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Role of Consumer Electronics in Heart Disease Prediction

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Role of Consumer Electronics in Heart Disease Prediction

by

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partial fulfillment of the requirements for the degree of
Master of Science

Major: Information Systems

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ABSTRACT

Acute myocardial infarction (heart attack) is one of the deadliest disease patients face. One of every three deaths in United States is caused by heart disease. The key to cardiovascular disease management is to examine large number of datasets, compare and mine for information that can be used to predict, prevent, manage and treat heart attacks. Predictive analytics, by using Big Data analytics, is expected to help in the prediction, prevention, management and treatment of cardiovascular disease. Consumer wearable electronics has been a great provider of health-related data in past few years. The growing popularity of such devices among consumers is providing a thorough statistics of person's day to day health status. This data can be very useful is a proactive approach for heart health monitoring which would in turn avoid any danger of potential heart disease. There is a huge market for such devices which is growing at an exponential rate. Although comprehensive and scalable, the data from such devices still can not predict hear disease chances with high confidence. There is a lot to be done for the data to be able to tell accurately about complex human body. There also are some data security risks associated with the use of such devices.

The future for such devices looks very promising with the increasing sophisticated technologies making the observation more accurate and useful. The day is not far when the doctors will use smartwatch's data in their analysis to accurately predict about any impending disease.

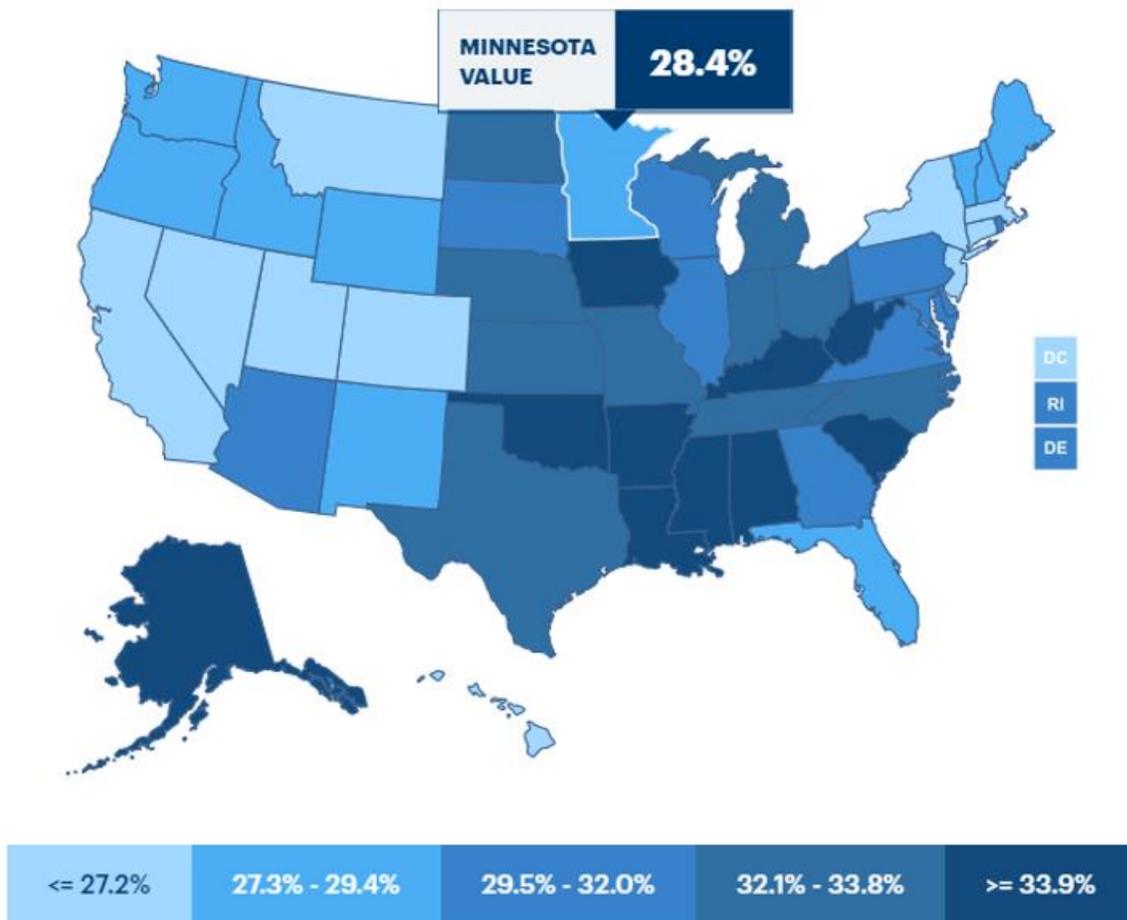
CHAPTER 1: INTRODUCTION

Heart is the most important organ of the body. It works 24*7*365 till we die, but the recent lifestyle trends and increasing environmental changes have taken a toll on the heart health in general. Heart attack was supposed to impact older age people earlier but now a days even the young males and females in their early thirties are having risk of heart attack. There are many factors which have contributed to this situation. Increased stress level, pollution, poor dietary habits, smoking, drinking alcohol and less exercise and sleep are one of those. Deteriorating Life style entails greater risk of a heart disease. The main motivation to choose this topic for me has been my personal association and attachment with the healthcare industry. Heart attack is number one cause of death in United States of America. Some scary statistics that tell how serious this is, are:

- 1 of every 3 deaths in United states is caused by heart disease.
- 99% of American need to improve their hear health.
- Each year an estimated 785,000 people will have their first heart attack
- Every 39 second someone dies from heart disease and stroke.

Following is the map of USA which tells the obesity rates among adults, state-wise:

Percentage of adults with a body mass index of 30.0 or higher based on reported height and weight



In olden days we had not much data available except that from clinical records. Acquiring data was expensive and we had limited analytical and modelling skills to make sense of the data. However, today, the situation is completely different. We have a large amount of data available on patient's health which we can make use of to study and possibly predict any impending heart disease. Data has become easily available, less expensive and includes a broader category/population of patients. We have electronic health record (EHR) available for patients.

As per the definition on web:

An electronic health record (EHR) is a digital version of a patient's paper chart. EHRs are real-time, patient-centered records that make information available instantly and securely to authorized users. While an EHR does contain the medical and treatment histories of patients, an EHR system is built to go beyond standard clinical data collected in a provider's office and can be inclusive of a broader view of a patient's care.

In this digital age, adding to the available data regarding a person's health are the electronics devices and wearables available in the market. These fitness monitors can be worn on one's wrist and are becoming widely popular among consumers especially young ones. Researchers are interested in the potential usefulness and uses of the data collected by these devices. The data obtained from such devices is thorough, scalable and arguably accurate.

Different studies have been conducted to gauge the efficacy of the data gathered from such devices, however there is still a lot to research for its usefulness with respect to predicting heart disease because getting "information" out of this huge amount of data and predict for a heart disease is a very challenging task. This is because human body is a very complex system and to predict about it from the heart-rhythm data that we get from the wearables has not been 100% possible till now. There are plenty of obstacles in this field and we are yet to reach to a point where we can confidently predict based on such data.

CHAPTER 2: LITERATURE REVIEW

Literature review was aimed at finding out the answers to below questions:

- 1: What are the modern electronics devices used to capture consumer data and how is that data used to assess customers on probable heart disease risk?
- 2: How effective are these measurements currently and what are the future developments in this field?
- 3: What are the security risks associated with the use of such devices and what is the perception of people towards such devices?

Various literature was found on the different aspects of such wearables which is discussed one by one in below sub-sections:

Consumer electronics used in data collection/ heart disease diagnoses:

There has been a surge in number of people opting for wearable smart devices lately. There are several reasons for this trend. An obvious one is that people are getting more informed about the health risks and given the unbalanced lifestyle issues, getting more and more unfit and hence feel the need of having a monitor to track their activities, calories count, and heart rate etc. Second and possibly equally prominent reason is the fashion statement and peer pressure. Companies such as Apple, Samsung and Fitbit have launched their wearable smart devices that not only record a person's health but also can virtually do all the work that a smart phone can. Moreover, these watches are trendy and stylish. People are preferring smart watches over traditional

Key Market Players:

Apple Inc., Fitbit Inc., Garmin Ltd., Adidas AG, Nike Inc., Samsung Electronics Co., Ltd., Sony Corporation, Huawei Technologies Co. Ltd., LG Electronics Inc., Motorola Solutions Inc., Fossil, Google, Misfit, Pebble tech. corp. etc.

Consumerization of cardiac monitoring: Rising Billion Dollar Industry:

A study says that 411 million smart wearable devices, worth a staggering \$34 billion, will be sold in 2020.

Furthermore, in a study by *Gartner* below statistics were predicted which shows that although Smartwatch is most-shipped wearable in currently, but we will have a new leader (hearables) in this segment by 2022. Approximately 225 Million devices are shipped worldwide currently which is expected to almost double in 3 years. This clearly shows the craze of smart devices among people.

Device	2017	2018	2019	2022
Smartwatch	41.50	53.00	74.09	115.20
Head-mounted display	19.08	28.40	34.83	80.18
Smart clothing	4.12	5.65	6.94	19.91
Ear-worn	21.49	33.44	46.12	158.43
Wristband	36.00	38.97	41.86	51.73
Sports watch	18.63	19.46	21.28	27.74
Total	140.82	178.91	225.12	453.19

Source: Gartner (November 2018)

Figure: Number of units sold by year worldwide

We can also see the global market share of for wearable device unit sale region-wise. We can see that North America will have a largest chunk of share with 40% market. Asia pacific is the second largest consumer and currently sits at almost same market share as North America.

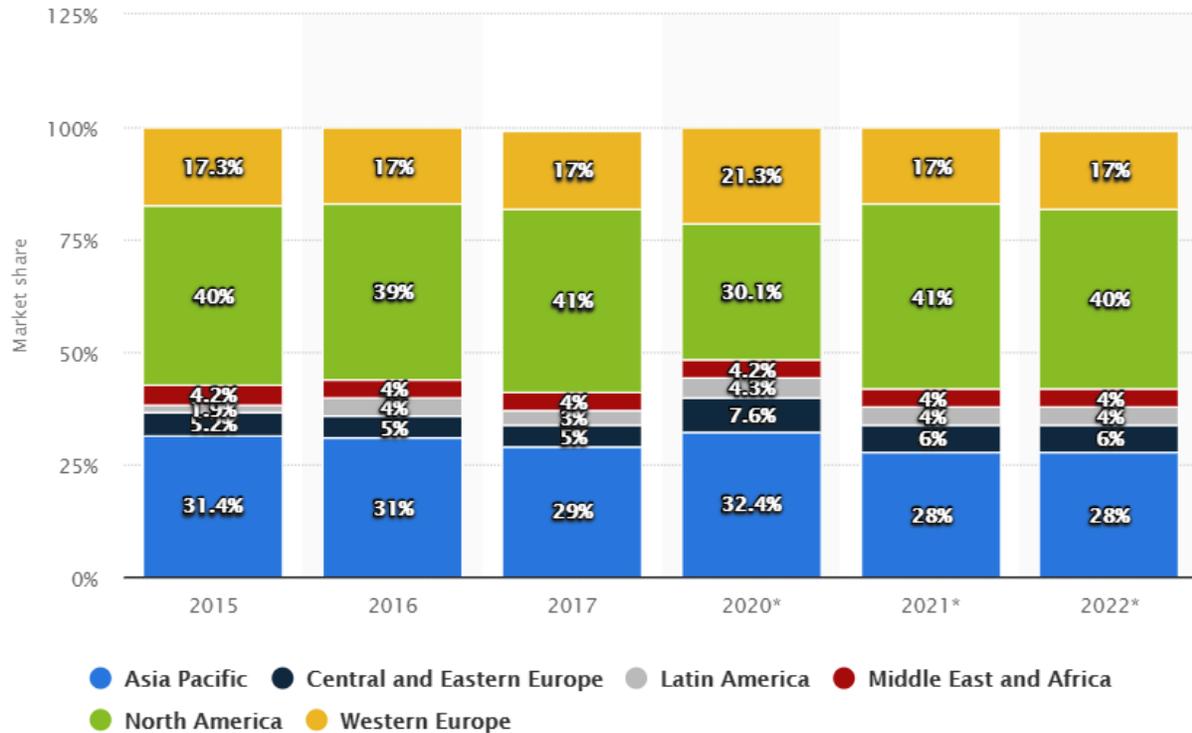


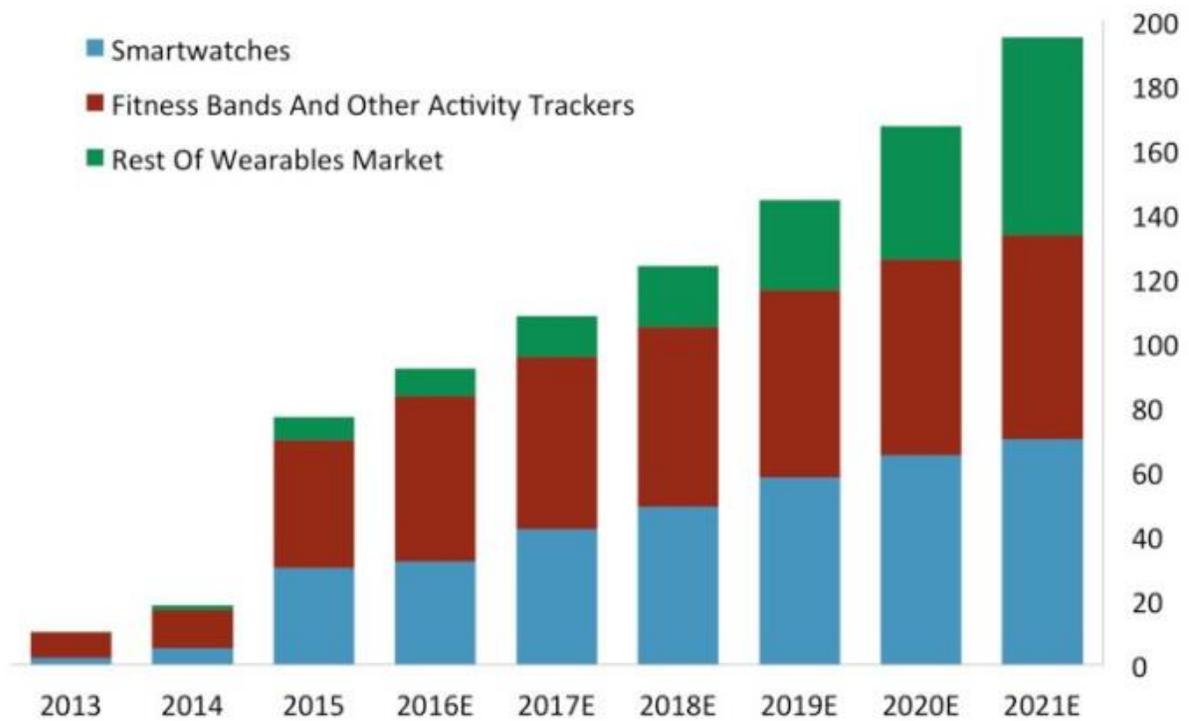
Figure: Wearable device unit sales market share worldwide

Below graph shows the global wearable forecast for number of units shipped by device type. We are comparing among three categories: Smart watches, Activity trackers and other wearables.

The graph shows that while it started with fitness bands, smart watch has quickly caught up the race and now beating fitness trackers in terms number of units old. This might be because of few reasons: One is that smart watch can do more work than fitness tracker. Other reason might be that smart watch is fashionable and trendy. One more interesting trend that we observe is that a third type of wearable which includes Hearables, Body wear, neck wear and eye wear, catching up with other 2 categories and will be a major wearable type in next 3 years. These third type of wearables are promising to collect more sensitive and accurate data.

Global Wearables Shipment Forecast, By Device

Millions



Another graph below compares worldwide unit shipments data among different vendors. We can see that while Fitbit used to be dominating brand till 2016, Apple has gained a lead and is leading this segment right now.

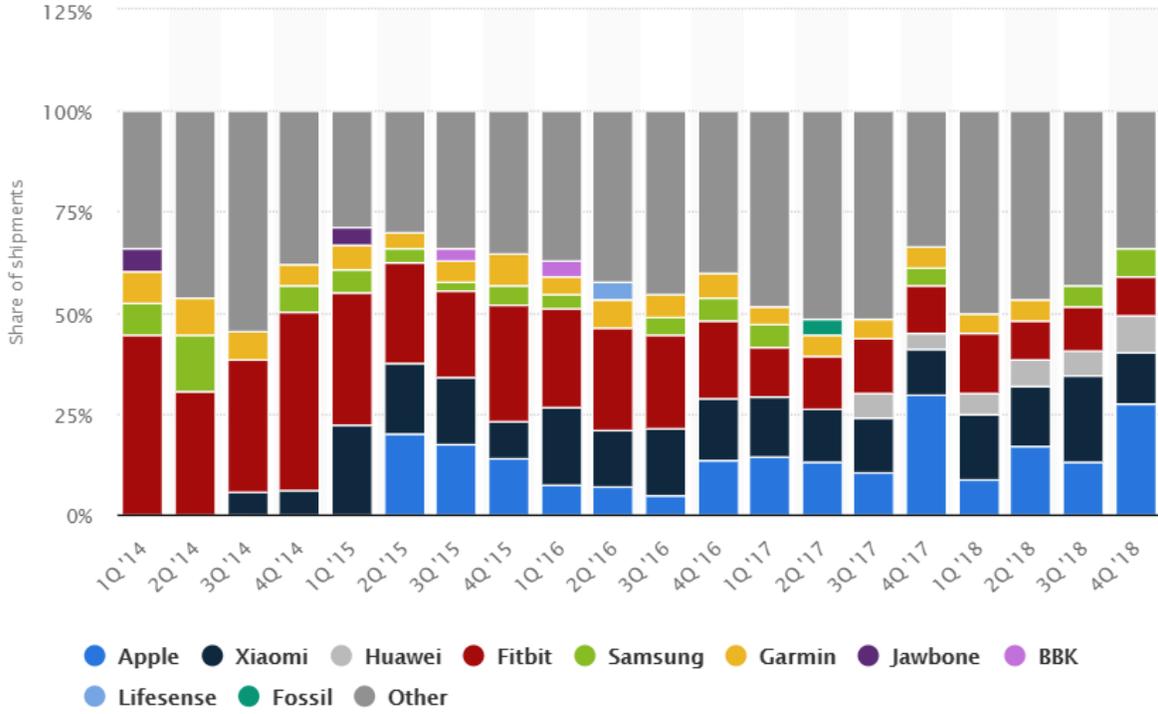


Fig: Market share of wearables unit shipments worldwide by vendor from 1Q'14 to 4Q'18

Efficacy of devices used in data collection:

Although, there are apps to measure heart rhythms and devices to measure your blood pressure and so on, the million-dollar question still remains: How reliable are these devices to be any useful in any serious prediction?

In an experiment conducted between Apple watch 3 and Fitbit charge 2, the Apple Watch 3 and the Fitbit Charge 2 provided acceptable heart rate accuracy ($\leq \pm 10\%$) across the 24 hour and during each activity, except for the Apple Watch 3 during the daily activities condition. This experiment showed that these devices can reliably be used in further research or clinical purposes.

As quoted by the who conducted the experiment:

“In theory, it will provide the ability to monitor patients in real-time manner, but we don’t yet understand how accurate this signal will be. In the past, devices like that have not been so accurate.”

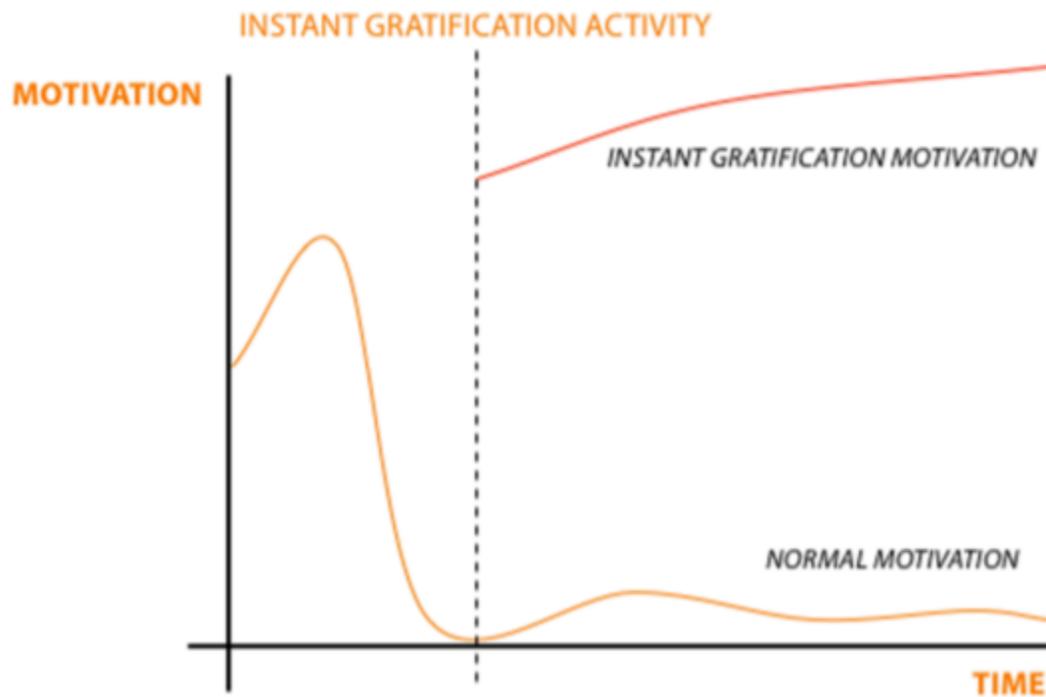
People perception of such devices:

As mentioned earlier in this article, smart wearables have brought on some behavioral changes in people and that is for the good. People are more health conscious, if they not already are, after buying such devices due to two main reasons:

1>It provides instant gratification (in terms of statistics of steps taken, floors climbed etc) for the hard work done.

2>It massages their “social ego”. Almost all of these devices give a user ability to connect to social media in some way and when people can share data with others, it “*reinforce, motivate and reward by turning exercise into a game*” (Carpio et all)

The graph below gives a clear representation on how instant gratification gives the person an impressive linear boost compared to the normal motivation without any gratification. (Carpio et al)



Even though these devices are wanted by everyone these days, their price is still out of reach for some or at least works as a deterrent to purchase. Below graph shows user satisfaction and willingness to buy in a survey (**Yuxi et al**)

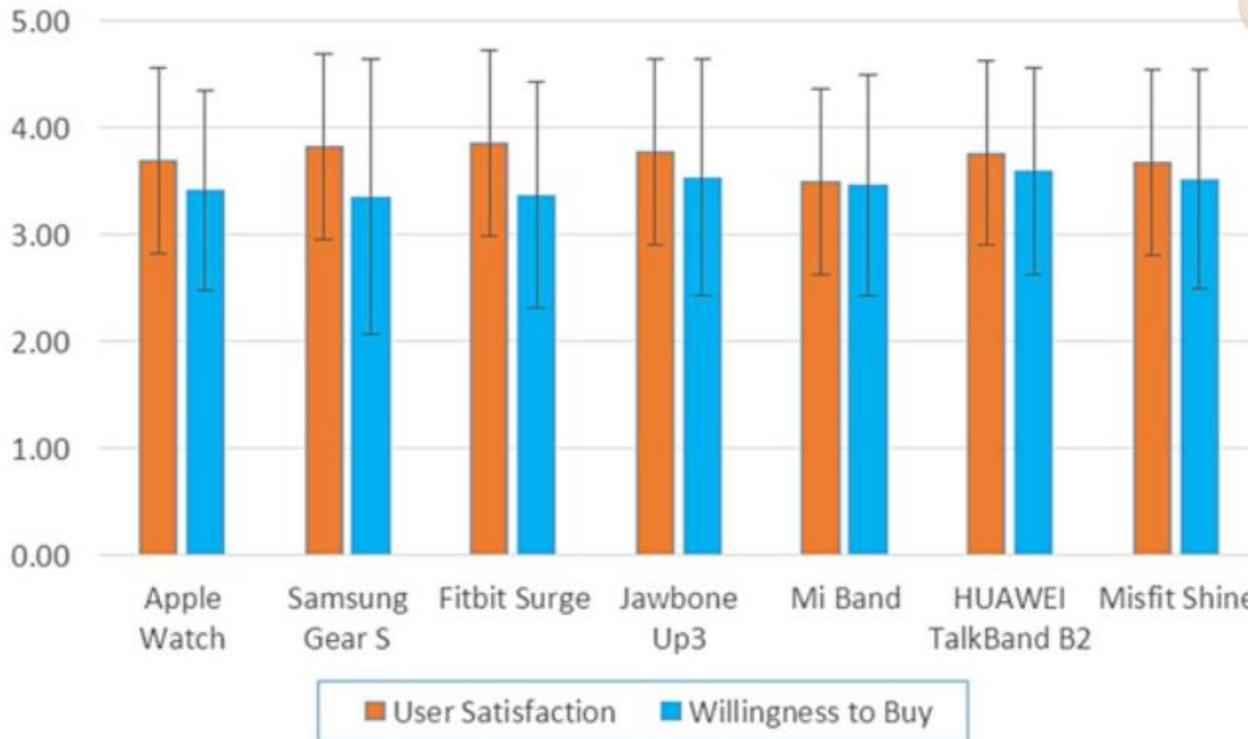


Figure: The mean satisfaction and willingness to buy scores for each device

As is also quoted in the survey:

“Users generally had positive subjective intent regarding fitness trackers but were less satisfied with their cost effectiveness. The users preferred health related features such as heart health monitoring, and professional fitness tracking. The rating of most of the current mainstream fitness trackers was fair with some significant differences among the devices. Thus, further improvement is needed.”

Below radar-graph compares 7 popular devices on the basis on 5 factors: Product design, Ease of Use, User rated accuracy, Durability, and Added features



(A) Apple Watch



(B) Samsung Gear S



(C) Fitbit Surge



(D) Jawbone Up3



(E) Mi Band



(F) Huawei Talkband B2



(G) Misfit Shine

Figure 2: **Radar graphs showing variations of five-dimension scores of the 7 Devices (Yuxi et al)**

Various literature points out one common theme and that is that we are yet to go far in digital strategies for it to be fairly dependable while it comes to cardio care. Digital strategies include smart wearables and other methods which track and record a person's health data.

“There is a clear need for rigorous research on digital strategies for ECCC (Emergency Cardiovascular Care), to build the scientific evidence base for their effectiveness and safety. As with more traditional medical therapies and interventions, rigorous research is needed to understand how digital strategies can be harnessed to have the greatest impact for improving outcomes for cardiovascular emergencies.” **(Rumsfeld et al)**

Doctors say that although smart wearables provide lots of fairly accurate data about heart health, a lot of work has to be done in this field in order for it to be truly helpful. As is stated below:

“Part of the problem is that current technology available to consumers only picks up on heart rhythms. That can be useful from a personalized standpoint, but it's not the same as actually predicting an arterial problem. And it certainly doesn't give Americans all the information (and, more importantly, the medical context) that they need to make the right decisions about their medical care when it comes to anticipating a disastrous heart problem.”

<https://www.health.com/mind-body/wearable-heart-attack-predict>

The data gathered from such devices is mostly used as self-monitoring and in clinical trials currently. With the advancement in sensor technology and clubbing that with Artificial Intelligence and Machine Learning will pave the way for an unprecedented tool and in

preventive care for heart disease.

Security issues related with the use of such devices:

Although wearable smart devices have given us so much to do with convenience, these are not without the security issues as is true for anything connected to internet today. Below are some security concerns that come up with the use of them:

→The most concerning fact is that almost all the wearables do not require any type of password or pin or biometric security to open lock/unlock the device. If the device is lost or falls in someone else's hands, all the sensitive data can be compromised.

→It is also very easy to take photos, videos and record audio with such devices. If one wants, he or she can capture someone's private information in a concealed manner.

→Connectivity requirements is another problem. These devices need to be connected to our smartphones all the time via Bluetooth or similar technology, which leaves our phone vulnerable to other possible nearby attackers.

→ There is no regulation with respect to security handling on these devices. They are still the responsibility of the manufacturer and not the cellphone company.

Chapter 3: Research Discussion

RQ1: What are the modern electronics devices used to capture consumer data and how is that data used to assess customers on probable heart disease risk?

RQ2: How popular are these devices and what is people's perception for such devices?

RQ3: How effective are these measurements currently and how does the future look like?

Propositions for Research Questions:

Below propositions are made in order to guide the research questions in intended direction.

Propositions for Research Questions1:

The data monitored or collected by such devices is useful in heart disease prediction.

Proposition for research question2:

These devices are becoming popular among consumers who are health conscious.

People don't see any deterrent for buying such devices

Proposition for Question3:

These measurements are somewhat effective currently and future would be promising with the advent of newer and better technology.

CHAPTER 4: EXPECTED RESULTS

After reviewing the literature and researching about the topic I would like to conclude with following finds with respect to propositions made:

Propositions for Research Questions1:

The data monitored or collected by such devices is useful in heart disease prediction.

I failed to reject this proposition because, although not much accurate or insightful the data does have the potential to help the doctors in reaching to a conclusion by going through a person's history of health data including heart rate, blood pressure, exercise routine, and sleep intervals etc.

Proposition for research question2:

These devices are becoming popular among consumers who are health conscious.

I fail to reject the hypothesis as one of the biggest reasons for the popularity of wearables is growing health-consciousness among people. Although this is not the reason always. Other reasons which may influence customers purchase for these devices are Peer pressure and/or just for the fashion sake.

People don't see any deterrent for buying such devices.

I reject this proposition as people sometimes do find such devices to be expensive and no value for money. Other factors influencing customer's decision include design, durability and brand of the device.

Proposition for Question3:

These measurements are somewhat effective currently and future would be promising with the advent of newer and better technology.

I fail to reject this hypothesis as we did find that such data is being used in research, clinical trials and elsewhere and has been found to be useful. With continuous improvement in technology the devices will improve in terms of their capability to record more accurate and sophisticated data. A lot of people with heart problems don't know about it until it is too late, and the doctor only gets to see the chronic condition. This is the area that fitness trackers can address with the accurate, detailed, and long-term data for the patient.

CHAPTER 5: FUTURE SCOPE

The future is very promising and data collection through fitness trackers is going to be better in terms of accuracy and detail. This data, then, can easily be used to diagnose and know the trigger that caused the disease. This in-turn will lead to better prognosis. Below are some trends that will shape the future of wearable technology and capture more sophisticated data:

→ Devices will be integrated with Machine Learning and Artificial Intelligence capabilities.

These are expected to perform even better task than existing medical guidelines and procedure.

→ Sensor is the most important part of data collection and the recent advancements in semi-conductor technology is equipping the sensor with the capability to capture the parameters that will be close to real-life.

→ Use of micro-sensors to design a body wear that can be worn all the time.

→ Wearable devices are being equipped to monitor ECG, EEG and skin temperature etc. That will allow doctors with unprecedented help and accuracy by such device.

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