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A Meta-Review of the Smartphone as the Measurement Device

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A Meta-Review of the Smartphone as the Measurement Device

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Abstract. With the development of increasingly affordable smartphone technology that is owned by almost everyone, making some activities can be done only by using this device. Smartphone computing capability that is quite powerful, accompanied by various sensors embedded in it, allows the smartphone to be used as a measurement device in various fields of research. This article tries to review the use of smartphones as a measure of one's mentality by conducting a meta-review of several review articles that have been done before. This article tries to look at research trends that measure a person's mental state by using sensors found on smartphones and also to help researchers decide on topics to explore.

1. Introduction

Along with the continued development of pervasive and ubiquitous computing, personalized context-aware e-learning continues to be developed, including in the form of mobile learning [1]. Nonetheless, the personalized context-aware e-learning models developed still focus on the presentation of learning material in a variety of contexts, various methods, and learning environments. The development of personalized context-aware e-learning models by considering the psychological aspects of learners as contexts and references to specific learning models is still limited in number [2]. The psychological condition of the learner also determines students' attachment and interest in the learning process [3].

Accurately measuring the human emotional state is not an easy task because the emotional state is a qualitative factor and varies between individuals. Excessive cognition is one of the emotional conditions that often occur during learning. Excessive cognition is usually caused by limited working memory capacity, which can cause the processing of new information to be changed or even stopped [4]. The cognitive burden that is too high means learning cannot occur; therefore, learning experiences become ineffective [5].

The psychological condition of the learner, primarily cognitive, can be measured using neuropsychological tests. Neuropsychological tests are usually done in a laboratory with relatively few disorders. This laboratory environment is usually not like the real everyday environment experienced by learners. In most studies investigating ecological validity, traditional neuropsychological tests for real-life behavior are still small [6], [7] to moderate [8]. The difficulty of investigating ecological validity is due to several factors that influence the relationship between neuropsychological tests and daily life functions, such as personal factors such as emotions, moods, education level, motivation, and stress [9]. Besides personal factors, one of the problems in showing ecological validity in traditional neuropsychological tests is the test environment [8]. The laboratory environment that has been set up

resembles the actual measurement conditions, with relatively few disturbances, and the existence of an examiner remains different from the real, everyday conditions experienced by a learner (Sbordone, 1996). Also, in these conditions, the learner is a guest, and the psychologist is the host. This condition can cause differences in user behavior [10], which will lead to less objective measurement results.
Mobile devices with internet connection capabilities that are always carried daily by users provide the potential for these mobile devices as a medium to measure and influence user activity in real-time [11]. Research for testing learners in everyday life has also been carried out using mobile devices. In the study, participants were expected to fill in a questionnaire or to carry out a specific task [12]–[16]. The use of this mobile device has shown significant benefits in exploring psychological conditions and functions during daily activities. First, mobile devices can be used to access large test samples [17]. Secondly, by bringing testing to participants can save time, money, space, and equipment. Third, it can be done more frequently so that it can detect fluctuations in cognitive performance [18]. Not so many studies have used mobile devices to measure cognitive function [15]–[17]. Current mobile devices equipped with sensors that are capable of measuring biological signals to their users. Further analysis of data obtained from sensors on smartphones provides the potential to predict the user's cognitive condition. Therefore, this study aims to investigate the use of mobile devices for measuring cognitive load in learners.
Several publications have shown the advantages, limitations, challenges of using smartphones, which have developed very rapidly in the last decade, as a measurement tool. It is essential to get a summary of the use of a smartphone as a measurement, especially for understanding cognitive conditions. Smartphones can be used to make learning personalization more meaningful. The findings of this study aim to provide resources that can be used for personalization by using one's cognitive condition.

2. Method
The steps taken in this review are as follows: planning, conducting reviews, and reporting reviews. A comprehensive bibliographic database from Scopus, ScienceDirect, and IEEE is the literature source for this review. These three databases were chosen because they contain an extensive literature collection that is valuable in maximizing journal coverage and ensuring the inclusion of all relevant studies. The keywords used to search for review articles are "smartphone" and "review" contained in the title. The review articles reviewed are limited to those published from 2010 to 2019. After that, it is necessary to identify if there are duplicates. After removing duplicates, limiting to the English, a total of 105 studies were identified. By identifying the titles, abstracts, and conclusions from the review paper, 12 relevant review studies were selected for inclusion. The papers collected are studied concisely, and only those that are under the scope of research on smartphones as a cognitive measurement tool are chosen for a more thorough reading. A discussion of the findings obtained from the literature is explained in detail in the next section.

3. Discussion
Based on a total of 12 journals reviewed, there are several sensors from smartphones that are used as measures. In this case, the sensors are built inside the smartphone, so no external sensor is needed. Sensors that can be used in measurements are cameras [19]–[28], gyroscope [25], [28], GPS [21], [25], [27], [29], microphone [26], [29], accelerometer [22], [23], [25], [27], [29], and heart rate sensors [26]. The camera and flash found on a smartphone can be used as a tool to measure heart rate by using image processing methods on color changes that occur on the skin [26], [28]. The camera is used as a Photo Plethysmography (PPG) sensor that can monitor several physiological parameters such as pulse rate, breathing rate, and blood oxygen saturation [28]. Accelerometer and gyroscope are used to measure vehicle movement, both from the direction and speed of movement of the vehicle [25], [28]. Besides, the accelerometer and gyroscope are also used in motion detection of physical activities that are typically carried out daily, such as silence, walking, or running [27], [30]. The GPS when combined with an accelerometer, can find out the condition of a person when making transportation (biking, driving a car, using a bus) because GPS can collect mileage data to a person's location, the location visited, and the selected road route [27]. Also, GPS can also find and measure the state of the road and the traffic that

exists through a system that uses servers and smartphones [28]. The application of the microphone itself is usually used for data sources that know a person's social activities [29].

Some smartphones have some sensors that are not commonly found on other smartphones, such as the Samsung Galaxy Note and S series, which have special sensors, namely heart rate & oxygen level. The sensor can be used to record heart rate data faster when compared to the use of image processing on a combination of camera and flash sensors (Portable microfluidic and smartphone-based devices for monitoring of cardiovascular diseases at the point of care). The smartphone sensing method is up-and-coming to be used as an objective measurement tool, but with limits only for survey-based measurements [27]. Currently, the use of smartphones and the sensors contained therein is a trend in the measurement of a study, both as an embedded smartphone measurement instrument (ESPMI) and as a smartphone measurement instrument interface (SPMII) (State of the art and future developments of measurement applications on smartphones).

4. Challenges

Analysis of smartphone data is becoming an auspicious way to understand users better. Still, there are some challenges to understanding users from a smartphone. There are some challenges in the following aspects: data (data collection, ground-truth collection, data processing); user representation, and modeling (effectiveness, performance metrics, interpretability, and generalizability); the fusion of heterogeneous data from other sources; user privacy issues; and uncertain factors that affect user behaviors.

Similar to many other fields of research in their early stages, currently functioning on smartphones as a gauge in cognitive load usually focuses on exploration and new concept ideas to drive innovative applications with initial experimental validation. However, it has not yet reached the convergence stage with unification so that different algorithms can be directly compared under the integrated benchmarking framework. This significant heterogeneity prevents our ability to answer more profound questions such as which features and methods are better for what type of problem and how big the comparative advantage is in the quantitative sense. For predictions and application recommendations, several studies were carried out on large-scale data sets and reported performance seemed to be more reliable than small-scale studies.

5. Conclusion and Future Work

Although there have not been so many review articles about using smartphones as a tool to measure a person's cognitive condition, the analysis of several review articles has provided potential information for future research. This meta-review article tries to show the tendency to use smartphones as a measurement, especially to measure a person's cognitive condition. The results of this study can be used in various fields, for example, in the implementation of mobile learning. Although it has shown some potential, there are still several things that researchers must do to develop this research topic. From several review articles, it was found that not many studies have used smartphones as a measurement of a person's cognitive condition. In the context of cognitive research, most still use smartphones as a subjective measurement medium, for example, by using surveys. The use of smartphones in research is most widely used for the detection of user activity. The data obtained is mostly still obtained in a laboratory environment and is implemented offline. Some future work that can be done is implementing the results of this research in real life and the user's daily context.

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