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Integration of Haptics Tactile Feedback into Heart Disease Monitoring Mobile Application: A Conceptual Model

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Abstract

Heart disease is one of the most prominent silent killers in the world. Treating the heart disease health problems is considerably costly. In the era of the 4th Industrial Revolution (4IR), heart patients are now able to monitor their heart conditions using heart disease monitoring applications on any mobile devices. Usability factors such as ease of use, ease of learning, efficiency, flexibility and the attitude of users towards the applications are deemed important in determining the usability of such mobile applications. This paper employs a systematic literature review method in analyzing 1,339 relevant articles. Based on the review, this paper theoretically contributes by proposing a conceptual model that integrates haptics tactile feedback into heart disease monitoring mobile applications with the aim of enhancing the usability of the heart disease monitoring mobile applications. This is expected to lead to ease of health monitoring by both patients and health professionals, and potentially reduce the frequency of visits to hospitals and the cost of medical expenses. This paper also investigates the potentials of haptics tactile feedback in the forms of vibration, pressure, touch, texture, and movement when users are interacting with the applications.

Keywords: Heart Disease; Usability Factors; Health Monitoring Application; Haptics Tactile Feedback

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1. Introduction

Heart disease is one of the most prominent silent killers in the world [1, 2]. According to [3], from the medical perspective, the symptoms of heart disease include tightness of the chest which indicates coronary heart problem, irregular heart beat levels for patients with heart disease and shortness of breath for patients with heart failure. There are various types of heart disease but for this study, the scope is a common heart ailment and the most common is coronary heart disease. Among the contributing factors for coronary heart disease are high levels of cholesterol, diabetes, hypertension, obesity, smoking, lack of exercise, and aging processes [4].

For treating heart disease, it involves high medical expenses. In the United States of America, the cost of treatment for 30 days of care could go as high as USD $ 22,416 [5] while in countries such as Indonesia the costs could reach up to Rp 80 Million for stent (heart ring installation operations). In the era of the 4th Industrial Revolution (4IR), heart patients could easily monitor the health condition of their heart using mobile applications. There are a plethora of heart disease monitoring mobile applications available and offered on major platforms such as Google Play and Apple App Store [6, 7]. They are either available as paid applications, on subscription basis or available for free but with limited features. In order to increase the use of these applications by heart patients, the usability factors need to be emphasized during the system development process. According to [8], among the usability factors required out of heart disease monitoring mobile applications are (i) easy to use, (ii) usefulness and problem solving capabilities, (iii) accuracy and clarity of presentation, and (iv) satisfaction with use and design. Other factors include ease of learning, effectiveness, flexibility, and attitude of user [9].

This paper proposes a model to integrate haptics tactile feedback with the purpose of enhancing the usability of heart disease monitoring mobile applications based on relevant literature reviews such as to (i) increase the usability of applications [10], (ii) reduce medical expenses [11], (iii) reduce treatment time [12], and (iv) ease of health monitoring [13].

This paper begins with a brief discussion on the research methods. It continues with a review of literature on haptics, heart disease monitoring technology and then proceeds with proposing and discussing on the integration of haptics tactile feedback into heart disease monitoring mobile application. The paper wraps with a brief conclusion and salient points for further research.

2. Materials and methods

This research followed a systematic literature review (SLR) methodology [14]. SLR consists of three (3) phases: (i) planning phase, (ii) conducting phase, and (iii) reporting phase. The planning phase was conducted in order to understand the issues related to heart desease, heart disease monitoring mobile applications and the trend of haptics tactile feedback for health monitoring. In the conducting phase, relevant articles were identified and retrieved from reputable online databases are Science Direct, IEEE, and BMC (BioMedCentral) using keyword phrases “usability”, “heart disease”, “haptics in health monitoring”, and “mobile applications”. Articles published from the year 2014 until 2018 are considered relevant articles for analysis. The search results yielded 1,339 articles. The articles were read mainly for the abstracts, results, discussions, number of citations and year of publication and are conducted using a similar protocol by [15], so that there are 29 articles that will be composed of 3 parts, 7 articles to haptics and its potential in health monitoring applications, 6 articles to heart disease monitoring applications and technology, and 16 articles to usability factors.

In the reporting phase, the literature from the haptics and heart disease monitoring technology domains were analysed and synthesized in order to propose a model of haptics tactile feedback to enhance usability of heart disease monitoring mobile applications. The reviewed articles are discussed based on the following sub-topics: i) haptics and its potential in health monitoring applications, ii) heart disease monitoring applications and technology, and iii) usability factors.

2.1. Haptics and its potential in health monitoring applications

Studies by [16, 17, 18] state that haptics technology is a form of human interaction by adding sensations, particularly in the form of pressure, vibration, touch, and texture or movement to users when they interact with the application. Tactile countermeasures are a kind of haptic countermeasure. Haptics feedback can be classified into two categories: (1) haptics kinesthetic in general, a kinesthetic response can be felt by a sensor in the muscles, joints, tendons in the limbs such as the arms and hands. For example, holding a cup of coffee in hand, with a kinesthetic response, we can feel the weight of the cup in comparison with our body. (2) For haptics tactile countermeasures too, it may be felt on the surface of the tissue and finger skin. There are several sensors located on the finger tissue so that the brain may feel and react to such as vibration, pressure, touch, and texture.

Based on relevant literature review, some of the haptics potentials are: (i) Enhances user-experience, through haptics sensation, along with its audio and visual setup, users would feel the experience a realistic environment, feeling the action of the application being used, and etc. For instance, in gaming applications, the user feels a vibration when a car collided with another car [18], (ii) Low-cost treatment, in which researcher such as [11] made an embedded haptics arm vibrotactile drive with a low cost of USD 8 for each haptics arm to help stroke patients make easy repetitive movements, (iii) Increase the speed of recovery, where researcher [12] made a preliminary ranking exercise for the treatment of osteoarthritis patients to reduce knee care through haptics feedback used behind the knees and legs in various parameters of kinematic forces involving a combination of kinematic changes in the tibial angle, foot development, and the angle of the stem drum. The results of the investigation may be an option to reduce the knee pains, (iv) Training tool for the post-stroke recovery, where researcher [19] made virtual reality and haptics as a training tool for post-stroke recovery which the results of improved studies were found to be in good manual dexterity and grip power in activities that were previously impossible to do, and (v) Simulation tool before the surgery, where researcher [20] realized a simulation of cutting teeth operation using haptic displays and microcomputers before performing dental surgery whose results are stable and realistic in one dimension and may be extended to three dimensions. Of the few studies gathered about haptics feedback potentials in the field of health, studies that focus on haptics feedback for heart disease monitoring is still lacking.

Based on research [16, 17, 18], haptics interface is part of the haptics mechanism and it consists of: (i) haptic interface, (ii) sensor, (iii) haptic rendering, and iv) actuators. Sensor works to detect information provided by user's finger through haptics interface and send it to haptics rendering. It then performs algorithm conversion process obtained from sensor containing patient health information and the last actuator displays it through the haptics interface.

2.2. Heart disease monitoring applications and technology

There are a number of relevant past studies on heart disease monitoring applications, technology and some relevant heart disease applications on iOS, Android and other platform are also reviewed. However, very limited of these studies are focusing on the usability and haptics factors. Instead, the focus was mostly on the technological features of the heart disease monitoring factors. For example, [21] developed *Support-HF* which provides tablet computers for heart patients that are available commercially to monitor blood pressure and heart rate, weight, and pulse oximeter for oxygen saturation measurement. Another, researcher came up with *HeartMapp* as a point of monitoring system to connect between patients and care providers on self-care and monitoring and improve communication with the providers [22]. [23] built *CHWs*, covers blood pressure monitoring, body mass index and weight. Meanwhile, researcher [24] developed *CONNECT*, covers to heart record, diagnosis of heart disease risk and its treatment. [25] developed *Mobile Pulse Waveform Analyzer* to cardiovascular health monitoring based on electrocardiogram (EKG), blood pressure and weight. Lastly, [26] built a Mobile Machine-Learning Model for Monitoring Cardiovascular Disease (M4CVD) specifically for mobile devices that facilitate the monitoring cardiovascular disease.

Table 1. Previous Researchers and Available Applications on iOS, Android others Platform for Heart Disease.

Researchers / Developer	Application	Usability Factors	Haptics Factor	Platform
[21]	The Support-HF	Ease of use	Touch	Android
[22]	HeartMapp	Ease of use and flexibility	Touch and Color	Android
[23]	CHWs	Ease of use and efficiency	Touch	The online CommCareHQ platform
[24]	CONNECT	Flexibility	Touch	Multi Platform
[25]	Mobile Pulse Waveform Analyzer	Efficiency	Pressure and Vibration	iOS and Android
[26]	M4CVD	Efficiency	Just Concept	A commercial wearable
Sung Do Kim	Cardiac Diagnosis	Ease of use	Touch and Color	Android (free)
BigBig Studio	iCare Health Monitor	Ease of use and flexibility	Touch and Pressure	Android (free)
PVDApps	Heart Rate Plus	Ease of use	Touch	iOS and Android (free)

Based on the findings summarized in Table 1, previous researchers and available applications on iOS, Android and others platform are not considering the usability factors and haptics elements in their mobile applications.

2.3. Usability factors

Usability is defined as measurement of the quality of a user's experience when interacting with a product or system [27, 28]. While, ISO 9241-11 defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction, in a specified context of use [29]. Usability factors for this research extends [29] standard definition of usability to include ease of use, ease of learning and attitude of users as illustrated in Fig. 1.

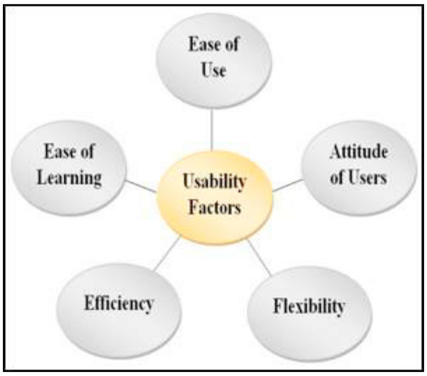

Fig. 1. The Common Usability Factors Identified from the Literature [30].

According to some researchers such as [31], ease of use is the extent to which a person believes that using a particular technology will require as less effort as possible (i.e., cognitive and physical efforts in learning how to use the system). [32] argues that ease of use is which an invention is seen as being not too difficult to understand, learn or operate while [33] claims that interaction with the system is easy when getting the system to do what is required. [21] apply the aspect of ease of use into health monitoring applications and define ease of use as the application be easier to use by patients and doctors when compared to other applications. Ease of learning is the ease with which beginner-level users can learn to interact with the system [34, 35, 36, 37, 38, 39].

Efficiency is conceptualised as the degree to which specified users can achieve specified goals with accuracy and completeness in a specified context of use [28, 34, 35, 37, 39, 40]. Flexibility on the other hand provides many ways for users and systems to exchange information [41, 42]. Lastly, attitude of users is the evaluation tso know the user's desire to use the product or not, and their satisfaction level in using the system [28, 37, 39, 43, 44]. While the discussed usability factors are not specific to heart disease applications only, they are considered relevant for this research as well. Table 2 summarizes the usability factors from the perspectives of extant studies.

Table 2. Usability Factors [30].

Usability Factors	Researchers
Ease of use	[21][31] [32] [33]
Ease of learning	[34] [35] [36] [37][38] [39]
Efficiency	[28] [34] [35] [37][39] [40]
Flexibility	[41] [42]
Attitude of Users	[28] [37] [39][43] [44]

Based on the findings summarised in Table 2, not many previous researchers have used all the five factors in studying about usability. Thus, to make the study on usability factors on heart disease mobile applications more holistic and comprehensive, this research intends to integrate as many as possible usability factors. However, due to space limitations, this paper will cover only five of the usability factors.

3. The proposed integration of Haptics Tactile Feedback Model into Heart Disease Monitoring mobile applications

Based on the literature review findings presented in the previous section, this part of the paper discusses and proposes on how haptics tactile feedback can be integrated into the heart disease monitoring mobile applications in order to improve usability of application. The proposed haptics tactile feedback model, adapted and updated from [30] had three key components: (i) input components consists of haptics interface, (ii) process components (i.e. the haptics factor) consists of sensors, haptics rendering, and actuator, and (iii) output components of the haptics tactile feedback consists of vibration, color, and information and usability factors (ease of use, ease of learning, efficiency, flexibility, and attitude of users). The proposed haptics tactile feedback model in heart disease monitoring mobile application is shown in Fig. 2.

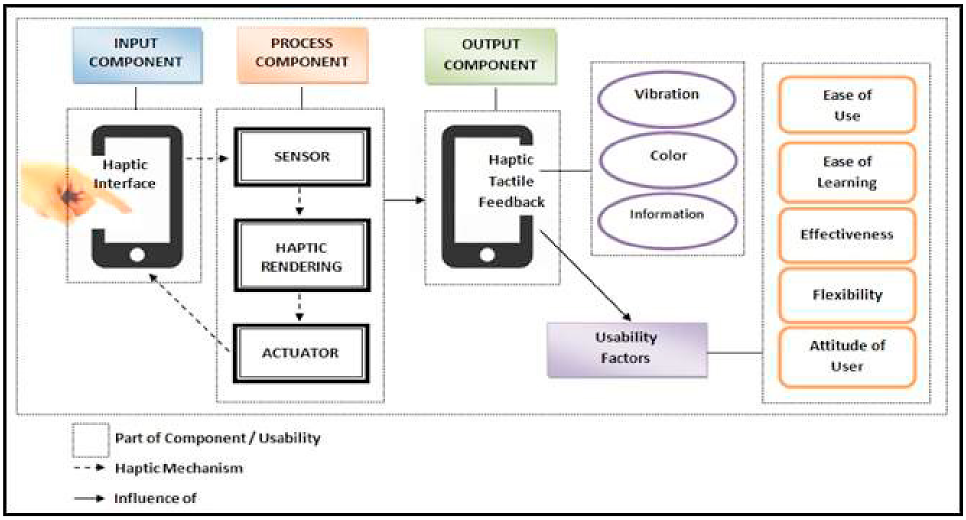

Fig. 2. The Proposed Haptics Tactile Feedback Model in Heart Disease Monitoring Mobile Application.

3.1. Haptics interface as input components

The input component for heart disease monitoring mobile application users will consist of a haptics interface. Application that will be built later using haptics tactile feedback by utilizing existing media of smartphone are camera and flash called photoplethysmography (PPG) capable to capture regular or irregular waveform output as captured by the device from users finger for heart rate monitoring [45]. This haptics interface consists of haptics devices and software-based computer control mechanisms. Based on research [16, 17, 18], haptics interface is part of the haptics mechanism and it consists of: (i) haptic interface, (ii) sensor, (iii) haptic rendering and iv) actuators as shown in Fig.2 using dash arrows. In addition to the touch, patients can also check their health by filling out the symptom-based checklist experienced to further obtain information before meeting their cardiologist for further medical checkup.

3.2. Process components

After users (heart disease patients) touched their finger into the haptic device via the haptics interface, the sensor based on the research [16, 17, 18] sensor works to detect information provided by users finger through haptics interface and send it to haptics rendering. It then performs algorithm conversion process obtained from sensor containing patient health information and the last actuator displays it through the haptics interface to the users in the form of vibration when moving to another a display, there is pressure when measuring e.g., heart rate and blood pressure, there is touch in each parts of the application, and there is difference in each parts of the application when in touch.

3.3. Output components

This paper proposes haptics tactile feedback model which gives feedback on vibration after the users (i.e., the heart disease patient) presses the button between the interface of haptics and accepts the reply in the form of color information (red, orange or green) of blood pressure and heart rate. Besides that, the patients will also get information in the form of vibrations featuring reminder alert to take medicine on time, and reminder alert to notification to complete the schedule to meet their cardiologist. For example, if a patient gets a red color indication, it could mean the system has detected sickness and thus, an urgent notification to seek immediate treatment will be pushed to the patient. If the notification turns to orange color, this could mean the patients to be cautious, restful and take the prescribed medicines. When a green notification is produced, it means a positive health indication and ask the patient to maintain their health, monitor their intake of food and continue taking the medicine. Thus, the form records that are reserved using the haptics tactile feedback will be able to enhance the usability factor that is compatible with the users to monitor the heart's own health.

4. Conclusion

This paper proposes how applying haptics tactile feedback model to enhance the usability of heart disease monitoring mobile applications for heart disease patients. By applying tactile feedback to enhance usability in the design of heart disease monitoring mobile applications, it can potentially increase the level of usability of the heart disease monitoring mobile applications by heart disease patients and their cardiologists. This research contributes to the knowledge of the application of haptics tactile feedback to enhance the usability in heart disease monitoring mobile applications that is currently understudied. The limitation of this research is that the proposed model has yet to be validated by the heart patients and cardiologists. Future research will follow Design Science Research (DSR) methodology and could embark on validating the proposed model by conducting empirical data collection to understand how and where patients require haptics tactile feedback in their heart disease monitoring mobile applications. In addition, a prototype will also be built based on the proposed model in order to evaluate and verify the suggested solutions.

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References

[1] Mathers, Colin D., Alan D. Lopez, and Christopher J. L. Murray. (2006) “Chapter 3: The Burden of Disease and Mortality by Condition : Data, Methods, and Results for 2001”, in *Global Burden of Disease and Risk Factors* **2003**: 45–93.

[2] Mozaffarian, Dariush, Emelia J. Benjamin, Alan S. Go, Donna K. Arnett, Michael J. Blaha, Mary Cushman, Sandeep R. Das, Sarah de Ferranti, Jean-Pierre Després, Heather J. Fullerton, Mark D. Huffman, Virginia J. Howard, Carmen R. Isasi, Monik C. Jiménez, Suzanne E. Judd, Brett M. Kissela, Judith H. Lichtman, Lynda D. Lisabeth, Simin Liu, Rachel H. Mackey, David J. Magid, Darren K. McGuire, Emile R. Mohler III, Claudia S. Moy, Paul Muntner, Michael E. Mussolino, Khurram Nasir, Robert W. Neumar, Graham Nichol, Latha Palaniappan, Dilip K. Pandey, Mathew J. Reeves, Carlos J. Rodriguez, Wayne Rosamond, Paul D. Sorlie, Joel Stein, Amytis Towfighi, Tanya N. Turan, Salim S. Virani, Daniel Woo, Robert W. Yeh, and Melanie B. Turner. (2016) “Heart Disease and Stroke Statistics—2016 Update.” *American Heart Association* **133(4)**.

[3] Homenta, and Rampengan Starry. (2014) *The Book of Practical Cardiology*, Jakarta, Fakultas Kedokteran Universitas Indonesia.

[4] Wolters, Frank J., Reffat A. Segufa, Sirwan K. L. Darweesh, Daniel Bos, M. Arfan Ikram, Behnam Sabayan, Albert Hofman, and Sanaz Sedaghat. (2018) “Coronary Heart Disease, Heart Failure, and the Risk of Dementia: A Systematic Review And Meta-Analysis.” *Alzheimer’s Dement,* 1–12.

[5] Pina, Ileana L., Nihar R. Desai, Larry A. Allen, and Paul Heidenreich. (2018) “Managing the Economic Challenges in the Treatment of Heart Failure.” *Progress in Cardiovasc Diseases.*

[6] Anshari, Muhammad, and A. Mohammad Nabil. (2016) “Mobile Health (mHealth) Services and Online Health Educators.” *Biomed. Inform. Insights*. pp. 19–28.

[7] Zahra, Fatima, Azham Hussain, and Haslina Mohd. (2018) “Factors Affecting Mobile Health Application for Chronic Diseases.” *J. Telecommun. Electron. Comput. Eng* **10 (1)**: 77–81.

[8] Athilingam, Ponrathi, Miguel A. Labrador, Elizabeth Frances J. Remo, Lauren Mack, Alyanna Bianca San Juan, and Amanda F. Elliott. (2016) “Features and Usability Assessment of a Patient-Centered Mobile Application (Heartmapp) for Self-Management of Heart Failur.” *Applied Nuring. Research* **32**: 156–163.

[9] Sobri, Muhammad, Mohamad Taha Ijab, and Norshita Mat Nayan. (2018) “Systematic Literature Review to Develop an Application to monitor Cardiovascular Health Status.” *Jurnal Rekayasa Sistem dan Teknologi Informasi* **2 (2)**: 458–464.

[10] Bonanni, Leonardo, Cati Vaucelle, Jeff Lieberman, and Orit Zuckerman. (2006) “TapTap: A Haptic Wearable for Asynchronous Distributed Touch Therapy.” *in CHI* **2006**: 580–585.

[11] Kapur, Pulkit, Sunthar Premakumar, Steven. A. Jax, Laurel J. Buxbaum, Amanda M. Dawson, and Katherine J. Kuchenbecker. (2009) “Vibrotactile Feedback System for Intuitive Upper-Limb Rehabilitation.” *Proc. - 3rd Jt. EuroHaptics Conf. Symp. Haptic Interfaces Virtual Environ. Teleoperator Syst. World Haptics* **2009**: 621–622.

[12] Pete B. Shull, Kristen L. Lurie, Mark R. Cutkosky, and Thor. F. Besier. (2011) “Training Multi-Parameter Gaits to Reduce the Knee Adduction Moment With Data-Driven Models and Haptic Feedback.” *Journal Biomech* **44 (8)**: 1605–1609.

[13] Rabin, Ely, Jason Chen, Lisa Muratori, Joanne DiFrancisco-Donoghue, and WilliamG. Werner. (2013) “Haptic Feedback from Manual Contact Improves Balance Control in People With Parkinson’s Disease.” *Gait Posture* **38(3)**: 373–379.

[14] Kitchenham, Barbara. (2004) “Procedures for Performing Systematic Reviews.” *Keele, UK, Keele Univ 33(TR/SE-0401)*. p. 28.

[15] Hosoya, Ding, and Kamioka (2017) “A Bibliographic Network Analysis of Big Data Literature.” *in PACIS 2017 Proceedings.*

[16] Abdulmotaleb, El Saddik. (2007) “The Potential of Haptics Technologies.” *IEEE Instrumentation and Measurement Magazine* **10 (1)**: 10–17.

[17] Alur, Anupam, Pratik Shrivastav, and Aditya Jumde. (2017) “Haptic Technology: A Comprehensive Review on its Applications And Future Prospects.” *International Journal Computer Science Information Technologies* **5 (5)**: 6039–6043.

[18] Arulmozhi, and Ayesha. (2017) “Emerging Haptics Technology and its Applications,” *International Journal of Advanced Research Trends in Engineering and Technology* **4 (4)**: 96–103.

[19] Broeren, Jurgen, Martin Rydmark, and Katharina Stibrant Sunnerhagen. (2004) “Virtual Reality and Haptics as a Training Device for Movement Rehabilitation After Stroke: A Single-Case Study.” *Arch. Phys. Med. Rehabil* **85 (8)**: 1247–1250.

[20] Wang, Daniel, Yuru Zhang, Yuhui Wang, Yuan-Shin Lee, Peijun Lu, and Yong Wang. (2005) “Cutting on Triangle Mesh: Local Model-Based Haptic Display for Dental Preparation Surgery Simulation.” *IEEE Trans. Vis. Comput. Graph,* **11 (6)**: 671–682.

[21] Triantafyllidis, Andreas, Carmelo Velardo, Tracey Chantler, Syed Ahmar Shah, Chris Paton, Reza Khorshidi, Lionel Tarassenko, and KazemRahimi. (2015) “A Personalised Mobile-Based Home Monitoring System for Heart Failure: The SUPPORT-HF Study.” *International Journal of Medical Informatics* **84 (10)**:743–753.

[22] Athiligam, Ponrathi, Bradlee A. Jenkins, Heather Zumpano, and Miguel A. Labrador (2018) “Mobile Technology To Improve Heart Failure Outcomes: A Proof of Concept Paper.” *Applied Nursing Research* **39**:26–33.

[23] Surka, Sam, Sisira Edirippulige, Krisela Steyn, Thomas Gaziano, Thandi Puoane, and Naomi Levitt. (2014) “Evaluating the Use of Mobile Phone Technology to Enhance Cardiovascular Disease Screening by Community Health Workers.” *International Journal of Medical Informatics* **83 (9)**: 648–654.

[24] Neubeck, Lis, Genevieve Coorey, David Peires, John Mulley, Emma Heeley, Fred Hersch, and Julie Redfern (2016) “Development of an Integrated E-Health Tool For People With, or at High Risk of, Cardiovascular Disease: The Consumer Navigation of Electronic Cardiovascular Tools (CONNECT) Web Application.” *International Journal of Medical Informatics* **96**: 24–37.

[25] Li, Bing Nan, Bin Bin Fu, and Ming Chui Dong. (2008) “Development of A Mobile Pulse Waveform Analyzer For Cardiovascular Health Monitoring.” *Computers in Biology and Medicine* **38 (4)**: 438–445.

[26] Boursalie, Omar, Reza Samavi, and Thomas E. Doyle (2015) "M4CVD: Mobile Machine Learning Model for Monitoring Cardiovascular Disease." *Procedia Computer Science* **63**: 384–391.
[27] Russ, Alissa L., Rollin J. Fairbanks, Ben-Tzion Karsh, Laura. G. Militello, Jason J. Saleem, and Robert L. Wears. (2013) "The Science of Human Factors: Separating Fact from Fiction." *BMJ Quality & Safety* **22 (10)**: 802–808.
[28] Kaufman, David R., Vimla L. Patel, Charlyn Hiliman, Philip C. Morin, Jenia Pevzner, Ruth S. Weinstock, Robin Goland, Steven Shea, and Justin Starren. (2003) "Usability in the Real World: Assessing Medical Information Technologies in Patients' Homes." *Journal of Biomedical Informatics* **36 (1–2)**: 45–60.
[29] International Standards Organization. (1994) "Ergonomic Requirements for Office Work with Visual Display Terminals. Part 11: Guidance On Usability (ISO DIS 9241-11)." *ISO DIS 92.* London: International Standards Organization.
[30] Sobri, Muhammad, Mohamad Taha Ijab, and Norshita Mat Nayan. (2018) "The Usability Factors of Cardiovascular Health Monitoring Mobile Application : A Conceptual Model." *in Digital Transformation Landscape in the Fourth Industrial Revolution (4IR) Era*, 80–90.
[31] Davis, Fred. (1989) "Perceived Usefulness , Perceived Ease of Use , and User Acceptance of lnformation Technology," *MIS Q*, **13(3)**: 319–340.
[32] Everett M, Rogers. (1995) "Diffusion of Innovations." *Macmillian Publishing Co.*
[33] Nelson, Jacob. (2006) "Factors of Online Learning Adoption: A Comparative Juxtaposition of the Theory of Planned Behaviour and the Technology Acceptance Model." *International Journal E-Learning* **5 (4)**.
[34] Abran, Alain, Adel Khelifi, Witord. Suryn, and Ahmed Seffah. (2013) "Usability Meanings and Interpretations in ISO Standards." *Software Quality Journal* **11 (4)**: 325–338.
[35] Booth, Paul A.(1989) "An Introduction to Human-computer Interaction." *New York: Pcychology Press.*
[36] Hix, Debora, and H. R. Hartson. (1993) "Developing User Interfaces: Ensuring Usability Through Product & Process." *1st ed. Wiley.*
[37] Nielsen, Jacob. (1993) *Usability Engineering*. San Francisco: Morgan Kaufman.
[38] Elizabeth, De Fortaleza, Mattos, and Vanderdonckt. (2003) "Improving Usability of an Online Learning System by Means of Multimedia, Collaboration and Adaptation Resources", in *Usability Evaluation of Online Learning Programs,* USA: Information Science Publishing. pp. 68–85.
[39] Jeng, Judy. (2015) "Digital Libraries : Effectiveness, Efficiency, Satisfaction, and Learnability." *Assessment* **55**: 96–121.
[40] Miler, Aaron S., Joseph A. Cafazzo, and Emily Seto. (2014) "A game Plan: Gamification Design Principles in Mhealth Applications for Chronic Disease Management." *Health Informatics Journal* **22 (2)**: 184–193.
[41] Dumas, Joseph S., Redish, and Lewis. (1999) "A Practical Guide to Usability Testing."
[42] Vest, Joshua R., and Larry D. Gamm. (2010) "Health Information Exchange: Persistent Challenges and New Strategies." *J. Am. Med. Informatics Assocc* **17 (3)**: 288–294.
[43] Shackel, Brown. (1991) "Usability-Context, Framework, Definition, Design and Evaluation." *New York: Cambridge University Press.*
[44] Kengeri, Rekha, Cheryl D. Seals, Hope D. Harley, Himabindu P. Reddy, and Edward. A. Fox. (1998) "Usability study of digital libraries: ACM, IEEE-CS, NCSTRL, NDLTD." *International Journal on Digital Libraries* **2 (2–3)**: 157–169.
[45] White Ryan D., and Greg Flaker. (2017) "Smartphone-Based Arrhythmia Detection: Should We Encourage Patients to Use The ECG in Their Pocket?" *Journal of Atrial Fibrillation* **9 (6)**: 1–4.