Acceptance and Usage of Smart Wearable Devices in Canadian Older Adults

by

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

I was responsible for the original study design and methods with input from Dr. Lee and Dr. Stolee. Dr. Lee guided and reviewed the statistical analysis and I executed the data analysis. I exclusively conducted the literature review, writing, data interpretation, figures, tables, and results. The wearable device selection was guided by Dr. Lee and I. Data extraction, entry and comparison of wearable device characteristics were assisted by student volunteers; Aein Zarrin, Ryan Chan, Shail Patel and Mark Mercado.

ABSTRACT

Background: As the Canadian older adult population grows rapidly, emerging solutions and technologies that have the potential to enable aging-in-place are garnering more attention from developers, public policy makers and international organizations. One category of emerging technologies is smart wearable devices; however, their acceptance is low. In addition, information about Canadian older adults' attitudes toward smart wearable devices is scarce and requires additional exploration.

Objective: To explore Canadian older adults' attitudes toward and acceptance of two smart wearable devices, the Microsoft Band and the Xiaomi Mi Band.

Methods: A mixed methods design was used to capture descriptive statistics and to explore participant's attitudes and experiences. Twenty older adults aged 55 or older were recruited from the cities of Kitchener-Waterloo, Cambridge, and Guelph, Ontario. Participants were invited to use two different smart wearable devices, the Microsoft Band and the Xiaomi Mi Band, for 21 days each. Questionnaires were used to capture descriptive statistics, acceptance and explore attitudes towards smart wearable devices. Subsequently, semi-structured interviews were conducted with a purposively selected sample of four participants (three females and one male) and a content analysis was performed.

Results: Older adults in the study ranged in age from 55-84 (mean = 64). Gender distribution was reasonably balanced and the sample had high levels of education. Older adults were willing to accept smart wearable devices and believed continuous health monitoring could be helpful. Older adults in the sample also had high levels of technology experience and smart wearable devices awareness. Older adults believed a smart wearable device should cost between $0-$200. The Mi Band gained higher levels of acceptance (80% accepted) compared to the Microsoft

Band (45% accepted). Most older adults used each smart wearable device for the entire 21-day testing period. Quantitative analysis revealed smart wearable device acceptance was associated with facilitating conditions, perceived risks and equipment characteristics. Content analysis resulted in the formation of four main themes regarding older adult's attitudes toward and acceptance of smart wearable devices: 1) smartphones as facilitators of smart wearable devices, 2) privacy concerns, 3) subjective norm and facilitating conditions, and 4) smart wearable device equipment characteristics.

Conclusion: This exploratory study contributes to addressing the scarcity of research that explores Canadian older adults' attitudes toward and acceptance of smart wearable devices. Findings from this study suggest that older adults are willing to accept smart wearable devices and find them useful. However, lack of knowledge and experience in operating smartphones, reduced facilitating conditions, and unfavorable equipment characteristics (regarding comfort, aesthetics, and battery life) may deter the usage and acceptance of wearable devices. Privacy concerns of using smart wearables were not impactful on acceptance for older adults in the sample. These findings add to emerging research that investigates acceptance and factors that may influence acceptance of smart wearable devices among older adults.

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1. Introduction

In 2015, for the first time in history Canadians aged 65 and older outnumbered Canadian children aged 0 to 14 [1]. This trend is predicted to continue into 2024, as Canadian older adults are projected to comprise 20.1% of the total population, or approximately 7 million individuals[1]. This fast growing aging cohort will present the unique challenge of overwhelming demand on the healthcare system, resulting in increases in aging-related healthcare spending [2].

Today, Canadian older adults are leading longer, healthier and more active lives compared to older adults from previous decades [1], [3]. However, an increase in life expectancy does not necessarily mean that the Canadian older adults are aging successfully. In fact, research shows that for many older adults, successful aging is achieved through aging-in-place [4], [5],[6]. Yet as a Canadian older adult passes the age of 65, they are less and less likely to live alone in their private homes and in collective dwellings instead [5]. This is attributed in part to age-related challenges such as increased risk of falls, hospitalization, or inability to care for oneself and one's home [7]–[10]. Despite these challenges, a majority of older adults continue to desire living in their current residences [11]. Results from a 2010 AARP (formerly American Association of Retired Persons) survey of 334 participants over the age of 65 show that more than 88% of respondents would prefer to remain in their current place of residence as long as possible[12].

Although there are varying definitions of aging-in-place, the notion is generally defined as continuing to live at "home" and to do so while maintaining levels of independence, social contact and dignity [4], [5] . "Home", in this context, is more than a dwelling or place of residence, rather a dynamic symbol that enables one to have varying experiences that may change over time [13], [14]. The notion of aging-in-place is well-documented and scholarly accounts of the benefits of aging-in-place can be traced to the late 80's when Myers advocates strategies of aging-in-place based on the theory having control over one's environment is tied to feelings of independence [15].

Numerous studies that examine the living arrangements of older adults suggest that in contrast with isolated retirement and long-term care facilities, aging-in-place is considered more desirable, graceful, and fulfilling among the aging cohort [4], [16], [17]. In addition to added health and mental benefits, aging-in-place can also be more cost-effective than residential care living [18], [19], [20]. Research data from a housing research study conducted in the United Kingdom suggests that for older adults, aging in place and living at home can cost 45% less than living in a residential care setting [21]. These findings are also valid in the Canadian and North American context as numerous scholarly works examining the cost of home care in comparison to residential care conclude that aging-in-place and home care options can be more cost effective than institutionalized care [18], [19], [22].

On a global scale, international organizations like the World Health Organization and the Organisation for Economic Co-operation and Development, made up of nations such as USA, Canada, Australia, and Denmark, also agree that in order to support healthy aging older adults should be able to live in their own residences as long as possible [23]–[25].

In response to the rapidly growing older adult population, the benefits of aging-in-place and the increased desirability to age in place, the issue of enabling and empowering aging-in-place is receiving more attention not only through research, public health programs, and policy planning [23], [26], [27], but also through numerous emerging technologies aimed at supporting aging-in-place with unique strategies. Most of these technologies focus on care and monitoring away from an institutional setting and moving it into the comfort of one's home [27]–[31]. Off the shelf smart wearable devices such as heart rate monitors and physical activity trackers have seen tremendous growth in the last decade [32]. Wearable devices also provide opportunities for innovative health services [33] and objective continuous data collection for predictive health monitoring [34]

However, as with any monitoring device, ongoing and voluntary use is critical to accurate and comprehensive data collection. While projected to increase over the next five years, the adoption and continued use of smart wearable devices among all age groups are still relatively low [14], [15] and attitudes that influence acceptance are not well known [35], [36]. Today, little research exists that appropriately and adequately explores older adults' attitudes towards, as well as acceptance, and usage of smart wearable devices [26], [37].

Therefore, this study aims to explore attitudes that may influence the acceptance and usage of smart wearable devices in Canadian older adults. Moreover, the study addresses a lack of descriptive statistics about Canadian older adult's usage, attitudes and acceptance of smart wearable devices.

2. Literature Review

2.1. Smart Wearable Devices

For the purpose of this research, a smart wearable device is defined as *a user worn accessory, with integrated electronic and computing technologies, that captures or reports on some form of data*. Wearable data range from physical activity, movement, heart rate, UV exposure, temperatures, to audio and video data, that can be later used for analysis and reference. Although the form that the device takes can vary from a band that is worn around the wrist, to a necklace-style smart pendant, their functionalities are often similar.

Though smartphones continue to be the most commonly used smart mobile devices in Canada [38], consumer research suggests there are abundant opportunities for smart wearable devices to be accepted and flourish [32]. In 2014, the worldwide wearable industry was worth $9.2B, a figure that is expected to grow to $30.2B in 2018 [32]. $22.1B of the growth is attributed to advances in consumer-oriented technology alone [32]. According to Price Waterhouse Coopers, consumers are fascinated and have high hopes for wearable technology, but have not yet embraced the technology fully [36]. While one in every five American adults owns a wearable device, only one in ten uses their devices everyday [36], [39], and a third of them stop using their devices within six months of its receipt [39].

Currently, the most common uses of off-the-shelf wearable smart devices include activity tracking, motivational feedback and health monitoring [11], [40]–[42], while the average user is a 36-year-old who holds a higher than average household income [36]. Irrespective of age, acceptance of smart wearable devices is low, and older adults' positive attitudes and acceptance of these devices are vital to their success [43]. Research by MaRS suggests baby boomers will be the next primary users of smart wearable technology [32], denoting the importance of exploring factors surrounding their adoption by the aging population.

It is important to note that though smart wearable technology is currently in its infancy, research indicates that wearable devices will continue to revolutionize the consumer health industry by providing opportunities to incentivize their use [35], [36]. Also, a push by employers is also expected through sponsored wellness initiatives to drive health behavior change [36]. In the case of older adults, smart wearable devices that monitor physiological signals and overall physical activity can be used to identify stark or subtle deviations from their average health in order to proactively address negative health outcomes [44]. Smart wearable devices also directly provide the motivation and drive to be more physically active, the ability to independently monitor one’s general health without the need of expensive clinical equipment, and observe irregular, gradual or sudden changes in physiological signals, all from the comfort of one’s home [45], [46]. According to consumers, privacy concerns [47] and price [36], [48] are among the obstacles may deter technology acceptance among older adults.

Furthermore, as wearable devices become smaller, inexpensive, and more feature-packed, the opportunity for use in various applications grows alongside. Technologies like Live!y, a smart wearable device that aims to capture physical activity, medication adherence, and in-house mobility data of older adults to share with family members provide thorough comprehensive reports. In addition, the device also provides one-touch emergency support and enables making living at home in older age a safe and dignified experience [49].

The BodyGuardian sensor is another example of technology capable of capturing health data such as cardiac ECG and rhythm data [50]. The data is then transmitted to a monitoring centre that can deliver the physiological data to physicians, without the need for continuous monitoring in a clinical setting, allowing older adults to remain independent and continue with daily routines instead of being confined to a hospital or face a plethora of repetitive clinical tests.

Tempo by CarePredict captures subtle changes in sleeping, eating, and activity patterns of older adults allowing for proactive intervention or treatment [51]. Smart wearable devices like the ones mentioned above often require costly mandatory monthly monitoring plans, creating a barrier for individuals who cannot afford these services, or for those who simply do not want to pay for recurring monthly monitoring costs. Nonetheless, the greater availability of older adult focused, off-the-shelf, and consumer-oriented smart wearable devices provides opportunities to learn about and monitor users' general health, while enabling them to stay at home, maintain their activities of daily living and their independence. Clifton e note that wearable devices are especially well suited for continuous monitoring efforts, as many hospital admissions are mobile after the first day in the ward [34]. Moreover, predictive monitoring initiatives such as those that aim to proactively warn of severe physiological harm so that appropriate care can be provided are also increasingly relying on wearable sensors to capture continuous physiological data [34], [52], [53].

Smart wearable devices are also used to measure adherence to physical activity regimens and other interventions as demonstrated by Bertram et al.'s 2015 study examining the adherence to physical activity intervention for 25 overweight or obese postmenopausal women through data collected from a Fitbit physical activity tracker. [54].

In the consumer market, a survey of Americans indicate that individuals are more likely to use wearable smart devices if they were to be subsidized by an employer or health insurance firm [35], [36]. A nationally representative survey of 10,000 American consumers suggests that though consumers are hopeful about the benefits smart wearable devices may bring to the table, less than 1 in 10 uses a device daily [36]. Moreover, the intended audience of the vast majority of off-the-shelf smart wearable devices are youth and young adults [39]. As such, the needs and use considerations of other age groups such as older adults are often overlooked, even though these devices may impact the lives of older adults more significantly than their younger counterparts [11].

2.2. Relevant Theories of Technology Acceptance

2.2.1. Theory of Reasoned Action (TRA)

Developed in the 1960s as a model for predicting behavioral intention, the Theory of Reason Action (TRA) posits that action is driven by behavioral intention to perform said action. This behavioral intention is moderated by an individual's attitudes and his or her subjective norms towards that behavior [55]. Figure 1 (below), depicts the relationships between acceptance or actual behavior and the chief dimensions in the TRA model.

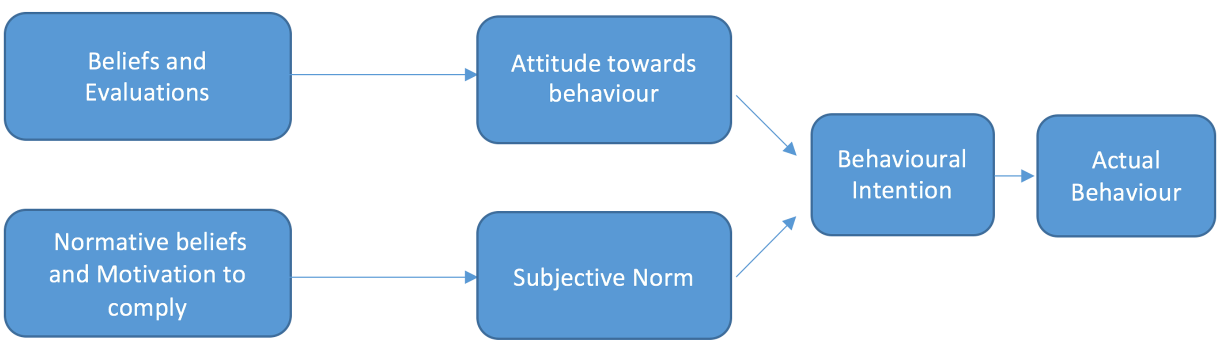


Figure 1: Theory of Reasoned Action (TRA)

Subjective norm is defined as an individual's "perception that most people who are important to him think he should or should not perform the behavior in question" [31]. According to TRA, attitude towards a particular behavior is motivated by his or her beliefs on and evaluations of the consequences of the behavior. As such, the framework suggests that factors external to an individual have the power to influence his or her attitudes by altering the belief one holds [31]. Hence, attitudes and subjective norms that support a certain behavior are more likely to result in the carrying out of the actual behavior [31].

Fishbien's framework is most notable for its use in developing strategies to alter a particular behavior. Although the TRA is recognized as a generic social-psychology theory that can be used as a general framework to understand reasoning behind a particular behavior, it lacks comprehensive identification of factors that ultimately affect behavioral intention.

2.2.2. Technology Acceptance Model (TAM)

Inspired by the TRA, Davis's Technology Acceptance Model (TAM) furthers Azjen and Fishbein's work with TRA to make it more suitable for recognition of the interaction of factors, as well as their effect on attitude and behavioral intention that lead to a particular behavior [Davis, 1989]. The framework's intended purpose was to determine employees' decision to adopt and use new technologies in the workplace [56].

According to the TAM, two key determinants, perceived ease of use and perceived usefulness, are essential in accurately predicting technology acceptance [56]. Davis defines perceived ease of use as "the degree to which a person believes that using a technology will be free from effort" [31] and perceived usefulness as "the extent to which a person believes that using a particular technology will enhance her/his job performance" [56]. Figure 2 (below) outlines the relationships between chief dimensions outlined in Davis's TAM.

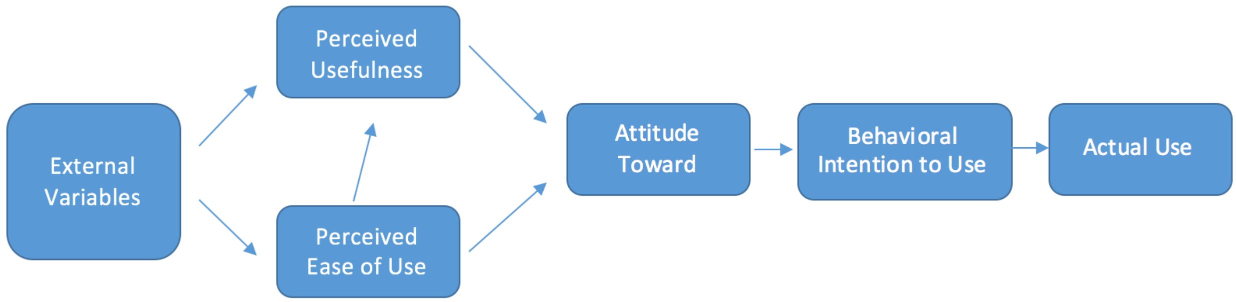


Figure 2: Technology Acceptance Model (TAM)

When comparing TRA and TAM, Davis examined the predictive power of behavioral intention on usage, how well TRA and TAM can explain a user's intention to use a system, and whether attitude is a mediator between beliefs and intentions [57]. The results of the comparison reveal that behavioral intention is a key predictor of acceptance, while perceived usefulness can be more important than perceived ease of use in predicting usage behavior [57]. This indicates that users may be willing to endure the pains of learning a new technology if it is useful to them. Furthermore, a relationship between attitude and behavioral intention is also proposed, suggesting that attitude, perceived ease of use and perceived usefulness, all together determine one's usage and acceptance of a technology [57].

In addition, multiple scholarly studies have demonstrated effective application of the principles and either the original or extensions of the model outlined in the TAM, to accurately predict acceptance of a variety of different technologies. These include the adoption of the Internet among Chinese older adults [58], predicting tablet computer use among physicians in the United States [59], consumers' acceptance of wearable solar-powered clothing [60], and electronic medical records [61].

While the TAM's appropriateness and applicability of acceptance testing in a variety of different fields (healthcare, e-commerce, workplace, education) has not been well established, the framework's application to health information technology has been supported by Holden and Karsh [62]. They assessed 16 of 20 studies of clinicians using health information technologies and found empirical evidence supporting the model's application to health information technology and its validity [62]. Furthermore, in comparison to models like the Technology Acceptance Model 2 (TAM2) which explains approximately 60% of the variance in technology acceptance and the Theory of Planned Behavior (TPB), the model outlined in TAM is a robust tool, explaining 40-50% of variance in technology acceptance [63], though it could benefit from certain modifications and additions to improve its ability to explain variance in technology acceptance [26], [59], [62]. Though TAM's application to older adults has been fruitful, the focus has been on assistive technologies [64]. As such dimensions such as price, social, and factors relating to aging (i.e. mobility/dexterity) have been neglected, citing a need for a more comprehensive and appropriate understanding of technology acceptance among older adults [64].

2.2.3. Existing Acceptance Research

Research examining attitudes that may affect acceptance of wearable devices among older adults is relatively new [8], [20], [59], [65]–[68]. As the evaluation of contemporary technology acceptance theories, factors that influence acceptance, and wearable devices themselves gain more attention from the academic community, much still remains to be revealed about their appropriateness and the applicability of the theoretical models to different populations and contexts.

The TAM, the most commonly used theory of technology acceptance [64] and other unique extensions of this model, are often utilized to study the influence various factors may have on acceptance; however, its validity and applicability to different subsets of the population still needs to be established. As mentioned previously, Holden and Karsh note that while the TAM can estimate a significant portion of technology acceptance, the theory may benefit from added variables and relevant constructs to improve its applicability to the health care context [62].

In addition, several studies indicate that as factors that influence acceptance may change over time [69]–[71], the TAM does not work to distinguish the influence of traditionally measured constructs, Perceived Use and Perceived Ease of Use, before and after the technology is used [72], [73]. As such, it is important to explore technology acceptance and the factors that influence acceptance after participants have had a chance to form ideas, attitudes and experiences after physically using a particular technology over a prolonged period. Furthermore, new research may be key to understanding the evolving and changing factors that may influence technology acceptance.

Many prior acceptance studies have concentrated on qualitative methods for data collection, dominated by focus groups and in-depth interviews. However, some recent studies have evaluated acceptance post-use and through quantitative methods. Gao et al. investigated factors associated with adoption of wearable technology in healthcare through the analysis of empirical data collected through a survey administered to 462 participants. Results from the study indicate that a consumer's decision to adopt wearables is affected by factors from a variety of different perspectives including technology, health and privacy [66]. Furthermore, the researchers also investigated and validated, though not statistically, the moderating effects of acceptance based on the type of product have an impact on consumer acceptation of technology. Though not concerned with older adults as a target population, the research is one of the first few that aims to explore acceptance through health, technology and privacy perspectives.

Similarly, McMahon et al. investigated older adult's experiences using a wearable to track their physical activity through 10-item surveys administered ten weeks and eight months after study commencement [74]. The study is among a small number of investigations that evaluate both the short and the long term acceptance (8 months) of a wearable device among older adults. Results from the study are encouraging and suggest that while it is feasible for older adults to use wearable monitoring devices to track their physical activity, the devices alone will not result in changes to physical activity levels. The authors also note that data visualization techniques of the information collected by the wearables may benefit from an adjustment to be more simplified for older adult consumption [74].

Mercer et al. employ a mixed-methods approach to the investigation of the acceptance of commercially available wearable devices among older adults with chronic illnesses [65]. Data were collected from a sample of 32 purposively selected older adults through focus groups and questionnaires. Only a few of the participants in the study were familiar with wearable activity trackers. Participants were asked to test five different activity trackers for a minimum of three days, after which they were invited to fill out a questionnaire based on proponents of the TAM. Results indicated varying levels of acceptance of the wearable devices, with the lowest acceptance score attributed to a basic pedometer, while the highest score of device acceptance was given to a wearable activity tracker [65]. In addition, a thematic analysis of qualitative data identified four primary themes; older adults' comfort zone with new consumer health technologies, appreciation of goal setting and self-awareness, wearables as motivators rather than quantifiers, and the likelihood of adoption [65]. The results of the study indicate that older adults are interested in the wearable fitness trackers and that these devices do offer motivation to be more physically active. In addition, the authors note that if wearable activity tracker awareness increases through promotion by health professionals, the potential for adoption exists alongside the secondary effect of fostering self-awareness of activity levels [65].

Chen and Chan's review of technology acceptance by older adults also suggests that while the TAM is undoubtedly useful in understanding acceptance of technology among older adults, additional variables such as biophysical, psychosocial characteristics and problems experienced with the technology may be helpful in providing a better understanding of acceptance behaviour [26]. In 2010, Heerink et al. proposed a model of technology acceptance to measure acceptance of assistive described as the "Almere Model" [75]. The scholars' rationale for the necessity of a new model was based on existing criticisms of TAM and the Unified Theory of Acceptance and Use of Technology (UTAT) such as the lack of social factors and the applicability of the measure to the older adult populations. As such, the authors were motivated to develop a model that was able to explain acceptance in various conditions, is quantitatively robust and identified the primary factors that influence acceptance [75]. The resulting model was capable of explaining 49-59% of the variance in actual use; however, the model's applicability to technologies beyond assistive social robots is unknown, and as such it has rarely been used for acceptance research for wearable devices. Nonetheless, research like Heerink et al.'s is a first attempt and indicative of the need to gain a better understanding of factors that influence acceptance of technologies among older adults.

To determine the effects, feasibility and acceptability of an intervention delivered through the use of wearable technology and telephone counselling for older adults, Lyons et al. conducted a randomized control trial with a sample of 40 individuals [33]. Participants were given a Jawbone UP24 physical activity monitor and a companion tablet to use for the duration of the study. In addition, participants were provided brief counselling sessions once a week.

Results indicated that high acceptability and feasibility of the intervention in the population. The researchers note that when combined with telephone counselling, wearable devices have the potential for increasing physical activity and lowering sedentary lifestyles [33].

As evidenced through the discussion of existing research in this section, many new scholarly works that analyze technology acceptance involving older adults are emerging in recent years. A recent systematic review of factors that influence technology acceptance for aging in place by Peek at al. indicates that much of the research relating to older adults' acceptance of technology has been primarily concerned with communication and assistive technologies [20]. Recent studies such as the ones conducted by Mercer et al. and McMahon et al. have begun to address this deficiency [65], [74]; however, it is evident that the fast-expanding category of technologies aimed at older adults could benefit from further exploration. If the factors that influence acceptance and usage of these innovative technologies and solutions, some enabled by smart wearable devices, are better understood, they may have the potential to facilitate successful aging-in-place and continuous data collection while also being resource efficient for health care administrations.

3. Study Rationale and Objectives

3.1. Study Rationale

The lack of research relating to acceptance and usage of smart wearable devices by Canadian older adults represents a gap in knowledge necessary to understand how the growing aging cohort uses smart wearable devices. Though some recent studies have explored the acceptance of different types of technology by older adults, research investigating factors that influence the acceptance of smart wearables is scarce. In 2016, Mercer et al. explored the acceptance of off the shelf, commercially available wearable activity trackers in a sample of adults with chronic illnesses over the age of 50 through a mixed methods study design [65]. Participants tested a total of 5 activity trackers over a three-day period and were then asked to full a questionnaire developed using the TAM. Mercer et al. explored the acceptance of commercially available wearable activity trackers quantitatively, however, the factors that influenced acceptance were not quantitatively tested or explored. Furthermore, other similar research studies also lack quantitative testing of influential factors [11], [74].

While Mercer et al.'s study is among the few recent accounts of scholarly work that investigates user acceptance of smart wearable technology post-implementation, there are several limitations that are addressed by this research. For instance, a testing period of 3 days may not be indicative of long term acceptance as research indicates that use of smart wearables such as activity trackers, which tends to drop after first few weeks of ownership [32]. The McMahon et al. study which explores older adult's experiences using a commercially available monitor to track physical activity demonstrates the importance of assessing both short-term and long-term experiences [74].

Moreover, the sampling techniques used by these research studies may be skewed as they only included older adults with chronic illnesses or older adults from other studies and as such may not be indicative of attitudes of the Canadian older population in general. A sample of healthy older adults, as used in this study, may offer more insight into factors that influence acceptance of smart wearables for the general older adult population. In addition, this study's longer smart wearable device testing period (3 weeks) is more appropriate to evaluate long term acceptance of smart wearable devices.

Finally, acceptance and attitude information collected by this study could prove to be important for future research with the aim of large-scale data collection based on voluntary usage of smart wearable devices. Big Data initiatives that look to leverage large amounts of data to predict certain ailments may also benefit from understanding usage patterns of older adults in order to develop proactive care protocols for the aging cohort.

3.2. Research Questions and Objectives

3.2.1. Objectives

The overarching aim of the study was to explore factors and attitudes that affect the acceptance and usage of smart wearable devices in Canadian older adults. In addition, descriptive statistics of Canadian older adults' experience with wearables, attitudes towards smart wearable devices, their acceptance, and important dimensions were investigated and comparatively analyzed.

Specific objectives of the study were to:

1. Gather descriptive, quantitative statistics of wearable device attitudes and usage in the older adult population via questionnaires.

2. Explore older adults' attitudes and acceptance of two different wearable devices.
3. Qualitatively follow-up on older adults' questionnaire responses with a purposively sampled subset to offer context to quantitative data.

3.2.2. Research Questions

To achieve the objectives outlined above, the following research questions were investigated:

1. What are the attitudes of older adults toward using wearable devices?
2. How do the acceptance levels of the two different wearable devices compare?
3. Are there relationships between socio-demographic factors and wearable device acceptance?

3.2.3. Hypotheses

The following were hypothesized about the dimensions and their relation to acceptance:

H1: Perceived Usefulness is associated with smart wearable device acceptance

H2: Perceived Ease of Use is associated with smart wearable device acceptance

H3: Subjective Norm is associated with smart wearable device acceptance

H4: Facilitating Conditions are associated with smart wearable device acceptance

H5: Privacy Concerns are associated with smart wearable device acceptance

H6: Perceived Risks are associated with smart wearable device acceptance

H7: Equipment Characteristics are associated with smart wearable device acceptance.

The dimensions outlined above and their importance relative to acceptance is discussed in detail later in section 4.6.1. Figure 3 “Proposed Extended Theoretical Framework”, below, represents the hypothesized relationships between the outlined dimensions and user acceptance.

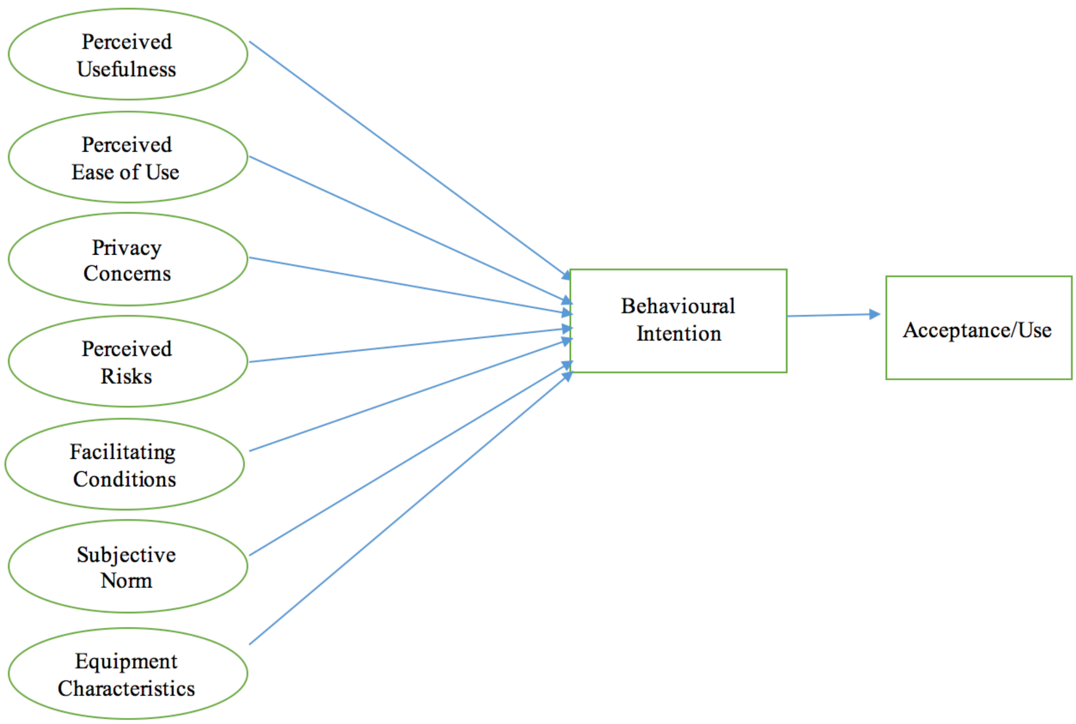


Figure 3: Proposed Extended Theoretical Framework

4. Methodology

4.1. Study Design

In comparison to quantitative or qualitative research design alone, a mixed methods design offers a better understanding of research [76]. Qualitative data offer greater depth in the understanding of research issues when combined with quantitative designs that work to validate existing theory and hypotheses. Hence, this study employed a two-phase sequential explanatory mixed methods design whereby quantitative data and results (Phase One) are followed up by qualitative data collection and results (Phase Two) from analysis to interpret quantitative data with greater depth and context [77].

Qualitative data were obtained through semi-structured interviews with a purposively selected subset of the sample. As this study aimed to explore the research gaps, using qualitative data to provide depth to quantitative results enables a better understanding of the exploratory research questions rather than providing summative results.

4.2. Sampling and Inclusion Criteria

This study employed a convenience sampling technique as it is frequently used in pilot research where collected data and results are used to identify key areas of interest and guide future research [78]. The targeted population of the study was older adults 55 years of age and older. In addition to the age requirement, participants must have been able to wear two wrist-worn smart wearable devices for 21 days each. A sample of 20 eligible participants was recruited from the cities of Kitchener, Waterloo, Guelph and Cambridge. Previously published research investigating acceptance of various technologies among older adults involve varying sample sizes.

Evaluating acceptance of assistive social agent technologies by older adults, Heerink et al.'s research used samples between 30-40 participants for four unique experiments [75]. In 2015, research by Mercer et al. employed a sample of 32 participants over the age of 50 and a mixed methods design to test acceptance of commercially available activity trackers but only a 3-day testing period [65]. Similarly, Fensli et al. use a quantitative design to test perceived acceptance of a newly developed ECG sensor among 11 patients [67]. Although these studies offer early results, further testing with larger sample sizes and random sampling is recommended in order to improve generalizability for future research. A sample of 20 participants was considered acceptable as this study is a pilot that is exploratory in nature; its aim was to investigate existing notions relating to technology acceptance as indicated by literature and acceptance of smart wearable devices within the Canadian context.

A purposive sample of four participants was selected in order to provide context and depth to responses collected during the Phase One of the study. The criterion for purposive sampling was determined by age and the potential of discovering rich information. Participants selected for interviews included three females aged 57, 65, 83 and one male aged 83. All four participants successfully completed Phase Two of the study. All 20 participants selected for Phase One of the study successfully completed the study.

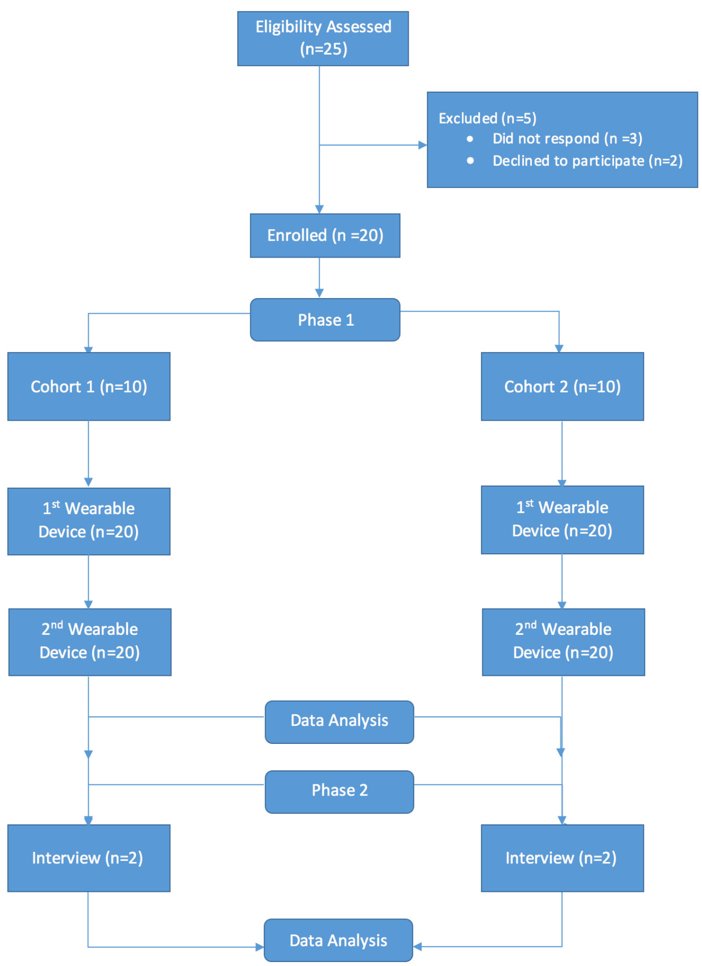


Figure 4: Methodology Flow

4.3. Participant Recruitment

Participants were recruited using flyers posted at local community centres and recreational facilities after gaining permission from individual facilities and cities if necessary. Local community centers, recreational facilities and social clubs provide a place for members of the community to gather and socialize. In addition, many facilities ran social activities for older adults and as such were prime recruitment locations. Interested participants were instructed to contact the research via phone or email. Participants were encouraged to tell eligible colleagues, family members, or friends to contact the researchers if they were interested in participating in the study. Recruitment started on March 8th, 2016 after ethics clearance was obtained from the University of Waterloo Research Ethics Committee and the Office of Research Ethics on March 8th, 2016 and concluded on May 2nd, 2016 after 20 participants were recruited.

4.4. Screening and Enrollment Procedure

Interested participants were contacted via phone or email to ensure inclusion criteria requirements were met, and confirm their age and ability to wear a wrist worn smart wearable device. An appointment was then set to provide the participant with an in-person 10-minute instructional brief, an opportunity to raise any questions or concerns. An information package for the study containing a printed information letter, consent forms, safety tips and reference materials was also provided. Each participant's age was verified through visual inspection of government issued official identification. Once all questions and concerns were addressed, the participant was enrolled in the study.

4.5. Data Collection and Management

4.5.1. Device and Equipment Selection

A review of 13 different commercially available devices was conducted after which two smart wearable devices were chosen for the study: the Microsoft Band and Xiaomi Mi Band. The selection criteria for the devices included battery life on a single charge, variety of sensors and data captured, software compatibility, hardware compatibility and price.

A table of the device characteristics is available in Appendix C. The ability to export data from the smart wearable device was also compared and considered to be an important distinguishing factor. In addition, there were budgetary limitations that played a role in the selection of the devices. The selected devices each offer unique features and may be considered to be on far ends of the smart wearable device spectrum in terms of cost, feature sets and ergonomics. These devices differ in price, function, and ergonomics and were selected for this study due to their different functionalities and feature sets that may be useful for monitoring older adults' health and exploring how acceptance of two uniquely different devices may vary.

4.5.2. Microsoft Band

The Microsoft Band was positioned as one of the most advanced smart wearable devices available for consumer purchase in 2015. It offers an extensive sensor array including an accelerometer, 3-axis gyroscope, optical heart rate monitor, galvanic skin response sensor, global positioning system, and a touchscreen color LCD display. The manufacturer's quoted battery life is approximately 48 hours, but varies based on individual usage.

In comparison to most other health tracking devices available to consumers, the Microsoft Band is heavier and more cumbersome to wear, but also offers more comprehensive health monitoring features. It is compatible with two of the most common and popular mobile operating systems, iOS and Android, as well as less popular, Windows Phone operating system. While the Microsoft Band offers a wide sensor array and smart-watch like functionality with its LCD display, it is considerably more expensive than basic activity and heart rate trackers available to the general consumer, at a cost of approximately $299 USD at launch.

The Microsoft Band is an advanced and relatively expensive smart monitoring wearable that offers the ability to monitor various physiological signals including heart rate, UV exposure, physical activity, location, sleep data, and galvanic skin response.

4.5.3. Xiaomi MI Band

In contrast to the Microsoft Band, the Mi Band is a low cost activity and heart rate tracker. While it is not available through the most popular brick and mortar retail outlets like the Microsoft Band is, it is beginning to become more popular as Xiaomi enters slowly the US market and expands their distribution channels; as such, the Mi Band is currently available through numerous large Internet retailers including Amazon and eBay. It offers a basic accelerometer and an optical heart rate sensor and is significantly less expensive than the Microsoft Band at a cost of $20 USD at launch.

The Mi Band has an estimated battery life of almost 30 days, with real world tests performed by the researcher indicating a single charge lasting between 45-50 days. Though the wearable device does not offer an LCD display, there are three individual LEDs located on the front of the sensor. These LEDs provide activity progress by lighting up one, two or all three LEDs. In addition, the device is light weight and can be worn on either wrist or neck, offering consumers more variability in placement. To sum, the Xiaomi Mi Band is a low-cost physical activity, sleep and heart rate monitoring smart wearable device that also offers various placement locations on the body including the neck, on your chest as a broach, or wrist.

4.5.4. Smartphones

As most smart wearable devices are paired with a smartphone or personal computer that can display historical data from the wearable device, participants were provided a smartphone to use during each of the two 21-day testing periods. The smartphone selection criteria were made up of the following categories; price, display, screen size, communication protocols, operating system and battery life. A Motorola G smartphone was selected to ensure all participants received the same smartphone and smart wearable device companion software experience. In addition, the open source nature of the Android operating system on the Motorola G facilitated objective raw sensor data collection that was used to calculate usage statistics for the Mi Band. The phones were not loaded with active SIM cards and as such did not have the ability to make calls. Participants had the ability to connect to Wi-Fi networks if they chose to.

Both smart wearable devices selected for this study offer on-device data storage and did not require to be in continuous communication with the smartphone. As such, participants were free to take the Motorola G smartphone with them or leave it at home. Bluetooth was used to transmit data collected on the smart wearable devices to the smartphone and the data were extracted at the end of the participant’s 21-day testing period.

4.5.5. Data Collection Procedure

The open source nature of the Android operating system on the Motorola G allowed for minor modifications to the Mi Band’s companion application, Mi Fit, to extract summary and raw data that were used to calculate usage statistics. Data available from the Microsoft Band’s companion application, Microsoft Health, was stored in the participant's study account and made available on the device's desktop platform, Microsoft Dashboard.

Due to budgetary constraints and the availability of wearable devices for testing, the data collection period was divided into two groups. Participants were split into two cohorts of ten participants each and data were collected for a total of 12 weeks with each cohort's data collection lasting 6 weeks, or 21 days with each of the two selected wearable devices.

Each participant was instructed to use the two selected off-the-shelf smart wearable devices, the Xiaomi Mi Band and the Microsoft Band, while carrying out their regular lives and daily activities.

After participants received a 10-minute in person instructional brief on basic usage instructions and safe usage tips, they were requested to wear each provided smart wearable device for a period of 21 days. During the instructional brief, participants were advised about each device's smartphone application and its ability to provide health data (such as physical activity, average heart rate and hours of sleep data in past 24 hours). In addition, charging instructions, usage guidelines and wearing instructions were provided.

The order of the two devices that a participant received was randomized in order to minimize behavioral bias. After using each device for 21 days, participants were given a questionnaire (Appendix A) designed to capture information about their attitudes and experiences with the device, and measure device acceptance. Participants were encouraged to fill the questionnaire in its entirety; however, there were no negative consequences for not answering any items. Questionnaires were collected at the end of the visit.

Smartphones were not connected to the Internet by default in order to prevent communication of personal information to device manufacturers. If a participant connected the smartphone to the Internet, the data collected from devices would automatically be synchronized to the manufacturer cloud storage systems and shared with the manufacturer of the device. In order to ensure anonymity of participants, anonymous user accounts were created by the researcher for each wearable device's companion software. This ensured that in the event the participant did connect the smartphone to the Internet, any data synchronized would be transmitted without any participant identifiers, ensuring anonymity.

After the second and final 21-day wearing period, the researcher visited the participant to provide the second and final questionnaire and if consent was provided, interviews were scheduled. A semi-structured interview guide was used to guide the interview process and is available for reference in Appendix B.

4.6. Data Collection Instruments and Methods

4.6.1. Questionnaire

A literature review was conducted to identify fundamental dimensions that influence user acceptance of technology to develop a 37-item, self-reported paper questionnaire for older adults. Items from the questionnaire are summarized in Table 1 below, while the full questionnaire can be found in Appendix A. In addition, demographics and information regarding previous experiences with technology and wearable devices were also collected. Participants were requested to respond to items relating to the key dimensions outlined in sections 4.6.1.1 - 4.6.1.7 using a five-point Likert response scale (*strongly disagree, disagree, neutral, agree, strongly agree*). These dimensions and their rationale for inclusion are described in detail in the ensuing sections.

Davis's research and questionnaires investigating perceived ease of use and perceived usefulness [56] were used as references to develop relevant items for the questionnaire used in the study. The sensor acceptance model by Fensli et al. was also reviewed to develop items that will collect responses relevant to equipment characteristics and to allow for exploration of the dimension's impact on acceptance of smart wearable devices within older adults [44]. The finalized questionnaire was reviewed by all thesis committee members to evaluate the clarity, readability, and relevance of questions asked prior to study commencement.

Table 1: Questionnaire Items

	Item
1	I think that monitoring my activity and health 24 hours a day, 7 days a week, can be a good thing
2	I was afraid that the device would discover a major health issue
3	I am comfortable with my health data being stored on the internet
4	I am able to get assistance from a friend of family member to use the device, if needed
5	I was able to wear the device easily without help from another person
6	I was able to remove the device easily without help from another person
7	I was able to perform my daily tasks as usual while wearing the device
8	The device was easily concealed underneath my clothing when worn
9	At times, I forgot I was wearing the device
10	I experienced skin irritations while wearing the device
11	The battery life of the device meets my expectations
12	The device's smartphone application was easy to use
13	I find the device easy to use
14	I find the display of the device easy to read indoors
15	I find the display of the device easy to read outdoors
16	The device was pleasant to wear during the night
17	I was concerned that the device is not securely attached to me
18	I was able to put the device on in a reasonable amount of time
19	I had no concerns about my privacy while wearing the device
20	I am comfortable with my health data being shared with equipment manufacturers as long as it is shared anonymously
21	I have the knowledge necessary to use the device
22	I think using the device is a more efficient way to monitor my health than visiting my doctor to collect similar information
23	Wearing the device motivated me to be more active
24	I think using the device can help me improve my overall health
25	Wearing the device caused me to have joint pain
26	I was able to shower or bathe normally while wearing the device
27	I was embarrassed to wear the device in front of family members
28	My friends would encourage me to use this device
29	My family members would encourage me to use this device
30	I think using the device can let me live at home longer by monitoring my health around the clock
31	The ability to use the device in a variety of locations is important to me
32	How useful did you find the information provided by the smart wearable device (such as step count, sleep data, heart rate) either on the wearable itself, or in the smartphone application?
33	Would you use the device you used during the last 21 days to continue to monitor or track your physical activity or health?
34	Over the last 21 days, how often do you think you wore the smart wearable device?
35	How much would you be willing to pay for the device you wore during the last 21 days?
36	Did you find yourself looking at your health data in the smartphone application more/less often after the first few days?
37	Do you consider yourself to be an active person?

4.6.1.1. Perceived Usefulness (PU)

Perceived usefulness is measured using 5 items (item number 1, 22, 23, 24 and 30) in the questionnaire and refers to the ability of the technology in question to improve one's performance. While the original construct's applicability was related to improvements in one's job performance, in the context of this study, perceived usefulness has been adapted to refer to the degree to which using a technology can help monitor older adults' health and support aging-in-place.

4.6.1.2. Perceived Ease of Use (PEOU)

Defined as "the degree to which a person believes that using a technology will be free from effort" [56], perceived usefulness has been established as a key predictor of user acceptance. This dimension will be measured using 7 items (item number 5, 6, 13, 14, 15, 18 and 26) in the questionnaire.

4.6.1.3. Privacy Concerns (PC)

Privacy concerns is a novel dimension in the framework and has been included due to the emergent tendency of smart device and technology manufacturers to use internet communication protocols to store and analyze data in the cloud, rather than on the particular device. This dimension is measured using 3 items (item number 3, 19 and 20) in the questionnaire.

4.6.1.4. Perceived Risks (PR)

Reinforced through a breadth of research [79] and originally presented by Raymond Bauer in 1960, the notion of Perceived Risks and its effects on consumer behavior is important when evaluating user acceptance of technology . Though the TAM does not explicitly account for Perceived Risks of adopting a technology, the dimension is included in the proposed framework in order to evaluate its significance within the Canadian older adult population and is measured through 3 items (item number 2, 10 and 25) in the questionnaire.

4.6.1.5. *Facilitating Conditions (FC)*

A review of literature reveals varying classifications of facilitating conditions [58], the original and most applicable of which has been adopted for this study. Based on a construct devised by Thompson et al., facilitating conditions are factors that can increase or decrease the effort required to use a technology [80]. These can include availability and affordability of use a particular technology, as well as the availability of training resources that have the potential to facilitate use of a technology. Facilitating conditions are evaluated using 2 items (item number 4 and 21) in the questionnaire.

4.6.1.6. *Subjective Norm (SN)*

Subjective norm is measured using 3 items (item number 27, 28 and 29) in the questionnaire and refers to a construct originally developed by Ajzen, (1991) to explain the likelihood of individuals who are influential in the lives of the technology user would recommend the use of said technology [57].

4.6.1.7. *Equipment Characteristics (EC)*

Equipment characteristics such as battery longevity, ergonomics and aesthetics are also important when deciding to adopt and accept a certain technology. Though the significance of equipment characteristics on acceptance may not be as pronounced as the other dimensions, qualitative research by Mihailidis et al. reveals that they are important nonetheless [81]. They are measured through 7 items (item number 7, 8, 9, 11, 12, 16, 17 and 31) in the questionnaire.

4.6.2. Semi-Structured Interviews

In following up with quantitative data obtained from phase one of the study, semi-structured interviews were conducted with a purposive sample. Patton notes that purposive sampling is particularly useful in research that seeks to identify and select information-rich cases from a larger sample and allows for the most efficient use of resources [82]. As qualitative methods are employed in order to gain depth of understanding [82], participants were interviewed to gain an additional insight into individual's experiences with the smart wearables provided during the study and to explore the relationship of the dimensions outlined earlier through qualitative inquiry. A semi-structured interview guide (see Appendix C) was developed to set a stage based on pre-determined areas of focus. Probes were developed prior to the interview in order to avoid leading questions and text.

Interviews were conducted at the participant's own residence in a private setting. Before starting, participants were provided with a brief overview of the ensuing interview, their right to refuse to answer any question they did not want to, and the estimated duration of the interview. In two cases, the participant's family members were present in the room during the interview. These participants were offered to relocate to a private room but they refused the suggestion.

5. Data Analysis

5.1. Questionnaire Data

The 37-item questionnaire from each smart wearable device testing period was used to provide descriptive statistics. The mode and median responses to each item were calculated to indicate most frequently picked responses among the sample. User acceptance was measured using one item (#33) and was based on a dichotomous response scheme (yes/no).

As described in Section 4.6.1, multiple items contributed to make individual Likert dimensions corresponding to each of the identified dimensions of influence. For each participant, a summative score was calculated for each dimension by using participant responses to the items that comprise that dimension. Given the small sample and the large number of dimensions being tested for association and correlation, logistic regression analysis with manual feature selection was conducted using the *MASS* library and the *dropterm* variable selection in R Studio to test for association between the dimensions and user acceptance [83].

The Chi-square test of independence and Spearman's Rho test of correlation were also conducted on each of the individual thirty-one Likert items, stratified by wearable device. The Wilcoxon signed-rank test was conducted to compare the median participant responses in order to determine whether the data distributions are identical between the two bands. A statistical significance level of 0.05 was used. Section 2 of the questionnaire was used to calculate sample demographics, explore descriptive statistics of previous technology use, and characteristics relating to smart wearable devices.

5.2. Interview Data

5.2.1. Reflexive Interview Process

Although a semi-structured interview guide was developed prior to the conduction of interviews, the interview process was responsive and enabled the researcher to adjust their interview approach. A reflexive approach was adopted to overcome the researcher's own postulations or presumptions of smart wearable devices [84]. This approach allowed for the modification of the interview technique and content as needed. After interviewing the first participant, the researcher noted early instances of potential bias in the form of leading questions, which was readjusted and corrected in the remaining three interviews.

Probes were also frequently used in the first interview and guided the adjustment and development of new probes to avoid tangential discussions. During the coding process, leading text was identified in order to explicitly state and caution interpretation later in the direct content analysis stage.

5.2.2. Coding Procedure and Code Book

To further explore and provide depth to the data collected from the questionnaire, data collected from semi-structured interviews were coded and themed using a directed content analysis strategy whereby the themes explored follow structure determined by concepts reviewed in literature, while also allowing for the discovery of previously undiscovered or unmentioned data and themes [85].

This strategy was chosen to provide depth and further explore if or how variables such as privacy concerns, subjective norm, perceived risks or others, not included in the original TAM created by Davis [56] relate to the acceptance of a smart wearable device.

The researcher first read through each interview transcript to familiarize himself with the data. Next, predetermined codes that were developed based on concepts and variables discovered during literature review. New data that were not represented by preexisting categories were then identified and analyzed. Irrelevant codes were discarded at this time of the coding process. Next, codes were combined into themes that appropriately and accurately describe the interview data. Irrelevant themes were discarded and retained themes were transformed into overarching themes. Pseudonyms were used to protect participant confidentiality. As phase two interviews were meant to provide additional insight and depth to quantitative data collected in phase one, theoretical saturation was not the end goal and hence not pursued.

6. Results

6.1. Demographic Characteristics of Sample

All twenty participants enrolled in the research completed the study. The results show respondents ranged in age from 55-84, and the average age for the sample was 64 years. The gender distribution of the sample was reasonably balanced as the sample was made of eight males (40%) and twelve females (60%). Education levels were high in the group as a large majority (85%) of the group had some post-secondary education or higher while the remaining (15%) had a high school education. Eight participants (40%) reported an annual income of $80,000 or more and nine (45%) below $50,000. Sample demographics characteristics are summarized in Table 2.

The Chi-square test of independence and Spearman's Rho test of correlation were conducted to investigate the relationships between demographics variables and user acceptance. None of the demographic variables measured (sex, marital status, education, or income) tested as significant.

Table 2: Demographic Characteristics of Sample

Demographics	Frequency	Percentage of Sample
Sex		
Male	8	40%
Female	12	60%
Marital Status	15	75%
Married	2	10%
Divorced	1	5%
Separated	2	10%
Widowed	0	0%
Never Married		
Education Level		
High School	3	15%
Some Post-Secondary	3	15%
Completed Post-Secondary	6	30%
Some Post-Graduate	1	5%
Completed Post-Graduate	7	35%
Income ~		
Less than 10,000	1	5%
10,000-19,999	1	5%
20,000-29,999	0	0%
30,000-39,999	5	25%
40,000-49,999	2	10%
50,000-59,999	0	0%
60,000-69,999	1	5%
70,000-79,999	1	5%
80,000-89,999	3	15%
90,000-99,999	3	15%
100,000-149,999	2	10%
150,000 or more	0	0%

~ = 1 missing response

6.2. Prior Experience with Technology

Participants were asked to answer seven questions about their background with technology and smart wearable devices. Of the twenty respondents, eighteen (90%) used a computer on a daily basis and fourteen (70%) personally owned a smartphone. Seventeen (85%) of the participants had heard of smart wearable devices before, showing a high degree of awareness among the group, though only one used a store bought tracker to monitor their health at the time of the study. A majority, sixteen participants (80%), also reported they would use any smart wearable device to track or monitor their health.

Furthermore, nine (45%) of the participants also indicated that a smart wearable device such as the one they wore in the study should cost $100, whereas another seven (35%) thought it should cost $200 dollars, and four (20%) indicated that it should be free. When asked about willingness to recharge a smart wearable device, participant responses varied with “every 2-5” days indicated as the most popular option as selected by six participants (30%) and thirteen participants (65%) selected a necessary recharging frequency of greater than 2 days and between 2-30 days. Detailed frequency distributions and responses can be found below in Table 3.

Table 3: Technology Background and Awareness

Background Questions	Frequency	Percentage of Sample
How much experience do you have with using a computer?		
None	1	5%
I use a computer once a month	0	0%
I use a computer once or twice a week	1	5%
I use a computer daily	18	90%
How much experience do you have with using a smartphone?		
I own a smartphone	14	70%
I have previously owned a smartphone	0	0%
I have used a friend or family member's smartphone	1	5%
I have never used a smartphone	5	25%
Have you heard of wearable smart devices before?		
Yes	17	85%
No	3	15%
Do you currently use store bought smart wearable device to track your health?		
Yes	1	5%
No	19	95%
Would you use ANY smart wearable device to track or monitor your health?		
Yes	16	80%
No	4	20%
In your opinion, how much should the device like the one you wore, cost?		
$0	4	20%
$100	9	45%
$200	7	35%
$300	0	0%
$500	0	0%
$1000	0	0%
How often would you be willing to recharge a smart wearable health monitoring device?		
Never	0	0%
Every 12 hours	1	5%
Every 24 hours	4	20%
Every 1-2 days	2	10%
Every 2-5 days	6	30%
Every 5-10 days	3	15%
Every 10-30 days	4	20%

6.3. Device Acceptance

Table 4 tabulates how the participants responded to the following question: "Would you use the device you used during the last 21 days to continue to monitor or track your physical activity or health?". Overall, the participants rated the acceptance the Xiaomi Mi Band (80%) over the Microsoft Band (45%). Acceptance results of the Mi Band are equivalent to the results of the participant's intention to use any smart wearable device to track or monitor their health (see Table 3).

Table 4: Acceptance Statistics

Acceptance	**Microsoft Band**		**Xiaomi Mi Band**	
	N	**%**	**N**	**%**
Yes	9	45%	16	80%
No	11	55%	4	20%

When analyzing the open-ended comments (see Appendix D) provided by the participants after using each band, several common elements emerged about each device's characteristics and the usefulness of features or characteristics that are important to older adults. These are described in the ensuing sections.

6.3.1. Microsoft Band Comments

The Microsoft band was often described as uncomfortable and bulky. Numerous participants criticized the size, weight and fit of the device, stating the device was too large and heavy in addition to being difficult to fasten. The device's battery life was often criticized to be below expectations and described as "poor" by participants. Availability of a display capable of displaying various types of information was a strength of the Microsoft Band as numerous participants appreciated the information being available immediately on the device's display. In addition, the device's software interface was also described as "easy to navigate".

Participants noted benefits of the availability and usefulness of features such as exercise tracking and time display as well as the usefulness of various type of collected data such as sleep times, step counts. These features were facilitated through the Microsoft Band's touch sensitive display. In addition, the importance of data and accuracy to participants emerged as a recurring note by participants as several noted the benefits of various types of data the Microsoft Band reports and criticized the Microsoft Band for being inaccurate at times.

6.3.2. Xiaomi Mi Band Comments

Comfort was the Mi Band's strength. The device's flexible and thin band was preferred by several participants. However, numerous participants experienced difficulty in closing the device's latching mechanism without the help of an additional person. The Mi Band's display, made up of three individual LED lights, does not carry the capability to display rich data or information display, a useful feature that was missed by several participants. Participants explained that they preferred to "see display on the bands opposed to looking on a phone screen" and "prefer the screen to show the actual data". While the device's long battery life was admired by several participants, one participant preferred a balance between battery life and screen usefulness, noting that she "would be willing to give up a bit of battery life in lieu of a display".

Perceived usefulness of the various data collected by the Mi Band emerged through several participant comments regarding the usefulness of sleep, heart rate and physical activity data. One participant explained that she found "it particularly interesting to discover sleep schedule and deep sleep". However, although data usefulness was well-regarded, several participants questioned the accuracy of the data provided by the Mi Band. One participant noted that he found the “data very inaccurate, particularly the heart-beat”.

Some participants also identified the price of the Mi Band to be appropriate for “a basic model” and that “it is priced right at $40-$50”. Although pricing information was not disclosed by researchers, participants were not blinded to any pricing information.

6.4. Descriptive Statistics

A majority of older adults in this study used each of the smart wearable devices for the entire duration of the study which was verified by the data collected by the smart wearable device. In addition, the Mi Band’s usage rates were slightly greater compared to the Microsoft Band (results summarize in Table 5). Moreover, when comparing participants’ self-reported usage levels, data were in accordance with the data collected by sensors in the smart wearable devices. Usage was defined by a minimum threshold of 100 steps distributed throughout a day.

Likert responses have an inherent order, as such reporting means has little value since an average of an *agree* or *neutral* response is not suitable or appropriate [86]. As such, central tendency is summarized by providing a median and mode value is for each item (Table 6). Table 7 (below) show the frequency distributions of each of the 31 Likert items. In sections 6.4.1 – 6.4.7, these items are descriptively examined as part of the dimensions described earlier in Section 4.6.

Table 5: Usage Statistics by Device

Participant ID	Number of days with more than 100 steps		Over the last 21 days, how often do you think you wore the smart wearable device?	
	Mi Band	**MS Band**	**Mi Band**	**MS Band**
1	21	21	Between 14-21 days	Between 14-21 days
2	19	21	Between 14-21 days	Between 14-21 days
3	21	11	Between 14-21 days	Between 14-21 days
4	13	20	Between 14-21 days	Between 14-21 days
5	21	21	Between 14-21 days	Between 14-21 days
6	21	19	Between 14-21 days	Between 14-21 days
7	21	21	Between 14-21 days	Between 14-21 days
8	21	21	Between 14-21 days	Between 14-21 days
9	21	21	Between 14-21 days	Between 14-21 days
10	21	21	Between 14-21 days	Between 14-21 days
11	21	19	Between 14-21 days	Between 14-21 days
12	21	21	Between 14-21 days	Between 14-21 days
13	21	21	Between 14-21 days	Between 14-21 days
14	21	17	Between 14-21 days	Between 14-21 days
15	21	21	Between 14-21 days	Between 14-21 days
16	21	21	Between 14-21 days	Between 14-21 days
17	21	21	Between 14-21 days	Between 14-21 days
18	21	10	Between 14-21 days	Between 7-14 days
19	21	20	Between 14-21 days	Between 14-21 days
20	21	21	Between 14-21 days	Between 14-21 days

Table 6: Item Central Tendency Measures

		Median		Mode		Range	
	Item	Mi	MS	Mi	MS	Mi	MS
1	I think that monitoring my activity and health 24 hours a day, 7 days a week, can be a good thing	4.5	4	5	4	2	2
2	I was afraid that the device would discover a major health issue	1.5	2	1	2	2	3
3	I am comfortable with my health data being stored on the internet	4	4	4	4	4	4
4	I am able to get assistance from a friend of family member to use the device, if needed	4	4	4	4	3	4
5	I was able to wear the device easily without help from another person	4	4	4	4	4	3
6	I was able to remove the device easily without help from another person	5	5	5	5	4	1
7	I was able to perform my daily tasks as usual while wearing the device	5	4	5	5	3	3
8	The device was easily concealed underneath my clothing when worn	4	2.5	4	2	3	4
9	At times, I forgot I was wearing the device	4	4	4	4	3	4
10	I experienced skin irritations while wearing the device	1.5	1.5	1	1	1	3
11	The battery life of the device meets my expectations	5	2	5	2	2	3
12	The device's smartphone application was easy to use	4	3	4	3	3	4
13	I find the device easy to use	4	4	4	4	2	4
14	I find the display of the device easy to read indoors	4	4	4	4	3	2
15	I find the display of the device easy to read outdoors	3	4	3	4	3	3
16	The device was pleasant to wear during the night	4	2	4	2	3	3
17	I was concerned that the device is not securely attached to me	2	2	2	2	3	3
18	I was able to put the device on in a reasonable amount of time	4	4	5	4	3	2
19	I had no concerns about my privacy while wearing the device	4	4	4	4	4	4
20	I am comfortable with my health data being shared with equipment manufacturers as long as it is shared anonymously	4	4	4	4	4	4
21	I have the knowledge necessary to use the device	4	4	4	4	3	3
22	I think using the device is a more efficient way to monitor my health than visiting my doctor to collect similar information	4	3	4	3	4	4
23	Wearing the device motivated me to be more active	3	4	3	4	3	3
24	I think using the device can help me improve my overall health	4	4	4	4	3	3
25	Wearing the device caused me to have joint pain	2	1	2	1	2	1
26	I was able to shower or bathe normally while wearing the device	4	3	4	2	4	4
27	I was embarrassed to wear the device in front of family members	2	1.5	2	1	2	4
28	My friends would encourage me to use this device	3.5	3	4	3	4	3
29	My family members would encourage me to use this device	4	4	4	4	4	3
30	I think using the device can let me live at home longer by monitoring my health around the clock	3	3	3	3	4	4
31	The ability to use the device in a variety of locations is important to me	4	4	4	4	2	2

Table 7: Item Frequency Distribution

		Strongly Disagree(1)		Disagree(2)		Neutral(3)		Agree(4)		Strongly Agree(5)	
		MI	MS	MI	MS	MI	MS	MI	MS	MI	MS
I think that monitoring my activity and health 24 hours a day, 7 days a week, can be a good thing	#	0	0	0	0	2	2	8	11	10	7
	%	0%	0%	0%	0%	10%	10%	40%	55%	50%	35%
I was afraid that the device would discover a major health issue	#	10	8	7	11	3	0	0	1	0	0
	%	50%	40%	35%	55%	15%	0%	0%	5%	0%	0%
I am comfortable with my health data being stored on the internet	#	2	1	5	2	2	3	9	13	2	1
	%	10%	5%	25%	10%	10%	15%	45%	65%	10%	5%
I am able to get assistance from a friend of family member to use the device, if needed	#	0	1	1	3	1	1	15	11	3	4
	%	0%	5%	5%	15%	5%	5%	75%	55%	15%	20%
I was able to wear the device easily without help from another person	#	1	0	4	2	1	0	8	10	6	8
	%	5%	0%	20%	10%	5%	0%	40%	50%	30%	40%
I was able to remove the device easily without help from another person	#	1	0	1	0	0	0	7	9	11	11
	%	5%	0%	5%	0%	0%	0%	35%	45%	55%	55%
I was able to perform my daily tasks as usual while wearing the device	#	0	0	1	2	0	1	7	8	12	9
	%	0%	0%	5%	10%	0%	5%	35%	40%	60%	45%
The device was easily concealed underneath my clothing when worn	#	0	1	2	9	3	4	11	5	4	1
	%	0	5%	10%	45%	15%	20%	55%	25%	20%	5%
At times, I forgot I was wearing the device	#	0	2	1	4	1	3	11	9	7	2
	%	0	10%	5%	20%	5%	15%	55%	45%	35%	10%
I experienced skin irritations while wearing the device	#	10	10	10	6	0	2	0	2	0	0
	%	50%	50%	50%	30%	0%	10%	0%	10%	0%	0%
The battery life of the device meets my expectations	#	0	5	0	8	1	1	7	6	12	0
	%	0%	25%	0%	40%	5%	5%	35%	30%	60%	0%
The device's smartphone application was easy to use	#	0	2	1	4	3	6	11	6	5	2
	%	0%	10%	5%	20%	15%	30%	55%	30%	25%	10%

I find the device easy to use	#	0	1	0	3	2	3	10	12	8	1
	%	0%	5%	0%	15%	10%	15%	50%	60%	40%	5%
I find the display of the device easy to read indoors	#	0	0	1	0	6	1	8	10	3	9
	%	0%	0%	5%	0%	30%	5%	40%	50%	15%	45%
I find the display of the device easy to read outdoors	#	0	0	1	3	8	1	7	12	1	4
	%	0%	0%	5%	15%	40%	5%	35%	60%	5%	20%
The device was pleasant to wear during the night	#	0	3	1	8	3	3	12	6	4	0
	%	0%	15%	5%	40%	15%	15%	60%	30%	20%	0%
I was concerned that the device is not securely attached to me*	#	7	6	9	10	1	2	3	2	0	0
	%	35%	30%	45%	50%	5%	10%	15%	10%	0%	0%
I was able to put the device on in a reasonable amount of time	#	0	0	5	0	4	1	5	10	6	9
	%	0%	0%	25%	0%	20%	5%	25%	50%	30%	45%
I had no concerns about my privacy while wearing the device	#	1	1	1	2	1	0	11	9	6	8
	%	5%	5%	5%	10%	5%	0%	55%	45%	30%	40%
I am comfortable with my health data being shared with equipment manufacturers as long as it is shared anonymously	#	1	1	1	0	1	2	13	13	4	4
	%	5%	5%	5%	0%	5%	10%	65%	65%	20%	20%
I have the knowledge necessary to use the device	#	0	0	1	3	2	1	14	13	3	3
	%	0%	0%	5%	15%	10%	5%	70%	65%	15%	15%
I think using the device is a more efficient way to monitor my health than visiting my doctor to collect similar information	#	2	1	3	3	3	7	8	7	4	2
	%	10%	5%	15%	15%	15%	35%	40%	35%	20%	10%
Wearing the device motivated me to be more active	#	0	1	4	6	7	6	4	2	5	4
	%	0%	5%	20%	30%	35%	30%	20%	10%	25%	20%
I think using the device can help me improve my overall health	#	0	0	2	1	3	6	12	11	3	2
	%	0%	0%	10%	5%	15%	30%	60%	55%	15%	10%
Wearing the device caused me to have joint pain	#	9	12	10	8	1	0	0	0	0	0
	%	45%	60%	50%	40%	5%	0%	0%	0%	0%	0%
I was able to shower or bathe normally while wearing the device	#	3	2	4	6	2	4	7	2	4	4
	%	15%	10%	20%	30%	10%	20%	35%	10%	20%	20%

I was embarrassed to wear the device in front of family members*	#	9	10	10	9	1	0	10	0	9	1
	%	45%	50%	50%	45%	5%	0%	50%	0%	45%	5%
My friends would encourage me to use this device	#	2	0	2	4	6	7	9	6	1	3
	%	10%	0%	10%	20%	30%	35%	45%	30%	5%	15%
My family members would encourage me to use this device	#	1	0	2	3	6	5	9	9	2	3
	%	5%	0%	10%	15%	30%	25%	45%	45%	20%	15%
I think using the device can let me live at home longer by monitoring my health around the clock	#	2	1	2	5	9	7	5	6	2	1
	%	10%	5%	10%	25%	45%	35%	25%	30%	10%	5%
The ability to use the device in a variety of locations is important to me	#	0	0	0	0	2	4	13	11	5	5
	%	0	0%	0	0%	10%	20%	65%	55%	25%	25%

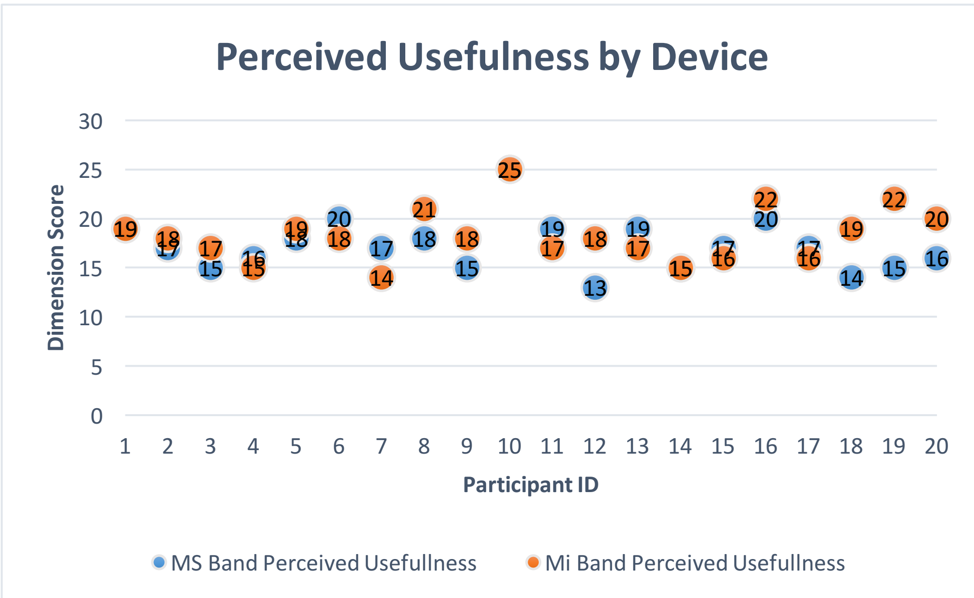
Item		Mi	MS	Mi	MS	Mi	MS	Mi	MS
		Very Useful		Somewhat Useful		Not very Useful		Not at all useful	
How useful did you find the information provided by the smart wearable device (such as step count, sleep data, heart rate) either on the wearable itself, or in the smartphone application?	#	9	8	9	11	2	1	0	0
	%	45%	40%	45%	55%	10%	5%	0%	0%
How much would you be willing to pay for the device you wore during the last 21 days?		$0		$1-50		$51-$100		$101-$200	
	#	3	6	10	3	5	6	2	4
	%	15%	30%	50%	15%	25%	30%	10%	25%

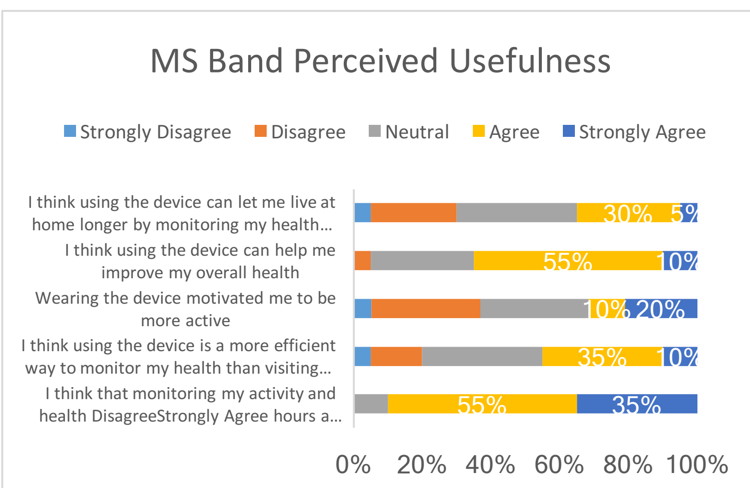
6.4.1. Perceived Usefulness (PU)

Perceived usefulness was measured through five items. Higher scores for the dimension indicated greater perceived usefulness of the tested smart wearable device. Overall, participants had more positive attitudes of perceived usefulness of the Mi Band. Ten (50%) of the twenty participants rated the perceived usefulness of the Mi Band to be greater than the Microsoft Band. Three participants (15%) rated the perceived usefulness of both bands to be the same, and seven (35%) rated the Microsoft Band’s perceived usefulness to be greater.

Diverging bar charts for the items (Figure 5) show that more participants (75%) either agreed or strongly agreed that using the Mi Band would improve their health than the Microsoft

Band (65%). In addition, a greater percentage of participants also agreed or strongly agreed the Mi Band was able to motivate them to be more active (45%), compared to the Microsoft Band (30%). Also, a greater percentage of participants (60%) agreed or strongly agreed that using the Mi Band is a more efficient way to monitor my health than visiting my doctor to collect similar information than did so in the case of the Microsoft Band (45%). The remaining two items in the category yielded equivalent levels of agreement among the two devices.





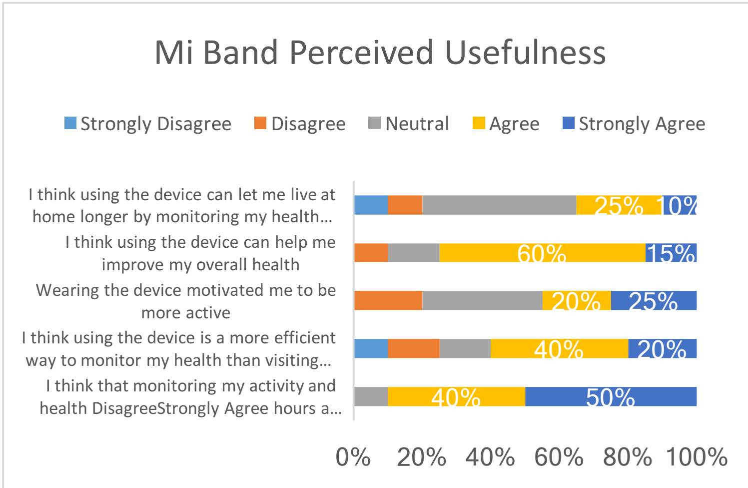


Figure 5: Perceived Usefulness by Device

6.4.2. Perceived Risks (PR)

Higher scores on the perceived risks dimension indicated increased perceived risks of using the two smart wearable devices; three items make up the dimension. As a whole, participants did not indicate high levels of agreement with the dimension indicating participants had low levels of perceived risks while using the two smart wearable devices (see Figure 6).

None of the participants agreed that using the Mi Band caused them to them to have joint pain, skin irritations, or that they were afraid the device would discover a major health issue. In contrast however, while testing the Microsoft Band two participants (10%) indicated experiencing skin irritations and one (5%) indicated that they were afraid the device would discover a major health issue.

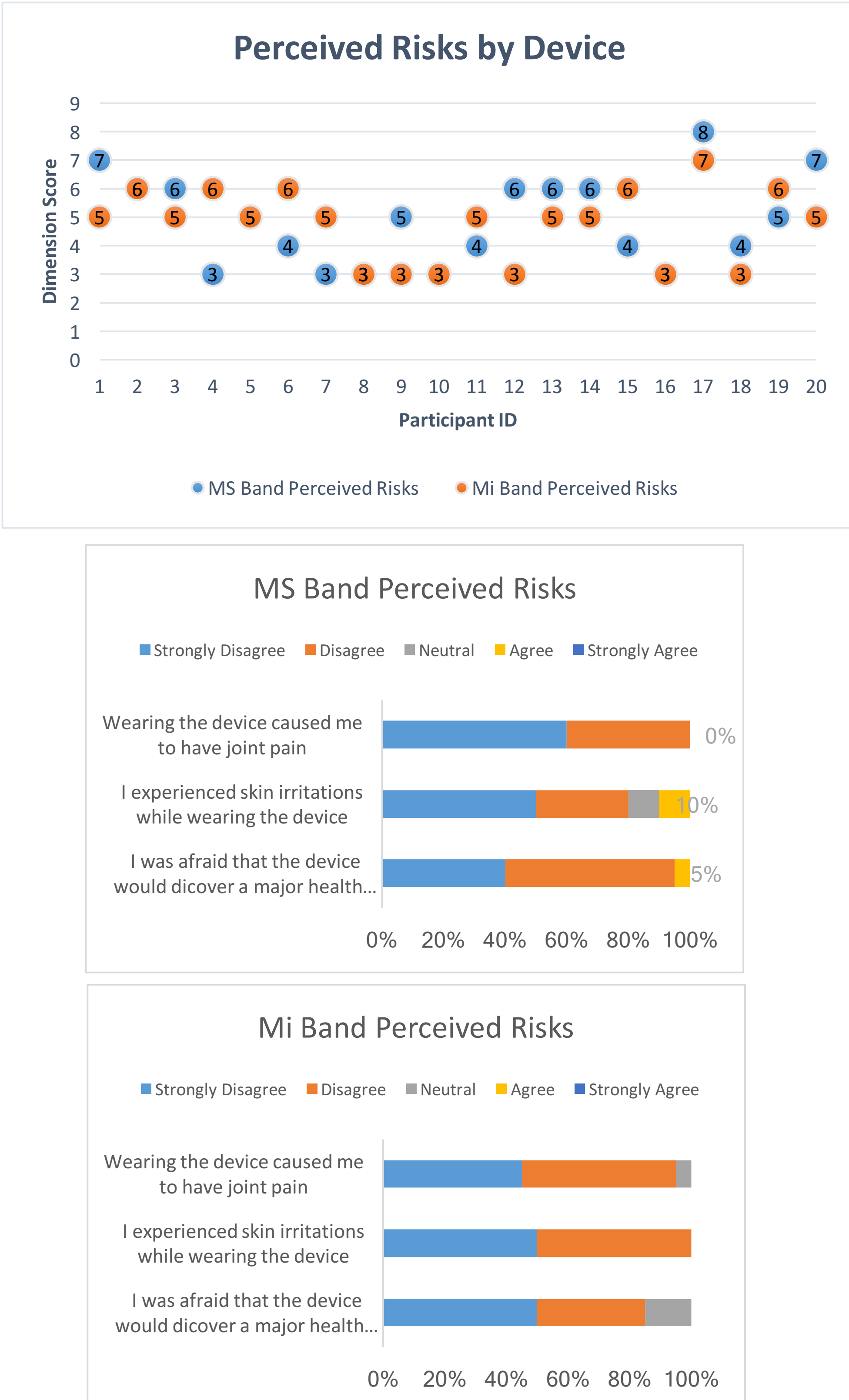
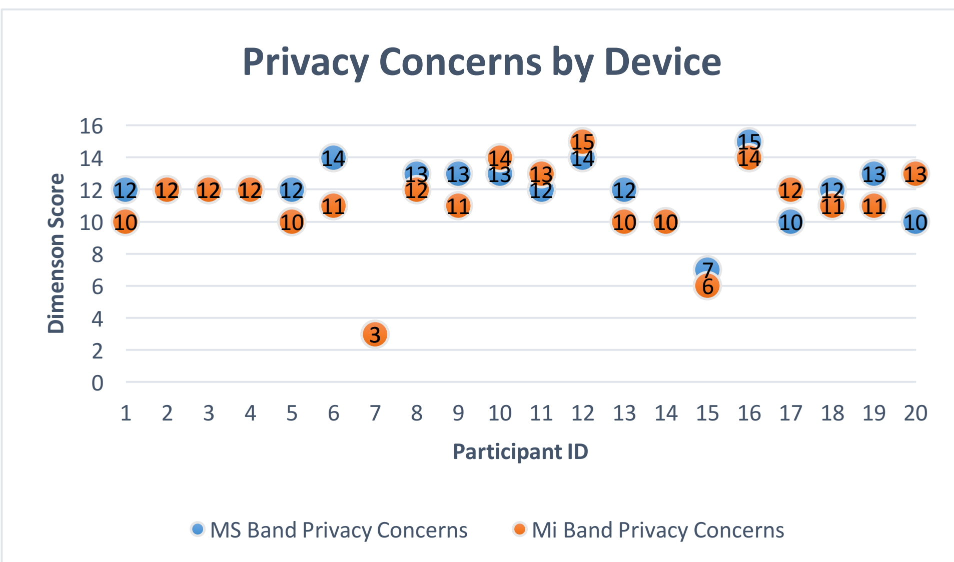


Figure 6: Perceived Risks by Device

6.4.3. Privacy Concerns (PC)

Privacy concerns were measured using four items; higher scores on the dimension are indicative of *lower* levels of privacy concerns. Overall, participants did not have many privacy concerns. In comparing privacy concerns from each smart wearable device were balanced; ten (50%) of participants rated privacy concerns to be lower while using the Microsoft Band, while five (25%) noted no difference, and five (25%) rated Mi Band lower. An examination of the diverging bar charts in Figure 7 reveals that fewer participants were comfortable with their health data being stored on the internet while using the Mi Band (55%) than while using the Microsoft Band (70%). Furthermore, participants were slightly more comfortable having their health data shared with the equipment manufacturers as long as it was shared anonymously while using either the Mi (90%) or Microsoft Band (85%). More participants comfortable with their health data being stored on the internet with the Microsoft Band (70%) than the Mi Band (55%)



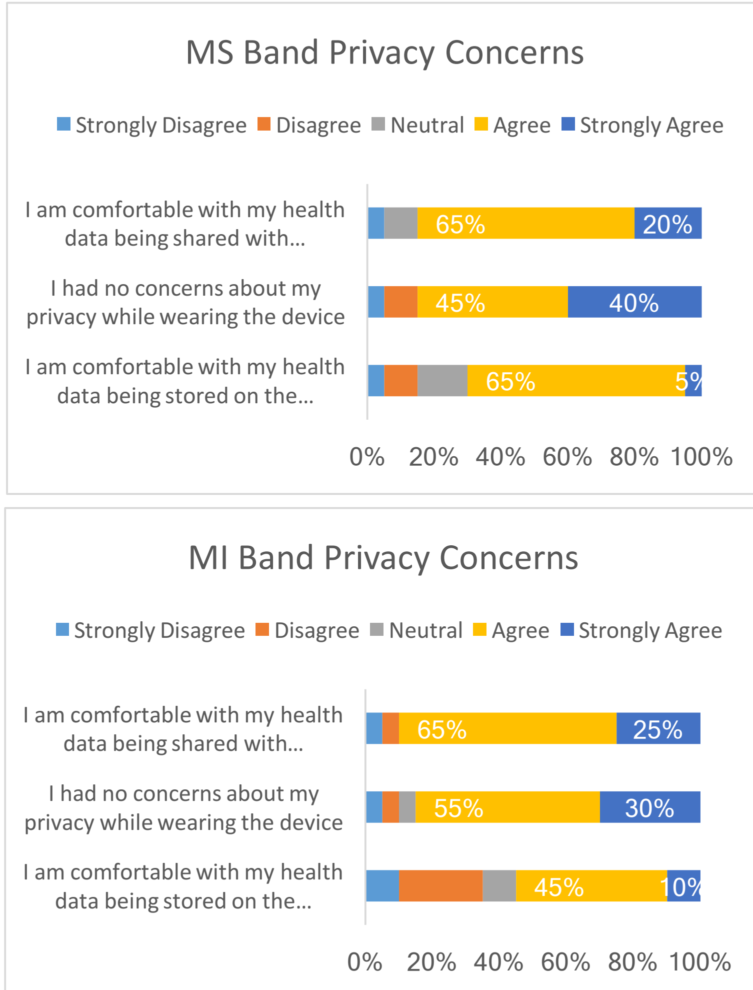


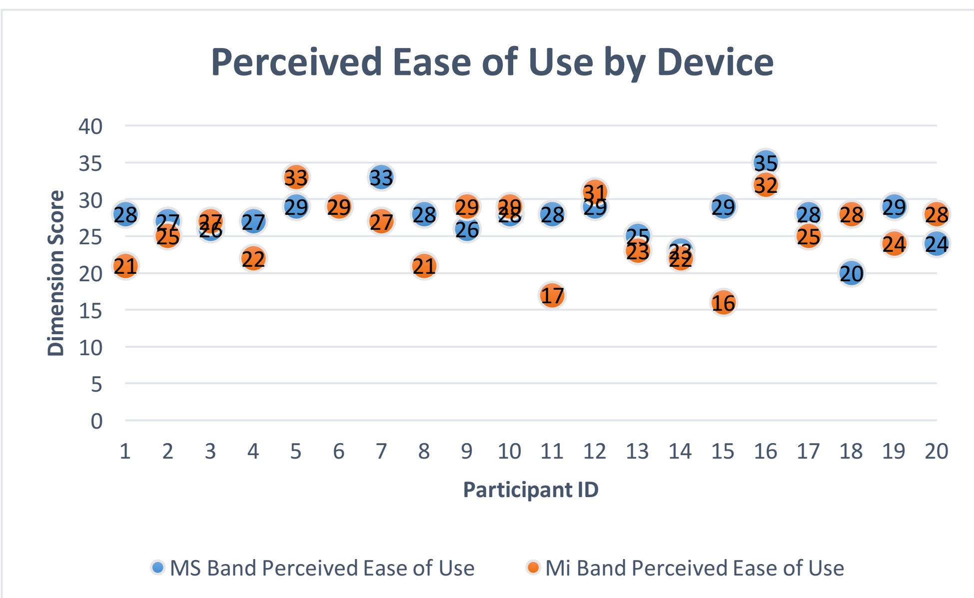
Figure 7: Privacy Concerns by Device

6.4.4. Perceived Ease of Use (PEOU)

Perceived Ease of Use was measured through seven items; greater scores on the dimension indicated greater perceived ease of use of the respective smart wearable devices. Overall, perceived ease of use of each device was high. However, more participants (60%) indicated greater perceived ease of use using the Microsoft Band than while using the Mi Band (35%), while one participant (5%) noted no different between the two.

Fewer participants agreed or strongly agreed that they could shower or bathe normally while wearing the Microsoft Band (35%) than the Mi Band (55%). The display of the Microsoft Band was easier to read both indoors (95% agreed or strongly agreed) and outdoors (80% agreed or strongly agreed) in comparison to the Mi Band, for which only 40% agreed or strongly agreed that they found the display easy to read outdoors and 55% agreed or strongly agreed the display was easy to read indoors.

Although more participants (90%) found the Mi Band to be easy to use than the Microsoft Band (65%), almost twice as many participants agreed or strongly agreed that Microsoft Band (95%) was easier to put on in a reasonable amount of time in comparison to the Mi Band (50%). In addition, more participants agreed or strongly agreed that they were able to wear the Microsoft Band (90%) without help from another person than the Mi Band (70%). Similarly, every participant felt that they could remove the Microsoft Band without help from another person whereas a slightly smaller percentage (90%) felt the same way about the Mi Band.



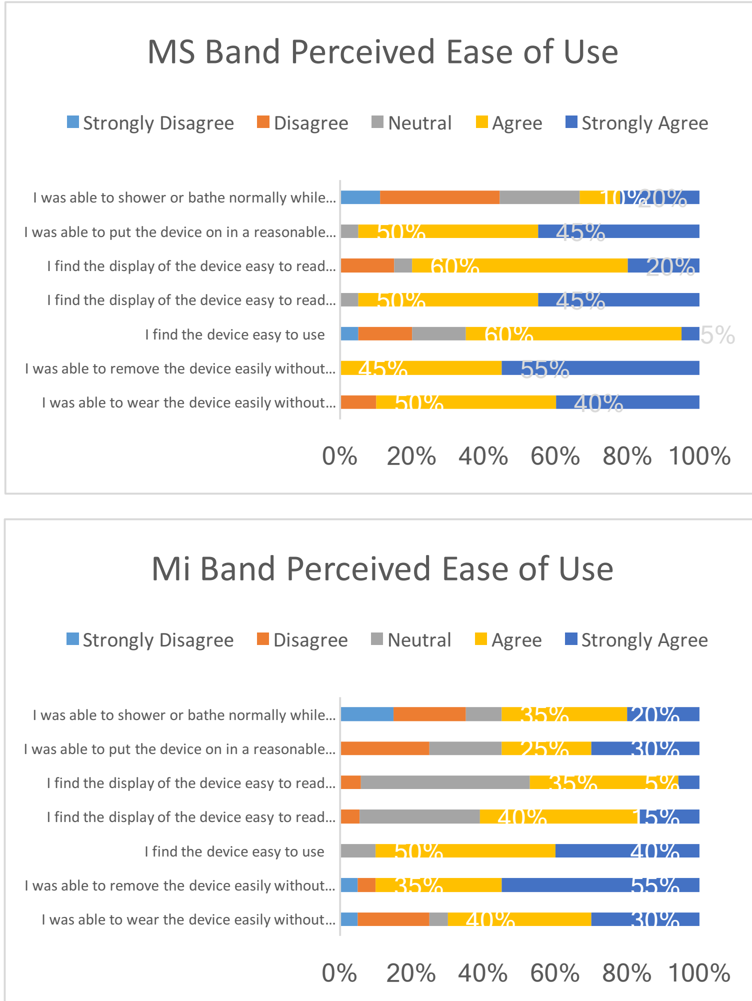
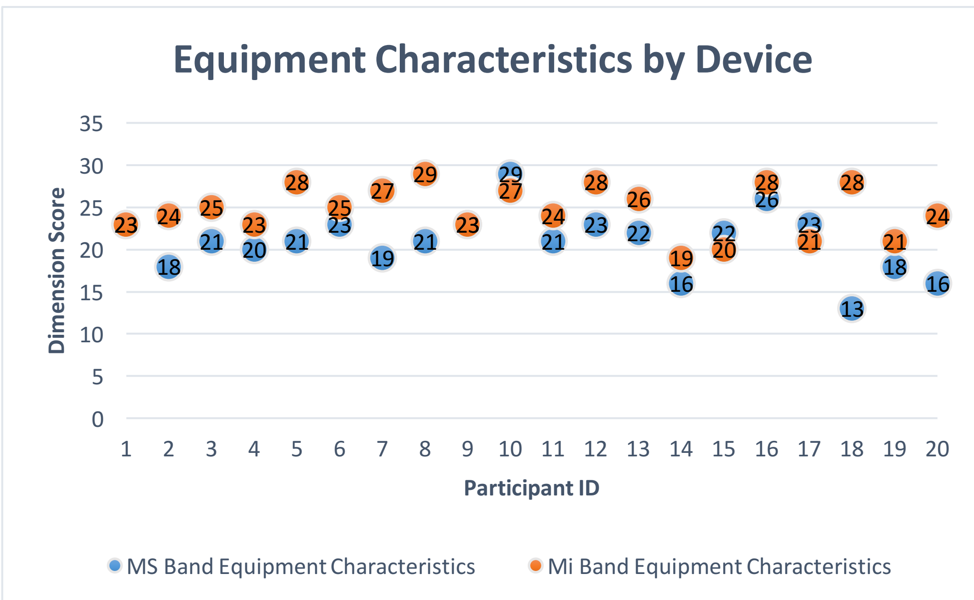


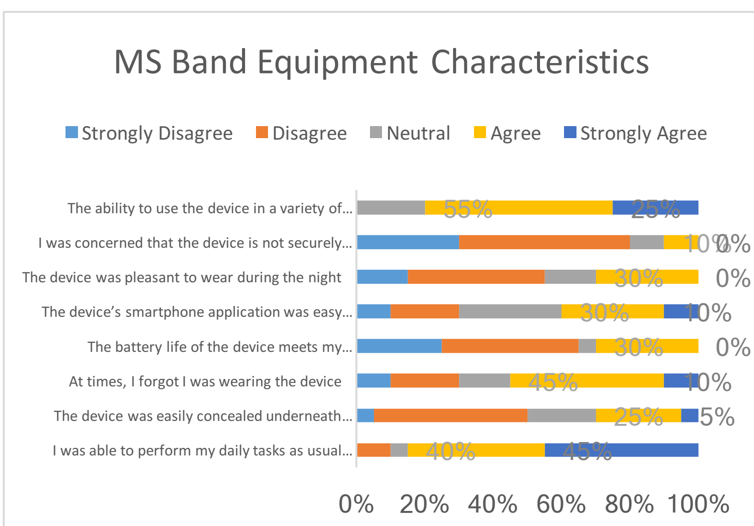
Figure 8: Perceived Ease of Use by Device

6.4.5. Equipment Characteristics (EC)

The Equipment Characteristics (EC) dimension was made up of eight items that measured several different traits of the smart wearable device being used. Greater scores on the dimension indicate greater positive attitudes about each respective device's qualities. Overall, participants were in greater agreement with the items while testing the Mi Band; signifying better overall equipment characteristics. Fifteen participants (75%) rated the Mi Band greater than the Microsoft Band. A greater percentage agreed or strongly agreed that the Mi Band (80%) was pleasant to wear during the night than the Microsoft Band (30%), and a greater percentage also felt that the Mi Band's (95%) battery life met their expectations than when compared to the Microsoft Band (30%).

Only a few participants (10-15%) were concerned that the smart wearables they used were not securely attached to them. Figure 9 shows the diverging bar charts for the remaining items in the dimension; participants responded more favorably to items tested with the Mi Band in comparison to the Microsoft Band. Measures of central tendency for each item can be found in Table 7 in section 6.4.





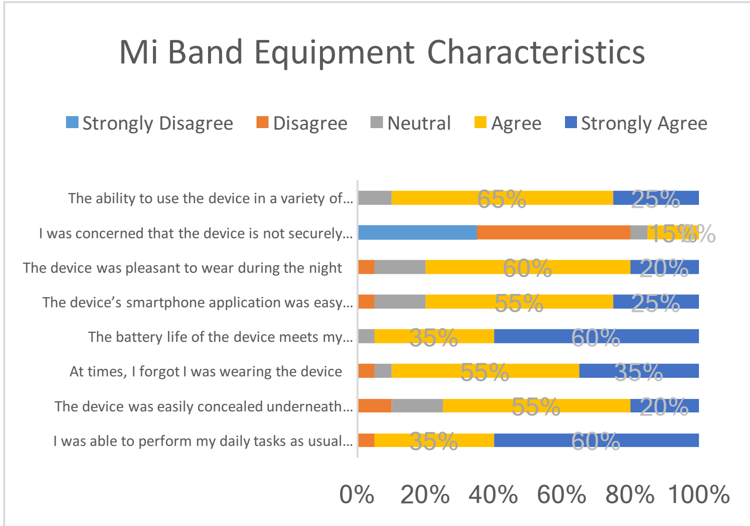


Figure 9: Equipment Characteristics by Device

6.4.6. Facilitating Conditions (FC)

Facilitating conditions were measured through two items in the questionnaire. Overall, participants rated facilitating conditions to be greater while testing the Mi Band than when testing the Microsoft Band; however, the difference between the devices was small. Whereas fifteen participants (80%) agreed or strongly agreed that they had the knowledge necessary to use the Microsoft Band, seventeen (85%) felt the same while testing the Mi Band. In addition, more participants felt they could get assistance from a friend or family member to use the device, if needed while using the Mi Band (90%) than the Microsoft Band (75%).

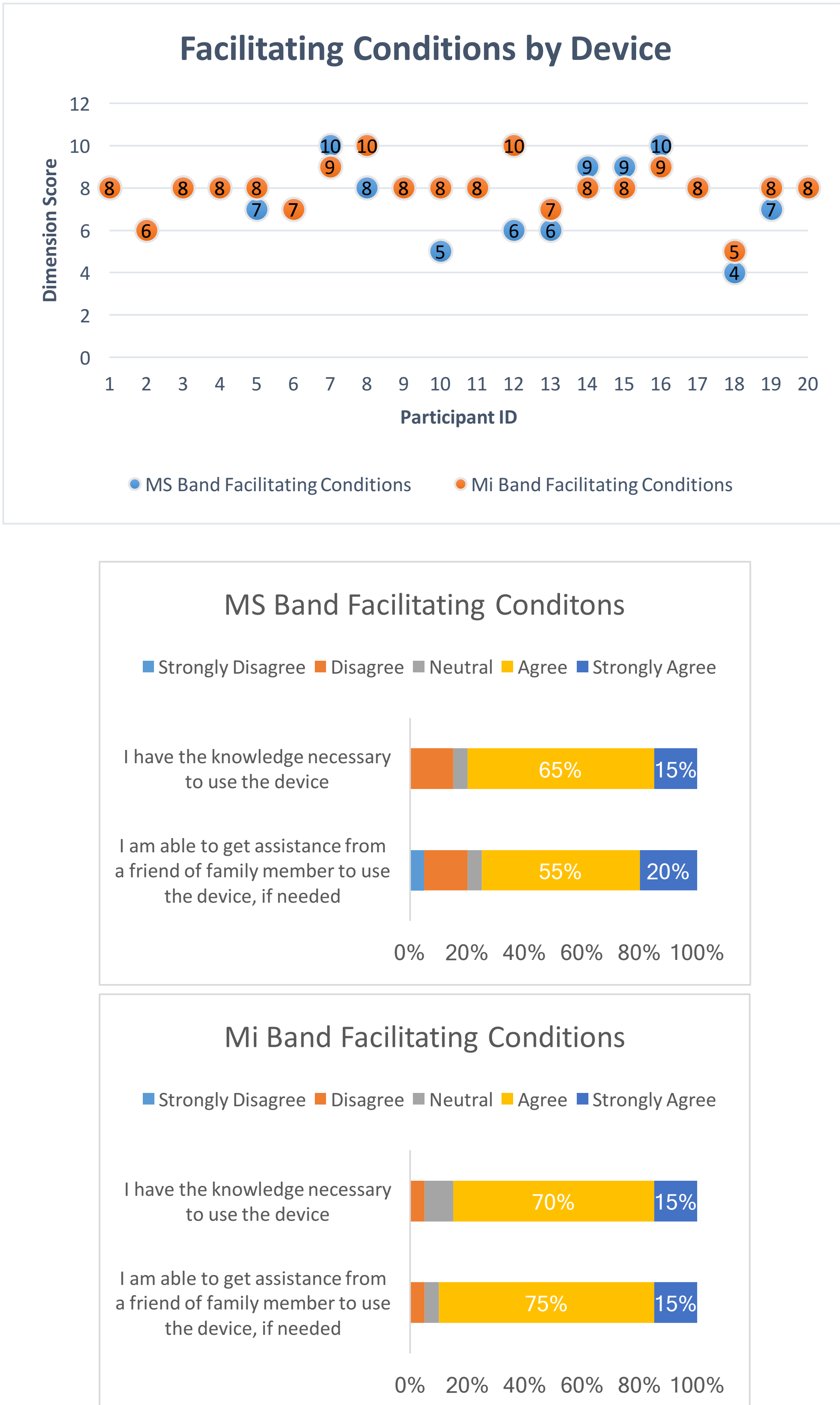
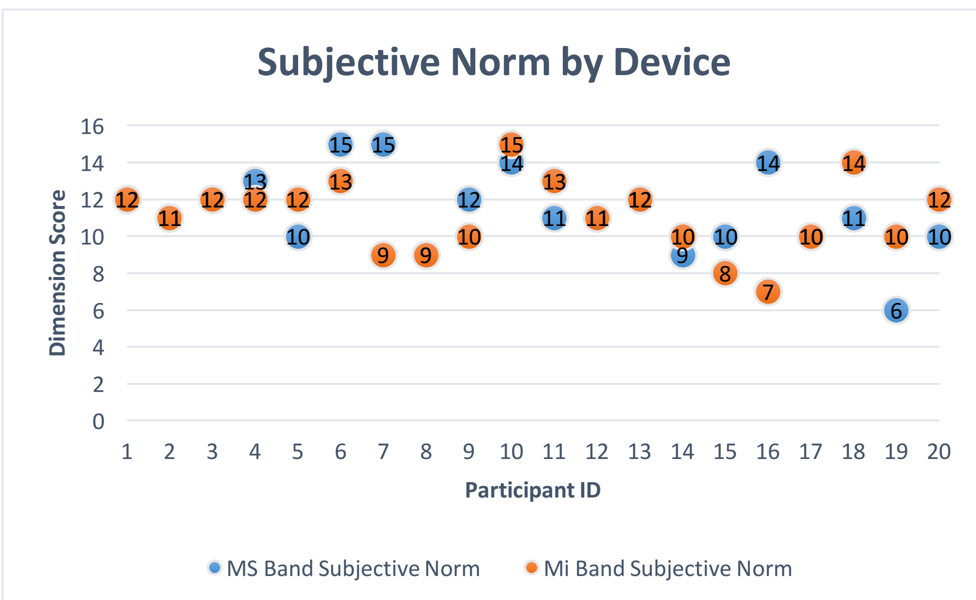


Figure 10: Facilitating Conditions by Device

6.4.7. Subjective Norm (SN)

Subjective norm was measured by three items in the dimension. Greater scores on the dimension indicated greater subjective norm. Overall, participant reported levels of subjective norm did not differ significantly between devices. Between 55% (Mi Band) and 60% (Microsoft Band) respondents felt their family members would encourage them to use the respective smart wearable devices. Eight (40%) of participants felt that their friends would encourage them to use the Microsoft Band while ten (50%) reported feeling the same way about the Mi Band. None of the participants felt embarrassed to wear the Mi band in front of friends or family, but one participant strongly agreed to feeling embarrassed while wearing the Microsoft Band in front of family or friends.



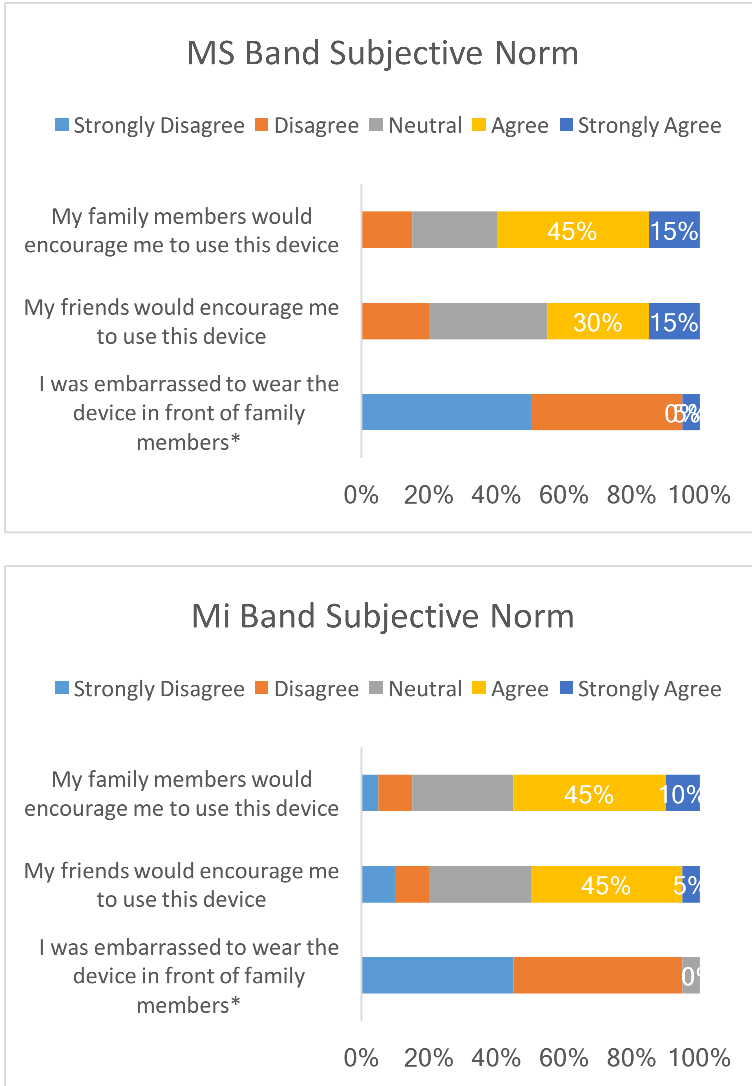


Figure 11: Subjective Norm by Device

6.5. Statistical Analyses

6.5.1. Chi-Square Test of Independence

The Chi-square test of independence was used to test for statistically significant relationships between user acceptance and participants’ responses to each of the Likert item (1-31) from the questionnaire. Significant results are shown for each respective device in Tables 8 and 9.

Table 8: Mi Band Item Correlation (Chi-Square Test)

Item		Chi-sq.	Dimension	p-value
15	I find the display of the device easy to read outdoors	8.571	PEOU	0.036
19	I had no concerns about my privacy while wearing the device	10.625	PC	0.031
27	I was embarrassed to wear the device in front of family members	7.500	SN	0.024
29	My family members would encourage me to use this device	10.278	SN	0.036
30	I think using the device can let me live at home longer by monitoring my health around the clock	10.278	PU	0.036
35	How much would you be willing to pay for the device you wore during the last 21 days?	14.375	N/A	0.002

Table 9: MS Band Item Correlation (Chi-Square Test)

Item		Chi-sq.	Dimension	p-value
35	How much would you be willing to pay for the device you wore during the last 21 days?	9.105	N/A	0.030
36	Did you find yourself looking at your health data in the smartphone application more/less often after the first few days?	10.600	N/A	0.014

6.5.2. Spearman's Test of Correlation

Spearman's Rho was calculated to test if a correlation between each participant's Likert item responses and user acceptance exists. Significant results are displayed in Tables 10 and 11 below.

Table 10: Mi Band Item Correlation (Spearman's Rho)

Item		Rho	Dimension	p-value
23	Wearing the device motivated me to be more active	-.473	PU	0.035
29	My family members would encourage me to use this device	-.577	SN	0.008
35	How much would you be willing to pay for the device you wore during the last 21 days?	.644	N/A	0.002

Table 11: MS Band Item Correlation (Spearman's Rho)

Item		Rho	Dimension	p-value
15	I find the display of the device easy to read outdoors	.473	PEOU	0.036
19	I had no concerns about my privacy while wearing the device	-.490	PC	0.028
21	I have the knowledge necessary to use the device	.593	FC	0.005
24	I think using the device can help me improve my overall health	.444	PU	0.049
35	How much would you be willing to pay for the device you wore during the last 21 days?	.559	N/A	0.023
36	Did you find yourself looking at your health data in the smartphone application more/less often after the first few days?	-.535	N/A	0.015

6.5.3. Wilcoxon Signed-Rank Test

A Wilcoxon Signed-Rank Test was conducted to examine whether there was a significant difference between the item responses for the Mi Band and the Microsoft Band. Significant results are displayed in Table 12 below; the data indicate that there is a meaningful difference in the item responses.

Table 12: Wilcoxon Signed-Rank Test

Item		Dimension	p-value
11	The battery life of the device meets my expectations	EC	< 0.001
16	The device was pleasant to wear during the night	EC	0.001
14	I find the display of the device easy to read indoors	PEOU	0.003
8	The device was easily concealed underneath my clothing when worn	EC	0.004
9	At times, I forgot I was wearing the device	EC	0.005
12	The device's smartphone application was easy to use	EC	0.007
13	I find the device easy to use	PEOU	0.007
18	I was able to put the device on in a reasonable amount of time	PEOU	0.017
15	I find the display of the device easy to read outdoors	PEOU	0.022
23	Wearing the device motivated me to be more active	PU	0.041

6.5.4. Feature Selection and Logistic Regression

A logistic regression model was fit and was used to describe the relation between the dimensions and user acceptance. Feature selection was conducted to select four dimensions to be included in the model as covariates. After feature selection, Perceived Risks (PR), Facilitating Conditions (FC), Privacy Concerns (PC), and Equipment Characteristics (EC) were kept in the model, while Perceived Ease of Use (PEOU), Perceived Usefulness (PU) and Subjective Norm (SN) were discarded. The logistic regression results are displayed in Table 13 below.

Table 13: Logistic Regression Results

Variable	OR	95%	p-value
Privacy Concerns (PC)	0.490	0.166, 0.904	0.0939
Facilitating Conditions (FC)	3.252	1.323, 7.995	0.0102*
Perceived Risks (PR)	3.222	1.132, 9.171	0.0284*
Equipment Characteristics (EC)	2.039	1.205, 3.451	0.0079*

**: Statistically significant ($p < 0.05$)*

Privacy Concerns was not significant in the model. Facilitating Conditions was indicated to be significant in the model. The odds of acceptance increases by a factor of 3.252 if Facilitating Conditions are increased by one unit. As such, the likelihood of accepting a smart wearable device increases as Facilitating Conditions increases. In addition, the Perceived Risks dimension was also found to be significant in the model. The odds of acceptance increases by a factor of 3.222 if Perceived Risks is increased by one unit, as indicated by the dimension's calculated Odds Ratio. The final dimension variable in the model, Equipment Characteristics, was also significant. The odds of acceptance increase by a factor of 2.039 if Equipment Characteristics score increases by one unit. Hence, the data indicate that the chance of accepting a smart wearable device increases as favorable Equipment Characteristics of a smart wearable device increase.

6.6. Directed Content Analysis

Participants selected for semi-structured interviews and their acceptance of each one of the smart wearable devices used in this study are described in Table 14 below. Pseudonyms were assigned in order to protect participant confidentiality.

Table 14: Participants Selected for Semi-Structured Interviews

Participant Pseudonym	Age	Gender	Band Acceptance	
			Mi	Microsoft
Anita	65 yrs.	Female	No	No
Paula	84 yrs.	Female	Yes	No
Francine	65 yrs.	Female	Yes	No
Greg	83 yrs.	Male	No	No

6.6.1. Smartphones as Facilitators of Smart Wearable Devices

Although several recently released smart wearable devices have features that can be performed without a smartphone (Samsung Galaxy Gear S3, LG Watch 2^{nd} Edition, ZTE Quartz), many smart wearable devices available today continue to rely on a smartphone, tablet, or another computing device to extract and visualize the data collected by the devices. This dependency makes understanding participants' prior experiences and impressions with smartphones, and their impact on acceptance of smart wearable devices particularly important; entailing further exploration.

When participants were asked various questions about their experience and attitudes related to smartphones, several common elements emerged, most notable of which were lack of prior experiences with smartphones, perceived usefulness and ease of use of a smartphone, and usage deterrents. Two of the four participants interviewed reported having limited or no prior experience with smartphones. Of the two participants with prior experiences, one described owning a smartphone for emergencies, and the other explained the inexperience with her newly acquired smartphone: *"well, I've only just…we have a smart phone, but it's an old one that was given to us by our son"*.

As participants were asked to describe their experiences with smartphones, now they had used one during the study, several accounts were described simply as *"Positive."*. Further exploration of what a participant may find useful or like about a smartphone resulted in participant accounts of interesting or useful qualities or features of a smartphone, enjoying smartphone use, and for some, an increased post-study intention to use or learn more about them. In addition, participant's perceived usefulness of smartphones began to materialize through their responses Anita, a 65-year-old female, noted that she liked *"the convenience"* of a smartphone and *"the fact that you just swipe it" … "I have an iPad mini so I do enjoy – I like that"*. Francine, another 65-year-old female noted that she appreciated the immediacy and convenience with which smartphones can provide information;

"…they can give me a lot of information that I would have to look up elsewhere. I like the idea that the information is right there when you want it, provided its charged or turned on. I like the idea that it's a source of information that is easily assessable, that it can hold information that you might not think is valuable at the time, but ends up being something that you really need."

Participants were also asked about their post-study experience and usage intentions of smartphones but responses varied. While some participants indicated hesitance towards future use, others exhibited a desire to learn and gain more experience; *"Well, I have tried to use it more. So I guess it helped to – made it decide that maybe we need to – I need to work more on it and try and figure out what exactly I can do with it"*, said Anita. Similarly, Francine noted that she would probably use one in the future and added, *"I would think that they are the way of the future. If they can tell me what my blood pressure would be at any time, that would be lovely"*.

In contrast, some participants also had some negative perceptions of smartphones as they described smartphones as a *"distraction"* or *"deterrent to conversation"* and for some participants, their self-described lack of experience and knowledge of using a smartphone, and feelings fear or confusion experienced while using the study provided smartphone were revealing of their roles as deterrents of smartphone usage. Paula and Greg both explain that smartphones could be useful in emergencies, but cited a lack of knowledge in using and navigating the smartphone as a challenging and a potential obstacle for future use. Greg explained:

> *"I don't feel guilty anymore about not knowing* [how to deal with them]". Greg then continued to explain the difficulties he encountered; *"I found if I went to from the data I had available on the wrist thing, to the smartphone, it wasn't available to me the way I wanted it to be available"*
>
> and that
>
> *"...in 50, 60, maybe more, maybe 90% of the occasions when I looked to see if there was a, part of a graph thing, the times I examined it or things like that, there was no – most of the time I couldn't find it on the smartphone any better than I could find other things."*

Paula also noted that a smartphone could be useful providing *"*[she] *knew how to use it"*, citing the importance of knowledge in using the smartphone as a prerequisite to its perceived usefulness. When Paula was asked to describe what she might dislike about smartphones, she resorted to describing her lack of experience and attachment to her house telephone, *"I know a little about it and that. But I'm not…I don't know if I'm ready to have a smartphone and get rid of my house phone"*.

While the two youngest participants interviewed, both 65 years of age, were open to the idea of using a smartphone in the future and displayed a desire to learn, the two eldest participants, 83 and 84, displayed hesitation in use a smartphone in the future; *"to tell you the truth, I was afraid to use it just in case I broke it because I didn't know anything about it"* explained Paula. Additionally, Greg described the overall general difficulty he has experienced in using smartphones and other new technologies in general:

> *"We are so behind in the world that trying to cope with those type of things, out of our own ignorance, it is really sort of impossible at times. There are people who have sat down with us for 15, 20 minutes at a time" … "but we get so confused and our memories don't hold long enough for us to get an extensive repetition under real circumstances".*

The participant responses outlined in this theme revealed some participant concerns about the perceived ease of use smartphones. In addition to feelings of confusion and a perceived lack of knowledge in using smartphones, three of the four participants interviewed identified remembering to carry a smartphone as a deterrence to its use. Paula explained that in her case her wardrobe would not be supportive of carrying a smartphone, hence, she noted that she *"would probably put it down and forget about it"*. Francine had similar thoughts and exclaimed; *"I'm* *not one to take a phone with me"*, while revealing that not remembering to carry the smartphone also played a part in her viewing the historical data aggregated by the wearable device's companion smartphone application much less often.

A lack of experience with smartphones among participants led to two different outcomes in an older adult's desire to use smartphones in the future; one where participants were intrigued to learn and experience more and another where older adults felt that prior knowledge of smartphone may be a prerequisite for effective use. Furthermore, while participant's perceived usefulness of smartphones was evident through their discussions of features or functions they found useful, for some participants, a lack of prior operational knowledge may even dissuade them from using smartphones future.

In addition, as described by the two eldest participants interviewed, a lower perceived ease of use of smartphones may overshadow their perceived usefulness, which may eventually dissuade acceptance. Moreover, as indicated by the differences of responses between the youngest and oldest older adults interviewed, age may also be a factor in the intention to learn how to operate a smartphone; affecting the likelihood of accepting a smartphone and consequently a smart wearable device. Participant's preferred viewing location of collected health data from smart wearables is explored later (Section 6.6.6), however participants generally indicated having a combination of both the smart wearable device and a smartphone for reference of collected data as preferable to the availability of only the smart wearable or smartphone alone. As smartphones currently play an important role in facilitating many smart wearable device functions; aggregating collected data, visualizing data with graphs, and enabling various other functions of smart wearable devices, participant responses indicated that a lack of prior knowledge or experiences with smartphones may deter some older adults from using smartphones regularly.

Furthermore, participants' accounts self-described experiences of feelings fear or confusion while using the study provided smartphone may also play a role in participant's reduced likelihood of using a smartphone. As such, if an older adult's desire to learn how to use smartphones is deterred as a result of a smartphone's low perceived ease of use and overwhelming feelings of fear or confusion experienced during use, smart wearable device's acceptance could reasonably be affected negatively.

6.6.2. Smart Wearable Devices: Pre-Study Usage Intention

Though participants' pre-study usage intention of smart wearable device was polled in Phase One of the study, it was important to further explore the quantitative results as 19 of the 20 participants responded that they had never used a store bought smart wearable device prior to the study despite high levels of smart wearable device awareness among the sample (85% indicated hearing of smart wearable devices prior to the study).

When participants were asked about the intention or consideration of using a smart wearable device prior to the study, three of the four participants interviewed confirmed giving it some thought before the study. Anita, a participant who had previously owned a smart wearable device that monitored her physical activity said that after losing it a few years ago explained that she wasn't *"compelled enough"* to buy another one. Whereas Greg, an 83-year-old male, noted that he had considered using a smart wearable device in the past device due to the ability to keep *"a permanent record of all those observations"*, but didn't use one currently.

This theme indicated that while majority of the interviewed participants may have considered using a smart wearable device for various reasons, elements may have dissuaded or prevented from formulating a behavioral intention to usage. Some of these elements, as identified by participant responses, are explored further in sections 6.6.4 - 6.6.6 below.

6.6.3. Smart Wearable Devices: Privacy Concerns

When participants were asked about the impact of privacy on their decision to use a smart wearable device, several common elements emerged that offered insight into participants perceived nature of the data collected by smart wearable devices and the potential impact of privacy concerns on smart wearable device acceptance.

The data collected by the smart wearables during this study was collected anonymously through anonymized user accounts created by the researcher. However, when purchasing a device from a manufacturer user data may be stored in manufacturer data centers, potentially with personal identifiers. With that reminder, participants were asked how they felt about their information being stored on manufacturer computers or data centers and if privacy concerns have any impact on their decision to use a smart wearable device, Greg, Francine, Paula and Anita all responded with a resounding, *"No"*. All participants indicated that they had no privacy concerns with regards to wearing a smart wearable device; *"It doesn't bother me!"* said Anita and Paula.

Furthermore, participant's perception of data collected by smart wearable devices emerged through responses that described the nature of the data collected by the smart wearable devices (such as steps, heart rate, and sleep information) with the help of analogies. These analogies were indicative of the impression that participants' perception of data collected by smart wearable devices is not private in the same way that information such as banking information may be considered private. For example, a majority of the participants explained that if the collected data was being used for a positive purpose, that the use of that information did not concern them. Another participant, Francine, explained her feelings in detail:

> *"There's nothing I have that no one else in this world has. So if it's connected with my name, great. I mean, there's all that information in my doctor's computer, which is linked to the hospitals and various other places I'm sure."*

Similarly, Greg drew a comparison to other forms of data to explain his perception of and comfort with sharing the data captured by smart wearables:

> *"It's like the information you have about your salary, how much you pay for your house, how much you pay for rent, how much you paid for your car" … "People don't want others to know about it, and I don't give a damn. As long as I don't have anything to be ashamed of or embarrassed about too much, and that's the key for me. I can share anything in my life and I don't get the feeling that I shouldn't be sharing that with somebody"*

Likewise, Paula shared similar views about privacy with relation to the data collected by smart wearables; *"I mean privacy – I would not like somebody to be able to go into my bank account or into personal details like that. But privacy; how I live or what I do, that's not a – not bothering me. No."*

In this theme, participant responses about privacy concerns in relation to smart wearable devices indicated participants' perception of data captured by smart wearable devices differs from traditional notions of privacy or private data. In addition, participant responses revealed a diminished sense of overall privacy due to widespread data sharing in other aspects of their lives. Moreover, participants noted that they had no privacy concerns that were specific to smart wearable devices and that they would have no bearing on their use of a smart wearable device. Furthermore, participants had no concerns about sharing the collected data with manufacturers, provided the data was being used to bring about positive change.

6.6.4. Smart Wearable Devices: Perceived Usefulness

To explore participant attitudes and views concerning the perceived usefulness of smart wearable devices older adults were asked to explain why they might be interested in using a smart wearable device. Most participants responded by identifying functions or data that were important to them, indicating the smart wearable's perceived usefulness. Three of the four participants reported appreciating the smart wearable device's ability to provide awareness of physical activity and sleep information. *"To make sure that I'm doing my 8000 steps a day or whether the number so I'm getting enough exercise"* said Anita. Similarly, Francine explained *"I'd like to know how inactive I am. I'd also like to know how much sleep I really do get"*. Notably, one participant went as far as expressing feelings of disconnect after not using a smart wearable device since the study; *"I miss not wearing it, either one of them, because I feel my – I haven't been doing as many steps as I could have been"* said Anita.

When participants were asked about how they felt about the information captured by the smart wearable devices they tested, a majority recognized the importance of the different types of collected data. In contrast, Paula appreciated physical activity information provided by the device for a different reason; *"knowing when to slow down",* which she described as difficult for her to achieve before using a smart wearable device.

Greg, on the other hand, felt that smart wearable aggregated data may be helpful but noted that information such as sleep information or heart rate was *"interesting, but not necessarily useful. Interesting – and if I needed reassurance that I was doing the right thing, yeah I suppose it would be useful. But I wasn't worried about whether I was doing the right thing or not"*.

Data from this theme demonstrate that most older adults perceive smart wearables and the information they provide to be useful. This was attributed primarily to useful smart wearable data useful and their ability to increase self-awareness and usefulness of data such as physical activity and sleep patterns. Though most older adults used the data provided to verify activity levels, one participant used the data to understand the importance of rest and taking a break.

6.6.5. Subjective Norm and Facilitating Conditions

Subjective norm is described as the perception that people important to one would think one should or should not perform the behavior in question [31]. When participants were asked about how friends or family may think about their decision to use a smart wearable device, two common response groupings emerged; one in which support of family members was confirmed and another in which participants initially expressed a friend or family member's opinion as negative, followed by positive outlooks.

Anita and Francine, the younger of the four participants interviewed explained that friends or family members would have no feelings towards their intention to use a smart wearable, while in contrast Paula and Greg, the two eldest participants in the group expressed some concerns.

Paula explained with some concern; *"my youngest daughter might think it is stupid"* … *"but I don't think my oldest daughter would have anything against it"*. Similarly, Greg noted that *"at first, they* [friends and family] *might think that I'm a, what do you call them, hypochondriac. But I don't care. And they will eventually come around to seeing that I'm taking it as an adult self-interest, a self-directive interest in my own being, my wellbeing."* Furthermore, participants were also asked if the opinions of their friends, family, or individuals close to them would impact their decision to use a smart wearable device. All of the participants shared the same response: *"It wouldn't"*. *"That's my opinion, if I want to do it, that's up to me to do it. If I want to walk…what I want to do, I do"* exclaimed Paula. Francine shared similar views and bluntly exclaimed *"It doesn't really, that's my decision!"*. This was common among all participants.

In addition to the discussing how the support of family and friends may affect the decision to use a smart wearable, Greg noted the importance of feelings of independence as part of his decision to not seek support to use a smart wearable from friends or family. He explained, *"I'm sure it's there* [the support] *but it means taking their time, and making my problem their problem. And that's hard for me to do because of my own attitudes about independence I think. I really resent supervision, which is intrusive and demanding; kinds of stuff like that within the family"*.

Moreover, Greg described availability of family members' help in using a smart wearable device with unease; *"It's hard to get. My kids are all distanced. They've all got their own lives and they're terribly busy and none of them are at the retired level yet."* … *"So, to bother them, I* *do it, but I don't like to do it a lot. And I don't like to do it regularly"*. Francine also noted having help from her husband while figuring out how to use the Mi Band smartphone application.

The emergence of common elements and responses in this theme were indicative of two differing scenarios of support or encouragement from friends and family in the decision to use a smart wearable device. However, in either scenario, participants reported that the final decision to use a smart wearable device would be their own and the opinions of those who were close to them are not important in their decision to use a smart wearable. In addition, for one participant the importance of older adults' independence was highlighted and was demonstrative of an impediment in reaching out for loved one's support in using smart wearable devices. As a result of this hesitance older adults may face reduced subjective norm and facilitating conditions which may potentially affect the acceptance of smart wearable device.

6.6.6. Smart Wearable Device Equipment Characteristics

The equipment characteristics of the two smart wearable devices selected for this study varied significantly. Therefore, to further explore participants' attitudes and importance of smart wearable devices features and individual equipment characteristics participants were asked several questions about their importance and preferences. Several common elements and their influence on device acceptance emerged, most notable of which were: display preference, battery life, aesthetics, and comfort.

When participants were asked about smart wearable device display preferences, all participants described the Microsoft Band's touch enabled LCD display to be superior and preferable to the Mi Band's 3-LED-array display. Francine explained *"I looked at the phone* *every once in a while and I saw it. Like, I looked to see how many steps I had and my pulse and all that kind of thing…. But because it* [Mi Band] *didn't have a display."* Francine, like all other participants interviewed didn't see or notice the Mi Band's display activate at all during usage. Greg also discussed the Mi Band's display not functioning as expected,

> *"But they didn't [light up]. I only saw them lit up at one point. And that was when the whatever was out of the bracelet and siting getting charged. And then I saw the lights. But other than that I didn't see the lights ever. I always thought I was doing something wrong but I didn't, but I couldn't prove it."*

When participants were asked about where they preferred viewing the data collected by the smart wearable devices, all participants noted preferring viewing health data information on the Microsoft Band, over its smartphone. However, in the case of the Mi Band, participants cited viewing information on the smartphone more often. *"I found that I was, I had to look at the phone in order to find out what was going on" …" for the Microsoft Band, it was already there* [on the device]*".*

In addition, Paula cited preferring the Microsoft Band's LCD display as it displayed more information and allowed her to be aware. *"They can tell me, well…its time to call it" … "Not overdo it"*. Francine also preferred the Microsoft Band's LCD display as it allowed her to not to rely on carrying the smartphone with her. *"yeah, I don't – I am not. I don't carry a phone all the time. I don't feel the need that I need to do that"* said Francine. Anita also preferred the Microsoft Band's display and explained, *"The Mi Band, obviously it didn't offer as many options. And it didn't encourage me to do as much exploring, maybe there just wasn't – it wasn't there. I don't know, I kind of gave up because I couldn't figure it out. But I looked up things on my iPad, which was easier"* she explained.

Battery life also emerged as a key equipment characteristic that participants found important in a smart wearable device. A majority of participants preferred the Mi Band's longer battery life. *"I like the fact that I didn't have to worry about the battery" … "Yes, if the battery's longer then yes, it's easier to use"*, explained Anita. Similarly, Francine described her experience with the Mi Band's long battery life; "*I was able to wear it two, three days and charge it and, you know, like you didn't feel you had to do this all the time or you had to be home*" … "*because of my lifestyle I am not usually home at certain times. I found the Microsoft Band, if I charged it over supper every night that it was…it worked better*". In contrast, Paula mentioned that she would forget to use a smart wearable device at all and hence better battery life would not matter.

Participants also described comfort of the smart wearable devices as an important factor in their decision to use the device. The Microsoft Band's large and rigid band is described as *"uncomfortable"* and *"rigid"* by participants, while the Mi Band's band is preferred due to its thinness and flexibility. Paula speaks about how comfort impacts her decision to use a smart wearable device,

> *"Well, I have very small wrists. So, if it doesn't fit nicely, then it's uncomfortable and is an irritation because it's flying around slipping down onto my hand. It's not comfortable. So yes, it has to be comfortable to wear".*

When participants were asked about if the aesthetics of a smart wearable device may impact their decision to use a smart wearable device, all female participants shared the same response: it was very important. *"Well. I wouldn't wear them out for the evening"* … *"Not if I was going out – depending on where I'm going, but they're definitely not formal wear"* said Anita. Likewise, Paula explained "*If it looked more like jewelry, I think more people would wear it"*. In contrast, the male participant Greg explained an opposing view *"No* [aesthetics don't matter*]. I don't see it as a fashion thing"*. In addition, both Paula and Anita noted that for them the ability to conceal a smart wearable device was important.

This theme identified several important equipment characteristics indicated by participants as an important consideration in the acceptance of a smart wearable device. Furthermore, these elements may also affect the perceived ease of use and usefulness of each of the wearable devices. For example, unacceptable battery lives and reduced comfort may entail increased frequency of charging and repeated adjustments or period use; limiting the device's perceived ease of use. In addition, the absence of an informative display on the device may result in reduced perceived usefulness of a device.

7. Discussion

7.1. General Discussion

The aim of this pilot study was to explore the attitudes toward and acceptance of two specific smart wearable devices among a sample of Canadian older adults with a mixed-methods study design. Twenty older adults were recruited and all successfully completed the study. Results indicated high smart wearable awareness levels among the group with seventeen participants (85%) reporting they had heard of smart wearable device prior to the study. In addition, high levels of experiences and background with technology were also noted as eighteen participants (90%) reported using a computer daily and fourteen (70%) owned a personal smartphone.

Only one participant used a smart wearable device to track their health prior to the study. Pre-study acceptance of smart wearable devices was also high among the group as sixteen participants (80%) reported they would use any smart wearable device to track or monitor their health. Acceptance results indicated notably higher acceptance scores for the Mi Band (80% accepted) in comparison to the Microsoft Band (45% accepted). The sample's relatively high rates of prior experience with computers and smartphones may partially explain the sample's high willingness to accept smart wearable devices.

Descriptive statistics of the questionnaire items also show several interesting findings regarding older adults' attitudes toward smart wearables. Older adults in the sample generally agreed that continuous monitoring of health can be a good thing. Most (85-90%) also felt that they had the knowledge required to use a smart wearable device and most (65-75%) agreed that using a smart wearable device could help them improve their overall health. Exploring the subjective norm dimension for the group, about half (45-65%) of the participants felt their friends or family would encourage them to use smart wearable devices and some (25-35%) were impartial. Although, the researcher observed the Mi Band's necklace option to be rarely used during testing periods, almost all (80-95%) older adults in the group agreed that a smart wearable device's ability to be used in a variety of different locations on one's body was important.

Contrary to existing research, quantitative analysis showed that Perceived Ease of Use and Perceived Usefulness were not significantly associated with acceptance of smart wearable devices among the sample. However, in agreement with previous studies of technology acceptance [58], [69], [80], [87], Facilitating Conditions were found to be associated with acceptance; suggesting participants' availability of support in using a smart wearable may play an important role in their acceptance of a smart wearable device. This has important implications for aging-in-place technologies aimed towards older adults as these initiatives may require increased external provisions to educate and support older adults' use of technology if avenues of support are not available through family or friends.

The Perceived Risks dimension was also found to be associated with smart wearable device acceptance for the sample. However, since all participants' responses to the Perceived Risks dimension were reported as either *strongly disagree* and *disagree,* the dimension data had a limited dynamic range. Almost all participant responses to items that measured Perceived Risks were either disagree or strongly disagree. As such, the direction of the association of Perceived Risks and accepting a smart wearable device may not actually be accurate due to the limited variability in response data. However, since the variable's significance in the model is demonstrated by the results, it is plausible that older adults who indicate increased Perceived Risks while using a smart wearable device are willing to consider using one more seriously.

In addition, Equipment Characteristics was also found to be significantly associated with technology acceptance. This study showed that an increase in favorable equipment characteristics increases the chances of accepting a smart wearable device. This result also has important implications for initiatives aimed at aging-in-place and the selection of technologies. In order to ensure long-term and continuous usage of smart wearable devices selected to enable aging-in-place, researchers should take steps to ensure characteristics such as aesthetics, comfort, and battery life are in line with older adult's expectations as they have the potential to deter usage and acceptance.

Individual item correlation analysis exhibited results that were also in line with Likert dimension variable significance. Items that measured subjective norm such as experiencing feelings of embarrassment while wearing a smart wearable device in front of family members or encouragement from friends or family were found to be associated with acceptance of a smart wearable device in the case of the Mi Band, which garnered significantly higher rates compared to the Microsoft Band. Varying results from each of the smart wearable devices acceptance and individual item association indicate minimal overlap between the two devices. This implies that universal relationships that apply to all smart wearable devices may be difficult to estimate.

In this study, price or how much a participant was willing to pay for a smart wearable device was found to be significantly associated with smart wearable device acceptance for both the Mi Band and the Microsoft Band. This was further confirmed through semi-structured interview data in which two of the four participants interviewed reported a greater likelihood of using a smart wearable device if it were free. Moreover, these results also agree with Chen and Chan's research that explores factors that influence acceptance for aging in place as the researchers identify high cost of technology to dissuade acceptance [26]. These results may also have important considerations for health promotion efforts (such as increasing physical activity, going outdoors, or increasing awareness of one's own health) aimed towards older adults that use smart wearables should consider subsidizing or giving away the devices free of cost to increase acceptance.

Comparable to the results of previous studies that evaluated the acceptance of physical activity trackers [65], [88], [89], descriptive and qualitative results indicated participants in the sample found smart wearable devices to be useful for motivation to be more active and in promoting self-awareness of their health status. In addition, this study also found acceptance to be associated with smart wearable devices' ability to motivate a participant to be more active. As such data collected by aging-in-place initiatives that use smart wearable devices should be shared with older adults in order to motivate an older adult create greater self-awareness of their health status. Hence, we suggest that aging-in-place technologies should provide a benefit to their users in addition to serving their purpose of unobtrusive monitoring as this may increase the device's perceived usefulness and consequently its acceptance.

Davis's TAM, which included the chief dimensions of Perceived Ease of Use and Perceived Usefulness, was complemented with the addition of Likert dimension variables (Privacy Concerns, Subjective Norm, Facilitating Conditions, Perceived Risks, and Equipment Characteristics), some of which previous literature suggested as influential in acceptance of technology by older adults. While the results from this study may reflect the TAM's suitability for the acceptance of smart wearables by older adults, further investigation with larger and representative samples are needed as Perceived Ease of Use and Perceived Usefulness of smart wearables was discussed in qualitative interviews but was not found to be significant in quantitative results.

Quantitative results from Phase One of the study were complemented with directed content analysis of qualitative data collected from Phase Two of this study. The content analysis resulted in development of four core themes that may influence the acceptance of smart wearable devices: 1) smartphones as facilitators of smart wearable devices, 2) privacy concerns, 3) subjective norm and facilitating conditions, and 4) smart wearable device equipment characteristics.

Smartphones were found to be important in enabling smart wearable devices to function to their designed potential. However, older adults lack of prior experience and knowledge of operation of smartphones may prevent the acceptance of smart wearables among the cohort. Similarly, like the results from Mercer et al.'s and other research [65], this study also found that some participants experienced frustration, confusion and fear when using the smart wearable device's companion smartphone application, despite being provided with manufacturer manuals.

In the future, smart wearable devices and their companion smartphone applications that are aimed at older adult audiences may benefit from the further simplification and more intuitive instructional materials. Furthermore, participants' indicated forgetting to carry a smartphone as a chief deterrent from their use. As such, it is hypothesized that to improve smart wearable devices acceptance and usage, the introduction of the ability to function independently of a smartphone may prove to be important for device acceptance. However, aggregated data should still be available for examination on external devices as older adults indicated preferring having both a smartphone and a smart wearable device to just a smart wearable device alone.

In exploring old adult's privacy concerns of smart wearable devices, this study found that participants' perception of privacy in relation to the health data collected by smart wearable devices differs from information that is traditionally defined as private. As such older adults indicated that as long as there were no negative consequences of data sharing, they had no objection with data being that may be share with device manufacturers. This is in line with Wild et al.'s research that explored unobtrusive in-home monitoring of cognitive and physical health among older adults where privacy concerns were not a major concern for the group [11]. Similarly, Mynatt et al.'s research suggests older adults may even be willing compromise on privacy concerns of using a technology if it creates an overall increased sense of independence [90]. Qualitative results from this study that indicated privacy concerns having no bearing on wearable device acceptance may also be explained by similar phenomenon. In addition, authors suggest that that technologies that enable independence are likely to succeed as a result of empowering older adults to be proactive and self-aware about their health [90]. Their analysis of smart technologies indicate older adult perceived a reduction in autonomy as a result of using a device that could support aging-in-place negatively [90]. Chen et al also support this notion and suggest that in order to appreciate the full potential benefits of smart wearable devices, creating a sense of independence is critical and yet to be undertaken by currently available technology [91].

Likewise, qualitative exploration of facilitating conditions in this research indicated that for older adults, retaining a sense of independence while having access to support is important. Henceforward device manufacturers and researchers should reflect on a wearable's ability to create a sense of independence and perceived usefulness, while also excelling at their ability continuously collect health data.

7.2. Limitations

Several limitations are present in this study. The first relates to the sample and sampling technique bias. A small sample was recruited for this study using a convenience sampling method and participants in this study were selected from a small number of geographical locations. As such the sample may not be representative of the general Canadian older adult population. Furthermore, since many of the participants in the sample were retired or were retiring soon at the time of the study, the convenience sampling technique posed a risk of including participants from a homogenous socioeconomic background.

In addition, while commercially available smart wearable devices may vary significantly from one another this study investigated only two smart wearable devices to gauge acceptance among older adults. As such, the smart wearable devices for the study may not be representative of wide range of devices currently available. Although the device testing period in this study (21 days) is lengthier than most previous research studies of smart wearable device acceptance, extended-term acceptance of smart wearable devices cannot be comprehensively explored with only one data collection interval.

Furthermore, responses on the Likert questionnaires used in this study were self-reported and filled after wearing the wearable devices for 21 days each which may introduce social desirability bias (the tendency to present a favorable image of self) [92] and recall bias. Likert scales also carry some weaknesses as they tend to have higher levels of acquiescence bias, where participants may agree with statements as presented in order to satisfy researchers.

Due to time constraints, only four semi-structured interviews with purposively selected participants could be conducted. The aim of the interviews was to provide depth and context to the data collected by the questionnaires, and as such saturation was not an end-goal. The directed content analysis approach employed in this study may not allow for the discovery of new overarching themes of attitudes and smart wearable device acceptance among older adults.

7.3. Future Research

The results from this study have important implications for future research that aims to investigate older adults' acceptance of smart wearable devices and feasibility of continuous data collection from commercially available smart wearable devices. It is important that future research use larger, randomized representative samples of the Canadian older adult population in order to improve generalizability of results.

As demonstrated by the results of quantitative data analysis in Sections 6.5.1 and 6.5.2, content analysis in Section 6.6, and discussions in Section 7.1, a universal model of acceptance for all smart wearable devices may be difficult to postulate. This may be partially attributed to smart wearable device's unique equipment characteristics, dependency on external equipment for full functionality, and older adult's varying needs of facilitating conditions and support required to operate a particular smart wearable device.

Hence, future studies should aim to test a larger variety of smart wearable devices among a larger sample of older adults in order to identify additional important considerations of smart wearable device acceptance. Moreover, as a result of the varying characteristics of different smart wearable devices, future research should continue to employ mixed-methods or qualitative research design to explore the acceptance of smart wearables as this enables the collection of data that may otherwise go unnoticed due to the nature and rigidity of answers to fixed-response questions used in quantitative analysis.

While the directed content analysis approach used in this study several important notions and factors that are essential in understanding the attitudes and acceptance of smart wearable devices among older adults, future research should employ conventional and summative content analysis techniques in order to allow for more emergent themes to be collected from qualitative data.

Furthermore, research that aims to collect continuous data from commercially available smart wearable devices should give significant consideration to a device's characteristics that affect a device's perceived ease of use or perceived usefulness (such as battery life and comfort) as these may impact acceptance and long term usage; affecting the ability to collect uninterrupted data from participants.

In addition, studies should be prospectively motivated since studies that use more frequent and longer data collection intervals would be better suited to understand the extended-term acceptance of smart wearable devices. Technology and smart wearable device awareness was relatively high among the study sample; this may not be representative of the awareness among the general Canadian older adult. As such future research should investigate awareness of technology and smart wearable devices in samples that are representative of the general Canadian older adult population.

Lastly, as indicated by the positive influence of facilitating conditions on smart wearable device acceptance in this study, continuous usage and data collection efforts among older adults may be aided through supports such as more detailed product manuals, readily available technical support, and other reference materials which can help older adults better utilize the devices being used for continuous data collection; reducing lapses in usage that arise due to a lack of operational understanding of equipment or prior experiences with the devices used for data collection.

7.4. Expected Impact

This study contributes to addressing the scarcity of data available about Canadian older adult's attitudes and acceptance of smart wearable devices. The results from this study have the potential to inform and guide future research that aims to evaluate the acceptance of smart wearable technology among older adults through the identification of influential variables.

In addition, technologies and innovations aimed at enabling aging-in-place may also benefit from the identification of factors that may support the long-term usage and acceptance of smart wearable devices. While off-the-shelf wearable devices should not be used as primary health monitoring devices, they can offer snapshots of an individual's overall health by providing data regarding physical activity, UV exposure, location, heart rate, and blood oxygen saturation in order to promote greater health awareness. The smart wearable devices used in this study were also used to collect anonymized health data from participants which can benefit future research and also be used as reference data for comparison of sample groups.

8. Conclusion

In conclusion, this study generated several important findings about older adults' acceptance of and attitudes toward two smart wearable devices. The results of this exploratory study should be explored further and can be used to guide future technology acceptance research among the Canadian older adult population. In agreement with similar acceptance research, this study provides evidence, as demonstrated by the logistic regression analyses, of the effect of factors such as facilitating conditions and subjective norm on increasing acceptance of smart wearable devices. The results from this study also support the notion that older adults are willing to accept smart wearable devices, provided they are useful, easy to use, have favorable equipment characteristics, and support from friends or family in using a smart wearable device is available if needed.

This study also has important findings for aging-in-place innovations, technologies, and the feasibility of data collection using commercial smart wearable devices. During participants' smart wearable device testing periods in this study, data collected from smart wearable devices such as physical activity levels, sleep patterns, exercise summaries and calories burned proved to be easier to capture with the Mi Band than the Microsoft Band. This was observed to be attributed in part to the Microsoft Band's equipment characteristics such as shorter battery life, reduced comfort, and its lower perceived ease of use which discouraged continuous and uninterrupted usage.

Although this study is a small step towards understanding Canadian older adults' acceptance and usage of smart wearable devices, it is a first step in guiding future large scale studies.

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Appendices

Appendix A: Questionnaires

OFFICE USE ONLY: ID# __________ Band ID#____________

Wearable Smart Device Questionnaire (Q1)

The main purpose of this research is to learn about your experiences with selected smart wearable devices, how they fit in with your daily life, concerns you may have, and how often you would wear one for proactive monitoring.

Please base your responses only on the interaction you have had with the wearable device(s) which you wore during the last 21 days.

For questions 1-31 please place an X in the empty box like this ☒. Please circle your choice for questions 32-37 and Section 2.

Time to complete: Approximately 15-20 minutes

Confidentiality: Your data will not be shared with any third parties. Your data will be stored in a secure facility at the University of Waterloo and will remain strictly confidential.

Contact: If you have any questions about this study, please contact Arjun Puri via email at a2puri@uwaterloo.ca

Month and Year of Birth: _____/______ Gender: __________ Country of Birth: ________________________

Occupation: ________________________

Section 1

Statements contained in this section are meant to capture information about your experiences and feelings with the smart wearable device you wore for the **FIRST 21 DAY PERIOD.**

Please read EACH the following statements, and indicate the extent to which you agree with each:

#	Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	I think that monitoring my activity and health 24 hours a day, 7 days a week, can be a good thing	☐	☐	☐	☐	☐
2	I was afraid that the device would discover a major health issue	☐	☐	☐	☐	☐
3	I am comfortable with my health data being stored on the internet	☐	☐	☐	☐	☐
4	I am able to get assistance from a friend or family member to use the device, if needed	☐	☐	☐	☐	☐
5	I was able to wear the device easily without help from another person	☐	☐	☐	☐	☐
6	I was able to remove the device easily without help from another person	☐	☐	☐	☐	☐

Please ensure all responses are filled. 1

OFFICE USE ONLY: ID# ____________ Band ID#____________

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7	I was able to perform my daily tasks as usual while wearing the device	☐	☐	☐	☐	☐
8	The device was easily concealed underneath my clothing when worn	☐	☐	☐	☐	☐
9	At times, I forgot I was wearing the device	☐	☐	☐	☐	☐
10	I experienced skin irritations while wearing the device	☐	☐	☐	☐	☐
11	The battery life of the device meets my expectations	☐	☐	☐	☐	☐
12	The device's smartphone application was easy to use	☐	☐	☐	☐	☐
13	I find the device easy to use	☐	☐	☐	☐	☐
14	I find the display of the device easy to read **indoors**	☐	☐	☐	☐	☐
15	I find the display of the device easy to read **outdoors**	☐	☐	☐	☐	☐
16	The device was pleasant to wear during the night	☐	☐	☐	☐	☐
17	I was concerned that the device is not securely attached to me	☐	☐	☐	☐	☐
18	I was able to put the device on in a reasonable amount of time	☐	☐	☐	☐	☐
19	I had no concerns about my privacy while wearing the device	☐	☐	☐	☐	☐
20	I am comfortable with my health data being shared with equipment manufacturers as long as it is shared anonymously	☐	☐	☐	☐	☐
21	I have the knowledge necessary to use the device	☐	☐	☐	☐	☐
22	I think using the device is a more efficient way to monitor my health than visiting my doctor to collect similar information	☐	☐	☐	☐	☐
23	Wearing the device motivated me to be more active	☐	☐	☐	☐	☐
24	I think using the device can help me improve my overall health	☐	☐	☐	☐	☐

Please ensure all responses are filled.

OFFICE USE ONLY: ID# ____________ Band ID#____________

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
25	Wearing the device caused me to have joint pain	☐	☐	☐	☐	☐
26	I was able to shower or bathe normally while wearing the device	☐	☐	☐	☐	☐
27	I was embarrassed to wear the device in front of family members	☐	☐	☐	☐	☐
28	My friends would encourage me to use this device	☐	☐	☐	☐	☐
29	My family members would encourage me to use this device	☐	☐	☐	☐	☐
30	I think using the device can let me live at home longer by monitoring my health around the clock	☐	☐	☐	☐	☐
31	The ability to use the device in a variety of locations is important to me	☐	☐	☐	☐	☐

32. How useful did you find the information provided by the smart wearable device (such as step count, sleep data, heart rate) either on the wearable itself, or in the smartphone application?
   a) Very useful
   b) Somewhat useful
   c) Not very useful
   d) Not at all useful

33. Would you use **<u>the device you used during the last 21 days</u>** to continue to monitor or track your physical activity or health?
   a) Yes
   b) No

34. Over the last 21 days, how often do you think you wore the smart wearable device?
   a) Never
   b) Between 0-7 days
   c) Between 7-14 days
   d) Between 14-21 days

35. How much would you be willing to pay for the device you wore during the last 21 days?
   a) 0
   b) $1-$50
   c) $51-100
   d) $101-$200
   e) $201-$300
   f) $300-$400

Please ensure all responses are filled. 3

36. Did you find yourself looking at your health data in the smartphone application more/less often after the first few days?
   a) No, I looked at the health data fairly consistently throughout the 21-day period
   b) Yes, I looked at the health data **more often after the first few days of use**
   c) Yes, I looked at the health data **less often after the first few days of use**
   d) I did not look at my health or am not interested in monitoring it

37. Do you consider yourself to be an active person?
   a) Yes
   b) No

Section 2

Questions in this section are used to provide context to your experiences and demographical information of the participants of the study.

1. What is the highest level of education you have completed?
   a. High School
   b. Some post secondary
   c. Completed post secondary
   d. Some post graduate
   e. Completed post graduate

2. What is your current annual income?
   a. Less than $10,000
   b. $10,000 to $19,999
   c. $20,000 to $29,999
   d. $30,000 to $39,999
   e. $40,000 to $49,999
   f. $50,000 to $59,999
   g. $60,000 to $69,999
   h. $70,000 to $79,999
   i. $80,000 to $89,999
   j. $90,000 to $99,999
   k. $100,000 to $149,999
   l. $150,000 or more

3. What is your current marital status?
   a. Currently Married
   b. Divorced
   c. Separated
   d. Widowed
   e. Never Married

4. Do you have any existing wrist or forearm injuries?
   a. Yes
   b. No

5. Do you have any existing vision impairments?
   a. Yes
   b. No

6. Do you have any existing upper limb impairments?
   a. Yes
   b. No

7. Do you currently or have you in the past worn a wrist watch on a daily basis?
   a. Yes
   b. No

8. How much experience do you have with using a computer?
   a. None
   b. I use a computer once a month
   c. I use a computer once or twice a week
   d. I use a computer daily

9. How much experience do you have with using a smartphone?
   a. I own a smartphone
   b. I have previously owned a smartphone
   c. I have used a friend or family member's smartphone
   d. I have never used a smartphone

10. Have you heard of wearable smart devices before?
    a. Yes
    b. No

11. Do you currently use store bought smart wearable device to track your health?
    a. Yes
    b. No

12. Would you use **ANY** smart wearable device to track or monitor your health?
    a. Yes
    b. No

13. In your opinion, how much should the device like the one you wore, cost?
    a. $0
    b. $100
    c. $200
    d. $300
    e. $500
    f. $1000

14.How often would you be willing to recharge a smart wearable health monitoring device?

a. Never
b. Every 12 hours
c. Every 24 hours
d. Every 1-2 days
e. Every 2-5 days
f. Every 5-10 days
g. Every 10-30 days

Please use the area below to provide any comments you may have.

Thank you for your time. This is the end of the questionnaire. If you have any questions regarding the submission of your completed questionnaire, please contact Arjun Puri via email at a2puri@uwaterloo.ca .

Appendix B: Semi-Structured Interview Guide

Semi-Structured Interview Guide (15-20 minutes)

Hello Participant,

Thank you for agreeing to participate in this discussion. I would like to assure you that the study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. Should you have any comments or ethical considerations with reference to your participation in this study, please contact the Director, ORE, at 519-888-4567 ext. 36005 or via email, at mauren.numellin@uwaterloo.ca

If you feel that you are uncomfortable speaking about a specific subject, you have the right to refuse any questions or topics you may not want to discuss. In addition, you may end the discussion at any time without any negative consequences. Just let me know and we can proceed to the next topic, take a break, or end the discussion at any time.

The discussion will last approximately 15-20 minutes. It is meant to be informal and I would like to learn a bit about your experiences with reference to certain topics. Please feel free to tell me about anything you may think is important to the time you spent wearing the device if it is not covered in the discussion topics.

Areas of interest to discuss and explore with participant:

1. Key Informant: Experiences/History with smartphones (2-3 minutes)
    a. Probes/Prompts
    - What experience have you had in using smartphones?
        - How would you describe your experience (positive/negative?
    - What do you like/dislike about smartphones?
    - Has your opinion about smartphones changed since using the smartphone device that was provided to you for the duration of the study?
        - Do you find them to be useful?
        - Would you use one?

2. Key informant: Privacy Concerns (3-5 minutes)
    a. Probes/Prompts

    Advise: When using the smart wearable devices, you were advised about the manufacturer storing some of the information, anonymously, on computers located in data centers accessible by the internet.

    - What do you think about your activity and health information being stored, albeit anonymously, on device manufacturers computers?
    - How does privacy factor into your decision to use a wearable device?

3. Key Informant: Social Stigmatization/Facilitating Conditions (4-5 minutes)

a. Probes/Prompts:
- Have you ever thought about using and wearing a smart wearable device?
    - How do you feel about wearing a smart wearable device in public?
- Does the ability to conceal a smart wearable device play a role into your decision to use it?
- What have/would people important to you, such as friends or family members, think about you using a smart wearable device to track your activity/health information?

4. Usefulness/Perceived Ease of Use (3-4 minutes)
    a. Probes/Prompts:
    - Why would you be interested to use a smart wearable device?
    - How did you feel about the information that the smart wearables provided on the device itself?
        1. Ex. Info by the three dots led on MI Band/Vibration feedback
        2. Ex. Info shown by the touch LCD on the MS Band
    - How did you feel about the information that the smartphone application provided?
    - Did you look at the information from the wearable or the smartphone application?
        1. Were you influenced to change anything about your daily activity or sleeping routines as a result of that information?
    - How do you feel about the historical (sleep/bio/activity) information that the smartphones retain and provide in the application (i.e. MiFit or Microsoft Health)?
        1. Do you value the information on the device more than the information on the phone? Or vice versa?
        2. Could you do without one or the other?

5. Equipment Characteristics (5-8 minutes)
    a. Probes/Prompts:
        - Do you currently you use a smart wearable device to monitor your activity/health/sleep?
            - or
        - Would you use a smart wearable device to monitor your activity/health/sleep in the future?
        - Is battery longevity something that impacts your decision to use a smart wearable device?
        - Does comfort impact your decision to use a smart wearable device in the long term?
            - How?
        - Are you embarrassed to wear a visible smart wearable device?
            - If yes, why?

- If no, is being able to conceal the device underneath clothing important to you?
- Do the aesthetics of a smart wearable device impact your decision to use it?
    - If so, how?

Finish

Is there anything else you'd like to tell me or talk to me about?

- Probe:
    - Perhaps something I may not have mentioned?
    - Or that you found particularly interesting or enjoyable?

Appendix C: Wearable Device Selection Research

Device	Manufacturer	Release date (Canada)	Countries available	Tracking Metrics	Sensor array	Battery Life: Quoted	Battery Life: Actual	Display type	Cost (CDN$)	Compatible platform availability	Compatible platform functional limitations	SDK Availability and Functions accessible by developers	Additional Functions	Source
Samsung Gear S2	Samsung	10/13/2015 (Best Buy)	Canada, USA, UK, Australia, France, Germany, India, Ireland, Italy, Japan, South Korea, Spain	Acceleration, orientation, heart rate, light intensity, pressure, location (3G only),	Accelerometer, Gyroscope, Heart Rate Monitor, Ambient Light Sensor, Barometer, GP3(3G only)	2-3 Days (Best Buy)	2 Days (Android Central)	1.2" Full Circular sAMOLED 360 x 360 (302ppi)	400 (Best Buy)	Android 4.4+	Limited to Galaxy Apps	SDK available (Samsung Developers)	Contacts, notifications, messages, email, S Voice, S Health, Nike+ Running, music player, gallery, maps & navigation, weather, calls, camera control, phone tracker, calendar, SMS, social media, silent alarm, vibration	http://www.samsung.com/global/galaxy/gear-s2/#!/spec
Samsung Gear S	Samsung	11/14/2014 (Best Buy)	Canada, USA, UK, Australia, France, Germany, India, Ireland, Italy, Japan, South Korea, Spain	Acceleration, orientation, location, heart rate, light intensity, UV exposure, pressure, calories, distance, steps, elevation, sleep	Accelerometer, Ambient Light Sensor, Compass, Altimeter, Ambient Temperature, Barometer, GPS, Heart Rate Monitor	1 Day (Best Buy)	2 Days (Techradar)	2.0" Curved Super AMOLED 360 x 480	350 (Amazon), 350 (Best Buy)	Android 4.3+	Limited to Galaxy Apps	SDK available (Samsung Developers)	Calls, Smart Phone Battery Alert, Music Controls, Camera Control, Phone Tracker, Voice Commands, Email, Calendar, SMS, Social Media accounts, Weather, Silent Alarm, Vibration, Illuminated Alerts	http://www.bestbuy.ca/en-CA/product/samsung-samsung-gear-s-smartwatch-with-heart-rate-monitor-medium-black-sm-r750/10327519.aspx
Apple Watch Sport	Apple	4/24/2015 (Apple)	Australia, Canada, China, France, Germany, Hong Kong, Japan, the UK, USA	Motion, Distance, Calories, Heart rate	Heart rate sensor (photoplethysmography) (LED lights & photodiodes), accelerometer	https://www.apple.com/ca/watch/battery.html		1.32" OLED 272 x 340 (38 mm), 312 x 390 (42 mm) 290 ppi	450 (38mm) & 520 (42mm) (Apple and Best Buy)	iOS 8.0 and above		SDK available (WatchKit)	Receive and respond to notifications (of apps on the phone), Advanced activity tracking, Voice based music control, Activity goal suggestions	https://www.apple.com/ca/watch/health-and-fitness/
Moto 360 (Gen 1)	Motorola	07/11/2014 (Best Buy)	North America, Latin America, Europe, Asia	Steps, heart rate	Accelerometer, Ambient Light Sensor, Heart Rate monitor	1 Day (Bell), 1.5 Days (Motorola)	2 Days (Best Buy reviews)	1.56", 320 x 290, 205ppi, Backlit LCD, Corning® Gorilla® Glass 3	200 (Best Buy), 230 (Bell), 200 (Videotron), 200 (TELUS)	Android 4.3+		SDK available (Android Wear)	Calls (incoming & missed), music control, voice commands, email, calendar, SMS, social media, weather, silent alarm, vibration, illuminated alerts	http://www.motorola.com/us/products/moto-360
Moto 360 (Gen 2)	Motorola	10/30/2015 (Best Buy)	Canada, US, Mexico, UK, France, Germany	Acceleration, light intensity, orientation	Accelerometer, Ambiet Light Sensor, Gyroscope, Vibration/Haptics engine	1 Day (Best Buy)	Not released yet	42mm model: 1.37", LCD, 360x325, 354ppi; 46mm model: 1.56", LCD, 360x330, 313ppi	500 (Best Buy)	Android 4.3+, iOS 8.2+		SDK available (Android Wear)	Customization options through Moto Maker (not available in Canada)	http://www.bestbuy.ca/en-ca/product/motorola-motorola-moto-360-46mm-smartwatch-with-heart-rate-monitor-black-00907nacrtl/10390179.aspx?path=10264a46378dea79a7289fe65c0fd435en02
Fitbit Charge HR	Fitbit	01/18/2015 (Best Buy)	https://www.fitbit.com/ca/countries	Heart rate, steps, distance, calories burned, floors climbed, active minutes	Optical heart rate monitor, 3-axis accelerometer, altimeter, vibration motor	5 days (Fitbit)	5 Days (Wareable)	OLED	180 (Best Buy)	iOS 8.2+, Android 4.3+, Windows 8.1		SDK available (Fitbit API)	Water resistance, incoming call notifications, sleep monitoring, silent alarm, wireless syncing, barcode scanner, leaderboards, chart and graph visualization, can use phone's GPS, virtual badge reward system	https://www.fitbit.com/ca/chargehr
Fitbit Charge	Fitbit	12/15/2014 (Best Buy)	https://www.fitbit.com/ca/countries	Steps, distance, calories burned, floors climbed, active minutes	3-axis accelerometer, altimeter, vibration motor	7-10 days (Fitbit)	7-8 Days (Techradar)	OLED	145 (Amazon), 145 (Best Buy)	iOS 8.2+, Android 4.3+, Windows 8.1		SDK available (Fitbit API)	Water resistance, incoming call notifications, sleep monitoring, silent alarm, wireless syncing, barcode scanner, leaderboards, chart and graph visualization, can use phone's GPS, virtual badge reward system	https://www.fitbit.com/ca/charge

Device	Manufacturer	Release date (Canada)	Countries available	Tracking Metrics	Sensor array	Battery Life: Quoted	Battery Life: Actual	Display type	Cost (CDN$)	Compatible platform availability	Compatible platform functional limitations	SDK Availability and Functions accessible by developers	Additional Functions	Source
Xiaomi MiBand	Xiaomi	3/12/2015 (Amazon)		Motion/ steps, Sleep	Accelerometer	30 days		No display, LED indicator	17-21	Mi 3, Redmi Note 4G, Andriod 4.4 and above, iPhone 4s and iOS 7.0 and above		SDK unavailable	Vibration for notifications, incoming calls, alarms	http://www.mi.com/sg/miband/
MS Band	Microsoft	6/1/2015 (Amazon)		Motion/ Steps, Distance, GPS/ location, Heart rate, Calories, Sleep, UV exposure	Optical heart rate monitor, 3-axis accelerometer, gyroscope, GPS, ambient light sensor, GSR sensor, UV sensor	2 days		0.43" x 1.30" Touch-enabled TFT full color display 320 x 106	190 (Amazon)	Windows Phone 8.1 update, iOS 7.1 and 8, Andriod 4.3-4.4		SDK available	Exercise monitoring, UV exposure, Alarm, Timer, Notifications for Calls, Messages, Calendar, Facebook updates, Weather	http://www.microsoftstore.com/store/msusa/en_US/pdp/Microsoft-Band/productID.308308800
MS Band 2	Microsoft	11/20/2015		Motion/ Steps, Distance, Climbing, Elevation, GPS/ location, Heart rate, Calories, Sleep, UV exposure	Optical heart rate sensor, 3-axis accelerometer/ gyroscope, gyrometer, GPS, Ambient light sensor, Skin temperature sensor, UV sensor, Capactive sensor, Galvanic skin response, Barometer	2 days		32mm x 12.8 mm AMOLED 320 x 128	330 (Best Buy)	Windows Phone 8.1 update, iPhone 4S and above, iOS 8.1.2, and many Android 4.3-5.0 phones		SDK available	Smart notifications from calls, calendar, other apps, Weather, Smart Alarm, Navigate using Cortana	http://www.microsoft.com/microsoft-band/en-us/features
Jawbone Up 3	Jawbone	5/1/2015 (Amazon)		Motion/ Steps, Heart Rate, Calories, Sleep	Bio impedance: Heart rate, Respiration, Galvanic Skin Response (GSR), tri-axis accelerometer	7 days		No display, LED indicator	180 (Best Buy) 180 (Amazon)	iOS, Android		SDK available	Activity tracking, Advanced sleep, Food logging, Smart coach, Hear health, Challenge friends, Idle alert, Smart Alarm	https://jawbone.com/store/buy/up3
Jawbone Up 2	Jawbone	4/15/2015 (Amazon)		Motion/ Steps, Calories, Sleep	Tri-axis accelerometer	10 days		No display, LED indicator	120 (Best Buy) 120 (Amazon)	iOS, Android		SDK available	Activity tracking, Sleep tracking, Food logging, Smart coach, Challenge friends, Idle alert, Smart Alarm	https://jawbone.com/store/buy/up2

Appendix D: Questionnaire Open-Ended Comments

MS BAND COMMENTS	MI BAND COMMENTS
This was interesting. I had conversations with other adults about why I was wearing it. I feel this could be useful long-term. It certainly increases self-awareness.	Found the band hard to put on/take off. It would be nice to see display on the bands opposed to looking on a phone screen. I enjoyed getting the information regarding steps, heartrate, and sleep historu. Cool to access the information.
Band was rigid and bulky, did not comfortably fit my wrist, irritable because it was too big for my wrist, design more like a watch that would be more comfortable, Fit was too large	Didn't like rubber wrist band, didn't like how it fastened, would liked if it had clock, if more like watch would be more comfortable, would like to access data from bracelet rather than smartphone
I liked the screen showing steps, heart rate, etc. I found the bracelet oart too wide and not overly comfortable. I liked the easy to fasten and the clasp on the bracelet. If the band was more narrow and a little flexible, this device would be perfect.	Width of the bandwas excelent byut hard to do up with only 2 fingers. Would prefer the screen to show the actual data.
Device band too wide and not flexible enough. Lack of warning signal when recharge required. Recharche required too often.	
1. The device seemed to stick out more and bump things, not catch though. It seems to be a bit tighter than the previous, even during sleeping sometimes it would seem to restrict a bit. 2. Easy to put on and off and to recharge but seemed to be too ofen, even though I charge my phone every night. I wanted to keep this on all the time to track my steps and compare for sleeping info also. I would have loved to play around with the UV settings and bike and gym sections but I usually forgot to click on it. Most people did not know what it was and it looked fashionable enough to wear proudly. I think the step function did not count all steps. Especially noticed that when i woke up in the morning. I would track it and it would be maybe 30 less. It sened ti ve aknist 39 kess steps than my previous band. My supervising activities are abit predictable and there seemed to be less with this model	1. I thought the looks of this device was real nice. Nobody really guess what it was at first. It never got caught like I thought it would. Nice size. 2. The step function missed some sleeping time, when I woke up for example at 4:00 AM; got up to go to the washroom and then went back to sleep, even though it probably wasn't a good sleep. Not sure what happened. 3. Would have been nice to see my heart beat when I would walk or go to the gym. To check it. 4. It was nice not to charge it for 21 days. 5. I did shower with it on, but it would been better to take it off. 6. Would have been nice to try it when I played hockey. Display with heartbeat would have been better for that or golf.
Band was very hard to fasten (needed 2 people for a week)	Band was very hard to fasten (needed 2 people for a week)
Very large and bulky, not waterproof, battery life very poor, good to be able to sync with smartphone for text, etc., does not alllow you to add all types of information	Hard to fasten for me without assistance, love the long battery life, unable to add different types of exercise e.g. aquafit, I think it is priced right at $40-50, small and comfortable to wear, like the heartrate feature.
Great band-sounds too expensive to buy. Too many M.L. functions for my use.	I was very surprised at how well this device worked. At $20.46 CDN from Amazon, I'll probably buy one unless I'm really impressed by the next one.
I would like a device that is lighter in weight. Like that the Microsoft band calculated my sleep efficiency as well as deep and light sleep. Like that I can get the information on the Microsoft band as opposed to the mifit. For some reason don't like hearing it in the bath or shower. Found I wasn't good at navigating the phone to get my personal information.	
I found the band to be cumbersome for my small wrist. I enkoyed being able to look at the screen and check my step progress at anytime. Wearing the band kept me motivated to keep moving. I was concerned about wearing the band 24 hrs a day and the electro-magnetic field. I am glad I was able to track my sleep patterns but would not wearit every night If I owned one, maybe just to periodically check. I liked the fact that I could download a workout routine onto the band, this was useful.	There were times I was very aware of the band and monitoring. It periodically bothered my wrist. Not with a wash (was not sure about this word; A.z.) but more electrical
Got bothersome when it was hot out. Found it stiff to wear and somewhat uncomfortable. Forgot towear it when I was going to sleep. Sometimes I woke up, said I was awake, then fell back to sleep! Data accurate? Don't like the fact I need 2 hands to see the time (until I figured out how to have time displayed).UV app did not work (actually for fair slanned person). Only counts steps as a measure of activity. Did not measure lifting, bending i.e. packing up stuff. Would like a "stretchy" band as watches have.	Since the goal was 8,000 steps/day. I found 3 lights confusing. I think there should be 4 digits-each one representing 25% of goal reached. 33% is too hard to calculate. One night it said I got 3 hrs of sleep-not accurate so I did not trust it completely. Comfortable to wear. a "stretchy" band might be easier to put on. I liked "steps" and "sleep data" but if i would buy one, I'd like more info-BP, HR, etc. Why couldnt it display time and replace a watch. I would choose one that's more feminine.
Took the device off to shower/swim	Q22-Doctor does NOT collect the SAME INFORMATION. Q23- This is my NORMAL activity level. I can see how it motivates people to be more active. Q26- Took device off to shower. Section-2-5 Glasses for reading.
Participant provided a two-page table to express her opinions towards the bands. At the end she concludes: "I would buy and wear a fitness band. I don't need a lot of functionality-steps and sleep is all I need/want. I would not buy either of the bands used in the study. I would want a discplay sreen so the Mi band is out and I want something that would be accurate so the Microsoft band is out. Also I am not a fan of anything Microsoft. The bands need to be able to work with a BlackBerry. If I had to choose between the 2 bands then I would recommend the Mi band for someone who is new to fitness bands, it is simpler and much more comfortable to wear.	For a basic model I liked the device. The only downside was that it was too hard to put on. It often required 2 of us to get it closed. I really liked that it had a long battery life. I often forget to recharge my blackberry. I wished these wearable devices worked with the Blackberry. My device was fairly accurate in that the steps recorded were consistent with my perdometer. It would be abetter device if it had a display. I would be willing to give up a bit of battery life in lieu of a display. I liked that it was simple and didn't try to do too much. I was most interested in the sleep function. This is why I would purchase this type of wearable monitor.
I only charged the device while I was having my shower; twice during the 21 day period, the device ran out of power and died. Once while I was sleep. It would be better to have a device with better battery life. Device was very user-friendly. It was interesting to see how little deep sleep I was getting. It was good at tracking a workout. Showed max heart rate and rate throughout. Device seemed to over-estimate calories burned and steps taken. The moving machine I used during one workout only showed half the calories burned that the device showed.	Didn't count all steps on treadmill.
Took a few days to get used to wearing it, then it was OK; didn't like it at first, then didn't notice it. Used it as a watch at the same time. Battery ran low regularly, took a long to charge. Travelled out of town and took laptop. I wanted to monitor steps while away. Not particularly attractive device to be wearingg; "chunky"	I enkoyed wearing and having this band more than the first one, easier to wear (more comfortable). I found that each day I was determined to meet the dood 8,000 steps. Found it particularly interesting to discover sleep schedule and deep sleep. I liked being able to compare stats with mu husband who was also participating in the study.
Fit of device was unforgivable.	Data very inaccurate-Particularly the heart-beat. Printed instructions very unhelpful. Need more detail, more careful wording, plus a glossary.
	I found this device much more comfortable than I expected, although in hot weather I feel it would be uncomfortable. I looked at the phone application in the morning and again when I get home from work. In the morning the information I learned about sleeping I found intersting. The device was set at 8,000 steps; If I was within 500 of the end of the day I would walk to achieve the goal.
Didn't like the green lights, wake up in night becase of them. Nulky under long sleeves. Needed to be charged everyday. Bulky when writing or using mouse. Was good to have for comparison purposes.	