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Usability and Acceptability of Wearable Authentication Devices

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***Abstract* – The Nymi Band wearable authentication device is the latest technological innovations in the wearable category of smart watches, fitness trackers, GPS running devices, and clip on, such as, the Misfit Shine. It is also a biometric authentication device that uses the unique heart rhythm of a user to verify that person and allow him or her to gain access to physical and logical devices, such as, at a door or at a computer. Therefore, the Nymi Band promises a security solution by eliminating the need for the user's password as an authentication tool. This study examined awareness of the Nymi Band as a new invention and the wiliness to purchase and to wear the Nymi Band as an authentication device.**

***Index Terms* – Heart rhythm, Nymi band wearable authentication device, Technology Acceptance Model (TAM), Diffusion of Innovation Theory, early adopters, perceived usefulness**

1. INTRODUCTION

The Nymi Band wearable authentication device is one of the newest invention in a growing list of biometric authentication devices. This is a wearable authentication wristband that is attached to the user's wrist; the band captures the user's heart rhythm as data. This data is transmitted to other authentication devices that performs a comparison of the data and grants access to the user once the biometric data matches. The Nymi Band wearable authentication device, in order to be a success in the marketplace, must first be accepted and used by the greater consumer population [1].

The Diffusion of Innovation (DOI) Theory, developed by E.M. Rogers in 1962, offers a deeper understanding on how the concepts for new ideas and new creations are accepted by its intended user group over time. This theory categorized users into five groups, which ranges from the eager adopters who are willing to try new technological advancements to the laggards who opposes change and may only try any new ideas when these ideas are already outdated by newer creations and discoveries that are already in use [2].

The Technology Acceptance Model (TAM), by Fred D. Davis, Jr. in 1980, examined how user's accept and use newly created devices according to a combination of factors that influence users [3]. These includes the user's behavioral intention, their attitude, their perceived ease of use that using the new inventions would be effortless, and the perceived usefulness that the technology will enhance their job. This model was tested by users wearing the Nymi Band authentication device, although more research is needed, the model was very accurate with all the tested scenarios and therefore, proved that users are governed in part by their perceptions, intentions, and their attitudes toward novel ideas [4].

II. LITERATURE REVIEW

The objective is to review the literature and gain a better understanding of factors affecting the adoption of biometrics technology, which is heralded as a significant tool for preventing identification and authentication deception. While still in the exploratory phase, research-to-date has found that for wearable technology to be successfully adopted, its body placement has to support a number of conditions. Namely, it must be accessible, wearable, and stable. It should convey information in an effective manner and be socially acceptable by the general public. Wearable technology (also called wearable gadgets) is a category of technology devices that can be worn by a consumer and often include tracking information related to health and fitness. Other wearable tech gadgets include devices that have small motion sensors to take photos and sync with mobile devices [5].

A more specific classification of wearable technology in relation to clothing is called smart clothing, or interactive or digital clothing, and is defined as a "garment-integrated device which augments the functionality of clothing, or which imparts information-processing functionality to a garment" [6]. The Nymi Band wearable authentication device resembles a wrist watch that when attached to the wrist, captures and transmits information about the user.

Another study conducted by Chae (2009) used extended the Technology Acceptance Model (TAM) by Davis (1989) to confirm the acceptance model in a context of smart clothing. The study viewed smart clothing as "innovative technology" where the aspect of clothing and an electronic product "allows the clothing to reveal innovation both in technology and in fashion". Chae used MP3 player jackets, sensor clothing, and optical fiber clothing to study smart clothing. Along with the original variables of TAM, perceived usefulness and perceived ease of use, the researcher extended the model by adding a third variable, clothing involvement [8]. In our study, the TAM variables were extended to the Nymi Band wearable authentication device.

The results of this study confirmed the validity of TAM because it revealed that perceived usefulness was the key variable that influenced consumer attitudes in accepting smart clothing and the Nymi Band. In addition, the results illustrated that perceived ease of use had indirect positive effects on consumer attitudes, but clothing involvement was not significantly related to consumer attitudes (Dunne, Ashdown,

& Smyth, 2005). Along with these variables, other studies indicated that some barriers to users' acceptance of wearable technology can involve the physical comfort of wearable devices [9]. This inference is accurate concerning the use of the Nymi Band. Users thought that it was easy to attach the device to their wrist because it resembles other popular wrist-wearable technology. Therefore, users were eager to accept and wear the device, but users' attitude were indifferent towards the Nymi Band when they actually attached and wore the device. See Table 5.

A mobile fitness application (MFA) is a type of mobile software that is specifically designed to educate, entertain, or assist people interested in fitness [10]. With a phenomenal adoption rate smartphones and tablet computers, the use of MFAs has also become popular among people interested in sports and fitness [11]. Although the use of technology for sports and exercise are common, only a few studies have studied how people use and adopt technology in relation to sports. Empirical research regarding MFAs is still sparse, however, there have been abundant academic efforts to examine how different technologies have been employed in our health and fitness-related activities [13]. A few of them include pedometer, heart rate monitor, Fitbit, and now, the Nymi Band. In our current study also, the fitness tracking feature of the Nymi Band that records the steps of users while they wear the device, is not the major emphasis of the study. But, it is noteworthy to mention that the Nymi Band fitness tracking feature, once enabled, will record the daily steps count of users and then transmit the data to the user's Apple Health or Google Fit devices.

By building the proposed model upon existing work in the field, the present research attempts to follow the advice of Keen (1980) who argues for the importance of establishing a "cumulative tradition" for MIS research [14]. The literature reviewed is drawn primarily from two fields: Management Information Systems (MIS) and Human Factors. MIS lab experiments have typically employed multi-time period decision-making simulations using student subjects. The Minnesota Experiments typify this paradigm. The major design features addressed have been information format (tabular vs. graphical information displays, raw vs. statistically summarized data), type of decision support tool [15]. Dependent variables are typically profit and expense performance within the decision simulation, although information usage and perceptual and attitudinal variables received scattered attention. In addition, several of these studies measure cognitive style and include it as one of the independent variables. These experiments have focused heavily on the performance relationship, in which performance impacts will not be derived if the user does not use the system (in decision simulations, the user is generally required to use the system) (Davis. 1980).

111. PAST WORK

In the last decade, the registration of the electrical activity of the heart on the body surface, namely the electrocardiogram (ECG), has been documented to be suitable for identity recognition [16]. Dedicated research on the ECG analysis has demonstrated its advantages in biometrics: ECG is present in all living individuals, exhibits the typical characteristics of a biometric and it is hard to forge [17]. In addition, ECG analysis is a robust method to detect the aliveness of the subject in authentication scenarios [18]. To date, many different approaches to human recognition via ECG have been reported in the scientific literature but no agreement exists on the appropriate methodologies [19, 20].

Moreover, the use of ad-hoc signal databases makes difficult the assessment of all existing techniques. ECG is the electrical activity of the heart often recorded at the chest level. During its activity, the myocardium—the heart muscle—behaves as a series of connected electric dipoles in a unique fashion called functional "syncytium". Heart's electrical activity is commonly described using an individual time-varying electromagnetic vector, whose projections can be recorded onto the body surface. Up to twelve specific electrodes positions (leads) are used to monitor heart functions and additional configurations have been proposed for specific purposes [28].

ECG is the electrical activity of the heart often recorded at the chest level. During its activity, the myocardium—the heart muscle—behaves as a series of connected electric dipoles in a unique fashion called functional "syncytium" [21, 22]. Heart's electrical activity is commonly described using an individual time-varying electromagnetic vector [23, 24], whose projections can be recorded onto the body surface [25]. Up to twelve specific electrodes positions (leads) are used to monitor heart functions [26] and additional configurations have been proposed for specific purposes [27].

IV. METHODOLOGY

The survey methodology allowed us the greatest opportunity to gather critical information that was used to determine the usefulness of wearable authentication using the subscriber's unique heart rhythms. Each team member created questions that were compiled into a master survey consisting of twenty questions. The survey questions were constructed using close-ended questions for greater control during the data collection process and data analysis. These questions were revised, amended, and the Likert scale of 1 to 5 applied, where 1 represented the most favorable response and five represented the least favorable response from the raw data collected. The survey was uploaded to the Qualtrics, a free web-based survey software for the Pace University faculty, staff, and students.

This study included a survey questionnaire that we distributed to three different groups. The control group, which consisted of twelve (12) students from our master's class. These students completed the survey from an online link using the Blackboard distribution email. The two experimental groups comprised of Twenty-five (25) employees of a service organization and sixteen (16) members of our family and friends. This population completed paper-distributed surveys that were presented to them by a members of our team. The surveyed population first completed the questionnaire after they physically examined two Nymi Bands, then they watched a video demonstrating how the Nymi Band authenticates a user at various physical and logical access points.

The familiarity to wearable authentication devices rated by the students in the surveyed population coincided with the awareness of the family and friends. On a scale of 1 to 5 where 1 was "very familiar" and 5 was "unfamiliar," both groups

indicated that they wore similar devices daily. When assessing passwords' effectiveness as a tool that prevents unauthorized network access, most respondents in both groups agreed that password is either extremely effective or moderately effective. There were similar results with the responses submitted by the employees, where more than fifty percent of the employees either have or use other wearable devices, such as, a Fitbit or Apple Watch. Also, all the groups in the survey were willing to pay a minimum of $100 for the Nymi Band wearable authentication device. See figure 2.

Fig 1: Sample of Questions taken from the Wearable Biometrics Survey – Pace University

Familiarity with wearable authentication devices
Password as an effective measure to prevent unauthorized access
Experience with wearable fitness device such as Fitbit
Technology adopter (first to try new inventions)
Willingness to wear cardiac rhythm wearable authentication device at work
Willing to pay $100 or more for a Nymi Band
Would recommend a cardiac rhythm device to a friend or colleague

Fig. 2: Graph showing the Results of the Survey

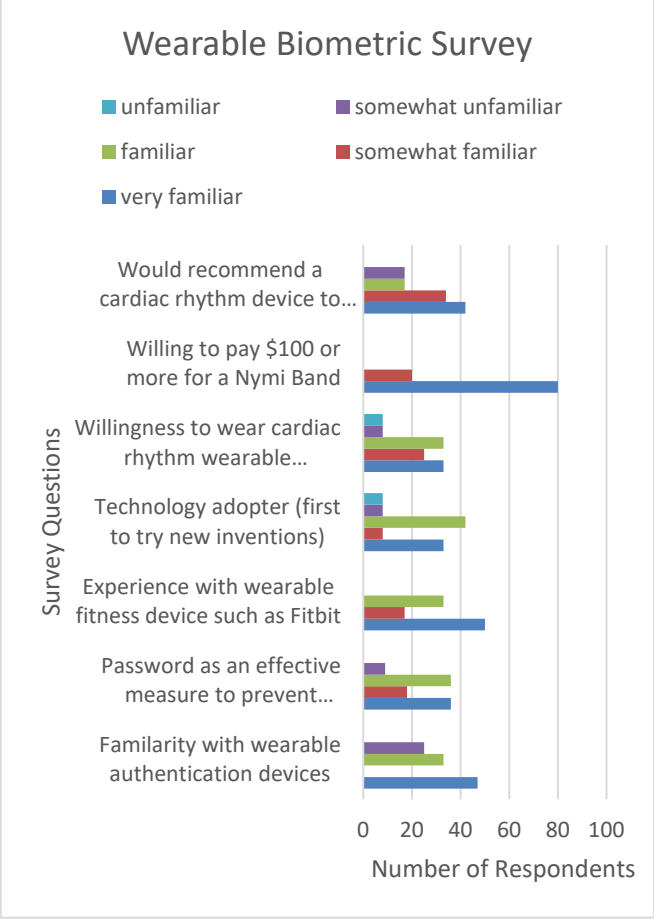

Table 2: Number of responses

Answer	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
1. Strongly Agree	7	6	7	8	9	9	9	9	10	16	10
2. Agree	4	5	4	3	1	1	1	1	0	0	0
3. Neither agree nor disagree	3	3	2	2	4	3	2	1	2	0	0
4. Disagree	2	2	3	2	2	3	4	4	3	0	3
5. Strongly disagree	0	0	0	1	0	0	0	1	1	0	3

V.PRELIMINARY FINDINGS/RESULTS

The supported our claim that usability and adaptability are driven by many factors including familiarity with similar device that resembles the new inventions, and the function that this new device will perform will make it worth owning. From the results of the surveyed population, most respondents in the survey were familiar with wearable devices, and they were owners of some of other wearable fitness device such as a Fitbit, Apple Watch, and Samsung Gear Fit. Most respondents were early adopters, who purchased and used new technology as soon as the technology becomes available. Most respondents also indicated that they would work for an organization if the only method to authorize access (computer login, unlock entry doors/turnstiles, pay for meal at cafeteria and retrieve voicemail) was through the use of a cardiac rhythm wearable authentication device. Table 1 showed the data collected from the control group and figure 3 showed its corresponding graph. While table 3 showed the sample collected from our family/friends, one of the population in the experimental group.

Table 1: Sample data set

Answer Choice	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Count
1	5	4	6	4	4	4	7	4	5	43
2	0	2	2	1	4	3	4	3	2	21
3	4	4	4	5	4	4	1	4	2	32
4	3	1	0	1	0	1	0	0	1	7
5	0	0	0	1	0	0	0	0	2	3

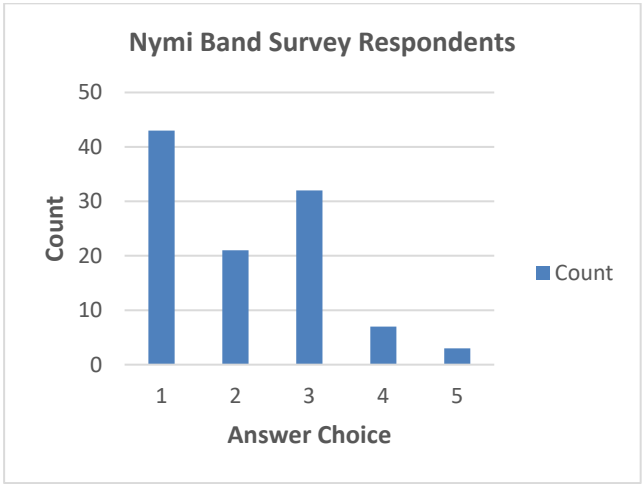

Fig. 3: Sample Data Set

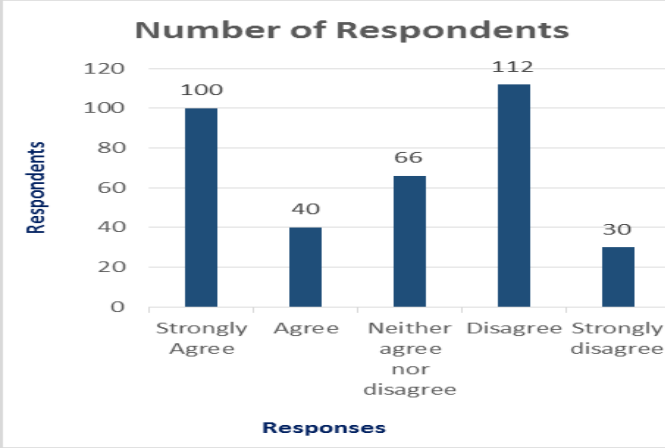

Fig. 4: Number of Respondents

The assumption is further strengthened from the responses that we gathered from the organizational respondents. These respondents viewed the new invention of the Nymi Band as a desirable device, that will offer peace of mind since they will not be required to remember their passwords or change it every ninety (90) day, but they will be authenticated to all their devices with their own heart rhythm. Some of these employees were willing to purchase the device immediately. Both Table 1V and Fig. 4 below showed the employees and the students comfort level at which they would purchase a Nymi Band, which is approximately $100 for and approximately $211 for students in this study.

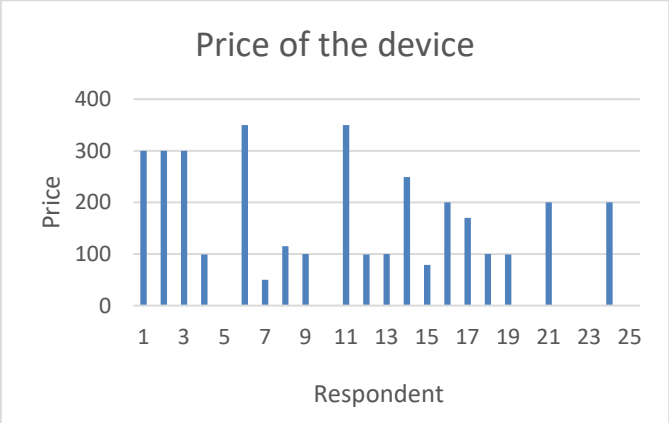

Fig. 5: Purchase Price for Nymi Band

Table 3: Students Mean Payment

Min Pmt.		Max Pmt.	Mean Pmt.	Pmt. Std Deviation	Pmt. Variance	Count
100		500	**210.92**	136.8	18714.24	12

Fig. 5 showed employees from the service organization were willing to work for an organization if the only method to authorize access (computer login, unlock entry doors/turnstiles, pay for meals at cafeteria, retrieve voicemail) used a cardiac rhythm wearable authentication device, such as, the Nymi Band Wearable Authentication device.

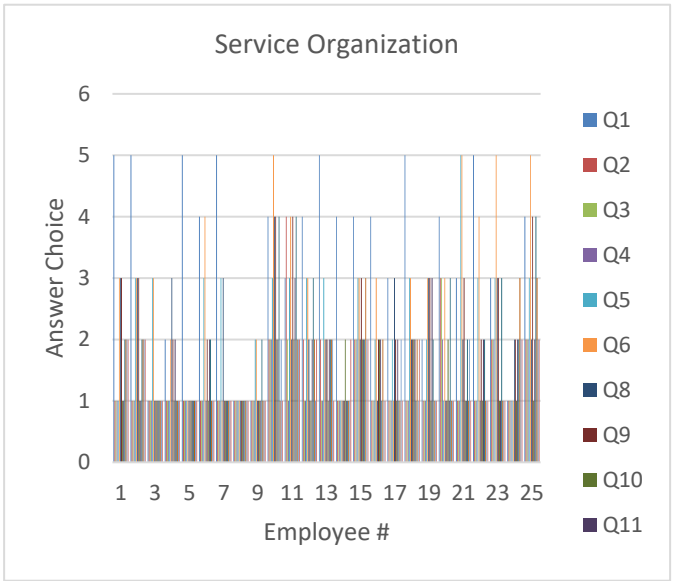

Fig. 6: Respondents Answer to Authorize Access

A few students at Pace University collected raw data by wearing and observing the Nymi Band authentication device for two weeks. The results from this experiment are illustrated as follows: The Nymi Band resembles a wrist watch, therefore, the students assimilated the Nymi Band use to that of wearing a wrist watch. However, they reported that attaching the device was not the same easy process as that of a wrist watch. Also, since the students were familiar with wearing other wearable devices, such as the Fitbit fitness tracker device, and wearing the Nymi Band was like wearing a Fitbit. These students, however, reported that the initial set up and authenticated process was difficult [4]. Once the device was programmed with the user's authentication information, the device was able to unlock their computers and iPhones. Also, the students reported that the Nymi Band will only accumulated to the Apple iPhones and Windows 10 operating system, which suggested that only newer technology platforms are compatible with the Nymi Band. Other discoveries that were reported included the $199 cost of the Nymi Band, which users were willing to pay because they believe that the Nymi Band would secure their passwords. Students wanted the device to perform more tasks than just securing their passwords. The table 4 below was created from the observations of students while they were wearing the Nymi Band.

Table 4: Nymi Band Raw Data Collection

Date of Data Collection	**Method of Collection**	**Observations of the Device**
2/10/2017	Attached to wrist	No printed instructions within the Nymi Band package when the device is first removed from the box

2/10/2017	Attached to wrist	For set up instructions, must go on the Nymi Band website
2/10/2017	Attached to wrist	Sync device to heart rhythm takes approximately 30 minutes for the device to recognize the user's heart rhythm
2/10/2017	Attached to wrist	The user must download the Nymi Band application from Apple store to iPhones or Windows 10 operating system only
2/17/2017	Attached to wrist	Physical touching the device with finger to input cardio information the information does not authenticate on the first try and user must do this more than once
2/18/2017	Attached to wrist	Band on the device is too long and hindered smooth wear ability and sure fit
2/19/2017	Attached to wrist	Must have iPhone or latest Apple device to download application
2/20/2017	Attached to wrist	Physical touch with finger to input cardio information. The phone shows a heart line with spikes
2/21/2017	Attached to wrist	Blue lights flashes when software is being downloaded and before user is authenticated
2/22/2017	Attached to wrist	When the user is authenticated, the user's iPhone shows the heart rhythm in high and low spikes
2/23/2017	Attached to wrist	The Nymi Band cost $199
2/24/2017	Attached to wrist	The Nymi Band does not recognize the user's cardio information at the first try, the user must repeat the steps
2/25/2017	Attached to wrist	Securing the Nymi Band to the wrist and removing the Nymi Band from the wrist may be difficult for some users
2/26/2017	Attached to wrist	The Nymi Band stores your password and unlock your iPhone and or computer. The device did not unlock the car
2/27/2017	Attached to wrist	The two-step process of downloading the Nymi Band application and the finger touch to input cardio information may take more than 40 - 45 minutes
3/4/2017	Attached to wrist	The Nymi Band was linked to the Step Count and it displays the number of steps the user took daily

Generally, wearable devices are designed specifically as a type of attire that is on or close to the user, which conveniently collects the user's personal information and transmit that data with significant accuracy to a source destination. Because wearable devices are usually easy to use and the data collected is accurate and reliable, these devices have been experiencing exponential growth where features such as access management and password authentication are future design considerations of wearable devices. The Nymi Band is worn on the user's wrist with the lower sensor of the Band touching the skin, the device creates electrical current that detect the user's heart rhythm or the electrical activity that the heart generates, this electrocardiogram (ECG) sensor then transmits signals to other network devices, which authenticate the user [31].

A major advantage of the Nymi Band wearable authentication device is that it improves usability and increase the goal of security effectiveness, efficiency, and offers satisfaction. This occurs when the user heart rhythm is use as an authentication tool when the Nymi Band captures the heart rhythm and transmits this data to other authentication devices, these devices grants the user access. Therefore, in an organization where identification badges are used as an access tool, the Nymi Band would replace the identification badge and captures the employee's heart rhythm and transmits that data to another access granting device, such as, a lobby turnstile this turnstile, will grant the employee access to the building [33]. And, once the employee reaches his workstation, the Nymi Band again would transmit the employee's heart rhythm to his or her personal computer, which will grant the employee access to use the computer. The idea of using the heart rhythm eliminates the password entry to the personal computer, thereby securing the employee's workstation.

This new idea of eliminating the need for password by using the user's unique heart rhythm must first be accepted by its intended consumers to be a successful device. Diffusion of Innovation Theory studies how the ideas for innovations are adopted by its intended group of end users (adopters) over time. New inventions are not readily accepted by all its end users at the same time but acceptance is sequential and based on the user's interaction and his/her social system.

Innovativeness is the one classification for end users and it describes how early or how late the end user will accept a new idea in comparison to other end users of his or her group or social system. In describing innovativeness, one must examine the following categories: The innovators or visionaries are the creators of new ideas and they represent the first 2.5 percent of the group, early adopters represent 13.5 percent, early majority and late majority represented by 34 percent each, and laggards represent the last 16 percent of the group. The innovators are described as those that are enthusiastic about trying new ideas, they are risk takers with significant financial means. The early adopters are the locals with the greatest amount of opinion leadership in the social system, there were few early adopters in the surveyed population, who were willing to purchase the Nymi Band immediately. These were managers in the service organization, who provides information, advice and are respected by their peers. Early majority are willing followers in adopting new ideas, they adopt the new ideas just before the average member of the social system. Many "early majority" were also among the surveyed population, they were also willing to purchase and wear this new device. At the other end

of this bell curve, are the late majority and the laggards. The late majority are classified as the skeptic, who are cautious about innovations and therefore, reluctant to adopt and must be pressured by their peers to adopt the new innovations. The laggards are referred to as traditionalists, who are suspicious of change and preoccupied with the past. Usually, by the time laggards adopt the innovations, it would already be outdated by newer ideas that are already in use. Categorization alone is not a sufficient model to describe, forecast or control end-user acceptance of new innovations [30].

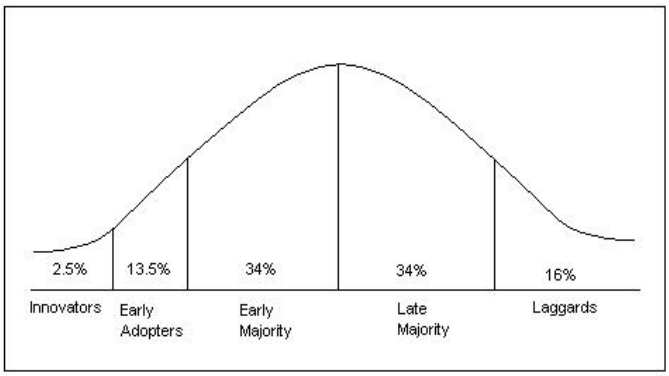

Fig. 7: Adopter (end users) categorization on the basis of innovativeness

The Technology Acceptance Model (TAM) is used to explain end-user's response toward accepting and using new innovations [31]. The TAM model (shown below) suggests that the user's behavior could be determined by considering his/her prior intentions, which is called the behavioral intention that is used to perform a behavior. The behavioral intention is determine by the user's attitude, a positive or negative feeling, and his/her subjective norm, which is his/her perception about other members of the group and his/her own motivation to perform a behavior. The major components of the user's attitude are: perceived usefulness (PU), which refers to the user's perception that using new innovations will enhance his/her job. Also, perceived ease of use (PEOU), the other component of attitude, refers to the user's perception that using new innovation will be effortless.

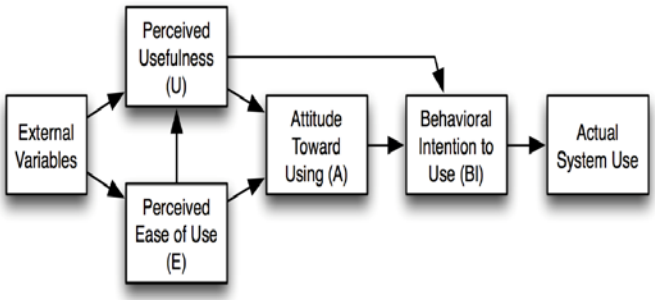

Fig. 8: The Technology Acceptance Model (1980) [7]

The technology acceptance model, once applied to the Nymi Band wearable authentication device was a useful theoretical model for explaining user's behavior for accepting and using a new innovation. Although the research was limited to one wearable authentication device over a few days, the technology acceptance model objective was achieved because it accurately predicted the user's acceptance and usability levels. The user that wore the device, perceived it to be useful and the device was then associated with an increased intention to use even though the device lacks directional instructions [37]. Also, the theory that an increased perception of ease of use are associated with increased intention to use was proven. Since, the device was a wristband, users thought that it was supposed to be easy to use, and thus, the user was determine to wear the authentication device although he encountered setup challenges. It can also be noted that a user that has been previously exposed to similar technology, such as, Fitbit will readily accept wearable authentication technology devices and an experienced user, such as the user who tested the device, rated the device as easy to use and perceived it as more useful.

At the core of the technology acceptance model is the perceived ease of use (PEOU), perceived usefulness (PU), user's attitude, and their behavioral intentions when making important decisions about a wearable authentication device such as the Nymi Band authentication device. If the Nymi Band is perceived to be a wearable authentication device of great value for a wider user group, such as, security personnel at large corporation, then the perceived benefits of the device will definitely compensate for its cost [32]. Assets security, access management, and customer information protection are the major focus of many security professionals, therefore, eliminating the threat to such assets is one of their ultimate goals [34].

VI. CONCLUSION

Wearable authentication devices constitute a fast-growing pioneering category of wearable and biometric devices and the Nymi Band is one of the latest development in this category [35]. The Nymi Band wearable authentication device offers a solution to password security since it uses the heart rhythm as an authentication tool, it offers fitness tracking by keeping count of the steps taken during the day, similar to the Fitbit fitness device. Another major implication is the cost-benefit inferences that the device must worth its $199 price tag in that the Nymi Band should offer more than just authentication to the end user. It must integrate other devices, application, and even the user's social communities similar to the value presented in the iPhone [36].

Though much more research is needed to prove the true value of the Nymi Band, one very important factor that will influence the successful acceptance and the ultimate use of the Nymi Band is that of the user's awareness, opinion, taste, and wiliness to pay for the benefit of secure authentication that it offers individual consumer despite its cost. On the other hand, major cooperation may be willing to pay for the Nymi Band and this cost may not even be a deciding factor to use the Nymi Band as a security tool that will keep customers, employees, and company-specific information safe from the risk of vulnerabilities that if realized, could potentially permanently damage the company.

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