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Article

Health Monitoring Apps: An Evaluation of the Persuasive System Design Model for Human Wellbeing

Asif Hussian [1], Abdul Mateen [1], Farhan Amin [2,*], Muhammad Ali Abid [3] and Saeed Ullah [1]

[1] Department of Computer Science, Federal Urdu University of Arts, Science and Technology, Islamabad 44000, Pakistan; asif.baig@kiu.edu.pk (A.H.); abdulmateen@fuuastisb.edu.pk (A.M.); saeedullah@gmail.com (S.U.)
[2] Department of Information and Communication Engineering, Yeungnam University, Gyeongsan 38541, Republic of Korea
[3] Faculty of Smart Engineering, The University of Agriculture, Dera Ismail Khan 29220, Pakistan; draliabidawan@gmail.com
* Correspondence: farhan@ynu.ac.kr

Abstract: In the current era of ubiquitous computing and mobile technology, almost all human beings use various self-monitoring applications. Mobile applications could be the best health assistant for safety and adopting a healthy lifestyle. Therefore, persuasive designing is a compulsory element for designing such apps. A popular model for persuasive design named the Persuasive System Design (PSD) model is a generalized model for whole persuasive technologies. Any type of persuasive application could be designed using this model. Designing any special type of application using the PSD model could be difficult because of its generalized behavior which fails to provide moral support for users of health applications. There is a strong need to propose a customized and improved persuasive system design model for each category to overcome the issue. This study evaluates the PSD model and finds persuasive gaps in users of the Mobile Health Monitoring application, developed by following the PSD model. Furthermore, this study finds that users misunderstand health-related problems when using such apps. A misunderstanding of this nature can have serious consequences for the user's life in some cases.

Keywords: big data; human-computer interaction; persuasive technologies; mobile health monitoring apps; persuasive system design model

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1. Introduction

Modern technologies that are designed to change the attitudes or behaviors of the users through persuasion and social influence and not through force are considered persuasive technologies. Such technologies are heavily used in trade, negotiation, politics, religion, military training, public health, and management, as well as in various areas of human-to-human or human-to-computer communication. Mobile applications are very effective tools that promote health, better attitudes, and good behavior in their users. As the number of smartphone users is rapidly increasing day by day, the number of applications is also increasing in smartphone app stores. Therefore, it is very important to build bridges between mobile Human-Computer Interactions (HCIs) and persuasive technologies as well as health psychology [1]. To influence the attitudes or behavior of users, persuasive technologies are used in different mobile applications. A framework introduced by researchers, known as the PSD Model [2], strongly influences the behaviors and attitudes of the user. Evaluation of the current state of mobile applications through persuasion to promote physical activity by changing the behavior of the user is very necessary. The PSD Model also helps to evaluate persuasive features in mobile applications [3]. The increasing influence of mobile health applications in the current technological era cannot be underestimated because they inform, educate, and persuade consumers. The current era of

mobile applications enables a user to access suitable health education from different reliable sources. It is the will of researchers to ensure that this expanding field will reach its greatest potential, so it is necessary to understand the current mobile technology resources which can be used to improve the wellbeing of people. It is also very important for governments to introduce design principles that influence the usefulness of persuasive technologies to be understood [3]. This research work endorses all basic categories for persuasive system design principles, i.e., Primary Task Support, Dialogue Support, System Credibility Support, and Social Support of the PSD. This study emphasizes that Health Monitoring Apps (HMA) must provide results and recommendations for the user by keeping emotional and mental values in view. As we all know, HMAs are directly linked with a user's life. Any misunderstanding or mistake can even be a threat to the user's life. This research work recommends that there is a strong need to develop a customized Persuasive System Design model for HMAs.

The rest of the article is organized as follows: Section 2 elaborates on the literature survey. Section 3 contains a description of the Persuasive System Design (PSD) Model. Section 4 describes a summary of the PSD model. Section 5 elaborates on some current research work in the field of study. Section 6 describes the user studies, results, and the actual problem statement and research objectives. Finally, Section 7 concludes the article with research contributions and future work.

2. Literature Review

Mobile applications are very effective tools that promote health, better attitudes, and behavior in their users. According to [4], 12 out of 57 studies show that self-monitoring was the most common behavior change technique. As the number of smartphone users is rapidly increasing day by day, the number of applications is also increasing in the app stores of smartphones. Therefore, it is very important to bridge the gap between mobile HCI and persuasive technologies as well as health psychology. Principles and theories must be considered in designing persuasive mobile apps for health and safety promotion, and on how to rigorously extend Mobile HCI evaluation methods to measure the effectiveness of such apps [1]. The lack of appropriate human behavior causes the degradation of the environment, but social societies try their best to overcome the issues for the sake of human wellbeing. They develop and maintain the world we live in. Ref. [5] describes good behavior, named pro-environmental behavior (PEB), which leads to benefits for the environment. The popular thesis on human behavior, known as the theory of planned behavior (TPB), describes that "an individual's intention towards behavior, subjective norms, and perceived control over his/her behavior together leads to intentions and behavior". In the presence of the generalized PSD Model, for designing and analyzing persuasive technologies, Ref. [5] suggested and proposed a specialized model for developing pro-environmental behavior. Ref. [6] conducted a review of current persuasive technology design strategies and gathered the frequency of each strategy being studied by the researchers. However, there is a strong need for user studies to be performed with the actual end-users of HMA, so that we can observe the persuasive gaps and analyze the results in light of existing persuasive principles. What are the troubles and hardships facing the end-users of mobile HMAs? In light of the above facts, there is a need for a specialized persuasive design model for health monitoring apps. Because mobile HMAs are directly linked with the user's life, these apps need special attention during the design process. Mobile health apps named Sehha and Mawid were developed by following the basic principles of the PSD model by the health ministry of the Saudi Arabia Government [7]. The Sehha and Mawid apps were found to lack social support. The study guesses about doubtful results of application social support, either due to a lack of developers' knowledge or the nature of the application. However, the study [7] endorses that the mobile health apps (Sehha and Mawid) had been developed by following the PSD model. The above facts also lead to work on the PSD model and need to be examined.

2.1. Persuasive Technologies

All the interactive information technologies which are designed for changing users' attitudes or behaviors are known as persuasive technologies [2]. Ref. [8] Persuasive technologies are defined as "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action". To determine and identify the behavior change applications, a study was conducted in 2018 [9] by researchers which found 212,352 apps. A total of 5018 apps remained after applying the filter criteria. Out of the total, only 344 applications were found to be persuasive (behavior change) applications [9]. That study [9] recommended improvements in the designing of apps to help users adopt a justifiable and substantial lifestyle.

2.2. Persuasion in Mobile Health Apps

All mobile applications are designed to influence the attitudes and behaviors of the human being. The main objective behind the scene is to convince them to buy the product. Ref. [10] suggests that "smartphone applications have shown promise in supporting people to adopt healthy lifestyles". Various human health-related mobile apps are easily available to every smartphone user. Ref. [11] A usable application can be designed and developed with the help of HCI modeling. Mental health care and suicide prevention inequities may also be effectively recognized, acknowledged, and addressed. A digital therapeutic alliance might also benefit from it.

2.3. Health Monitoring Apps

Applications that are dedicated to monitoring health problems and self-assistance to adopt a healthy lifestyle are considered health monitoring apps. The following are examples of health monitoring apps.

- iCare Health Monitor (Figure 1)
- Wii Fit
- Wii Zumba Fitness or Wii Sports Resort

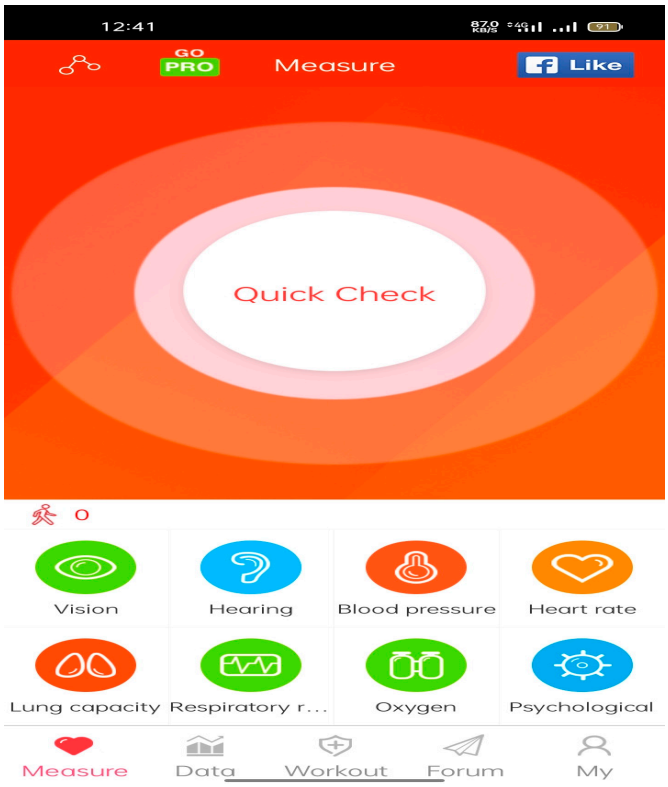


Figure 1. iCare Health Monitor (HMA).

Runtastic—Laufen and Fitness Fit4Life [12] In the literature, there are various theories and frameworks [13] centered around designing a persuasive system or technology, such as:

- Theory of Reasoned Action/Theory of Planned Behavior
- Reasoned Action Approach
- Technology Acceptance Model
- Information Processing Model
- Captology [6]
- Principles of Influence
- Persuasive Systems Design (PSD) Model
- Virtual Narrator [14].

Mobile health apps that track the symptoms of the patient were examined in a systematic review [15]. They have used the words cancer, oncology, and symptom tracker to search relevant apps in the iOS App Store and Android Google Play. Patients with cancer could record their symptoms and PROs by utilizing apps that included a symptom-tracking feature. A mobile app rating scale was used to assess each app's engagement, functionality, aesthetics, information, and subjective quality. After screening the titles and descriptions, 101 apps were found to be eligible out of a total of 1189 apps after the initial search. That study included 41 apps that met the eligibility criteria. A single cancer patient-friendly app has been tested in their review study [15]. The above facts from existing knowledge determine that there is a strong need for interactive and persuasive designing strategies to develop HMAs. The PSD model is also providing design strategies for designing such apps, so this study focuses on the evaluation of the PSD model.

3. The Persuasive System Design (PSD) Model

A model named PSD [16] was proposed which discusses the process of designing and evaluating persuasive systems and describes what kind of content and software functionality may be found in the final product. It also highlights seven underlying postulates behind persuasive systems and ways to analyze the persuasion context (the intent, the event, and the strategy). In light of the PSD model, Ref. [2] lists 28 design principles for persuasive system content and functionality, describing example software requirements and implementations. The basic design principles consist of four categories. These categories are primary task, dialogue, system credibility, and social support. For a better representation of the model, we have designed Figure 2 which will help the audience to easily understand the principles of the PSD Model.

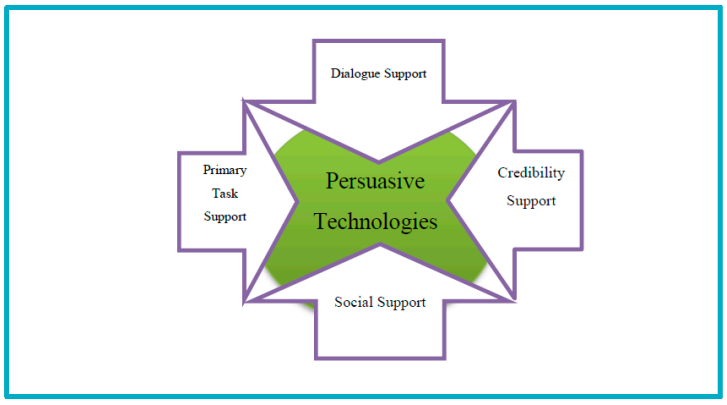


Figure 2. Basic Principles of the PSD Model.

Each category for the PSD principle has seven postulates. This study presents all twenty-eight postulates for a better understanding of the literature [3].

3.1. Primary Task Support

Primary task support facilitates users to interact with a system and helps them to track their performance through features such as self-monitoring. The design principles in primary task support are as below:

i. Reduction: Making simpler tasks by reducing the complexity of the system design.
ii. Tunneling: Guiding users through a process or experience.
iii. Tailoring: The system must provide appropriate information for its user groups.
iv. Personalization: The system must offer personalized content and services for its users.
v. Self-monitoring: The system must provide means for users to track their routine or status.
vi. Simulation: Immediately observe the link between cause and effect.
vii. Rehearsal: The system must offer means to practice.

3.2. Dialogue Support

Dialogue support features improve dialogue between the user and the system, especially in terms of system feedback to better guide the user through the intended behavior/attitude change process. The seven design principles in system dialogue support are as follows:

i. Praise: The system must allow for criticism in order to have user feedback.
ii. Rewards: Providing a virtual environment to give credit for performing target behavior.
iii. Reminders: Reminders should be allowed to achieve targeted behavior.
iv. Suggestions: The system should suggest that users carry out behaviors during the system use process.
v. Similarity: The system must follow its users by some particular method.
vi. Liking: Visually attractive content that feels appealing to its users.
vii. Social support: The system should adopt a social role to provide a virtual environment.

3.3. System Credibility Support

Features such as authority, expertise, a real-world feel, and verifiability promote the credibility of a persuasive system.

i. Trustworthiness: The system must provide information that is true, fair, and unbiased.
ii. Expertise: Must provide knowledge, experience, and competence.
iii. Surface credibility: This should be a firsthand inspection.
iv. Real-world feel: The system must provide information about the organization and/or actual people behind its content and services.
v. Authority: the system should refer the inquiries to authorized powers.
vi. Third-party endorsements: Feedback from well-known and credible sources.
vii. Verifiability: Must offer means to verify the accuracy of system content via outside sources.

3.4. Social Support

Social support features foster user motivation through components such as cooperation, normative influence, social comparison, and social learning.

i. Social learning: The system must offer to have information from others.
ii. Social comparison: The system must offer an element of comparison on social forums.
iii. Normative influence: The system must gather peoples who have the same goals.
iv. Social facilitation: The system should provide means for recognizing other users who are performing the same behavior.
v. Cooperation: The system should offer a cooperative platform.
vi. Competition: The system should provide means for competing with other users.

vii. Recognition: The system should provide public recognition for users who perform their target behavior.

4. Short Summary of the PSD Model

Heading III summarizes the PSD Model, persuasive technologies, and health monitoring apps in light of the existing literature. The principles of the PSD model have been focused on. Each category of PSD principle has seven sub-principles. All twenty-eight principles are used to design a persuasive system. From the literature, it has been derived that information technology is never neutral. People like to share their views about the world for organizing and improving the promotion of their products. The hidden agenda behind persuasion is to gain maximum benefit from the targeted audience. Therefore, it will never be affordable for persuasive system developers to evaluate health monitoring technologies with the same generalized model which is designed to gain users' attention to adopting the system. During the design and analysis of any health-related application, developers should adopt moderate and selected principles to persuade users. Because these types of applications are directly involved in human life, any unintentional usage of health-related apps can even threaten the user's life.

5. Design and Extension of the PSD Model

During the writing of this study, a conference paper has been published in "*Proceedings of the 2021 International Symposium on Human Factors and Ergonomics in Health Care*" [17] that claims that users of fitness apps belong to different social and cultural involvements. That empirical study [17] focuses on two different social and cultural groups, which are discussed below.

5.1. Individualist

The Individualist group preferred more Primary Task Support, focusing on the basic targeted objectives of fitness apps which are Self-Monitoring and Goal Setting.

5.2. Collectivist

The collectivist group preferred more Dialogue Support which focuses on the basic targeted objectives of fitness apps, which are Reminders and Suggestions.

That study also recommends presenting an extended PSD model by including the following additional features for fitness application development.

- Goal Setting
- Verbal Persuasion

In 2019, the "*Gallup Global Emotions Report*" showed that 55 percent of America's population is observing stress, which is the highest stress level in the world. In addition, the same issue is observed in 35 percent of the world [18]. That study also recommends that design strategies can improve persuasiveness and ultimately increase the positive effects of stress management among users of HMAs [18].

The above [17,18] study endorses the need for improvements in the PSD model, but this study specifically evaluates the PSD model and elaborates on the need for presenting customized persuasive models for each category of applications. In addition, this study highlights the sensitivity of mobile health apps and the importance of the provision of moral support to users through mobile health apps.

6. User Studies

The results and findings have been presented from three consecutive user studies. Considering the length and conciseness of this paper, only the pertinent findings of the studies have been incorporated. The targeted study area is persuasion in mobile HMAs and smartphone users. These are planned user studies to extract appropriate data for further analysis. User studies have been conducted using the questionnaire method. The questionnaires have been designed according to the design rules of a popular HCI book,

"*Human-Computer Interaction An Empirical Research Perspective*" [19]. There are four major portions in each user study. Detailed descriptions regarding these user studies are described on page eight. The four major parts of the studies are:

- Consent Form
- Pre-Study Questionnaire
- Tasks to be performed
- Post-study Questionnaire

In this paper, the results of the user study are included based on the researcher's observation to present the evaluation of the PSD model.

6.1. Introduction to User Study

The purpose of this study is to determine users' motivation and behavior by analyzing the PSD model and to evaluate HMA. The case study is based on a mobile health monitoring app (iCare Health Monitor). The iCare Health Monitor (Figure 1) is a mobile health monitoring app available in the Play Store for smartphone users which can be used as a health assistant. A questionnaire was used to generate quantitative results from participants after using this app. This mobile health app is recommended to users, and they are encouraged to perform some specific tasks and evaluate the system by answering questions. Users are also encouraged to share their points of view regarding system design and their behavior/motivation level after using the application.

The following basic tasks/tests were given to participants:

1. Vision test
2. Hearing test
3. Blood pressure test
4. Psychological test, etc.

6.2. Background

It is a mobile health monitoring system that uses wireless body sensors and smartphones to monitor the health of commoners and the elderly for general wellbeing. The system enables the user to check their health conditions at any time from anywhere. The system is also enabled with tailored functions like a vise for each individual. The system is a real-time living assistant which can help users to live a convenient and comfortable life [20]. If we look at mobile applications, the most important thing with the respective user is persuasion. How many users are persuaded by the use of the application? This is the key thing for the success of the developer as well as the authority of that application. Either the user's behavior is changed or not. If it is changed what is the level of behavioral/motivational change? All these things are the ultimate demands of persuasive applications. This study aims to improve the healthcare system of the current world. Preventing health monitoring systems from persuasion will be a big failure of the research, developers, and health service providers, as it is already proven that a framework PSD model provides theories and methods to analyze the persuasive contents of technologies [2].

After investigation, Ref. [21] declared that persuasive technologies are supposed to change the behavior of patients with the help of technology available at home. The basic reason behind this is that those investigated technologies have incompetent persuasive design considerations. Our selected persuasive application is named the iCare Health Monitor (Figure 1) for health care and is a popular and well-known health monitoring technology that is web-based and available on smartphone application-based platforms like the Play Store, etc. [20]. To check the success level of designers concerning persuasion, it is necessary to check persuasive features in such a specific, highly available, and used app in the current era of ubiquitous computing and technology.

As the PSD Model is a well-known and recent persuasive design model [13], the iCare Health Monitor is designed to keep the PSD model in view [20]. In light of the above facts, investigating real-time users of iCare can be the most credible study for the evaluation of

the PSD Model as well as persuasive principles. Why do users quit the application or why is the user not ready/motivated to use such apps in practical life? Of course, a very big population uses these applications, but the aim of the research, and specifically this user study, is to take the technology to the level where it actually should be. While conducting and designing a research study on HCI, it is very important to keep the persuasive context (the event, intent, and persuasive strategy) in view [2].

It is a basic characteristic of persuasive technology to influence the behavior of users through information and feedback [22]. All smartphone applications that are designed to change the attitudes or behaviors of their users through persuasion and social influence rather than force are termed persuasive technologies.

Mobile health is the creative use of emerging mobile devices to deliver and improve healthcare, health delivery, health communication, public health, health promotion, and self-management [23]. The terms mHealth, eHealth, and digital health are directly or indirectly linked with the smart technologies and tools which help users with real-time health management and monitoring.

According to [23], there are currently more than 165,000 mobile health applications (apps) publicly available in major app stores.

There is a strong need for the perfect integration of persuasive features for improving the usefulness of mobile health (mHealth) results [24]. Therefore, it remains a perpetually challenging task for mobile health application developers to balance the required persuasive features in health monitoring apps. For the ease of developers, a review study of four persuasive design models was previously conducted.

The following four models are taken by [25] in his review process:

1. Persuasive Systems Design (PSD) Process Model [2]
2. Design with Intent (DwI) Method
3. Behavior Wizard Model
4. Eight-Step Design Process

All the above models are generalized. Designers/developers of applications face tremendous problems attempting to maximize persuasion because of their general principles. For example, the expectations and needs of different categories/application users are never the same. There is a strong need for time to categorize applications with respective users' needs/expectations. There is also a need for time to develop specialized persuasive design models for each category by focusing on the expectations of users. For example, the needs and expectations of social media application (Facebook, Instagram, Twitter) are different from respective health monitoring application (iCare Health Monitor, Connected Living, CureDiva) users. We kept some questions for future researchers to answer, such as "How can designers embed arguments into designs? And if they are not embedding arguments, how can we speak of persuasion? None of the analyzed PD models for good reasons—help us answer these problems". To answer the above question [25], a user study has been planned. For this purpose, we designed a questionnaire by which questions were asked of the targeted users of one category as there is a need for proper categorization of applications. Questions are related to the needs and expectations of the selected application/technology/smartphone app and the targeted user. During the design of the questionnaire, the twenty-eight basic principles of the PSD model have been kept in view.

Questionnaires are the primary instrument for survey research, a form of research seeking to solicit a large number of people for their opinions and behaviors on a subject such as politics, spending habits, or the use of technology [19].

6.3. Problem Statement and Research Objectives

The PSD model is found to be the most recent and precise model with respect to the other frameworks for persuasive design. At the same time, [26] states that the "PSD model does not yet provide a comprehensive list of persuasive features". The facts motivated me to work on the PSD model for determining more persuasive features. That was the problem specification stage of research. The following are the main objectives of this research study:

- To find persuasion gaps in health monitoring apps.
- To overcome persuasion gaps in HMAs.

6.4. Methodology

For the sake of gathering appropriate research data for quantitative analysis, a hypothesis questionnaire is used as a key tool in this study. Questions have been derived from the literature and different research articles [10]. To measure and analyze the end-user persuasive level of any specific application, it is necessary to provide an environment where users can use an application in a free and unbiased way so that he/she can share his/her experience of behavior change regarding the application. The ultimate goal of gathering quantitative data through this questionnaire is to reach a decision to present any improved (specialized) PSD model for health monitoring apps. The PSD Model is the generalized model and, as discussed earlier, specialized models for each application category or targeted group of users need to be presented. The generated set of numerical data has been used for validating and upgrading the model.

The participants are workers in IT, professionals, and students. Keeping this in mind, we tried to get positive feedback by asking one qualitative question as well.

6.5. Study Design

The questionnaire of each study has six steps/parts as described below. Study two is discussed in detail but only the relevant results from the first and third studies have been included.

i. Consent form
ii. Pre-study questionnaire
iii. Installation of a smartphone application (iCare Health Monitor) (Figure 1)
iv. Specific tasks to be performed
v. Post-study questionnaire
vi. Questions regarding system design
vii. Questions regarding the user's persuasion level/behavior
viii. Feedback from participants/users' opinions

There are eleven questions in the pre-study questionnaire and the post-study questionnaire consists of twelve questions. Questions are designed by keeping the persuasive principles in mind. The personal data and feedback regarding the persuasion level of the user have been gathered through a questionnaire. The Likert-scale mechanism has been adopted to answer the post-study questions. The very last question aimed to get suggestions/feedback from users as suggestions/feedback will be helpful to analyze the overall persuasion level of participants.

6.6. Study Participants

As detailed in Section 6, our research encompassed a series of three user studies. Each study contains twenty-six participants. For study two and study three, we purposefully selected random participants from diverse age groups and educational backgrounds to ensure comprehensive insights into the effectiveness of our research. In the interest of clarity and focus, we have decided to provide a more in-depth elaboration of the design and procedure of user study two. This allows us to offer a comprehensive understanding of the conduct, planning, and findings of the whole user study. By judiciously presenting the details of user study two, we aim to convey a clear and concise message about our research methodology and acknowledge the relevance and significance of the other two studies within the broader context of our investigation. In the second user study, a total of twenty-six participants were involved, with an equal gender distribution of thirteen males and thirteen females. The study aimed to evaluate the participants' level of persuasion toward health monitoring apps. We have selected well-educated participants purposefully in the first user study who are familiar with the proper and effective usage of smartphones and applications. Notably, in the second study, 74% of the participants held graduate degrees,

while the remaining 27% possessed higher educational qualifications such as MS/M-Phil degrees. It is worth mentioning that almost all participants in study one reported being daily users of the Internet, indicating their familiarity with digital technologies. Figure 3 provides a visual representation of this observation, reaffirming the widespread use of the Internet among the study participants. These factors collectively contribute to a well-informed and engaged participant group, ensuring valuable insights into their attitudes and responses toward health monitoring applications. All the participants of the three user studies are general users of smartphones who use mobile HMA for self-health monitoring.

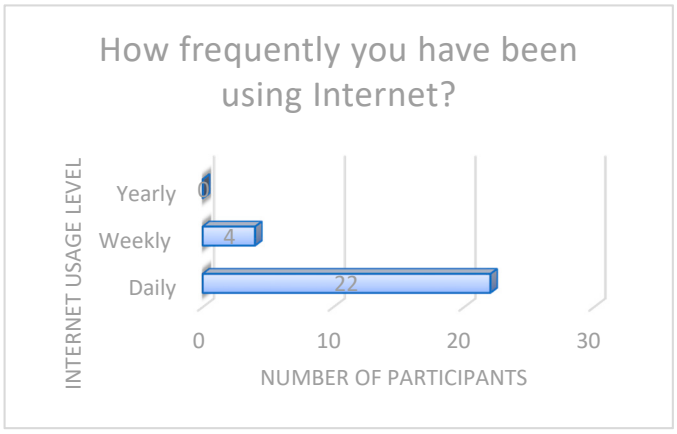


Figure 3. Participants' Internet Usage Level.

We have purposefully selected participants who frequently use the Internet as well as mHealth applications.

A total of 19 (73%) are IT professionals who now work in different organizations, and 7 (27%) of them are students. All of them have been using computers for more than ten years and smartphones for more than five years. All of them are using the Internet for education, jobs, social media, health, and news. More interestingly, Figure 4 shows that all participants are already aware of health monitoring apps.

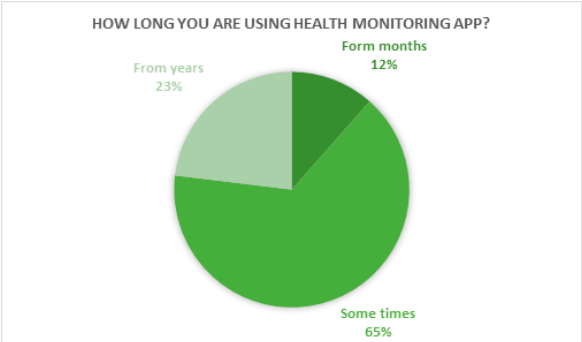


Figure 4. Participant App Usage Duration.

A total of 65% of participants use the app sometimes when needed. Collected data show that 23% of participants used these apps for a few years and 12% of participants used these apps for a few months.

6.7. Experimental Study Design

To obtain exact data, a sound and peaceful environment was provided for the duration of the study. A proper introduction to the application (iCare Health Monitor) was given to participants (Figure 1). During usage of the app, no time frame was defined. The user was open to taking his time accordingly. To aid with the research process and for the sake

of contribution to the body of knowledge, a humble request was made to participants regarding their moral duties.

6.8. Study Procedure

First of all, the questionnaire was provided to the participant. After showing willingness, participants signed the consent form to become part of this research user study. After that, they filled out the pre-study questionnaire, which is about their personal information regarding their profession, education, age group, Internet usage, smartphone usage, the purpose of using the Internet, how long he is using Internet services, for what purpose he/she is using the Internet, etc. After that, participants were asked to download the app (iCare Health Monitor). If he is aware of the smartphone health monitoring app, then he/she had to perform different tasks using the app. Next, they filled out the post-study questionnaire. Suggestions/feedback regarding the app was also taken from participants. All participants are aware of health monitoring apps, while the specific app is new for various users. He/she is requested to fill out the post-study questionnaire followed by a five-point Likert scale. Finally, written feedback/suggestions were taken from the user to check the general persuasion level. The feedback question is about the worst feature of the app and any features they thought would be a necessary part of the app.

6.9. Data Analysis

There is a total of 26 participants who participated in this user study. There are 13 male and 13 female participants. Concerning their qualifications, seven out of 26 hold MS/MPhil/Ph.D. degrees, and 19 out of 26 are graduates. Almost all participants belong to the same age group, (20–35). Nineteen participants are students, while the remaining seven are professionals in different departments. Almost all participants are daily (regular) users of the Internet (Figure 3). The purpose of using the Internet has been observed for different needs accordingly, such as education, social networking, news, jobs, health, and entertainment purposes. All the participants are regular users of smartphones and have been using smartphones for more than five years and computer technology for more than ten years. Figure 5 illustrates that all the participants are already aware of health monitoring apps.

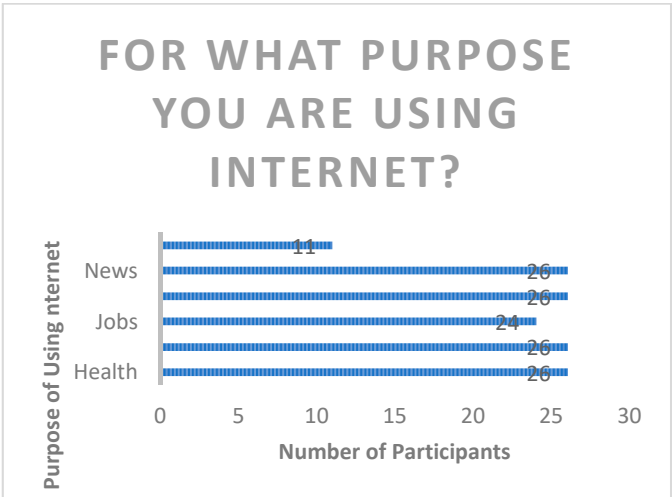


Figure 5. Purpose of using the Internet.

Figure 5 of this study shows that almost all participants are using the Internet for adopting a healthy lifestyle and looking at health-related problems.

The description of HMA usage duration (Figure 4) for participants is as follows: 65% of participants use mobile HMAs sometimes when needed, while 23% of participants used mobile HMAs for a few months and 12% of participants used mobile HMAs for years.

6.10. Results and Discussion

The mean and SD of the post-study questions are shown in Figure 6. As the study questions are divided into two categories, the first four questions are about system design and the next eight questions are about the impact of the application on the user's behavior/persuasion/motivation level. The means and SDs of the post-study questions are shown in Figure 6. The questions help us to decide whether the PSD strategy has been followed or not. There is a total of twelve questions, which have been asked of the participants by keeping the basic principles of persuasion in mind. The current technological hike gives rise to new potentials in developing more progressive and improved medical equipment as well as health applications. If we look at the rapidly growing population of elderly people, there is a strong need for time to develop a more advanced and personalized medical system that can be equally applicable for each individual to adopt a healthy life [27]. The division of the post-study questionnaire is as follows:

- Questions regarding PSD
- Questions regarding participant's behavior change
- Feedback/Suggestions from the participant
- **Result of Questions Regarding System Design**

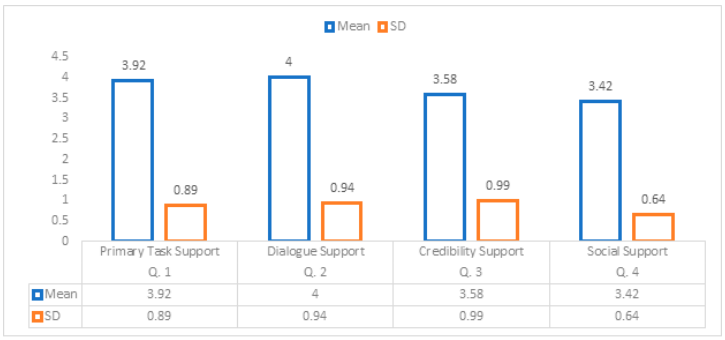


Figure 6. Post-Study Result of System Design.

The graph of basic PSD principles with respective SDs and means is shown below in Figure 6. The graph of basic PSD principles with respective Likert scales is also shown below in Figure 7.

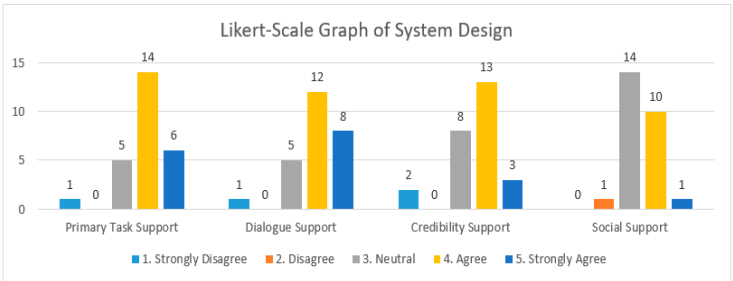


Figure 7. Likert-Scale Graph of System Design.

a. SD and Mean Graph of System Design

The results of the system design support questions are shown in Figure 6. The first question is about system primary task support, with a mean= 3.92 and SD= 0.89. The second question is about system dialogue support, with a mean = 4.00 and SD = 0.94. The third question is about system credibility support, with a mean = 3.58 and SD = 0.99. The fourth question is about system social support, with a mean = 3.42 and SD = 0.64.

The mean and SD of questions regarding PSD basic principles are almost strongly agreed by participants, which indicates that the app design is proper and not questionable in light of the PSD model.

- **Liker-Scale Graph of System Design**

Figure 7 shows the verbal response of participants using an interval scale (Likert scale). The result of questions regarding system design support has been presented graphically.

In Figures 6 and 7, the results of questions regarding system design have been shown. The values of the SD and mean in Figure 6 show that the system has been designed by following the PSD model. Figure 7 (Likert-Scale Graph of System Design) also illustrates that the system design seems to be effective with respect to the PSD model.

The results in Table 1 show that the app has been designed by following PSD model strategies. Social support must be included more but as per the author's observation, the app must persuade the user in a better way. Primary Task Support and Dialogue Support have high performance. A total of 2 out of 26 (7.69%) participants raised a question on systems credibility and 8 out of 26 (30.76%) participants showed a neutral response to the system credibility question. It means that 30.76% are not sure whether the system is credible or not.

Table 1. App Test Results in the Context of the PSD Model.

Questions about Application Test						
Q. No	**Questions**	**1. Strongly Disagree**	**2.Disagree**	**3.Neutral**	**4.Agree**	**Strongly Agree**
Q.1	Primary Task support	1	0	5	14	6
Q.2	Dialog Support	1	0	5	12	8
Q.3	Credibility Support	2	0	8	13	3
Q.4	Social Support	0	1	14	10	1
Sum		4	1	32	49	18

- **Results of Questions Regarding Participants' Behavior**

Results of questions regarding participants' behavior levels after using the application are shown in Figures 8 and 9.

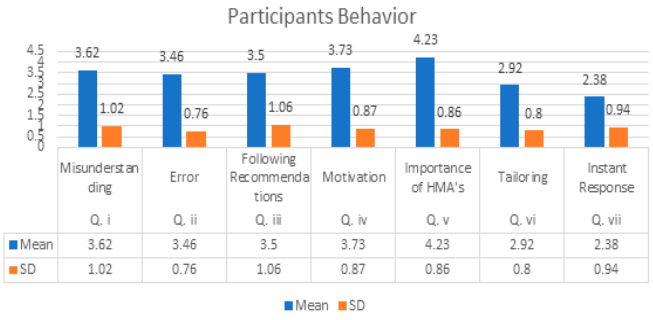


Figure 8. SD and Mean of User Behavior.

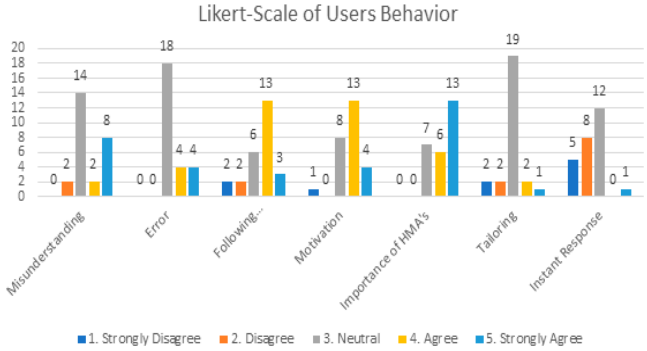


Figure 9. Likert-Scale Graph of Participant's Behavior Change.

b. SD and Mean Graph of Participants' Behavior

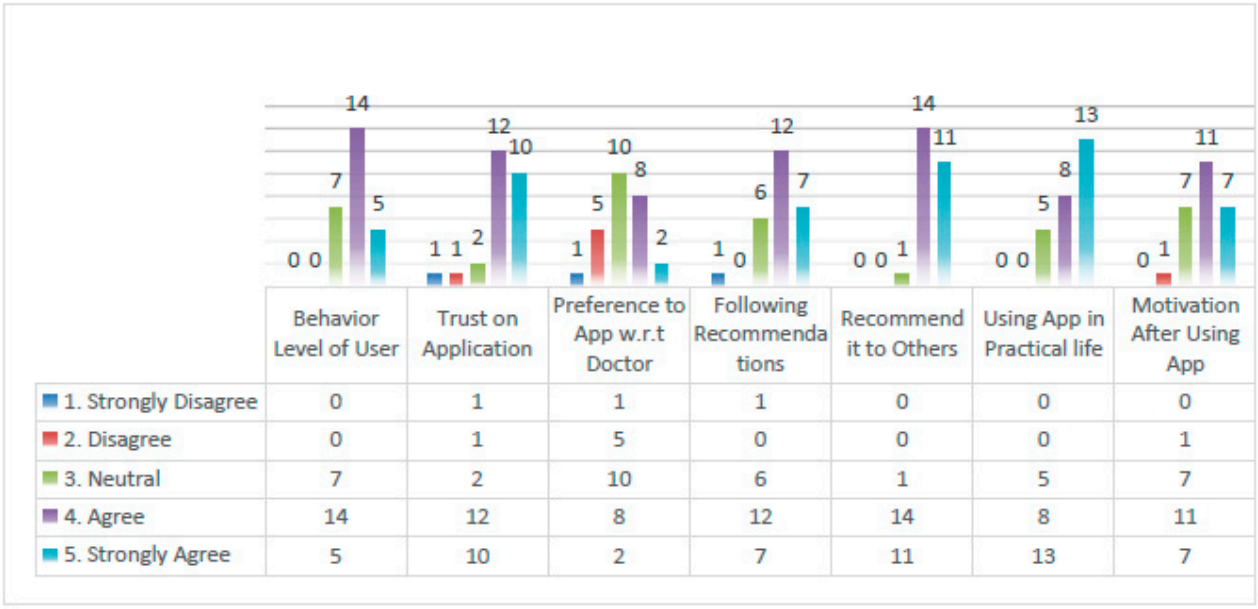
The first question is about misunderstandings, where the mean = 3.62, SD = 1.02. The second question is about errors, where the mean = 3.46, and SD = 0.76. The third question is about following the recommendations of the app, where the mean = 3.5, SD = 1.06. The fourth question is about motivation, where the mean = 3.73, SD = 0.87. The fifth question is about the importance of HMAs, where the mean = 4.23, SD = 0.86. The sixth question is about tailoring, where the mean = 2.92, SD = 0.8, and the seventh question is about instant response, where the mean = 2.38 and SD = 0.94.

Figure 8 illustrates that participants observing that app can lead to misunderstandings regarding self-health management and monitoring. In addition, participants faced low instant responses. However, the participants showed great interest in following the recommendations of the app. It means that the user does not get any moral support from the app.

c. Likert-Scale Graph of Participants' Behavioral Change

Figure 9 shows the verbal responses of participants using an interval scale (Likert scale). These are the results (Figure 9) of questions regarding participants' behavioral changes after using the app.

Figure 10 from the first user study shows the post-study results regarding the participant's level of behavioral change, which have been described below.



	Behavior Level of User	Trust on Application	Preference to App w.r.t Doctor	Following Recommendations	Recommend it to Others	Using App in Practical life	Motivation After Using App
1. Strongly Disagree	0	1	1	1	0	0	0
2. Disagree	0	1	5	0	0	0	1
3. Neutral	7	2	10	6	1	5	7
4. Agree	14	12	8	12	14	8	11
5. Strongly Agree	5	10	2	7	11	13	7

Figure 10. Likert-Scale Result of Questions Regarding Participant's Behavior Change.

1. Participants showed interest in using the application and also recommended it to others.
2. In some cases, participants preferred to use the app when visiting the doctor and in their practical life, along with following the recommendations of the app.

The above results show that the application has a great influence on the user's life but Figure 11 shows that, in the third user study, the application also creates misunderstandings regarding health-related problems. The results also show that app design can be improved and suggested that some results of health-related problems should be hidden from the user for the sake of his/her safety. Therefore, the results of such problems could be appropriately given to users so that he/she can be focused on adopting a healthy lifestyle instead of being disturbed by harsh results.

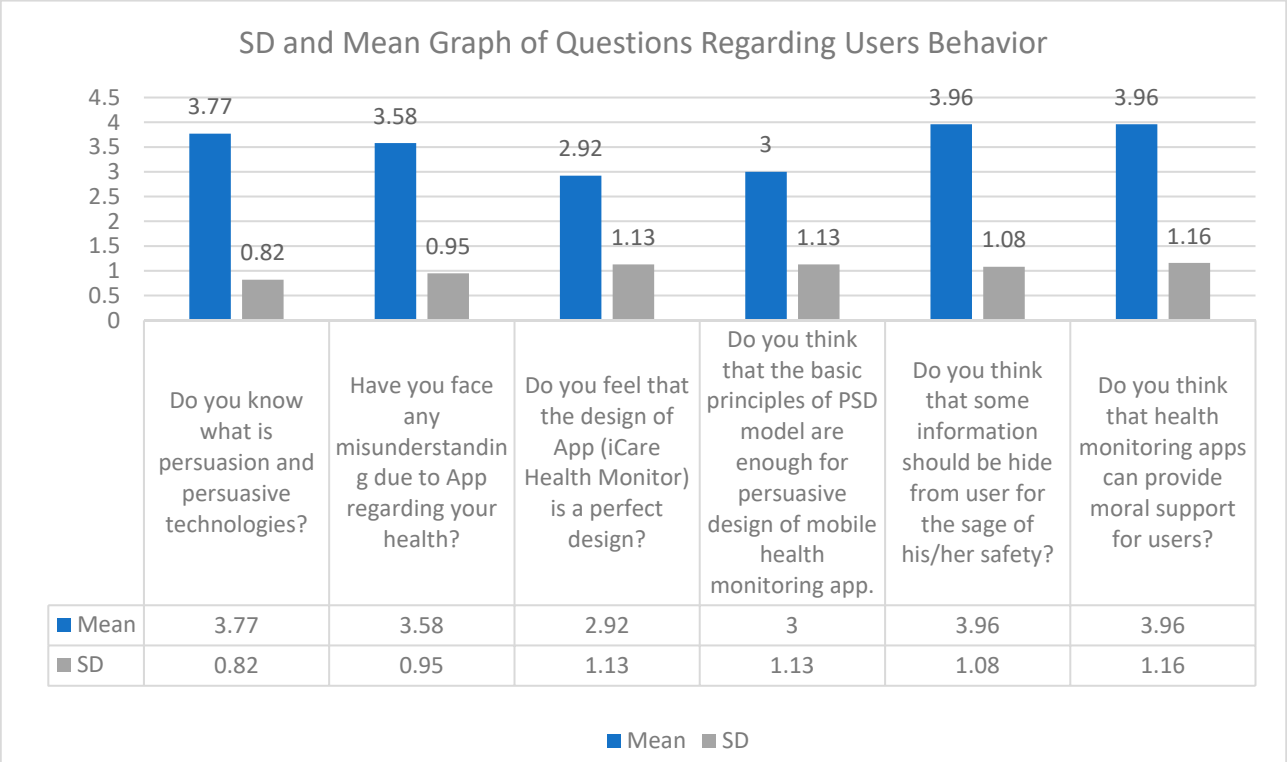


Figure 11. SD and Mean Graph of Questions Regarding User's Behavior.

Figure 11, from the third user study, shows that users have been asked some questions to learn about the actual problems behind persuasion gaps in health monitoring applications. They have also been asked about possible remedies to improve the effectiveness and usefulness of such apps.

During study two, we discovered that the application was designed with enough consideration of the PSD model's basic principles. However, the post-study results of question three in Figure 11 show some evidence that the app design can be improved. The results of post-study questions five and six reflect that this improvement can be added to the apps through providing moral support for users by hiding some particular types of test results from users, keeping his/her safety in mind. Essentially, not every result of the test should be displayed directly to the user.

6.11. Feedback/Suggestions from Participants

Fourteen participants (53.84%) out of twenty-six provided feedback/suggestions. That was a good sign because all the participants are well educated, and their suggestions/feedback will be highly encouraged. The feedback/suggestions regarding users' overall experience of the app are also shown below in Table 2.

Table 2. Participants' Feedback/Suggestions.

S No	Feedback/Suggestions of Participants after 2nd User Study
1	The app must be linked with well-known health experts.
2	For system credibility, there must be a linkage with some real-time health centers.
3	The system provides feedback on the user's interaction while the system is unaware of the user's previous health records.
4	Who is the owner of the app? For system credibility, it is very important to know who the owner is.

Table 2. *Cont.*

S No	Feedback/Suggestions of Participants after 2nd User Study
5	General tips for a healthy life are appreciable but monitoring any real health issue may not be possible.
6	Sometimes systems offer irrelevant predictions. To improve, the system should record all previous health records first.
7	The system should be linked with any hospital.
8	Some people have psychological problems. We should hide their issues in front of them but this app gives results directly.
9	The app should hide the direct result of psychological problems but, provide tips, on how to get rid of issues.
10	The app should advise on a healthy lifestyle. Giving direct feedback to the psychological user is not a good sign.
11	I look at these applications neutrally, but these apps could be more helpful if they help users subconsciously.
12	Some people have issues, but the app treats everyone equally.
13	Good application.
14	Personalized behavior is necessary for women.

7. Conclusions and Future Work

Although the PSD model provides a comprehensive framework for designing and evaluating persuasive systems and describes the content and software functionality, it does not provide specific guidance on how to balance the need for persuasion with the need to respect users' autonomy and privacy. The model assumes that persuasion is always a positive force and does not consider the potential negative consequences of persuasive systems. The model is relatively complex and may be difficult to apply in practice without significant expertise in persuasive design. This study analyzes and evaluates the user's behavior change level and system design in the context of mobile health monitoring app users. According to the post-study results, some system designing features do not align with the user's motivation level. These studies find that users face misunderstandings regarding health-related problems. According to Figure 8, the application's social support is low, and the application can create misunderstandings regarding health-related issues. Furthermore, Figure 11 illustrates that the recommendations and test results of users should be presented differently and not show serious harmful results regarding life directly to users. Instead of this, the app must suggest excellent healthcare techniques which can help the user to get out of the situation. The application must hide some results for the sake of user safety and must provide moral support to seek medical attention immediately to ensure that the user receives the proper care and treatment to manage the condition. Figures 6 and 7 and Table 1 demonstrate that the application's design adheres to the PSD model without any problems. Therefore, we can say that either the design of the application is wrong or the PSD model fails to provide the perfect persuasive design strategies for users of the application. On the other hand, Figure 8 shows that users strongly agreed to follow the recommendations of the app regarding their health-related issues. However, the basic principles of the PSD model have been followed with enough consideration by designers. This means that the app does not provide any moral support to users while using the app. Despite this, HMAs need more steps to improve user behavior and motivational levels. As mentioned previously, the majority of the participants in the first study are HCI researchers and the rest are well-educated. With this in mind, the feedback and suggestions provided by participants after the study are also not ignorable. A tailored persuasive system design model for HMAs must be presented to analyze and assess the user's behavior change level and system design principles in the context of the user's point of view. This study also investigated how mHealth apps can address the widespread issues of the emotional and

mental health of users. The study also recommends designing an improved PSD model for each category of persuasive technologies so that it will be possible to get maximum reliable results and feedback. To develop a benchmark persuasive framework for HMAs, a special study is needed. As a result of the PSD model's generalized design strategies, we cannot promote these strategies for medical and health-related applications. These types of applications are directly related to human life, so any misunderstanding can affect human life. This study suggests that mHealth apps must provide moral support for their users. In short, this study has found that the PSD model fails to provide moral support for their users and strongly recommends that "technology must provide moral support for their users".

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