Designing and Testing a Continuous Blood Pressure Monitor

(Technical Topic)

Social Forces Shaping the Adoption of Mobile Health Technologies and Health Literacy

(STS Topic)

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On my honor as a student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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INTRODUCTION

Innovations in the health-monitoring technologies have the potential to greatly enhance people's knowledge of their health and decrease rates of cardiovascular disease. In the context of medicine, they can provide clinicians with better tools to help their patients, and for the patients, they can facilitate connection and improve their abilities to make health-related decisions. Despite technical advancements, social forces seem to be the most prominent factors facilitating and holding up the adoption of new health technologies, which occurs largely due to the competing interests of different people with different visions for technologies and different perspectives on their importance.

The technical project aims to design and validate a blood-pressure monitoring device providing more accurate, comprehensive, and accessible data about individuals' cardiovascular health, and the STS project aims to explore the connections between the development of mobile health technologies, health literacy, and rates of cardiovascular disease in the U.S.

TECHNICAL TOPIC: AN IMPROVED BLOOD PRESSURE MONITOR

The Problem

In the United States, nearly 50% of adults have been diagnosed with chronically high blood pressure, or "hypertension", yet only about a quarter of them get properly treated for it, and many more experience it without knowing [3]. Hypertension can subtly damage the body for many years before clear signs and symptoms- such as heart failure, stroke, or dementia- emerge, so it is crucial to accurately recognize it as early as possible [8]. The current standard for blood pressure and heart rate monitoring involves trained medical professionals performing manual spot checks by hand. Unfortunately, these methods often yield results of limited accuracy and often miss underlying problems. For example, the settings they are conducted in can provoke

"White Coat Syndrome"- the tendency of patients to get nervous and experience rises in blood pressure while at the doctor's office, thereby making results less reflective of actual health. Furthermore, they cannot get accurate readings during movement, and can only measure over brief periods of time, which limits their applicability to day-to-day situations and provides limited insight into longer term patterns. Overall, enhanced blood pressure monitoring could lead to earlier diagnoses of cardiovascular problems, educate patients and practitioners more thoroughly, and facilitate connection between individuals and their health care, all of which ultimately serves to improve people's cardiovascular health and well-being.

Project Description

The technical project involves machine learning and medical study design to refine and test a continuous blood pressure monitor to be used at hospitals and people's homes. This work- an instance of rapidly developing health monitoring technologies- aims to provide a technological solution to unsatisfactory blood pressure monitoring. Project deliverables include a successful IRB application for a human subjects study, machine learning algorithms, and fully-analyzed data that either confirms or rejects the novel device's equivalence to an established blood pressure monitor. Ultimately, the project aims to address the important challenges of managing and preventing hypertension.

The novel blood pressure monitor has already been physically designed: it has a wrist unit, a "master" chest unit, and electrodes that connect to the user's heart area. The electrodes pick up electrical signals from the pulse in the wrist and the heart beating, which the overall system integrates, providing data that can be easily analyzed with our machine learning algorithm (to be discussed later). Major innovations of this device include its ergonomics and low sensitivity to motion artifacts; it is lighter and more portable than current blood pressure monitors, and it allows for more freedom of movement. These factors should reduce the burden on people wearing blood pressure monitors in their day-to-day lives and encourage more widespread use of continuous-monitoring technologies.

The machine learning aspect involves creating algorithms to analyze the frequency waves obtained by the device- which are directly based on heart rate- convert them into usable information about blood pressure. The algorithm, which is in the early stages of being developed, will take advantage of the proportionality between heart rate and blood pressure and seek to account for heart rate variability, short-term fluctuations in heart rate that complicate the correlation between heart rate and blood pressure. When applied to data collected by the device's wrist and chest units, it ought to provide an accurate picture of a person's blood pressure trends under a variety of scenarios (i.e. when sitting, standing, lying down, or performing light to moderate exercise). The code we develop and use will serve as a deliverable at the end of next semester.

We plan on testing the device on twenty to thirty young, healthy adults. Participants will be tested across a range of conditions, including sitting still, standing, and during different stages of exercise to test the device's accuracy across conditions. We will compare measurements made by the experimental device to measurements made by an approved device assumed to accurately measure blood pressure. We will set up an equivalence interval and use equivalence testing to verify the new device's accuracy. If the device "passes" this equivalence testing, it will move one important step closer towards being widely used to help patients manage and prevent hypertension. We have already applied for IRB approval, the decision for which is expected over winter break, and we plan on beginning testing in January and finishing by the end of February.

STS TOPIC: TECHNOLOGY, LITERACY, AND HEALTH

Overview

The thesis will explore the growth and innovation of mobile health technologies with respect to effects on health literacy and rates of cardiovascular disease. The research focuses on cardiovascular disease as the health problem and health literacy improvements as a primary means of connecting technical innovation to better health outcomes, which ought to provide valuable insight despite the limited scope. The Social Construction of Technology framework- with its emphasis on design variability and conflict arising from competing interests among social groups- provides the ideal tools for analysis of the social factors underlying the technological developments and their adoption. The guiding research questions are two-fold: "what social factors facilitate and act as barriers to the widespread adoption of mobile health tools?" and "how can advancements in mobile health technologies improve overall health literacy and decrease rates of cardiovascular disease?". There are three main areas of focus for gathering research: the problem of hypertension in the U.S. and associated cardiovascular diseases, the development of mobile health tools as driven by social forces as part of a solution to the problem, and health literacy rates in the U.S.- which have been correlated with less disease and better health.

The Social Construction of Technology (SCOT)

The Social Construction of Technology (SCOT) describes the principles needed to analyze technological successes and failures from a social perspective, and it puts forth a methodology for this analysis. Generally, it asserts that technological innovation is a complex process wherein various social groups negotiate the meanings, importance, and utility of new technologies. It emphasizes looking to the social world to understand how and why technologies fail and succeed, holding that “technological determinism” is a myth resulting from the tendency of people to look backwards and believe that the actual path taken to the present was the only one possible [18]. The research methodology involves three general stages. The first stage involves reconstructing alternative interpretations of a technology, analyzing the problems the alternatives provoked, and connecting the problems to design features. The second stage demonstrates how closure- or the decline in interpretive and design flexibility- occurs as technologies either stabilize or become obscure. The third stage involves extrapolating technological designs to broader socio-political contexts [18].

SCOT was motivated by ideas of the Strong Programme of the Sociology of Scientific Knowledge, which holds that both accepted and rejected scientific theories and innovations should be recognized as products of social conditions, such as cultural context and self-interest [13]. This “Principle of Symmetry”, which acknowledges social forces on both successful and failed theories, became arguably the central tenet of SCOT. Furthermore, the strong programme holds that all human knowledge- as something that exists in human cognition- must have been influenced by social forces in its development; this concept is central to the Sociology of Scientific Knowledge itself [18].

Key tenets of SCOT include the “Principle of Symmetry”, “Interpretive Flexibility”, and “Closure”. Interpretive flexibility suggests that different social groups- “relevant social groups”- will interpret the meanings of new technologies differently [18]. These differing interpretations generate different problems to be solved, which can give rise to a multitude of competing designs. These competing designs and the array of possibilities not realized- formally termed “design flexibility”- can give rise to conflicts that are difficult to resolve technically. If people’s values misalign enough or directly oppose one another, conflicts can become personal.

Therefore, to ease the problems and conflicts arising from design flexibility, we must look to common values and analyze how social structures shape demand for innovations. Finally, closure refers to the collapse of interpretive and design flexibility over time as technologies develop. Closure mechanisms are not permanent: new social groups can reintroduce interpretive flexibility and spark more debate and innovation with respect to a technology [18].

Alignment of Mobile Health Tool Adoption with SCOT

Mobile health, also termed eHealth, has been defined by the World Health Organization as medical and public health practice supported by mobile devices", which includes cell phones, tablets, and patient monitoring devices [16]. Mobile health tools- applications that support mobile health and its aims- support individuals' abilities to monitor their own health and include apps used for recording fitness data (such as the "Health" app for iOS devices) and mobile heart rate monitors (such as those implemented in Apple watches). Mobile health has particular potential to benefit people in rural communities who have less access to actual medical facilities than their urban counterparts. Regardless of geography, mobile health tools can help put health considerations more at the forefront of people's minds and improve clinician's abilities to communicate with their patients.

Social factors heavily influence medical technologies due to the complexity of designs and the rigor of regulations. Regarding the Principle of Symmetry, similar social factors cause certain technologies to flourish and lead others to fade out or never catch hold. Regarding interpretive flexibility, a plethora of medical devices have highly complex designs, inevitably leading to a multitude of opinions on how the technologies should be used, how they should be brought to the public, and how they could be improved. Relevant social groups include patients, medical practitioners, medical device companies, and regulatory agencies. Each of these broad groups views medical technologies through a different lense, and there is much diversity within them. This creates conflict between individuals and organizations with differing values and visions for a particular device or the medical field as a whole. Furthermore, there are objectively many ways to construct a device to perform a medically-related task- such as record blood pressure or respiration over time. Regarding closure, many medical technologies no longer generate debate or are subject to design changes. This can result from newer, more effective alternatives taking their place or other social or market-related dynamics that cause them to become obscure.

Regarding mobile health tools, socioeconomic barriers heavily influence rates of technology adoption, even more so than technical forces. For example, efforts to make new mobile health technologies universal have provoked tension in the health care community, especially in the context of scarce resources, because of unequal access to health care within the population and sometimes conflicting interests between clinicians and device innovators [4]. If a technology allows more people access to a health service, it tends to proliferate, whereas if it becomes too restricted to a select few, it tends to not become popular in the near term until it becomes more cost-effective. This exemplifies the Principle Symmetry in that the same type of explanation (related to universality of access and cost-effectiveness) causes medical technologies to have more or less success in clinical practice. Also, the tension between different companies, researchers, clinicians, and the public- an example of interpretive flexibility- gives rise to multiple competing designs. For instance, wireless upper arm cuffs, hypertension apps, and cuffless blood pressure devices all seek to provide technical solutions to improving blood pressure monitoring, yet they inevitably compete with one another and are driven by social forces [6].

Research Methods

I plan to delve into modern literature on adoption of mobile health technologies, health literacy, and effects on cardiovascular disease. Numerous researchers have synthesized research on these and related topics, which will be useful for the thesis.

First, it seems important to describe new technological advancements aimed at improving the detection of hypertension and the important insights and questions from recent reviews. A 2016 paper discusses privacy, accuracy, and cost concerns as barriers to the widespread adoption of wearable blood pressure trackers and mobile health tools, despite strong interests from clinicians and patients because of their potential to improve hypertension control and medication adherence [6]. Similarly, a 2019 review paper discusses how emerging technologies might support the improved detection and management of hypertension, citing that several studies have shown benefits associated with tele-monitoring coupled with co-intervention [10]. It seems that mobile health tools have much promise but the speed of advancements have outpaced society's ability to adapt, and along with competing interests, has made their benefits uncertain.

Next, it makes sense to look to research on social factors affecting the adoption of mobile health tools. A 2013 review discusses the challenges associated with providing universal access to health care due to different stakeholders having different and sometimes competing interests- a central issue [4]. For example, manufacturers want to be adequately rewarded for their innovations and seek funds to further research efforts, policy makers have tightly regulated programs for assessing technology which often restrict access to care, and, most importantly, patients perceive the immense benefits mobile health technologies could have and feel concerned about being denied access to them [4]. A second review cites the evidence supporting the ability of mobile health tools to reduce health care costs, enhance access, and improve the quality of patient care, acknowledging that a deeper understanding of the factors impacting adoption of such technologies is crucial for success [9].

Health literacy must also be addressed directly with reference to groups at particularly high risk for developing cardiovascular disease. Our rapidly aging population presents numerous challenges to optimally supporting its needs, and improving health literacy serves as a key part of this support [11]. The American Heart Association defines health literacy as "the degree to which individuals are able to access and process basic health information and services and thereby participate in health-related decisions" [15]. It has been established that limited health literacy is highly prevalent in the United States and strongly associated with patient morbidity, mortality, healthcare use, and costs [15]. Factors affecting health literacy include education, socioeconomic status, ethnicity, and geographic location, which interrelate with one another [1, 14]. If someone has less education with respect to health-related terminology, they are less likely to be able to understand the terminology used by their doctors or take initiative in their own lives to adopt healthier habits or follow a medication regimen properly. Similarly, people of lower socioeconomic status and minorities typically receive less health-related education and typically have less access to resources (including books and mobile technologies) that would promote learning and better health literacy.

Despite their potential to drastically improve access to health information, mobile health technologies could cause more harm than good if not developed and used properly. Therefore, research on improper usage and other potential consequences of the technology must be considered as well. Since they collect sensitive personal information and require certain levels of education and wealth to obtain and use properly. Technology developers must prioritize data privacy to prevent hackers from gaining access to others' medical records and using the information in harmful ways. Therefore, preventative measures must be taken to secure people's medical records and associated information once they are collected. Also, mHealth technologies require access to technology that not everyone can afford, and not everyone who has access to such technologies knows how to use them or what the benefits could be. Thus, unequal access could create a deeper divide in health literacy rates and overall health.

Thus, low health literacy has negative consequences for cardiovascular health, since people lack the knowledge or tools to make informed decisions. Among older populations, research suggests that mobile health technologies can effectively support efforts to manage chronic conditions and improve literacy, yet other work suggests that while mobile health tools show great promise, "that promise has not been fulfilled" [5,10]. The challenge of matching technological development with the realities of illness and the social world complicates using mobile health tools widely in health care, which makes further research essential [5].

Conclusion

While technologies aimed at improving health literacy and reducing cardiovascular have demonstrated potential, relevant social factors must be better understood and integrated into strategies at harnessing them effectively. Cardiovascular disease, due to its prevalence and severe consequences, clearly needs to be better addressed by health care, and technology has provided platforms to improve people's knowledge and connection to health care providers. However, translating such innovations into better health is not always straightforward. The thesis, by exploring this connection, seeks to provide insight to facilitate the translation from mobile health tools to less cardiovascular disease and better health.

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