related to the functions of measuring reaction time, considering color difference (hard and easy to see color).

3.2. Design phase
From several concepts that were built, one concept was chosen to be developed (Figure 1). The concept uses three factors that can be manipulated to measure reaction time. These factors are the color difference factor, the number of lights flashing (flash rate), and light intensity. In the concept that was built, these three factors serve as rounds of play on the tool.
Table 2. Functional Breakdown

| User requirement           | Function                                           | Subfunction                                      |
|----------------------------|----------------------------------------------------|--------------------------------------------------|
| Measure reaction to light  | 6.1 Build starting mechanism (to start the game)  |                                                  |
| color                      | 6.2 Giving the order (as input)                    |                                                  |
| Measure reaction time      | 6.3 Display output                                 |                                                  |
| considering color difference| 6.4 Measure time to think (cognitive time)         |                                                  |
| Measure reaction to bright color | 6.5 Measure actuation time                      |                                                  |
| time considering color     | 6.6 Receive user’s respond                        |                                                  |
|                            | 6.7 Display the outputs                           |                                                  |

a. Round 1: Color factor
Red and white lights represent the color difference. Red represents bright colors that are easier to see than white. Red and white lights were randomly changing. To measure the reaction time, the user must choose a lamp that lights up as quickly as possible. This round is done twice. The final value displayed is the average of the two trials

b. Round 2: The number of blinking lights
Flash is often used to signify a special condition, such as danger or state of emergency. This steady and flash condition is used as a factor in measuring reaction speed. Flash rate is set into three levels, namely low flash rate (300 blinks/minute, medium (700 blinks/minute), and difficult (2000 blinks/minute). This round is done twice. The final value shown is the average of the two trials

c. Round 3: Light intensity
The level of light intensity consists of low and bright light levels. There is a button (rotary switch) that is used to set the level of light intensity, namely the level of low light with the symbol Low (R) 170 lux or high light level with the symbol High (T) 225 Lux. This round is done twice. The final value displayed is the average of the two trials

The cognitive response is measured the first time the response was given, until just before the hand moves to respond. The motor response is measured starting from the hand moving until the hand turns off the signal. To measure both times, a sensor was used to detect motion. The hand is placed as close as possible to the motion sensor. After the signal is turned on and the cognitive time is over, the hand reacts by approaching the button. When moving, the hand activates the motion sensor. This time will be recorded as the beginning of movement time and ended when the hand has turned off the signal. Cognitive time is calculated by calculating the total response time to motor response time. In the chosen concept, the user must press the button located at the bottom of the lamp that is considered to have the correct answer. When the respondent has completed all three rounds, the screen will display the reaction time along with the number of errors made on the screen.

![Figure 1 Selected Concept](image)
3.3. Construction

The final design and component of the selected concept are presented in Figure 2 and Figure 3. The device is portable and has total dimension of the casing is only 15x9x10 cm$^3$ to make the device easy to carry. To start the time calculation, the user must press the big green push button. This push button will trigger the program to start the time and display the game. At round-1, reaction time was tested against 2 different colors, red and white. This round consists of 2 sub-rounds. At each sub round, the program will turn on the white or red lights randomly. The user must press the small push button on the bottom of the active lamp to stop the time calculation. The finger must pass the infrared sensor to press the push button located at the bottom of the light. The sensor stops the cognitive time calculation. When the user pushes the small push button at the bottom of the lamp, the program automatically stops the total time calculation. The cognitive and motoric time is displayed on the screen. To continue the game to the next sub round, the user must press the big green push button again.

![Figure 2 Developed Concept](image)

Broadly speaking, the measurement tool for the speed of human reaction is divided into several sections, namely as follows:

1. Casing
2. Adaptor
3. Arduino Board
4. Fishbone
5. LED lamp
6. Infra-red sensor
7. LCD
8. PCB
9. Green push button
10. Small push button
11. Switch
12. Battery’s holder
13. Frame
14. Intensity switch

![Figure 3 Components of the developed device](image)
After completing round 1, the respondent presses the large green push button to start the next round. This round using flash rate to examine the difference in reaction time. This round consists of three rounds. The sub round 1, 2, and 3 represent slow, medium, and high flash rate sequentially. Similar to round one, the user must press the small push button under the flashing lights and automatically activate the infrared sensor. The cognitive and motoric time then is displayed on the screen. After finishing round 2, the user starts round 3 by pressing again the green push button. In this round the respondent will test the light intensity factor. Before starting the round (by pressing big green button), user must turn the rotary switch to set the intensity of light. To have a bright or dim light, the switch must be switch upward or downward. For this round, there are two sub rounds for each intensity level.

3.4. Testing

After construction, the tool was tested on users. A series of experiments were conducted to prove that the device is sensitive to distinguish conditions of the user's reaction time, especially when fatigued. Based on the results of trials on 280 samples, it was concluded that the device could differentiate normal conditions with fatigue significantly (p-value < 0.05). The value of reaction time when fatigue is greater than normal.

3.5. Limitation and Recommendation

The developed tool has shown its performance to measure cognitive and motoric reaction time. However, during the construction, some limitations were also found. Of the six pushbuttons used on the lights, two buttons are rather difficult to press. The difficulty sometimes causes it is necessary to press the button repeatedly until the button responds. The problem can be caused by PCB lines that are too small or push buttons not soldered properly. The second limitation is the Arduino engine which gets hot easily so that it sometimes causes errors in the running of the program. For example, the push button does not respond properly or an abnormal display. Arduino itself requires output between 9v - 12V. It turns out that the adapter used has an output of more than 12v, which is 16v. The unfit specification makes the tool hot quickly when used. It is also recommended to use an industrial component as a push button. The industrial component button has a larger field than the push button currently in use so that it can receive responses better. Besides, the adapter used must be adjusted to the needs of the program, so it does not cause the tool to heat up quickly.

4. Conclusion

The reaction time device was designed and constructed to distinguish cognitive time and motor time. The device has the ability to consider the factors of light color difference, flash rate, and light intensity. With dimensions that are quite small and portable, these reaction time gauges are quite easy to carry. The device is proven to be able to distinguish between reaction time in normal and fatigue conditions. The current weakness is in the tool components that have limited capabilities, especially in the sensitivity
of the buttons and component durability. For further research, it is expected to develop a device with more reliable components.

5. References

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