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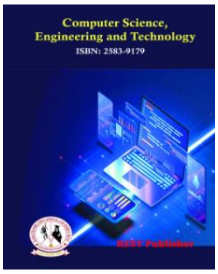

Evaluating Usability in mHealth Applications: A TOPSIS Approach to Enhancing User Engagement and Health Outcomes

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Abstract: *A mHealth application has revolutionized the way healthcare is accessed, delivered, and managed. With the widespread adoption of Smartphone and the increasing availability of mobile networks, mHealth has emerged as a powerful tool to improve healthcare outcomes and promote well-being. These applications harness the convenience and ubiquity of mobile devices to provide a range of health-related services and support, empowering individuals to take control of their own health. mHealth applications offer a diverse range of functionalities, catering to various aspects of healthcare. They enable users to track their fitness activities, monitor vital signs, manage chronic conditions, and access personalized health information. The convenience of mobile technology allows individuals to access healthcare services and resources anytime and anywhere, breaking down geographical barriers and improving healthcare accessibility, especially in underserved areas. Overall, mHealth applications have the potential to transform healthcare delivery, empowering individuals, and improving health outcomes. They serve as valuable tools for health promotion, disease prevention, self-care management, and remote healthcare access. If an app is difficult to use or confusing, users are less likely to engage with it and may abandon it altogether. Research can identify usability barriers and suggest improvements that enhance user engagement and increase the likelihood of app adoption. Usable mHealth applications empower individuals to actively participate in their healthcare management. When an app is intuitive and easy to navigate, users can more effectively monitor their health, adhere to medication schedules, track their progress, and make informed decisions. Research on usability can inform the development of user-centered designs that promote patient empowerment and self-care. Usable mHealth applications have the potential to improve health outcomes. When users can easily access and understand health information, follow treatment plans, track symptoms, and communicate with healthcare providers, they are more likely to achieve positive health outcomes. Research can explore how usability factors contribute to improved health outcomes and inform best practices for app design. Overall, research on the usability of mHealth applications is essential for creating user-friendly, effective, and engaging apps that empower individuals, improve health outcomes, and drive the successful adoption of mobile health technologies. TOPSIS is a straightforward and intuitive method for decision-making, providing a systematic approach to evaluate alternatives based on multiple criteria. It helps decision-makers consider different factors and their relative importance when selecting the most suitable option. However, it's important to note that TOPSIS does not account for trade-offs between criteria and assumes that all criteria have equal importance, unless weighted differently. Instant Heart Rate, PulsePoint Respond, Blood Pressure Monitor, Cardio, Blood Pressure Companion, Qardio, Forecheck, Cardiac Diagnosis (Arrhythmia) Learnability, Efficiency, Memorability, Error, Navigation, Cognitive Load Result is showing that the first rank goes to instant heart rate and the last rank is secured by PulsePoint Respond.*

Keywords: *Total costs, Implementation time, reliability, R&D capability and the capability, Organizational reputation.*

1. INTRODUCTION

Numerous mobile communication systems have exploded in popularity. Software developers, academics, and consumers at large have all been paying close attention to mobile health applications (mHealth apps). Access to a variety of health information is made simple through mobile health applications. According to a study [1], around 20% of smartphone users have installed at least one health application, and approximately 31% of mobile phone users access health-related news on their devices. Mobile health technologies (mHealth) are considered a promising field for improving condition management in the daily lives of children and adolescents under the age of 18 who have chronic illnesses. Although there is no precise definition, mHealth generally refers to the use of mobile devices, particularly smartphones and apps, to monitor health data. This enables users to assess and improve their treatment, symptoms, and overall well-being while also interacting with healthcare professionals [3, 4]. In some cases, mHealth has facilitated better communication between minors and healthcare providers, leading to increased involvement, stronger relationships, and greater trust [2]. A lot of people are interested in employing mobile health (mHealth) apps to help conventional healthcare research because to the quick uptake of mobile devices. The monitoring of chronic conditions, remote patient monitoring, and the treatment of diseases including HIV testing, medication, and data gathering have all made extensive use of these applications. Using mHealth tools in conjunction with other treatments may enhance care overall. Any mobile technology has significant hurdles in terms of ensuring security and privacy. Sensitive patient data in mHealth apps needs to be properly guarded. For instance, mHealth apps may save users' daily routines, including sleeping habits, on their mobile devices, where Android advertising networks may gather private information [7]. According to the research, mHealth apps in developing countries primarily improve the sustainability and efficiency of the healthcare system and make it easier for the general public to get medical treatment (e.g. Mechael 2009; Kaplan 2006). However, after doing a thorough literature search and analysing 64 current mHealth initiatives in poor nations, we discovered that barely one-third of the identified apps are really in use (Niemöller et al. 2016). The design of the app itself, as well as the dearth of statistical data supporting the advantages of mHealth apps, are potential causes of a deficit in use of the application (app) once the pilot stage is over (Friederici et al. 2012). Additionally, it is frequently difficult for foreign researchers, such as those from rich countries Globally, the delivery of health care services is being quickly transformed by the use of mobile health (mHealth) applications Mobile technology has changed how health resources and information are given recently (Logan, 2013), with an emphasis on enhancing patient experiences and lowering healthcare costs (Chaudhry et al., 2006). By enabling users to manage, monitor, and track chronic conditions through the use of mHealth programmes (or apps), mobile technology has increased medication adherence, provided remote support, and improved health outcomes (West, 2012). As a result, the worldwide mHealth industry has grown and gained acceptability over the past ten years (worldwide QYResearch, 2019). By the end of 2020, the worldwide mHealth industry is predicted to increase to 58.6 billion dollars, according to latest data (Statista Research Department, 2020). The digitization of healthcare is another factor. There are still several obstacles to the continuous use of mHealth applications as a health behaviour intervention, despite the recent rise of these systems and the potential advantages of these programmes to enhance the health and wellbeing of their target end users. According to the Pew Research Centre, 42% of persons 65 and older in the U.S. own a personal smartphone, making the overall smartphone ownership rate in the country close to 77%. With almost 165,000 mHealth apps available across the iPhone, Google Play, and Android platform app stores, 31% of this population of smartphone owners use their devices to download mHealth applications to track their health status or conduct health information searches. However, a lot of these programmes are frequently dropped soon after being downloaded. prior investigation

2. MATERIALS & METHODOLOGY

Instant Heart Rate: Instant Heart Rate is a mobile application designed to measure and monitor your heart rate using the camera or sensors on your smartphone or smartwatch. It utilizes the principle of photoplethysmography (PPG), which measures changes in blood volume through the skin to estimate heart rate.To use Instant Heart Rate, you typically place your finger gently over the camera lens or touch the sensors on your device, and the app measures the subtle color changes in your fingertip caused by blood flow. It then analyzes these changes to calculate your heart rate in beats per minute (BPM). Some versions of the app may also provide additional features like heart rate zone tracking, activity monitoring, and integration with other fitness apps.It's important to note that while Instant Heart Rate and similar applications can provide an estimate of your heart rate, they may not be as accurate as dedicated medical devices or professional monitoring equipment. Factors such as lighting conditions, the quality of your camera or sensors, and user error can affect the accuracy of the measurements. Therefore, it's always advisable to consult a healthcare professional for accurate and reliable heart rate monitoring, especially if you have any underlying medical conditions or concerns.

PulsePoint Respond: PulsePoint Respond is a mobile application that aims to improve the chances of survival for individuals experiencing cardiac arrest or other life-threatening emergencies in public settings. It connects trained CPR (Cardiopulmonary Resuscitation) responders with nearby incidents through a system of notifications. When someone calls emergency services to report a cardiac arrest or a related emergency, the PulsePoint Respond app sends a notification to registered users who are within close proximity to the incident. The notification alerts these users of the emergency location, allowing them to provide immediate assistance before professional medical help arrives.It's important to note that PulsePoint Respond's availability may vary depending on your location, as it requires collaboration between the app developers and local emergency response agencies.

Blood Pressure Monitor: It's important to note that while mHealth blood pressure monitor apps can be convenient, their accuracy may vary, and they are not a substitute for professional medical advice. The readings obtained through these apps may not be as reliable as those obtained with validated medical devices, and factors like user error and device limitations can affect accuracy.If you choose to use a blood pressure monitor app, it's recommended to select one that has been validated and approved by reputable organizations or regulatory bodies. It's also a good idea to consult with a healthcare professional about using the app and interpreting the results properly. They can provide guidance on selecting a reliable app and ensure that your blood pressure management is based on accurate information.

Cardiio: It is a mobile health (mHealth) app that aims to measure and track heart rate and other cardiovascular health metrics using the camera on a smartphone or tablet. It utilizes the principle of photoplethysmography (PPG) to estimate heart rate and other related parameters.To use Cardiio, you typically place your finger gently over the camera lens of your device, and the app captures the subtle color changes in your fingertip caused by blood flow. It then analyzes these changes to calculate your heart rate in beats per minute (BPM).If you have any specific concerns about your cardiovascular health or need accurate and reliable heart rate monitoring, it's always advisable to consult with a healthcare professional. They can guide you on the most appropriate methods and devices for monitoring your heart rate and provide personalized advice based on your specific health needs.

Blood Pressure Companion: Blood Pressure Companion is a mobile health (mHealth) app designed to help individuals monitor and manage their blood pressure. The app allows users to track their blood pressure readings, store them over time, and provide insights into their cardiovascular health.

Qardio: Qardio offers a range of mHealth devices and an accompanying app that allows users to track and monitor various aspects of their cardiovascular health. Their product line includes blood pressure monitors, EKG (electrocardiogram) devices, and weight scales. The app enables users to record and analyze their blood pressure, EKG, and weight measurements, track trends over time, set reminders, and share data with healthcare professionals.

Fibri Check: Fibri Check is a smartphone-based app that specializes in the detection and monitoring of cardiac arrhythmias, specifically atrial fibrillation (AF). It uses the smartphone's camera or integrated sensors to measure the user's heart rate and rhythm. The app can perform regular screenings, alert users to irregularities, and generate reports that can be shared with healthcare providers for further analysis and diagnosis.

Cardiac Diagnosis (Arrhythmia): It's unclear which specific app you're referring to as "Cardiac Diagnosis," as there may be multiple apps with similar names. However, there are various mHealth apps available that assist in diagnosing arrhythmias or irregular heart rhythms. These apps often employ PPG technology or EKG sensors integrated with smartphones to measure and analyze heart rate and rhythm. They can detect abnormalities and provide information that can aid in the diagnosis of arrhythmias, allowing users to seek appropriate medical attention. “It's important to note that while these mHealth apps can be useful tools for monitoring and providing insights into cardiac health, they are not substitutes for professional medical advice or diagnostic tools. If you have concerns about your cardiovascular health or suspect an arrhythmia, it's essential to consult with a healthcare professional who can conduct a comprehensive evaluation and provide accurate diagnosis and treatment recommendations”.

Learnability: A highly learnable interface allows users to quickly grasp its features, functionalities, and navigation without extensive training or prior knowledge.

Efficiency: Efficiency measures how quickly and easily users can accomplish their tasks or goals within a system or application. An efficient design minimizes the number of steps, interactions, and time required for users to complete their desired actions.

Memorability: A memorable design ensures that users can easily recall how to perform tasks and navigate the interface even after a hiatus, reducing the need for relearning.

Error: Error refers to the occurrence of mistakes or failures during user interactions with a system or application. A good design aims to minimize errors by providing clear instructions, meaningful feedback, and error prevention mechanisms, as well as making error recovery straightforward.

Navigation: Navigation relates to how users move through a system or application to find information or perform tasks. Effective navigation design provides clear and intuitive pathways, such as menus, buttons, and links, enabling users to locate and access desired features or content with ease.

Cognitive Load: Minimizing cognitive load involves reducing unnecessary complexity, presenting information in a clear and organized manner, and ensuring that interactions align with users' mental models. “Considering these factors in the design of software or applications helps create user-friendly experiences that are easy to learn, efficient to use, memorable, error-resistant, and cognitively manageable".

3. TOPSIS METHOD

Criteria Identification: In this step, the relevant criteria that will be used to evaluate the alternatives should be identified. These criteria should be measurable and meaningful for the decision at hand. For example, if the decision is about selecting a new car, criteria such as price, fuel efficiency, safety ratings, and reliability can be considered. Criteria Weighting: Once the criteria are identified, weights need to be assigned to each criterion based on their relative importance or priority. The weights reflect the significance of each criterion in the decision-making process. These weights can be determined through discussions, surveys, or expert opinions. For instance, if safety is considered more important than price, a higher weight would be assigned to safety. Normalize the Decision Matrix: A decision matrix is created to include the performance values of each alternative for each criterion. However, since the measurement units of the criteria may differ, normalization is required to bring the values to a common scale. Typically, normalization involves converting the values to a range between 0 and 1. This step helps eliminate the influence of different measurement units and allows for meaningful comparisons. Determine the Ideal and Negative Ideal Solutions: Using the decision matrix, the ideal solution is identified for each criterion. The ideal solution is the alternative with the highest value for each criterion. Conversely, the negative ideal solution is the alternative with the lowest value for each criterion. For example, if one alternative has the highest price and lowest fuel efficiency, it would be the negative ideal solution for those criteria Calculate the Separation Distances: The separation distances between each alternative and the ideal and negative ideal solutions are calculated using a suitable distance metric. Common distance metrics include Euclidean distance or Manhattan distance. This step quantifies the difference between each alternative and the ideal or negative ideal solutions for each criterion. Calculate the Relative Closeness: The relative closeness of each alternative to the ideal solution is calculated by comparing its distance to the ideal solution with the sum of its distances to both the ideal and negative ideal solutions. This step provides a measure of how well an alternative performs compared to the ideal solution. Higher relative closeness values indicate greater proximity to the ideal solution. Rank the Alternatives: Based on their relative closeness values, the alternatives are ranked. The alternative with the highest relative closeness value is considered the most preferred or optimal solution. This ranking allows decision-makers to identify the best alternative that aligns with their preferences. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) provides a systematic approach for decision-makers to evaluate and compare alternatives based on multiple criteria. By considering the relative importance of criteria and calculating the proximity to the ideal solution, TOPSIS helps in selecting the best alternative that aligns with the decision-makers' preferences

4. RESULTS & DISCUSSION

TABLE 1. TOPSIS of The Usability of mHealth Applications

The Usability of mHealth Applications						
Apps	**Learnability**	**Efficiency**	**Memorability**	**Error**	**Navigation**	**Cognitive Load**
Instant Heart Rate	120	121	94	83	75	69
PulsePoint Respond	122	108	87	83	74	88
Blood Pressure Monitor	120	105	93	87	76	71
Cardiio	127	105	99	96	70	82
Blood Pressure Companion	118	103	114	99	71	82
Qardio	121	100	93	68	73	81
FibriCheck	119	116	108	92	73	75
Cardiac Diagnosis (Arrhythmia)	129	107	99	87	78	76

Table 1 shows Alternative Parameters Instant Heart Rate, Pulse point Respond, Blood Pressure Monitor, Card dio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load using Topsis method

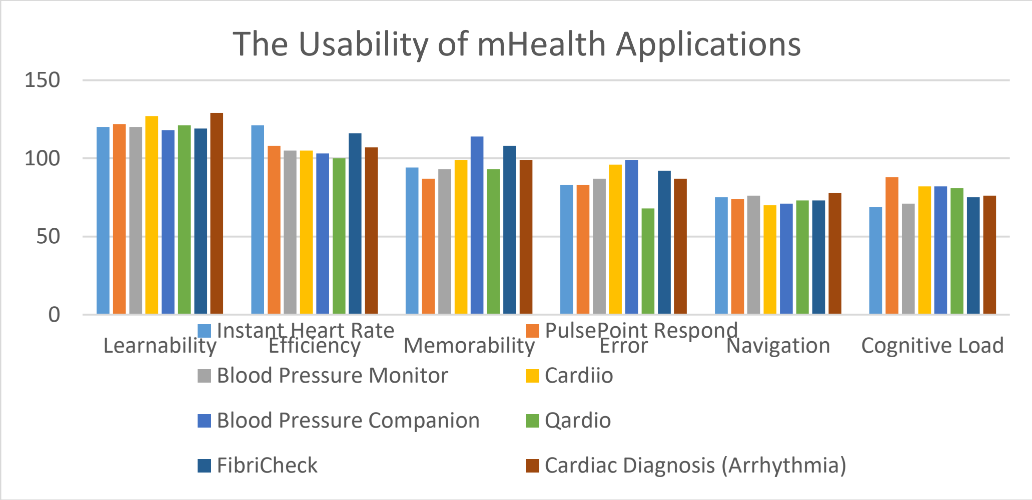

FIGURE 1. TOPSIS of The Usability of mHealth Applications

Figure 1 shows the usability of different apps where all apps are evaluated with 6 different evaluative parameters.

TABLE 2. Normalized Data

Normalized Data					
0.348	0.350	0.272	0.240	0.217	0.200
0.353	0.313	0.252	0.240	0.214	0.255
0.348	0.304	0.269	0.252	0.220	0.206
0.368	0.304	0.287	0.278	0.203	0.238
0.342	0.298	0.330	0.287	0.206	0.238
0.350	0.290	0.269	0.197	0.211	0.235
0.345	0.336	0.313	0.266	0.211	0.217
0.374	0.310	0.287	0.252	0.226	0.220

Table shows the normalize data of Alternative Parameters Instant Heart Rate, Pulsepoint Respond, Blood Pressure Monitor, Carddio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load.

TABLE 3. Weight

Weight					
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167
0.167	0.167	0.167	0.167	0.167	0.167

Table 3 Weight shows the informational set for the weight all same value 0.167.

TABLE 4. Weighted normalized decision matrix

Weighted normalized decision matrix					
0.058	0.058	0.045	0.040	0.036	0.033
0.059	0.052	0.042	0.040	0.036	0.042
0.058	0.051	0.045	0.042	0.037	0.034
0.061	0.051	0.048	0.046	0.034	0.040
0.057	0.050	0.055	0.048	0.034	0.040
0.058	0.048	0.045	0.033	0.035	0.039
0.057	0.056	0.052	0.044	0.035	0.036
0.062	0.052	0.048	0.042	0.038	0.037

Table 4 Weighted normalized decision matrix shows the informational set for the Normalized Data multiplication Weight we used the formula.

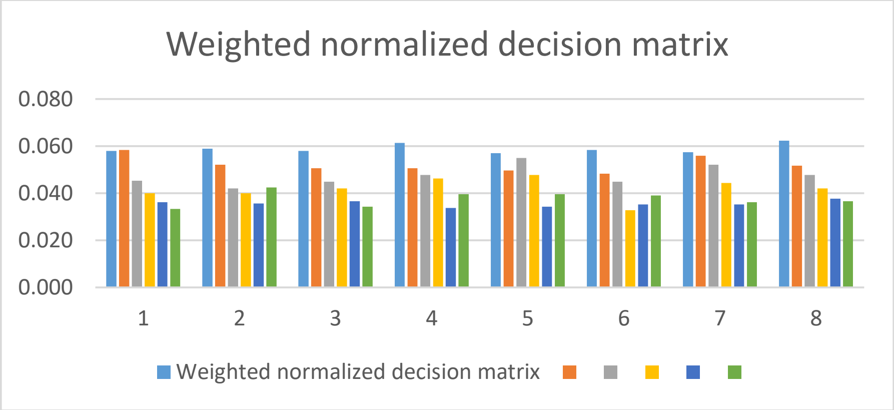

FIGURE 3. TOPSIS of The Usability of mHealth Applications

Figure 3 Weighted normalized decision matrix shows the informational set for the Normalized Data multiplication Weight we used the formula.

TABLE 5. Positive Matrix

0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033
0.062	0.058	0.055	0.033	0.034	0.033

Table 5 shows the positive matrix of Alternative Parameters Instant Heart Rate, Pulsepoint Respond, Blood Pressure Monitor, Carddio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load.

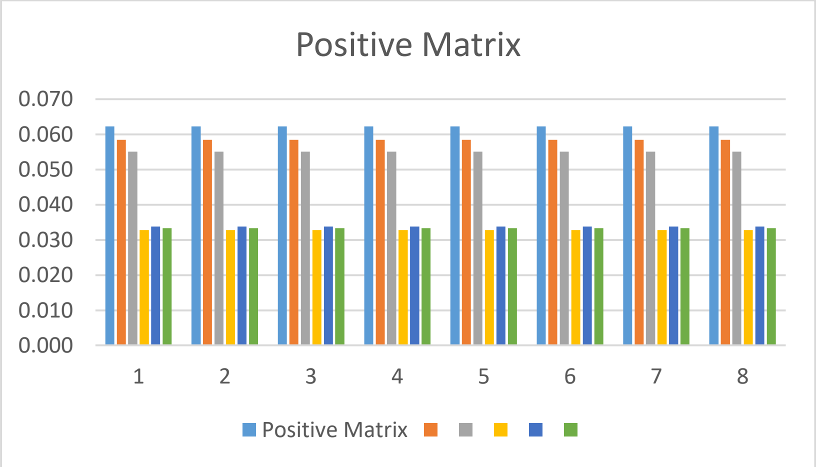

FIGURE 4. Positive Matrix

Figure 4 **shows** the positive matrix of Alternative Parameters Instant Heart Rate, Pulsepoint Respond, Blood Pressure Monitor, Carddio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load.

TABLE 6. Negative matrix

0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042

0.057	0.048	0.042	0.048	0.038	0.042
0.057	0.048	0.042	0.048	0.038	0.042

Table 6 shows the negative matrix of Alternative Parameters Instant Heart Rate, Pulsepoint Respond, Blood Pressure Monitor, Carddio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load.

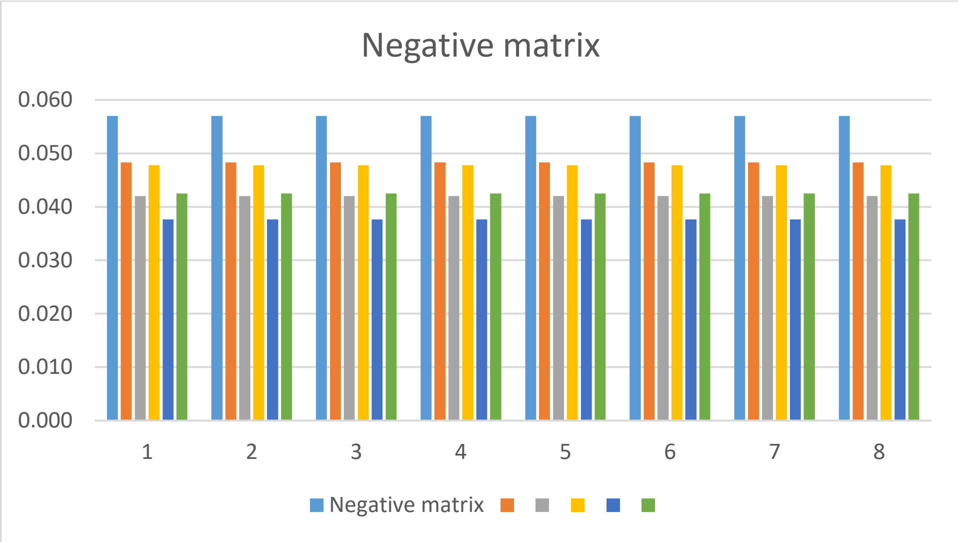

FIGURE 5. Negative matrix

Figure 5 shows the negative matrix of Alternative Parameters Instant Heart Rate, Pulsepoint Respond, Blood Pressure Monitor, Cardio, Blood Pressure Companion, Qardio, FibriCheck and Cardiac Diagnosis and Evaluative Parameters Learnability, Efficiency, Memorability, Error, Navigation and Cognitive Load.

TABLE 8. Si Positive & Si Negative & Ci, Rank.

SI Plus	Si Negative	Ci	Rank
0.013	0.016	0.553	1
0.019	0.009	0.323	8
0.017	0.011	0.395	6
0.018	0.009	0.333	7
0.019	0.014	0.419	5
0.016	0.016	0.498	3
0.014	0.015	0.523	2
0.014	0.012	0.451	4

Table 8 Si Positive & Si Negative & Ci shows the informational set for the value this table. And last column ranks the alternatives.

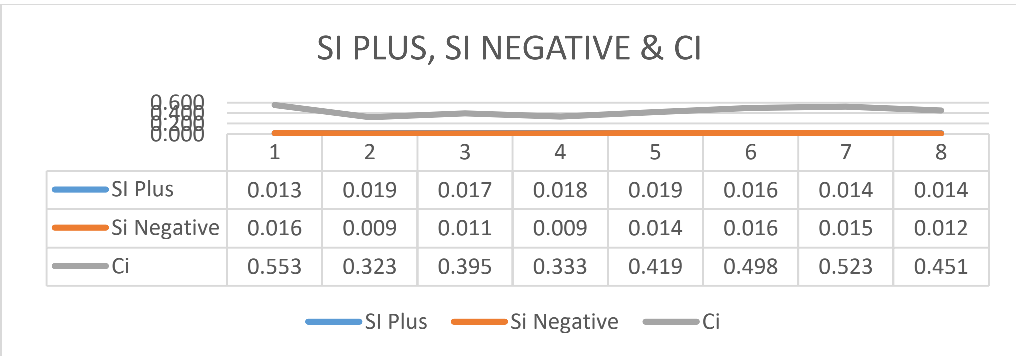

FIGURE 6. Si Positive & Si Negative & Ci, Rank.

Figure 6 is showing Si Positive & Si Negative & Ci shows the informational set for the value this table.

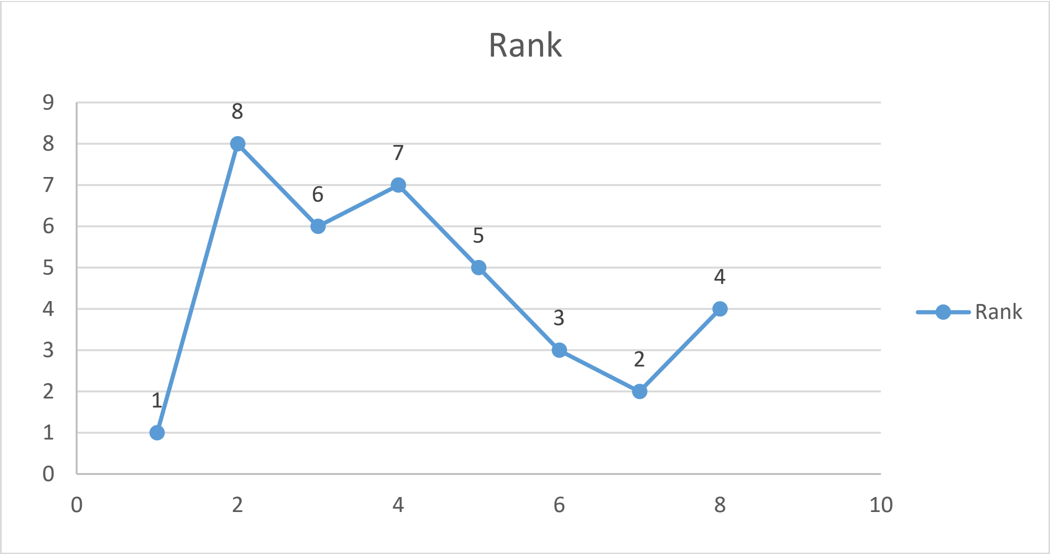

FIGURE 7. Rank

Figure 7 is showing that the first rank goes to instant heart rate and the last rank is secured by PulsePoint Respond.

5. CONCLUSION

In conclusion, the usability of mHealth applications plays a crucial role in their effectiveness and user satisfaction. Let's summarize the usability aspects of the mentioned mHealth applications: Instant Heart Rate: Instant Heart Rate provides a convenient method for estimating heart rate using the smartphone's camera or sensors. It offers a simple and intuitive interface, allowing users to quickly measure and track their heart rate. The learnability and efficiency of the app contribute to its usability. PulsePoint Respond: PulsePoint Respond focuses on connecting trained CPR responders with nearby emergencies. The app's usability lies in its ability to provide timely notifications and location information, allowing users to quickly respond to cardiac arrest incidents. The efficiency, memorability, and navigation aspects are critical for its usability. Blood Pressure Monitor: Blood Pressure Monitor apps offer a convenient way to measure and track blood pressure using smartphones or wearable devices. The usability of these apps depends on their accuracy, ease of use, efficient recording of readings, clear visualization of data, and features like reminders and data sharing. Cardiio: Cardiio utilizes smartphone cameras or sensors to estimate heart rate and other cardiovascular metrics. Its usability relies on the simplicity of the measurement process, clear presentation of results, and additional features like heart rate variability analysis and stress monitoring. Learnability and efficiency contribute to its usability. Blood Pressure Companion: Blood Pressure Companion enables users to track and manage their blood pressure readings over time. Usability factors include ease of entering readings, visualizing trends through graphs and charts, setting reminders, and exporting data. Learnability, efficiency, and memorability play key roles here. Qardio: Qardio offers a range of mHealth devices and an accompanying app for monitoring cardiovascular health. Its usability lies in the seamless integration of various health metrics, intuitive data recording, visualization, and features such as reminders and data sharing. Efficiency and cognitive load management are important for user satisfaction. FibriCheck: FibriCheck focuses on detecting and monitoring cardiac arrhythmias, specifically atrial fibrillation. Its usability lies in its ability to provide accurate and real-time monitoring using smartphone sensors, timely alerts for irregularities, and generation of reports for healthcare professionals. Efficiency, error prevention, and navigation contribute to its usability. Cardiac Diagnosis (Arrhythmia): There may be multiple apps in this category, but their usability focuses on accurate arrhythmia detection, intuitive interfaces for recording EKG data or heart rhythm, clear visual feedback, and easy sharing of results with healthcare providers. Learnability and error prevention are crucial usability factors. To maximize the usability of mHealth applications, it is essential to consider factors such as learnability, efficiency, memorability, error prevention, navigation, and cognitive load management. By addressing these aspects, developers can create user-friendly applications that effectively support individuals in monitoring and managing their cardiovascular health.

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