informatics

Article

Modeling Subcutaneous Microchip Implant Acceptance in the General Population: A Cross-Sectional Survey about Concerns and Expectations

Shekufeh Shafeie [1,†], Beenish Moalla Chaudhry [1,*,†] and Mona Mohamed [2]

[1] School of Computing and Informatics, University of Louisiana at Lafayette, Lafayette, LA 70504, USA; shekufeh.shafeie1@louisiana.edu

[2] Department of Business Analytics and Technology Management, Towson University, Towson, MD 21252, USA; mmohamed@towson.edu

* Correspondence: beenish.chaudhry@louisiana.edu; Tel.: +1-337-482-1676

† These authors contributed equally to this work.

Abstract: Despite the numerous advantages of microchip implants, their adoption remains low in the public sector. We conducted a cross-sectional survey to identify concerns and expectations about microchip implants among potential users. A total of 179 United States adults aged 18–83 years responded to two qualitative questions that were then analyzed using the thematic analysis technique. The identified codes were first categorized and then clustered to generate themes for both concerns and expectations. The prevalence of each theme was calculated across various demographic factors. Concerns were related to data protection, health risks, knowledge, negative affect, ease of use, metaphysical dilemmas, monetary issues, and negative social impact. Expectations included medical and non-medical uses, dismissal of microchips, technical advances, human enhancement, regulations, and affordability. The prevalence of concerns and benefits differed by immigration status and medical conditions. Informed by our findings, we present a modification to the Technology Acceptance Model for predicting public's behavioral intention to use subcutaneous microchips. We discuss the five newly proposed determinants and seven predictor variables of this model by surveying the literature.

Keywords: NFC (near-field communication); RFID (Radio Frequency Identification Device); microchip; chip; implant; subcutaneous; embeddable; insideable; RFID-SM; insertable; injectable; public; taxonomy; qualitative analysis; expectations; concerns; demographics; adoption; TAM (Technology Acceptance Model)

check for updates

Citation: Shafeie, S.; Chaudhry, B.M.; Mohamed, M. Modeling Subcutaneous Microchip Implant Acceptance in the General Population: A Cross-Sectional Survey about Concerns and Expectations. *Informatics* **2022**, *9*, 24. https://doi.org/10.3390/informatics9010024

Academic Editor: Antony Bryant

Received: 20 December 2021
Accepted: 22 February 2022
Published: 7 March 2022

1. Introduction

A subcutaneous microchip implant is an integrated circuit encased inside a transponder, measuring about 2 mm (0.08 inches) in diameter and 10 to 12 mm (0.4 to 0.5 inches) in length (about the size of a large rice grain). It is surgically inserted underneath the skin (subcutaneously) of a human (or an animal) for medical and/or non-medical purposes [1]. There are many kinds of subcutaneous microchips (SM)—the most common one consists of a Radio Frequency Identification Device (RFID) inside a silicate glass capsule. Based on their capabilities, SMs can be active, semi-active, or passive [2]. An active microchip has its own battery to power its internal circuitry and transmission components; a semi-active microchip has its own power source for internal circuitry but not for transmission; and a passive microchip has no internal power source. Instead, it uses electromagnetic signals from an external reader for power and transmission purposes. A Near-Field Communication (NFC) microchip that utilizes high-frequency RFID protocols is an example of a passive microchip. NFC-SM can communicate with readers, such as a smartphone, from up to 10 cm in distance compared to 25 to 100 m. Some microchips also have sensing capabilities to measure parameters such as temperature, pressure, etc.

The information stored inside a microchip is typically linked to an external database from where the individual's personal information, law-abiding history, medical history, prescribed medications, allergies, and contact information can be retrieved with the help of RFID signals [3]. The "human chipping" movement started in 1998, when Dr. Kevin Warwick, a British scientist at the University of Reading in the United Kingdom, voluntarily opted to implant an RFID-SM in his arm via an invasive surgery. The chip was removed from his body after nine days and placed on a display in the Science Museum London to mark the accomplishment of humans in the field of ubiquitous computing [4]. After this first experiment, from 1998 to 2000, RFID-SM were successfully tested in several other human volunteers in different parts of the world [5].

Since these first successful tests in alive individuals, many useful medical and non-medical applications of the SM have been proposed. We first draw your attention to a few most recent ones. The Pentagon recently developed microchips that can be implanted under the skin to detect COVID-19 and prevent the spread of the virus during the pandemic [6]. Carr et al. [7] suggested that an implanted microchip should be used to perform contact tracing of those exposed to the COVID-19 virus. In 2003, during the SARS outbreak, the Show Chan Hospital in Taiwan established the "Intelligent digital health network" project, using active RFID tags to monitor and track body temperatures of patients with fever for potential infection [8]. Implantable Drug Delivery Systems equipped with microchips have been used for on-demand release of various drugs, with the objective of improving treatment efficacy and patient morbidity [9]. Non-medical uses of microchip implants include identification and access control [10], including employee identification in the civilian workplaces [11–14] and high-security military sectors [15]. SMs have also been developed for Bitcoin transactions [16], and to make payments [17]. Similarly, for everyday household/personal tasks, such as unlocking a phone or a car [18], and controlling home lights, devices, etc. [19], SMs are also seeing rising adoption in many countries [20].

Despite continued interest in SMs and their documented applications, the overall adoption of SM in general population is still low [5]. For example, in the United States (US), the first RFID-SM (Veri Chip) was approved for human implantation in 2004, as a way to store and access a person's health record [21,22], but its adoption in healthcare practice has been scarcely witnessed [5]. Several researchers concede that the reality of RFID-SM adoption is far behind the earlier expectation [23]. Werber et al. [5] mention that the RFID-SM adoption has lagged behind in Europe even though there "have been no technological barriers keeping this technology from being introduced". With so many potential benefits of SMs, reasons behind their limited popularity need to be clarified.

Many researchers suggest that the main reason behind low SM adoption is the little attention toward understanding and considering the perspectives of individuals who are going to be chipped (i.e., potential end users) [5,24,25]. This issue has remained true until recently, whereby Werber et al state [5] that "there are many studies regarding the adoption of RFID-SM, but only a few of them deal with RFID-SM usage by individuals". Indeed, most researchers and studies in this area consider viewpoints of decision makers, managers, and developers, but not of the end users when it comes to understanding adoption and success of SMs. For example, Fakhr et al. [26] explored barriers and critical success factors around RFID-SM adoption in the health care sector in Iran, but they limited their investigation to the perspectives of healthcare decision makers, managers, and Information Technology professionals. The patients and employees, who were the actual end users, were not interviewed or included in this study. Similarly, a plethora of articles cover ethical and political implications of SMs [27–30], and potential benefits of human implants [31,32] from experts' perspectives, instead of end users'.

Motivated by these research gaps, we conducted a survey to explore the perceptions of implantable microchips in the general population (public) in the US. Specifically, our goal was to build a model for predicting the acceptance of implantable microchips by directly considering concerns and expectations of the public. A model of acceptance can help future SM researchers understand public's sentiments about the state-of-the-art and identify future areas for research.

2. Literature Review

Researchers have used various technology acceptance models to understand what factors impact the acceptance of SMs in certain populations. Čičević et al. [33] considered three original components of the Technology Acceptance Model (TAM) [34], which are Perceived Usefulness, Perceived Ease of Use, and Behavioral Intentions to Use. In addition, they added two additional external variables ("Health Concerns" and "Perceived Trust"). The model was tested in 100 young undergraduate students, who were enrolled in specific courses at the University of Belgrade, Serbia. Descriptive statistics were calculated for the five dimensions. The results indicated that although the majority of respondents considered the implantation procedure to be very painful, estimates for Perceived Usefulness and Perceived Ease of Use were very high. The authors state that reliance on TAM and sample composition limit the generalizability of their findings.

Werber et al. [5] also used an extended version of the TAM model with similar determinants (i.e., Perceived Trust, Health Concerns, Perceived Ease of Use, Perceived Usefulness) to examine the likelihood of RFID-SM acceptance in healthcare from potential the end user's point of view in Slovenia. A total of 531 participants were recruited from researchers' social networks, public media organizations, a primary school, and a retirement home, with age ranges from 12 to 90 years. The authors found that almost half of the participants in their study indicated their Intention to Use microchips for healthcare reasons, which was highest among other proposed purposes such as identification, shopping, or home usage. In addition, they indicated that a lack of trust presents a significant obstacle for acceptance. The researchers confirmed their hypothesis that age has a negative impact on Behavioral Intention to Use RFID-SM; i.e., the older a potential user, the less likely he/she is to consider the possible use of RFID-SM. They concluded that more research must be done to prove the reliability and harmlessness of RFID-SM, and its technical possibilities should be improved to enhance patients' health. They also suggested conducting a paper survey to reach a more representative sample of older adults (i.e., those without internet access).

Pelegrin [25] developed a model called the Cognitive–Affective–Normative that combines the cognitive determinants from TAM, i.e., Perceived Usefulness and Perceived Ease of Use, and Subjective Norm from other TAM models with the affective determinants, i.e., Positive Emotions, Negative Emotions, and Anxiety. The model was tested on a sample of 600 randomly selected individuals, who were people over the age of 16 residing in Spain. Through structural equation modeling, the researchers found that the model was 73.9% accurate in terms of predicting the acceptance of insideables.

Boella, Gîrju, and Gurviciute [35] conducted interviews with university students (n = 22) and experts from different fields (n = 4) to identify determinants of SM adoption by potential consumers in Sweden. Overall, the participants noted both benefits and drawbacks in terms of how technology affects the performance of tasks. In relation to the benefits, participants mainly cited convenience and health monitoring for both fitness and illness. Drawbacks exemplified by respondents were in regard to the limited features of the technology, a decrease in task quality, and privacy concerns. As a whole, Performance Expectancy was found to have a major influence on participants' willingness to adopt SMs. The study is characterized by several limitations. The first part of the study focused primarily on exploring perceptions of university students in Sweden, who may not represent all potential users in Sweden. Furthermore, the age, gender, and cultural contexts of the respondents were not considered as mediating factors in understanding their perceptions of microchip adoption. Finally, the second part of the study included insights of a limited number of experts (n = 4) from different fields, thus not providing specific, in-depth perspective from one field of expertise.

Cristina et al. [36] considered five ethical dimensions ("Moral Equity", "Relativism", "Utilitarianism", "Egoism", and "Contractualism") to propose a working hypothesis about acceptance of human capacity-enhancing technologies (both wearable and implantable/insideable devices such as implanted micorchips). The survey included 1563 young digital natives who were higher education university students in seven countries, including 53 from the US. Based on their findings, the researchers concluded that ethical judgment is key for the acceptance of wearables and insideables. Moreover, ethical judgement has greater explanatory capacity for insideables than for wearables among young adults. They also found that "Egoism" (versus "Altruism") has the highest explanatory power for Intention to Use insideable devices, implying that the millennial generation is likely to adopt implantable microchips for self-enhancement in the future.

Chebolu [37] explored the acceptance of microchip implants in human body from psychological view point by considering potential users' personality traits, and attitudes. Their investigation explored how trust in technology varied by race, gender, religion, or spirituality. Limitations of this study include a specific population, i.e., undergraduate students (n = 111) at the University of Central Florida over 18 years of age (mean = 21.1). The survey consisted of Likert scale questions, and the analysis examined individual differences related to acceptance, use, or perception of implantable technologies based on comparison between the following personality factors: self-reported Extraversion versus Introversion, Agreeableness versus Antagonism, Conscientiousness versus Lack of Direction, Neuroticism versus Emotional Stability, and Openness versus Closedness to Experience [38]. The researcher also concluded that there is a relationship between trust, motivation to use, and acceptance of microchip implants.

Pettersson [39] studied how the public perceives microchip implants as a digital interaction tool as well as which features of microchip implants are important to them. The authors conducted eight semi-structured interviews (face-to-face, over the phone, and via Skype respectively) with young, mostly Swedish, folks (aged 22–37, with a median age of 26), who were identified as non-experts and belonged to the public. Based on their thematic analysis results, the researchers found high skepticism toward the technology due to worries about security and privacy and a lack of knowledge. Benefits included keeping better track of health and making everyday actions easier as well as excitement about this new technology. The small sample size and sample composition precludes the generalizeability of these findings.

Gauttier [14] examined the press coverage of initiatives taken by three companies (Epicenter in 2015, followed by Three Square Market and New Fusion in 2017), in three different countries, to propose chip implants to their employees ('insideable' technology). The study sought to identify prevalent topics, the motivations and measures taken by the companies, the drivers and barriers of employees toward the chips, and the issues raised by experts in the newspaper articles. A qualitative analysis of the corpus was performed, and it led to the identification of issues such as concerns about privacy, the management of the chip, market opportunities, and lack of policies. The author concluded the microchips should also target personal uses in workplaces rather than work-related tasks alone.

Most published works use some type of a model as an entry point to their research with the end users [5,33]. Some researchers claim that this may have prevented them from collecting diverse perspectives [33], as participants were limited to answering Likert scale questions. In other studies, determinants are based on perspectives of smaller sample sizes [35,39], and/or homogeneous study populations [33,35–37], and/or are restricted to certain contexts [5,14]. Moreover, it is not always clear what was the knowledge/familiarity level of participants regarding microchip implants. Our work attempts to address these limitations by identifying determinants of SM acceptance via deductive analysis of qualitative data collected from a larger and diverse study sample.

3. Materials and Methods

3.1. Study

The aim of this study was to find answers to the following research questions (RQs):

- RQ 1: What are the public's major concerns about microchip implants?
- RQ 2: How are these concerns represented in various demographics?
- RQ 3: What are the public's positive expectations (hopes) about microchip implants?
- RQ 4: How are these hopes represented in various demographics?

3.2. Methods

This study was approved by the institutional review board of the University of Towson (ID #1056). Given that we were interested in creating a new model of acceptance, we chose a qualitative study design [40] to collect rich, detailed, and emotionally driven insights based on participants' personal views of the topic. The goal was to distill these insights through the identification of recurring ideas and attitudes using thematic analysis [41]. Moreover, to recruit a larger, more diverse set of participants for a broader coverage of insights, we chose a survey technique. The aim was not statistical generalization but pilot identification of significant concerns and expectations in the general population.

A survey consisting of two open-ended questions was prepared after an extensive literature review. The questions aimed to collect public's personal opinions about SMs and have also been used by Pettersson [39]. The survey was distributed via mailing lists, social media platforms, and online patient communities between March 2020 and May 2020. Eligibility conditions were that the survey respondents should be (1) aged $\geq$ 18 years and (2) comfortable with reading and understanding English. The total expected time to complete the survey was 30–45 min. Participants voluntarily agreed to participate after reading and accepting the informed consent presented at the beginning. During the survey, participants were free to skip any question they did not want to answer, and they could also quit at any time by closing the browser. No compensation was provided for completing the survey in its entirety.

3.3. Survey Design

The survey was prepared using the web-based Qualtrics software. The participants first had to complete an informed consent and then watch a 10-min informational video (https://youtu.be/Gu44w4yJmxI (accessed on 21 February 2022) about microchips. The video covered history, current uses, and existing debates about microchip implants. Following this, participants completed a few questions to provide their demographics such as age, gender, race, nationality, chronic conditions, etc. However, no identifying information such as name, email, and mailing address was collected. We chose demographic factors and personality characteristics that are known to have moderating effects on technology adoption. Finally, participants answered the following open-ended questions: (a) What are your major concerns about microchip implants? (b) What excites you about the future of microchip implants?

3.4. Participants

A total of 179 participants completed the survey. The majority of the participants (54%, or 96 out of 179) were US nationals; 40% (72 out of 179) were foreign nationals residing in the US; and 6% (11 out of 179) of the participants did not mention their immigration status, but were living in the US at the time of the survey. A total of 126 participants were females, 50 were males, one was fluid, and two preferred to not disclose their genders. Participants' ages ranged from 18 years to 83 years with the majority, i.e., 41% (73 out of 179), belonging to the 18–29 year age group. The highest degree earned by most, i.e., 30.2% (54 out of 179) of the participants, was bachelor's. Nearly half (44%, 78 out of 179) of the participants had at least one chronic condition, 14.5% (26 out of 179) reported having a disability, and 3.5% (6 out of 179) had some sort of an implant (e.g., birth control, insulin pump, etc.). Further details about participants are summarized in Table 1.

Table 1. Demographic survey questions and responses.

Demographic	Answer Choice
Age	1. 18–29 years (n = 73) 2. 30–49 years (n = 60) 3. 50–64 years (n = 36) 4. 65–79 years (n = 8) 5. 80 years and above (n = 1) 6. Unspecified (n = 1)
Gender	1. Male (n = 50) 2. Female (n = 126) 3. Fluid (n = 1) 4. Prefer not to disclose (n = 1) 5. Other (n = 1)
Race	1. African American or Black (n = 48) 2. Asian or Pacific Islander (n = 14) 3. Hispanic/Latino (n = 6) 4. Native American or American Indian (n = 0) 5. White or Caucasian (n = 86) 6. Other (n = 18) 7. Unspecified (n = 7)
Immigrant?	1. Yes (n = 72) 2. No (US national) (n = 96) 3. Unspecified (n = 11)
Medical Conditions?	1. Yes (n = 78) 2. No (n = 95) 3. Unspecified (n = 6)
Disability?	1. Yes (n = 26) 2. No (n = 148) 3. Unspecified (n = 5)

3.5. Data Analysis

We used the thematic coding technique to identify insights from the qualitative data. Two researchers first, independently, coded the open-ended responses using the inductive coding technique. Then, they met to discuss and compare the emerging codes over several meetings. The discussions mainly focused on resolving coding differences and agreeing on a coding language. By the end, the researchers had agreed on a set of codes to move forward with. Then, a second round of coding and analysis ensued, which was guided by the deductive coding technique. This was accomplished over several sessions with both researchers working together. Once the coding was completed, the researchers worked together to cluster the related codes into categories and then group the related categories into themes. Discussion continued over several meetings before a final report was generated. We used Microsoft Excel to code all the interview responses. Once coding was finalized, we used features and functionalities within Microsoft Excel to generate descriptive statistics for the codes.

4. Results

The themes and codebook generated for the two survey questions have been individually presented in Tables 2 and 4. We describe the concepts and codes related to each theme along with its prevalence in various demographics (specifically, medical conditions and immigration status) below.

4.1. RQ 1: Concerns about Microchip Implants

The taxonomy describing participants' concerns is given in Table 2. Respondents' main concerns were related to data protection, health risks, lack of knowledge, and negative affect. Other concerns were about ease of use, metaphysical dilemmas, monetary issues, and negative social impact. Only a few participants (2.23%, or four out of 179) stated that they do not have any concerns. Below, we elaborate these themes from participants' viewpoints.

Table 2. Mapping codes to categories for theme generation for RQ1: Concerns related to microchip implants.

Theme	Category	Code	Code Frequency in % (*n* out of 179)
Health Risks	Risk Type	All Health Risks	40.8 (*n* = 73)
		Mental Issues	6.7 (*n* = 12)
		Physical Issues	5.0 (*n* = 9)
	Risk Temporality	Long-Term Side Effects	12.2 (*n* = 22)
		Short-Term Side Effects	7.3 (*n* = 13)
	Risk Nature	Generally Unnatural	4.5 (*n* = 8)
Data Protection	Data Misuse	Steal Data	29.0 (*n* = 53)
		Misuse Data	31.0 (*n* = 55)
	Surveillance	Organizational	22.9 (*n* = 41)
		Governmental	6.7 (*n* = 12)
		GPS tracking	1.1 (*n* = 2)
Knowledge	Inadequate	Side effects	4.5 (*n* = 8)
		Efficacy	1.7 (*n* = 3)
		Regulations/Limitations	1.7 (*n* = 3)
		General/Other	1.1 (*n* = 2)
	Ambiguous	Uncertainty	5.0 (*n* = 9)
Negative Affect	Surgery Related	Removal	4.5 (*n* = 8)
		Implantation	6.7 (*n* = 12)
	Usage Related	Everyday Pain	0.6 (*n* = 1)
		Other	1.1 (*n* = 2)
Metaphysical Dilemmas	Ethical and Moral	Personal Conscience	5.6 (*n* = 10)
	Religious	Belief Conflict	6.2 (*n* = 11)
Ease of Use	Task Completion	Malfunctions	6.7 (*n* = 12)
	Task Safety	No Control	5.6 (*n* = 10)
Monetary Issues	Expenses	Others	6.7 (*n* = 12)
		Maintenance Fees	0.6 (*n* = 1)
Negative Social Impact	Problems	Social Inequality	1.7 (*n* = 3)
		Monetary Laundering	0.6 (*n* = 1)
Absence	No Concern	Nothing	2.3 (*n* = 4)

Data Protection: This theme highlights participants' concerns about the safety of the data captured/stored within microchip implants. Participants were concerned that data within microchip implants might be stolen and misused by the hackers, exposing the user to bigger problems, such as higher insurance premiums and identity thefts. The other concern was that the powerful entities such as employers or government agencies would use this device to gain access to people's personal and private data, exposing people to unnecessary scrutiny, and harm. A few participants, specifically, mentioned that the Geographical Positioning System (GPS) tracking capability of SMs would be a threat to their freedom. Some quotes describing this concern are given below:

> "Invasion of privacy, issues with who controls the microchip, cyber-security concerns, overall creepiness factor." (White Female, 65–79 years, with medical condition(s), but no disability).

> "Unethical use of the microchip by government, business owners and society members. Additionally, right now the microchip seems to have limited capabilities (for example: turning on lights and opening doors). My concern is more would be tracked than is communicated." (White Female, 30–49 years, no medical condition and no disability).

> "My main concern with microchip implants is that the data acquired from the implants could get into the wrong hands and become misused and abused. I think companies would use this data for their own financial gain by exploiting the people who have chips in them. I also think the "big brother" aspect comes into play if the government were to require people to have microchips. I do not think the government should be so heavily involved that they require people to have a device in them that tracks their data, what they are doing, and where they are at all times." (Asian or Pacific Islander Female, 18–29 years, mo medical condition and no disability).

Health Risks: There was a major concern about SM-related health risks, which participants expressed in three ways. First, participants were concerned that microchip use would produce both physical and mental health problems in the user. For example, chips would react with the body and cause allergies, interfere with people's ability to think, harm the normal internal body functions, etc. Second, participants were concerned about the duration of such health problems. While some were okay with short-term risks, the majority were averse to the idea of both short and long-term health risks. Finally, participants were concerned about the nature of the health problems. They rationalized that since microchips were unnatural and inorganic, they would lead to incurable and unnatural (new) health issues. In short, no one was willing to accept any health-related risks that came with microchips due to their novelty and uncertainty. Following quotes explain these concerns further:

> "I am concerned that microchips will cause heavy dependence on technology and will not allow humans to think naturally." (Asian or Pacific Islander Female, 50–64 years, with medical condition(s), but no disability).

> "My only concern would be if it had a long-term health risk to you . . ." (White Female, 50–64 years, with medical condition(s), but no disability).

> "Regarding microchip implants my concerns include adverse tissue reactions, . . ." (White Female, 65–79 years, with no medical condition and no disability).

> "Side effects to my immune system. Will my body think it is a foreign substance, fight it and lose? What types of infections can it cause?" (White Female, 30–49 years, with medical condition(s) and disability).

Lack of Knowledge: Participants thought that the lack of knowledge about microchip implants in the public sector makes it difficult for them to accept or reject microchips. Participants wanted to know about the risks and benefits of SMs as well as expected technical advances are expected in the future. Overall, participants thought that current benefits of microchips were not based on sufficient science and more research was needed to establish the advertised promises. Participants were unaware of any regulations concerning SMs, and were concerned whether the existing ones were sufficient to protect them. They were also worried about not knowing government's and scientists' motivations behind the propagation of this technology. Participants mentioned that apparent indifference or deliberate obfuscation of information about SMs heightened their distrust in microchip implants. The following quotes explain how participants felt about the current state of the knowledge.

> "Does not sound right. Insufficient science. No compelling reason to face its risks." (African American or Black Female, 18–29 years, with medical condition(s), but no disability).

> "There would need to be a lot of trial and error in testing subjects for me to not be concerned about the use of microchips in humans. I believe we would need years and years of observing this practice before something come on the market and people agreed to buy it and use it. Eventually, personal stories from people who have the implant and their pros and cons would be helpful to know." (White, Female, 30–49 years, no medical condition or disability).

Negative Affect: A number of comments revealed negative feelings toward microchips. Participants expressed dislike with the idea of undergoing implantation and removal surgeries. Most of them did not feel comfortable with the idea of having a foreign substance inside their bodies that could not be removed at will. Some quotes that express such negative sentiments toward microchips are as follows:

> "I fear having anything implanted in my body." (White Female, 30–49 years, with medical condition(s) and disability).

> ". . . if it is implanted in the brain that could be very scary if something were to go wrong." (White Female, 18–29 years, with no medical condition and no disability).

Ease of Use: Generally speaking, participants did not foresee any challenges with using a microchip, but they believed that microchips would impact the tasks for which they were being used (effectiveness). For example, participants feared that microchips would prevent them from using diagnostic devices such as Medical Resonance Imaging (MRI) or cause inconvenience at the airport body scanners. They also did not feel that a microchip provides sufficient control to users over its functions. They did not feel that SMs would make error and mistake correction easier, because it was embedded inside the body (safety).

> ". . . Also a malfunction could leave me worst off with me not being able to complete many tasks." (White Female, 18–29 years, with no medical condition and no disability).

> "Regarding microchip implants my concerns include. . . incompatibility with medical equipment such as MRIs, which would prevent me from going through airport scanners or getting diagnostic tests." (White Female, 65–79 years, with no medical condition and no disability).

Metaphysical Dilemmas: Beyond physical worries, participants also associated many metaphysical dilemmas around using microchips. Mainly, participants stated that some potential advantages of microchips created ethical concerns for them, such as giving them unfair advantages over others by enhancing their mental capabilities. Some participants also looked at microchips from a religious point of view. They saw microchip implants as in direct conflict with their religious tenets, explaining that using microchips for enhancement purposes would conflict with the original purpose of creation. They saw microchips as interfering with free will and infringing upon people's ability to think and make decisions for themselves. The following quote sums up how religiously inclined participants viewed microchips:

> "With the implants, the lines get sticky when people start talking about bringing in church and state. While the video just did a quick skip over the two, this topic has been a hotbed in my church for as long as I can remember. The mark of the beast, never let them implant you with anything. I am in my fifties now and have been hearing this at just about any church I have gone to since I was a kid. So why now? With the state of the world that it is, why would I be comfortable now? And as far as the government, the same thing. We have been told, never give them too much power over you. And here we are. My problem is I literally just found out that the pain pump that I have installed is most likely indeed

microchipped already. Something I did not particularly feel positively having for myself. " (White Female, 50–64 years, not reported medical condition, but no disability).

Monetary Issues: Participants were also concerned about the expenses associated with microchip implants. Some participants mentioned ongoing maintenance expenses, e.g., periodic medical checkups, while others mentioned surgical costs, i.e. initial surgery, removal surgery, corrective surgery, etc. Some participants were concerned that their insurance premiums would increase as health insurance companies would have more data about them. While others were worried that microchips would cause further health problems, leading to additional medical issues and expenses. Here are a few quotes explicating this theme:

"My only concern would be if it had a long-term health risk to you, or if the cost of it was astronomical." (White Female, 50–64 years, with medical condition(s), but no disability).

"Who pays for the surgery and what will costs entail?" (White Female, 30–49 years, with medical condition and disability).

Negative Social Impact: This theme covers categories that highlight participants' concerns about both real and imaginable impacts of microchips on the society. Participants were concerned that microchip use would enhance existing social inequalities and result in monetary gain for some at the expense of others. For example, participants were worried that microchips would be stolen and sold in the black markets or that microchips would create opportunities for criminals to harm people. Participants belonging to racial minorities (specifically, African Americans) expressed concern that this technology can easily to be used to discriminate against people. Others were concerned that microchips would be, ultimately, used to control people's freedom based on their backgrounds. For example, based on their demographics, people might be prevented from doing certain things, such as traveling to various places, eating at specific locations, etc. Related to this, there was also a concern that microchips would be ultimately used to control people's behaviors and trick them into doing things that they did not want to do.

Here are quotes of some of our participant from our survey related to this theme:

"Funding issue: who is funding this research and why; I am aware of the business interests behind medical industry and drug companies. Their priorities are not ethically in the right place. If they need to choose between profit and well-being of the patients, they choose the former." (White Female, 65–79 years, with medical condition(s), but no disability).

"My concerns are government control, control from business or people in power, being black" (African American or Black Male, 18–29 years, with medical condition(s), but no disability).

"What if Trump or his ilk were president and got the idea to control the vote or other things via microchip." (White Female, 30–49 years, with medical condition(s), but no disability).

4.2. RQ 2: Prevalence of Identified Concerns in Various Demographics

The prevalence of all the identified concerns was higher among participants with medical condition(s) in comparison to participants without any medical condition (Table 3). However, the concerns are ranked in the same order in both groups. Specifically, the top two concerns of both groups were 'Health Risks' and 'Data Protection'. The remaining concerns were not very common, with 'Negative Social Impact' having a very low prevalence among both groups. A few (n = 4) participants with no medical condition expressed no concern but no one with a medical condition(s) was in the "Absence" (i.e., absence of concerns) theme.

In terms of immigration status, more non-immigrants were concerned about health risks, metaphysical dilemmas, data protection, and monetary issues as compared to immigrants. The immigrants were a little more concerned about lack of knowledge and negative social impact in comparison to the non-immigrants.

Table 3. Prevalence of Concerns-Related Themes in Various Demographics: [Medical Conditions: Yes (n = 78), No (n = 96); Immigration Status: Yes (n = 72), No (n = 96)]

Theme	Medical Condition %		Immigrant? %	
	Yes	No	Yes	No
Health Risks	96.0 (n = 75)	65.3 (n = 62)	60.0 (n = 43)	90.6 (n = 87)
Data Protection	85.0 (n = 66)	61.0 (n = 58)	50.7 (n = 37)	85.4 (n = 82)
Knowledge	18.0 (n = 14)	11.6 (n = 11)	15.2 (n = 11)	10.4 (n = 10)
Negative Affect	14.1 (n = 11)	12.6 (n = 12)	12.5 (n = 9)	12.5 (n = 12)
Metaphysical Dilemmas	12.8 (n = 10)	10.5 (n = 10)	11.1 (n = 8)	13.5 (n = 13)
Monetary Issues	11.5 (n = 9)	4.2 (n = 4)	2.8 (n = 2)	10.0 (n = 9)
Negative Social Impact	6.4 (n = 5)	1.0 (n = 1)	4.2 (n = 3)	3.1 (n = 3)
Absence	0.0 (n = 0)	4.2 (n = 4)	2.8 (n = 3)	2.1 (n = 2)

4.3. RQ 3: Participants' Positive Expectations (Hopes) Regarding Microchip Implants

The taxonomy of future hopes for microchip implants is presented in Table 4. The majority of participants hoped for further medical uses in the future. Other notable hopes included other uses, regulations, affordability, etc. Out of all the participants, 2.2% (4 out of 179) of the participants had no future hopes for microchips and 14.0% (25 out of 179) of them hoped that microchips would cease to exist. Below, we explore each theme in more detail.

Medical Uses: The highest number of participants were hopeful that, in the future, microchip implants would be used to advance medical science. Participants hoped that microchips would be used to fix mental and physical disabilities, such as vision problems. Participants were hopeful that in the future, microchips would provide personalized care including medication management and health monitoring to critical care patients. Some participants also mentioned that microchips should be used for controlling emergency health situations such as a pandemic, and disseminating vaccines at scale. Participants believed that microchips have the potential to lower self-care burden and enhance patients' quality of life. Finally, participants hoped that in the future, microchip implants would facilitate disease diagnosis, e.g., cancers, ahead of time. Some participants were also hopeful that microchips would improve our overall understanding of human body and psychology, leading to better treatments for the humanity. Here are some quotes from survey participants about this theme:

> "I was diagnosed with cancer last year, if it could monitor certain levels within the body that would be great, also monitoring temperature could be helpful. In addition, getting vaccines or other life-saving medication could be a great use. Hospitals could also download health info immediately if patient is unresponsive. Maybe could also monitor certain chemical levels in the body to give information on patient's mental health." (White Female, 50–64 years, with medical condition(s) and disability).

> "I would hope to get answers to different health conditions I suffer with, and I would want to be able to better my illnesses or quality of life." (White Female, 50–64 years, with medical condition(s) and disability).

> "That it could help many people, including research communities, understand the human body and psyche better." (Asian or Pacific Islander Female, 65–79 years, no medical condition or disability).

Table 4. Mapping codes to categories for theme generation for RQ2: Hopes with respect to microchip implants.

Theme	Category	Code	Code Frequency in % (*n* out of 179)
Medical Uses	Corrective Uses	Solve Mental Disabilites	8.4 (*n* = 15)
		Fix Physical Disabilities	40.2 (*n* = 72)
	Healthcare Services	Personalized Care	2.8 (*n* = 5)
		Health Monitoring	14.0 (*n* = 24)
		Enhance Quality of Life	16.8 (*n* = 30)
	Research	Understand Mind and Body	1.7 (*n* = 3)
		Diagnose Diseases	3.9 (*n* = 7)
Other Uses	Convenience	Replace Cash and Cards	2.8 (*n* = 5)
		Secure Entry into Buildings	2.3 (*n* = 4)
	Law Enforcement	Track Criminals	0.6 (*n* = 1)
		Control Crimes	1.1 (*n* = 2)
	Public Awareness	Knowledge	18.4 (*n* = 33)
Dismissal of Microchips	No Hope	Indifference	2.2 (*n* = 4)
		No Future	14.0 (*n* = 25)
Technical Advances	Improved Safety	Safe to Use	4.7 (*n* = 8)
		Better Performance	0.6 (*n* = 1)
	Data Protection	Security Mechanisms	3.9 (*n* = 7)
		Privacy Controls	2.2 (*n* = 4)
	Surgery-Related	Not be Implantable	1.7 (*n* = 3)
		Temporary Implant	1.1 (*n* = 2)
Human Enhancement	Enhancement Uses	Mental Capabilities	1.1 (*n* = 2)
		Other Capabilities	12.3 (*n* = 22)
Regulations	Affirmations	Regulate Use	1.1 (*n* = 2)
		Keep it Optional	3.9 (*n* = 7)
	Clarifications	Religious Verdict	0.6 (*n* = 1)
		Safe Uses	1.1 (*n* = 2)
Affordability	Reduced Cost	Maintenance and Surgery	3.9 (*n* = 7)

Other Uses: Participants hoped that microchips would produce positive changes in the society. Some mentioned the prevalence of everyday conveniences such cashless/cardless payments and secure entry into buildings. Some participants were hopeful that microchip implants would facilitate law enforcement, including tracking of criminals and control and reduction of crimes; kidnapping was mentioned as an example. Many participants were looking forward to a society where public awareness about risks and benefits of SMs would be well-known and well-established by the scientific community. In other words, participants saw a better and brighter future with SMs in their public and private lives. Some quotes from the survey participants on these themes are listed below:

> "... ability to find someone who has been kidnapped or someone with dementia" (White Female, 50–64 years, with medical condition(s) and disability).

> "... better control and stop crimes in society." (White Female, 30–49 years, without any medical condition and disability).

Technical Advances: Participants saw improvement in microchip technology as key to acceptance. They were hopeful that, in the future, microchip technology will improve and all currently known shortcomings will be addressed. They were hopeful that in the future, microchips will be safer to use and have lower health risks. Many participants also assumed that microchips will become more secure over time. Some mentioned how this will address the data privacy concerns, and others discussed how this will improve data storage and the handling capabilities of microchips. Others mentioned that the future microchips will have better performance and secure data transmission. Some participants were also hoping that the future microchips will either not be implanted inside the human body, or people will be able to remove and implant them at will. Some participants also discussed how future microchips could be made from organic materials. The following quotes describe this theme further:

> "I hope the information on microchip implants can one day be controlled by the patient and the patient only with a guarantee of no data leaks." (White Female, 65–79 years, without any medical condition and disability).

> "Able to encrypt data and only able to access certain portions for certain reasons." (White Male, 30–49 years, with medical condition(s) but no disability).

> "It could be made in a way where it will be actually part of a body not some foreign object implanted inside." (Asian or Pacific Islander Male, 18–29 years, without any medical condition and disability).

Human Enhancement: Participants were hoping that in the future, microchip implants will be able to enhance various human abilities, making humans more energetic and efficient. Some hoped that microchips will be able to enhance the mental capabilities of humans, allowing them to solve pressing and wicked problems in the world. Below are a few quotes related to this theme:

> "With respect to microchip implants, one hope is that if they became an option in the future, that they would enhance performance (physical and mental). However, it could be seen as an unfair advantage to those who do not have one. I also hope that they can be used to improve diseases and conditions in people, if and only if that is what they are used for." (White Male, 30–49 years, without any medical condition and disability).

> "Lots of interesting possibilities for use to enhance one's innate abilities" (White Female, 30–49 years, with medical condition(s) but no disability).

Regulations: Participants hoped that future regulations around microchips will prevent their illegal and improper usage. No one was interested in seeing microchips become mandatory. Everyone wanted to have their right to use microchips preserved. A few participants also wished for more clarity around the use of microchip implants from both religious and medical points of view, i.e., when microchips are safe and acceptable to use. Here is a related quote of one participant from our survey:

> "I hope that it doesn't get regulated and mandated by the government because it's another form of tracking and hindering citizens of privacy." (African American or Black Male, 18–29 years, without any medical condition and disability).

Affordability of Microchips: Participants wanted the cost of microchips and associated surgeries to become more affordable and accessible in the future. Some participants also hoped that surgery will be covered by public funds or insurance companies. Here are some quotes from the survey participants on this theme:

> "To make the implantation easy and temporary with lowering the cost and ensure that it has no negative impact on human life." (African American or Black Male, 50–64 years, without any medical condition and disability).

> "That microchips will be publicly funded or covered by insurance for individuals who would benefit most from the technology (e.g., individuals with disabilities, cancer patients)." (White Female, 30–49 years, with medical condition(s) but no disability).

Dismissal of Microchips: Some participants indicated that they did not believe that microchip implants have a future because they did not believe that microchips' benefits were based on facts and evidence. Some participants wanted to take an active stance to eliminate microchips from the society, and to prevent their misuses and harmful effects on human. A few also indicated indifference, explaining that they did not care whether microchips existed or not. Some quotes on this theme are given below:

> "That people stand up against it unless it is done to help with severe medical conditions." (White Female, 50–64 years, with medical condition(s) but no disability).

> "That they don't become widely used." (White Female, 30–49 years, with medical condition(s) and disability).

4.4. RQ 4: Prevalence of Identified Expectations in Various Demographics

The prevalence of themes related to hopes and expectations in various demographics is given in Table 5. More participants with medical conditions and disabilities wanted to see microchips being used for medical uses (98.7% and 100%) and human enhancements (15.4% and 26.9%), compared to those with no medical condition and disability. A higher percentage of participants with medical condition(s) hoped that microchip technology would advance in the future, and that their usage will be expanded to other aspects of life.

Compared to participants with medical condition(s), those with no medical condition hoped that microchips will become more affordable, and there will be better and clearer regulations concerning their usage.

Immigrants were less hopeful about medical uses and human enhancement benefits of microchips compared to non-immigrants. However, immigrants had higher hopes for regulations and other uses in comparison to non-immigrants. Overall, immigrants were less inclined toward dismissing a future with microchip implants.

Table 5. Prevalence of Hopes-Related Themes in Various Demographics: [Medical conditions: Yes (n = 78), No (n = 95); Immigration Status: Yes (n = 72), No (n = 96)]

Theme	Medical Conditions %		Immigrant? %	
	Yes	No	Yes	No
Medical Uses	98.7 (n = 77)	78.6 (n = 75)	63.9 (n = 46)	90.6 (n = 87)
Other Uses	28.2 (n = 22)	24.2 (n = 23)	26.4 (n = 19)	22.9 (n = 22)
Human Enhancement	15.4 (n = 12)	13.7 (n = 13)	9.7 (n = 7)	15.6 (n = 15)
Affordability	1.3 (n = 1)	6.3 (n = 6)	4.2 (n = 3)	4.2 (n = 4)
Technical Advances	17.9 (n = 14)	14.7 (n = 14)	16.7 (n = 12)	16.7 (n = 16)
Regulations	1.3 (n = 1)	8.4 (n = 8)	6.9 (n = 5)	4.2 (n = 4)
Dismissal of Microchips	20.5 (n = 16)	13.7 (n = 13)	13.9 (n = 10)	17.7 (n = 17)

5. Discussion

The aim of this study was to research current attitudes toward microchip implants in the US general population. More precisely, we wanted to investigate the concerns and expectations of the potential end users about this technology. We present our findings as taxonomies along with the frequency of each identified concept. In addition, we found that the prevalence of these themes was influenced by the presence of medical condition(s) and one's immigration status. Based on the reported findings, we propose a modification to TAM with five new determinants for predicting the acceptance of SM in the general population for varied usages (including both medical and non-medical). Future research should aim to generalize these themes and validate the model by targeting a larger population.

5.1. Determinants of Acceptance

The determinants are based on the themes reported in Tables 2 and 4. All of the themes were considered significant and useful while deriving model determinants, even though these themes appear with varying frequencies. The purpose of reporting theme frequencies was analytical generalization within the sample as opposed to statistical generalization [42] (page 311). Figure 1 presents the hypothesized relationships among the determinants with signed arrows, where a plus sign (+) represents positive impact and a minus sign (−) represents negative impact. We discuss each determinant along with the hypothesized impact below.

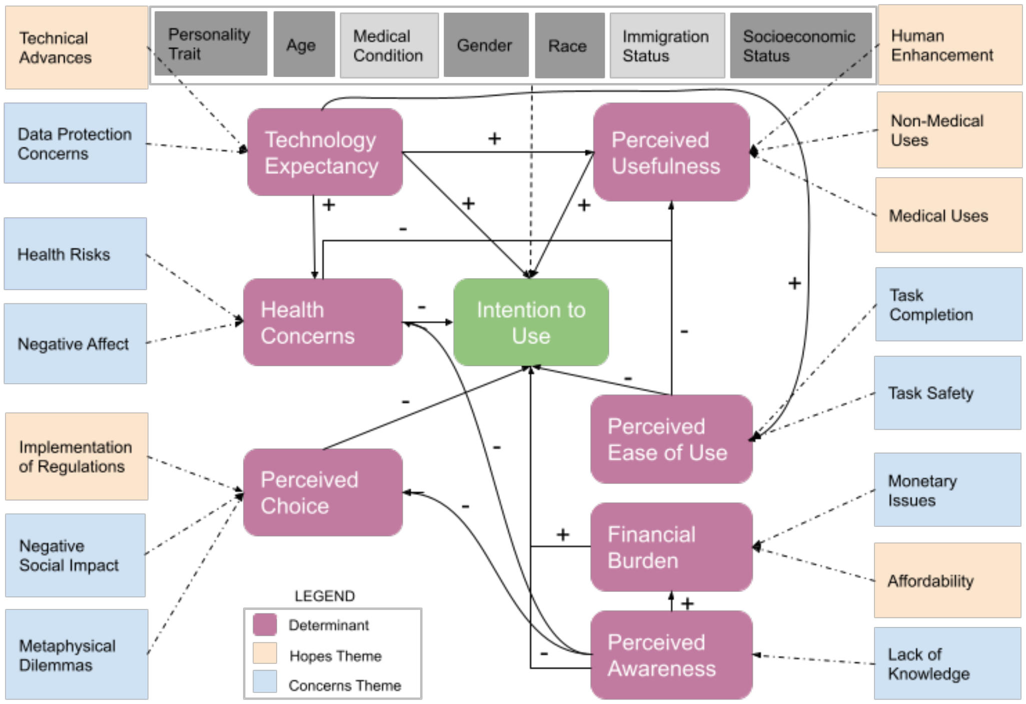

Figure 1. Proposed model for behavioral intention to use subcutaneous microchips.

5.1.1. Perceived Usefulness

This determinant also appears in the original TAM model. For our model, we suggest a slight modification to this determinant's original definition; i.e., we define Perceived Usefulness as an individual's perception that using SMs will improve their quality of life in every domain where SMs can possibly make an impact. This determinant is based on three themes: human enhancement, non-medical uses, and medical uses.

Medical uses may have emerged as a standalone theme because the informational video shown at the beginning of the survey discussed several potential medical applications. However, SMs have other applications that have been covered within "Non-Medical Uses". Our study suggests that, generally speaking, the public is in favor of positive use cases of SMs. Especially, human enhancement is of interest to the general population. Other researchers [5,43] have also found that the Perceived Usefulness of capability-enhancing nano-implants significantly influences people's acceptance attitudes toward such devices. Heffernan [20] states that the participants they interviewed "had a range of reasons for getting insertable devices. These reasons included wanting a new body modification, seeing insertables as the next big thing, extending human functions and capabilities." Based on this evidence, we hypothesize that Perceived Usefulness is associated with a positive impact on the acceptance of SMs.

5.1.2. Perceived Ease of Use

This determinant is also found in the original TAM model, and it can be defined as an individual's perception of the effort involved in using SM.

The Ease of Use theme was identified as a concern among study participants. Some concerns about microchip implants have also been mentioned in the literature. For example, Mark Gasson [18], a researcher at Reading University's School of Systems Engineering, believes that the very attribute of an RFID implant that makes it so convenient—the fact that it cannot be forgotten or left at home—is also its biggest drawback. "When a subcutaneous gadget goes wrong, the experience can be far more harrowing. Implantable technology can't be easily removed, or in this case even switched off", Gasson says. ". . . I felt like the implant was a part of my body, so there was a real feeling of helplessness when things weren't right".

There was a concern among study participants that microchips may not be MRI-safe, which would automatically reduce their ease of use. However, research shows that this concern is not pervasive across different microchip types. Lamberg et al. [44] concluded that the VeriChip™ RFID human implant device is MRI-safe but not MRI-compatible. That is, VeriChip™ would not create adverse medical effects for an implanted patient, but it may be inactivated as a result of MRI testing. Grauer [45] states that other implantable microchips are compatible with MRI machines and are not picked up by metal detectors or airport scanners. This suggests that microchips may not have an adverse impact on user experience.

In other studies, for example, Heffernan [20] found that participants in their study claimed that insertables provide increased usability over existing solutions, in terms of learnability, efficiency, accessibility, and user satisfaction. However, SM still needs improvements in terms of its ability to support primary task completion and task safety. Unless technical advances are made in these two areas in the future, we hypothesize that this determinant is going to negatively impact the acceptance of SMs.

5.1.3. Technology Expectancy

This refers to an individual's belief that SM technology is likely to improve in the future and also overcome its existing shortcomings. This determinant is based on themes of "Technical Advances" and "Data Protection". We hypothesize that this determinant should have a positive impact on an individual's intention to use SM. Although "Data Protection" has a negative impact on Technology Expectancy, this concern is probably going to become less important due to recent technical advances.

The SM are now protected with protocols, passwords, and pins in the same way regular microchips in bank debit/credit contactless cards are protected [18]. Similar data protection is also being offered by microchips installed in modern passports holding owners' biometrics [18]. Hence, RFID technology is already been safely carried around by people all day in their wallets, indicating microchips' acceptance by the public.

In addition to pin and password-based protection, other recent advances in SM include NFC functionality that offers an additional layer of security [18,46]. This functionality means that when connected to an appropriate reader, only a short-range, wireless transmission of data is possible between a microchip and a reader. Hence, GPS tracking is impossible with microchips. Williams [18] states that data protection offered by microchips is not concerning, as it can only be activated if it is placed a few centimeters from a reader. This means an individual has full awareness and control over who can access their data and what is installed on their SMs. Rotter, a biomedical engineer at the University of Science and Technology in Kraków, Poland, says, "Mobile phones are much more dangerous to our privacy. If hacked, phones can convert into the perfect spy with microphones, cameras and GPS. Compared to them, the privacy risks from RFID are really small" [18].

5.1.4. Health Concerns

This determinant refers to an individual's perception that using SMs will be associated with physical harm. "Health Concerns" is also present in the TAM models proposed by Čičević et al. [33] and Werber et al. [5]. Indeed, health risks of SMs were a major concern among the study participants, with many expressing fear and uneasiness with having something implanted inside their bodies.

Research indicates that these fears and concerns are valid. Kazmeyer [47] says that as with any foreign object that enters the body, implantable RFID tags could pose health risks. The microchips are extremely small to minimize trauma, but injection sites still may become infected, and the chips may also work their way to the surface of the skin over time. In addition, a powerful enough RFID pulse could damage the chip, possibly causing irritation or trauma to the surrounding tissue.

In [48], the authors surveyed 332 patients who had undergone hardware removal in 2009 and 2010 at a German level one trauma center regarding their personal experiences with implant removal. The researchers found that the most frequent indication for removal was a doctor's recommendation (68%), which was followed by pain (31%) and impaired function (31%). The patient-reported implant removal complication rate was 10%. Hence, health risks and individual's knowledge of the inherent risks of implants will have a negative influence on their acceptance of SMs.

5.1.5. Financial Burden

This determinant refers to an individual's perception that using SMs will be expensive and financially infeasible. According to [49], implanting a chip in an individual costs around $150 to $200. Furthermore, "Those implanted must pay for the doctor's injection fee and a monthly $10 database maintenance charge", says the advertisement's spokesman Matthew Cossolotto [50]. Getting a birth control implant—also called Nexplanon—can cost anywhere between $0 and $1300. Implant removal can cost between $0 and $300. However, the good news is that since the passage of the Affordable Care Act, these implants are totally free (or low cost) with most health insurance plans, Medicaid, and some other government programs [51].

Graafstra, the owner of VivoKey Technologies in Washington state, US, started selling microchips online for US $49 to US $129 each [52]. People can buy them and then go to a willing doctor or piercing specialist to get them injected, most often into the soft tissue between the thumb and pointer finger. Graafstra claims that he has seen more than 700% growth in sales since 2014. "The first couple of years", he says, "I went from zero to selling thousands of implants around the world". The affordability and convenience of SM is one reason they are finding a broad market appeal.

5.1.6. Perceived Awareness

This determinant refers to an individual's self-awareness about SM's overall benefits and risks. Our study indicates that this determinant is negatively impacting the acceptance of SMs, which is mainly because the awareness about the risks and benefits of this technology is low. Participants in our study indicated that in the future, they would expect more transparency and clarity from entities about why they are trying to enforce and/or promote SMs usage. Indeed, studies show that public knowledge or even awareness about microchip implantation is low, while the fears about its privacy threats are high [53]. Al-Sebae et al. [54] also mentioned that, "It is important to raise awareness related to the importance and seriousness of the RFID technology, where it requires more legal control and support". Participants in our study specifically stated that accurate knowledge about the pros and cons of this technology and observing/hearing personal stories from people with implants (actual users) and anecdotal evidences would be helpful.

Since SM is an emerging technology, scientists have a very important role to play in dispelling misconceptions and disseminating accurate knowledge about SMs. This is because the public often believes that scientists lack transparency and accountability, and that scientists often act in self-serving ways [55]. For example, research shows that trust in medical researchers (35%) tends to be significantly lower than trust in medical practitioners (57%) [55]. Participants in our study explained that microchip implant researchers can improve public's trust in this technology by bringing more clarity and transparency behind the motivations of its broader deployment.

5.1.7. Perceived Choice

To define this determinant, we refer to the definition of ethics. The sociologist Raymond Baumhart explains that the meaning of ethics is not easy to grasp as it varies by individuals [56]. Therefore, to comprehend this concept, we first establish what should not be considered ethics. In a revision of the article of Valasquez et al., "Thinking Ethically" [57], Markkula Center for Applied Ethics at Santa Clara University [56], California, US, elucidates that ethics should neither be equated with an individual's feelings nor with laws. This is because both can diverge from ethical standards. Being ethical is also not about following and/or accepting social norms, since they can also deviate from ethical standards. Furthermore, social consensus is often impossible to achieve on certain issues, e.g., abortion. Finally, religion should also not be equated with ethics, even though religions prescribe certain moral values that motivate individuals to behave ethically.

The Markkula Center goes on to explain that "ethics are well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtues". The goal of ethical standards is adherence to principles that are grounded in well-established moral values such as honesty, justice, and loyalty. For example, ethics in the context of SMs would refer to those standards that would prevent others from stealing and/or misusing an individual's personal data stored within SMs, etc. We are already seeing the emergence of such ethical measures in our society, and it is only a matter of time before they will become more specific. Mendez and Jaremus [58] explain that implanted employees can claim intentional discrimination under Title VII [59], Genetic Information Nondiscrimination Act [60], or other similar laws, if they find that their employers are using workplace technology to gather non-obvious demographic data (e.g., ethnicity, national origin, religion), or genetic information from employees' implants. This applies even if the employer does not intend to use this information to discriminate.

Ethical standards also include "standards relating to rights, such as the right to life, the right to freedom from injury, and the right to privacy". Dr. Warwick [18] explains this further, "It is not a huge leap from having this technology in our pockets to having it under our skin. The key point is it should be a choice for each individual. If a company says we will only give you a job if you have such an implant, it raises ethical issues". More precisely, microchips' acceptance in individuals is only possible if individuals perceive that powerful entities (organizations, government) are not going to take away their right to accept or reject risks and benefits associated with SM implants.

The second aspect of ethics refers to "the study and development of one's ethical standards". This means that it is incumbent upon every individual and institution to monitor their compliance with logical and well-grounded principles upon which ethical standards are founded. This definition of ethics is becoming important in the context of the current pandemic. It is turning the table around and forcing people to evaluate their own ethical standards. This is, if getting a microchip implant is in the favor of the entire society or an organization that an individual is a part of, should a microchip implant still be an individual's choice? The survey participants clearly indicated that they want ethical standards that preserve their rights to make a choice about being chipped; no one discussed their personal responsibility toward contributing to the social good, i.e., making ethical decisions at an individual level. Cristina et al. [36] also report that "Egoism" as opposed to "Altruism" had a greater impact on Intention to Use microchips in their study population.

Therefore, we define this determinant as the preservation of an individual's right to make a choice about getting chipped. Based on our survey, it appears that people do not believe that such standards are yet well-defined and/or implemented. Even though laws that protect an individual's SM data have started to emerge, overall, the existence of such provisions is unknown by the public. Therefore, this determinant is negatively impacting the acceptance of SM.

5.2. Predictor Variables

Our findings show that the percentage prevalence of the concerns and hopes was influenced by medical conditions and immigration status. That is, people with medical conditions were, generally, more concerned and more optimistic about microchips than people without medical condition(s). Similarly, non-immigrants appeared to be more concerned and more hopeful about microchips compared to immigrants. Due to the limitations of the study, we could not establish statistical significance of these observations. However, based on the descriptive statistics, we have added these two demographics as predictor variables in the proposed model. Personality traits, age, gender, race, and socioeconomic status have also been added, even though these have not been analyzed in this manuscript. We explain our rational for their inclusion below.

Chebolu [37] and Pelegrin [25] have both considered personality traits as possible influencers on an individual's intention to use SMs. These earlier works may be considered limited because they studied a certain type of population. However, several participants in our study also indicated that they had aversion and/or fear of having an object inside their body (covered by the "negative affect" theme). Hence, we incorporate this variable in the model.

Werber et al. [5] report that age has a negative impact on Behavioral Intention to Use RFID-SM; that is, the older a potential user, the less likely they are to consider the possible use of RFID-SM. Furthermore, Werber et al. state that young people are always in favor of new technology and ignore the possible side effects, while older potential users are more critical toward innovations and are more concerned about their health. Indeed, other studies also show that older adults usually do not feel as comfortable with manipulating technological products, which impacts their decision to use them [61,62]. Therefore, we maintain age as an predictor variable in our model.

A number of researchers have suggested that significant gender differences exist in the acceptance of technology when considering personal use. In a 2003 study by Cap Gemini Ernest and Young [63], it was found that women's health concern ratings around RFID implants usage was higher than men's. Other researchers [64,65] report that men's ratings of self-efficacy, perceived usefulness, perceived ease of use, and behavioral intention to use technology, such as e-learning and computer software applications, tend to be higher than women's. Smith [66] concluded from the results of his study that, compared to females, males, in general, have a better mastery over some of the technological barriers in utilizing RFID and microchip implantation. Based on this existing evidence, gender has been included in our model.

Research indicates that technology adoption differences exist between races. For example, Katz [67] reports that Asians' Internet adoption and usage patterns are quite different from African-Americans' and Hispanics'. In a 2009 study [53], it was found that younger and non-White participants were less concerned about privacy compared to older and White participants. However, their study was characterized by a low percentage of non-White participants. Chebolu [37] mentioned that race along with demographics may alter users' perspective toward microchips. Based on this existing evidence, we have added race as another predictor variable in our model.

Lastly, socioeconomic status, which is defined as the social standing or class of an individual or a group, and measured as a combination of education, income and occupation, has also been chosen as a predictor variable. The American Psychology Association [68] states that the "examinations of socioeconomic status often reveal inequities in access to resources", which includes technologies. Indeed, several researchers have found that socioeconomic factors moderate the relationship between perceived usefulness and intention to use a digital technology [69–72]. Moreover, socioeconomic status provides insights into the "issues related to privilege, power and control" [68], which can have a direct impact on "Perceived Control". For example, because there is no democracy in military, military personnel, as opposed to civilians, are going to have lesser say in making a decision to adopt microchips. Hence, we have added this variable to the proposed model.

6. Conclusions

The public believes that SMs are a useful technology that will improve in the future. Future research should focus on improving the usability and reducing the health risks of SMs. However, wider acceptance of SMs is only possible when individual's right to choose is preserved, risks and benefits of SMs are made transparent, and technology is made affordable. However, demographic factors such as age, personality traits, medical conditions etc., will play an important role in the adoption of SM by the public. The proposed model should be verified in a future study with a larger population.

Author Contributions: Conceptualization, B.M.C. and M.M.; methodology, B.M.C. and M.M.; formal analysis, S.S. and B.M.C.; writing—original draft preparation, S.S. and B.M.C.; writing—review and editing, S.S., B.M.C. and M.M.; supervision, B.M.C. All authors have read and agreed to the submitted version of the manuscript.

Funding: The study did not receive any external funding.

Institutional Review Board Statement: The study was conducted according to federal regulations set forth by the US Department of Health and Human Services, and approved by the Institutional Review Board of the University of Towson (protocol code: #1056 and approval date: 11 February 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Requests for survey data set can be sent to the corresponding author.

Conflicts of Interest: The authors' employers are not involved in the reporting and conducting of this study. The authors and their employers have no conflict of interest to declare.

Abbreviations

The following abbreviations are used in this manuscript:

US	United States
RFID	Radio Frequency Identification Device
SM	Subcutaneous Microchip
NFC	Near Field Communication
RQ	Research Question
TAM	Technology Acceptance Model
GPS	Geographical Positioning System
MRI	Magnetic Resonance Imaging

References

1. Nsanze, F. ICT implants in the human body-A review. In *The European Group on Ethics in Science and New Technologies to the European Commission*; European Communities: Luxembourg 2005.
2. Moessner, M. Secure Authentication Scheme for Passive C1G2 RFID Tags. *Comput. Netw.* **2012**, *56*, 273–286. [CrossRef]
3. Microchip Implant (Human)—Wikipedia. Available online: https://en.wikipedia.org/wiki/Microchip_implant_human (accessed on 19 November 2021).
4. Is Human Chip Implant Wave of the Future? Available online: http://edition.cnn.com/TECH/computing/9901/14/chipman.idg/ (accessed on 14 January 2022).
5. Werber, B. Factors affecting the intentions to use RFID subcutaneous microchip implants for healthcare purposes. *Organizacija* **2018**, *51*, 121–133. [CrossRef]
6. Microchip Developed by Pentagon to Detect Covid-19. Available online: https://nypost.com/2021/04/12/microchip-developed-by-pentagon-to-detect-covid-19/ (accessed on 27 January 2022).
7. Carr, N.K. As Society Strives for Reduced Contact During the Pandemic, How Can Human Microchipping Help? *Villanova Law Rev. Online* **2020**, *65*, 46.
8. Tzeng, S.-F.; Chen, W.-H.; Pai, F.-Y. Evaluating the business value of RFID: Evidence from five case studies. *Int. J. Prod. Econ.* **2008**, *112*, 601–613. [CrossRef]
9. Eltorai, A.E.M. Microchips in medicine: Current and future applications. *BioMed Res. Int.* **2016**, 2016, 1743472. [CrossRef]
10. Perakslis, C.; Michael, K. Indian Millennials: Are microchip implants a more secure technology for identification and access control? In Proceedings of the 2012 IEEE Conference on Technology and Society in Asia, T and SA, Singapore, 27–29 October 2012.
11. Tech Company Workers Agree to Have Microchips Implanted in Their Hands. Available online: https://abcnews.go.com/Technology/tech-company-workers-agree-microchips-implanted-hands/story?id=48818529 (accessed on 27 January 2022).
12. Work 2035: How People and Technology Will Pioneer New Ways of Working. Available online: www.citrix.com/fieldwork/employee-experience/new-ways-of-working-2035.html (accessed on 29 January 2022).
13. Michael, K.; Aloudat, A.; Michael, M.G.; Perakslis, C. You Want to Do What with RFID?: Perceptions of radio-frequency identification implants for employee identification in the workplace. *IEEE Consum. Electron. Mag.* **2017**, *6*, 111–117. [CrossRef]
14. Gauttier, Stéphanie, 'I've got you under my skin'–The role of ethical consideration in the (non-) acceptance of insideables in the workplace. *Technol. Soc.* **2019**, *56*, 93–108. [CrossRef]
15. Michael, K.; Michael, M.G.; Galliot, J.C.; Nicholls, R. Socio-Ethical Implications of Implantable Technologies in the Military Sector. *IEEE Technol. Soc. Mag.* **2017**, *36*, 7–9. [CrossRef]
16. Michael, K. RFID/NFC implants for bitcoin transactions. *IEEE Consum. Electron. Mag.* **2016**, *5*, 103–106. [CrossRef]

17. Half of Brits Expect to Replace Cash with New Technologies, NFC World. August 2015. Available online: http://www.nfcworld.com/2015/08/28/337345/half-of-brits-expect-to-replace-cash-with-newtechnologies/ (accessed on 26 January 2022).
18. Richard Gray. The Surprising Truths and Myths about Microchip Implants. 2 August 2017. Available online: https://www.bbc.com/worklife/article/20170731-the-surprising-truths-and-myths-about-microchip-implants (accessed on 27 January 2022).
19. Michael, K.; Michael, M.G.; Perakslis, C.; Abbas, R. 5 Überveillance and the Rise of Last-Mile Implantables: Past, Present, and Future. *Embodied Comput. Wearables Implant. Embed. Ingestibles* **2020**, *97*. Available online: https://www.katinamichael.com/research/2019/8/1/uberveillance-and-the-rise-of-last-mile-implantables (accessed on 27 January 2022).
20. Heffernan, K.J.; Vetere, F.; Chang, S. You put what, where? Hobbyist use of insertable devices. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, CA, USA, 7–12 May 2016; pp. 1798–1809.
21. Khan, N.A. RFIDs chip implants and their related ethical issues. *Res.Rep*. **2015**, *unpublished*. [CrossRef]
22. Rotter, P.; Daskala, B.; Compano, R. RFID implants: Opportunities and and challenges for identifying people. *IEEE Technol. Soc. Mag.* **2008**, *27*, 24–32. [CrossRef]
23. Yao, W.; Chu, C.-H.; Li, Z. The adoption and implementation of RFID technologies in healthcare: A literature review. *J. Med. Syst.* **2012**, *36*, 3507–3525. [CrossRef] [PubMed]
24. Niemeijer, A.R. Ethical and practical concerns of surveillance technologies in residential care for people with dementia or intellectual disabilities: An overview of the literature. *Int. Psychogeriatr.* **2010**, *22*, 1129–1142. [CrossRef]
25. Pelegrin-Borondo, J.; Reinares-Lara, E.; Olarte-Pascual, C. Assessing the acceptance of technological implants (the cyborg): Evidences and challenges. *Comput. Hum. Behav.* **2017**, *70*, 104–112. [CrossRef]
26. Fakhr, A. Barriers and Critical Success Factors in Adoption of RFID in Healthcare Sector: Case Studies of Iranian Hospitals. Master's Thesis, Information Security Luleå University of Technology Department of Computer Science, Electrical and Space Engineering, Lulea, Sweden, 2011.
27. Wagemakers, S.; van Zoonen, L. Research about Human Chipping. 2013. Available online: http://www.imprintsfutures.org/assets/images/pdfs/ResearchaboutHumanChipping.pdf (accessed on 25 February 2022).
28. Bramstedt, K.A. When microchip implants do more than drug delivery: Blending, blurring, and bundling of protected health information and patient monitoring. *Technol. Health Care* **2005**, 13, 193–198. [CrossRef]
29. Michael, K.; McNamee, A.; Michael, M.G. The emerging ethics of humancentric GPS tracking and monitoring. In Proceedings of the 2006 IEEE International Conference on Mobile Business, Copenhagen, Denmark, 26–27 June 2006; p. 34.
30. Foster, K.R.; Jaeger, J. Ethical implications of implantable radiofrequency identification (RFID) tags in humans. *Am. J. Bioeth.* **2008**, *8*, 44–48. [CrossRef]
31. Gadzheva, M. Getting chipped: To ban or not to ban. *Inf. Commun. Technol. Law* **2007**, *16*, 217–231. [CrossRef]
32. Masters, A.; Michael, K. Lend me your arms: The use and implications of humancentric RFID. *Electron. Commer. Res. Appl.* **2007**, *6*, 29–39. [CrossRef]
33. Čičević, S.; Samčović, A.; Dragović, M. Factors Affecting RFID Subcutaneous Microchips Usage. In Proceedings of the Sinteza 2019-International Scientific Conference on Information Technology and Data Related Research, Novi Sad, Serbia, 20 April 2019; pp. 235–243.
34. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* **1989**, *46*, 319–340. [CrossRef]
35. Boella, N.; Gîrju, D.; Gurviciute, I. *To Chip or Not to Chip? Determinants of Human RFID Implant Adoption by Potential Consumers in Sweden & the Influence of the Widespread Adoption of RFID Implants on the Marketing Mix*; Lund University Publications: Lund, Sweden, 2019.
36. Cristina, O.P.; Jorge, P.B.; Eva, R.L.; Mario, A.O. From wearable to insideable: Is ethical judgment key to the acceptance of human capacity-enhancing intelligent technologies? *Comput. Hum. Behav.* **2021**, *114*, 106559. [CrossRef]
37. Chebolu, R.D. Exploring Factors of Acceptance of Chip Implants in the Human Body. Master's Thesis, College of Sciences at the University of Central Florida, Orlando, FL, USA, 2021.
38. John, O.P.; Srivastava, S. *The Big-Five Trait Taxonomy: History, Measurement, and Theoretical Perspectives*; University of California Berkeley: Berkeley, CA, USA, 1999.
39. Pettersson, M. Microchip Implants and You: A Study of the Public Perceptions of Microchip Implants. Master's Thesis, Department of Informatics Human-Computer Interaction and Social Media, UMEA University, Umea, Sweden, 2017.
40. Patton, M.Q. *Qualitative Evaluation and Research Methods*; SAGE Publications, Inc.:Thousand Oaks, CA, USA, 1990.
41. *Social Research Methods*; Oxford University Press: Oxford, UK, 2016.
42. Ritchie, J.; Lewis, J. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*; Sage: London, UK, 2003.
43. Reinares-Lara, E.; Olarte-Pascual, C.; Pelegrín-Borondo, J.; Pino, G. Nanoimplants that enhance human capabilities: A cognitive-affective approach to assess individuals' acceptance of this controversial technology. *Psychol. Mark.* **2016**, *33*, 704–712. [CrossRef]
44. Lamberg, J. *Magnetic Resonance Imaging and VeriChip RFID Human Implant at 1.5 Tesla*; University of Minnesota Twin Cities: Hauppauge, NY, USA, November 2005; Volume 1, p. 2010.
45. Grauer, Y. A practical guide to microchip implants. *Ars Tech* **2018**, *3*. Available online:https://arstechnica.com/features/2018/01/a-practical-guide-to-microchip-implants/(accessed on 25 February 2022).
46. Top 4 Benefits of Near Field Communication (NFC) Technology. 25 June 2019. Available online: https://www.fisglobal.com/en/insights/merchant-solutions-worldpay/article/top-4-benefits-of-near-field-communication-nfc-technology (accessed on 30 January 2022).

47. Kazmeyer, M. The Advantages & Disadvantages of Implantable RFID Tags. Available online: https://itstillworks.com/rfid-technology-disadvantages-alternatives-2097.html (accessed on 5 February 2022).
48. Reith, G.; Schmitz-Greven, V.; Hensel, K.O.; Schneider, M.M.; Tinschmann, T.; Bouillon, B.; Probst, C. Metal implant removal: Benefits and drawbacks–a patient survey. *BMC Surg.* **2015**, *15*, 1–8. [CrossRef] [PubMed]
49. Tanne, J.H. FDA approves implantable chip to access medical records. *BMJ* **2004**, *329*, 1064. [CrossRef]
50. Implantable Chip, On Sale Now. Available online: https://www.wired.com/2002/10/implantable-chip-on-sale-now/ (accessed on 5 February 2022).
51. How Can I Buy the Birth Control Implant & What Does it Cost? Available online: https://www.plannedparenthood.org/learn/birth-control/birth-control-implant-nexplanon/how-can-i-get-the-birth-control-implant:Implantremovalcancostbetween,andsomeothergovernmentprograms (accessed on 5 February 2022).
52. Hague, M. Would You Implant a Microchip in Your Hand? Available online: https://www.cpacanada.ca/en/news/pivot-magazine/2019-10-31-vivokey-implants (accessed on 5 February 2022).
53. Katz, J.E.; Rice, R.E. Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology. *Int. J. Med. Inform.* **2009**, *78*, 104–114. [CrossRef]
54. Al-Sebae, M.; Abu-Shanab, E. Big Issues for a Small Piece: RFID Ethical Issues. In Proceedings of the 7th International Conference On Information Technology (ICIT2015), Amman, Jordan, 12–14 May 2015; pp. 12–15.
55. Funk, C.; Heferon, M.; Kennedy, B.; Johnson, C. Trust and Mistrust in Americans' Views of Scientific Experts. 2021. Available online: https://www.pewresearch.org/science/2019/08/02/trust-and-mistrust-in-americans-views-of-scientific-experts/ (accessed on 15 November 2021).
56. A Framework for Ethical Decision Making. Available online: https://www.scu.edu/ethics/ethics-resources/a-framework-for-ethical-decision-making/ (accessed on 3 February 2022).
57. Velasquez, M.; Andre, C.; Shanks, T.; Meyer, M.J. Thinking ethically. In *Issues in Ethics*; Santa Clara University: Santa Clara, CA, USA, 2015; pp. 2–5. Available online: https://www.scu.edu/ethics/ethics-resources/ethical-decision-making/thinking-ethically/ (accessed on 25 February 2022).
58. Mendez, K.F.; Jaremus, C. Future Employer: Are Humans with Microchips in Their Brains the Future of Work? 2021. Available online: https://www.seyfarth.com/news-insights/future-employer-are-humans-with-microchips-in-their-brains-the-future-of-work.html (accessed on 25 February 2022).
59. Title VII of the Civil Rights Act of 1964. Available online: https://www.eeoc.gov/statutes/title-vii-civil-rights-act-1964 (accessed on 23 November 2021).
60. Genetic Information Discrimination. Available online: https://www.eeoc.gov/genetic-information-discrimination (accessed on 23 November 2021).
61. Brandtzæg, P.B.; Lüders, M.; Skjetne, J.H. Too many Facebook "friends"? Content sharing and sociability versus the need for privacy in social network sites. *Int. J. Hum.-Comput. Interact.* **2010**, *26*, 1006–1030. [CrossRef]
62. Liu, Q.; Yao, M.Z.; Yang, M.; Tu, C. Predicting users' privacy boundary management strategies on Facebook. *Chin. J. Commun.* **2017**, *10*, 295–311. [CrossRef]
63. Juban, R.L.; Wyld, D.C. Would you like chips with that?: Consumer perspectives of RFID. *Manag. Res. News* **2004**. doi:10.1108/01409170410784653. [CrossRef]
64. Ong, C.-S.; Lai, J.-Y. Gender differences in perceptions and relationships among dominants of e-learning acceptance. *Comput. Hum. Behav.* **2006**, *22*, 816–829. [CrossRef]
65. Venkatesh, V.; Morris, M.G. Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. *MIS Q.* **2000**, 24, 115–139. [CrossRef]
66. Smith, A.D. Gender preferences of efficiencies and ethical issues: Commercial, personal, and governmental applications of RFID-based implants and technologies. *Int. J. Bus. Inf. Syst.* **2013**, *12*, 455–492. [CrossRef]
67. Katz, J.E.; Rice, R.E. *Social Consequences of Internet Use: Access, Involvement, and Interaction*; MIT Press: Cambridge, MA, USA, 2002.
68. Socioeconomic Status. Available online: https://www.apa.org/topics/socioeconomic-status (accessed on 25 February 2022).
69. Abu-Shanab, E. Income Divide: A Determinant of Technology Acceptance. *Int. Arab. J. e-Technol.* **2013**, *3*, 121–127.
70. Riddell, W.C.; Song, X. The Role of Education in Technology Use and Adoption: Evidence from the Canadian Workplace and Employee Survey. IZA Discussion Papers 6377. *Inst. Study Labor (IZA)* **2017**, *70*, 1219–1253. [CrossRef]
71. Durodolu, O. Technology Acceptance Model as a Predictor of Using Information System' to Acquire Information Literacy Skills. 2016. Available online: https://digitalcommons.unl.edu/libphilprac/1450/ (accessed on 5 February 2022).
72. Porter, C.E.; Donthu, N. Using the technology acceptance model to explain how attitudes determine Internet usage: The role of perceived access barriers and demographics. *J. Bus. Res.* **2006**, *59*, 999–1007. [CrossRef]