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Article
Assessing the Acceptance of Cyborg Technology with a Hedonic Technology Acceptance Model

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Abstract: Medical implantable technologies, such as cochlear implants or joint prostheses, have been commonly used since the late 20th century. By contrast, the market for this type of technology is expanding when the purpose is not medical, even though it is more marginal. This study tests a technology acceptance model for the latter type of insideable technology based on an extension of the technology acceptance models TAM and TAM2 proposed for hedonic technologies by van del Heijden. So, the behavioral intention of insertables is explained by the perceived usefulness and perceived ease of use, as well as social influence, as proposed in the TAM2 by Venkatesh and Davis. Additionally, the perceived enjoyment, included in the extension by Van der Heijden, is added as an explanatory factor. We applied structural equation modeling to the theoretical scheme provided by the modified TAM and performed a necessary condition analysis. Statistical analysis showed that all variables considered in the model have a significantly positive influence on behavioral intention. Likewise, the model has good properties both from the point of view of the fit obtained, since it predicts 70% of behavioral intention, and from the predictive point of view. The necessary condition analysis allows us to analyze whether the presence of some of the latent variables postulated to explain the attitude toward implantables is necessary to produce the said acceptance. Therefore, its absence is a critical aspect of expansion. We observed that perceived usefulness manifests itself as a necessary condition for behavioral intention with a medium size. Perceived ease of use and enjoyment also present a significant necessity effect size, but their strength is smaller. By contrast, the subjective norm does not have the status of a necessary variable.

Keywords: implantable technologies; cyborg technologies; technology acceptance model; PLS-SEM; necessary condition analysis

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1. Introduction

One of the most significant effects of the information technology revolution that occurred in the late 20th century was the loss of boundaries between entities, such as machines, humans, and information technologies. This technological revolution has also transformed humans through the integration of information technologies into entities capable of continuously receiving and emitting information to their environment [1]. This fusion of humans and information is carried out through smart intelligent technological devices, with wearables and implantables being the most common [2].

The main difference between wearables and implantables is that while the former are attached to the body like a conventional accessory (a bracelet, a watch, or glasses), the latter becomes part of the human body [3]. Although wearing devices or elements in a noninvasive manner is more common than inserting them into the body, the insertion of objects is very ancient. Notably, dental implants were used in ancient Egypt [4].

The use of wearables for nonmedical purposes is widespread and does not generate controversy [3]. Likewise, it is common practice to use implantables for esthetic purposes, such as dental or breast implants [5]. The use of implantable technologies for medical purposes, such as pacemakers or cochlear implants, whose purpose is to restore damaged vital functions, does not seem controversial [2]. However, the use of implantable technologies for nonmedical purposes raises various social and ethical concerns [6–8].

Because medical implants can improve or even completely restore the capabilities of a person with a given disability, there is no reason why their implantation cannot improve the capabilities of a standard human [9] or even achieve some form of immortality [10]. These enhanced capabilities can occur in an intellectual plane, for example, by increasing the memory or calculation capacity [11], or an exclusively physical plane [12]. These potentialities lead [13] us to speculate on the possibility of frontline service employees who, by using insideable tech, take advantage of being, in part, robots (for example, with an increased data-handling capability) but also offer complete human assistance. In contrast, [13,14] reflect on the distortions that cyborg technologies could cause in sports competitions.

The reality of the current use of nonmedical implantables and their performance, in any case, is more modest than some intellectuals have imagined, as the process of cyborgization is closer to a process of evolution or a quiet revolution than a revolutionary proper [15]. The most commonly used insertable technologies in nonmedical applications are passive radio frequency identification chips (PRFICs), near-field communication chips (NFCCs), and magnets [16,17]. The wider use of passive PRFICs includes in-store antitheft mechanisms, toll-collection passes on roads, pet microchips, contactless payment credit cards, and modern passports [18]. NFCC technology is based on PRFIC technology and is often found in smartphones. When inserted into the hand, they can be used to share contact details, launch apps, and unlock phones, doors, and cars [18]. Finally, magnets enable the feeling of electromagnetic fields so that relevant artists within countercultural movements, such as cyborg art and Moon Ribas, use this type of implant to capture seismic movements [19].

The current use of insertable technologies for nonmedical reasons can be divided into instrumental and playful reasons. The reasons for convenience are relatively limited and often linked to the identification and sharing of information, avoiding the use of cards or passwords [18,20]. By contrast, playful and hedonistic motivations are broader, as they go beyond the actual performance of these technologies, and the reason for their adoption is justified for sensory and ideological reasons. Thus, these types of devices can enhance existing senses or create new ones [19]. Other motivations may include being pioneers of the next major thing, such as the rise of cyborgs, being devoted to body modification, or the search for extending human capabilities and functions or tiring wearables [4]. Other motivations may include considering the use of insideables as a form of personality affirmation [1] or combating death anxiety [7].

Although the market for implantables has great growth potential [17], this technology is currently far from domestication and mass customization [21]. Within playful uses, unlike wearables, which are commonly used, implantables have a market niche in heterogeneous underground cultures, such as grinders [19], do-it-yourself (DIY) collectives [21], certain feminist streams [22], and people with deep transhumanist convictions [10,17].

Since the emergence of implantables for nonmedical use is relatively new, empirical studies on the drivers of their acceptance are relatively scarce, which contrasts with the extensive literature on the adoption of wearables [23]. Based on the results of these empirical studies, we can find qualitative analyses, such as those in [4,17,19]. On the other hand, as Chaudhry et al. [24] noted, quantitative analyses have been based on the use of theoretical frameworks for the adoption of information technologies, such as the technology acceptance model (TAM) [25], and certain models derived from it, such as the TAM2 [26] and the unified theory of acceptance and use of technology (UTAUT) [27] or the cognitive–affective–normative (CAN) model [5]. Similarly, given the profound ethical and moral implications of implantable technologies, also makes suitable the use of a multiple ethics scale (MES), as in [28]. Therefore, relevant contributions in this way are seen in the TAM framework [20,29–32], UTAUT groundwork [2,33], CAN [5,34,35] model, and MES [2,28,36–38].

The conceptual approach used in this work is based on the extension of van de Heijden [39] of the family of TAMs [25,26] for hedonic information systems, which we call the hedonic TAM (HTAM). We feel that this is an adequate focus because motivations for using implantables in practice are often oriented toward obtaining new sensations [24]. These objectives are in line with van der Heijden's [39] definition of hedonic technologies, which he defines as those that try to fulfil a purpose rather than an instrumental value and are focused on leisure activities focused on fun and pleasure rather than productivity.

In this study, we examine the explanatory capacity of the input latent variables proposed by van der Heijden [39], perceived usefulness, enjoyment, and perceived ease of use, on behavioral intention. The subjective norm is a variable present in the extension of the TAM by Venkatesh and Davis [26], the so-called TAM2, and is justified by the controversies that arise both at the level of social perception [17] and ethically [14] about the use of cyborg tech.

Therefore, this study has two research objectives (ROs):

1. RO1: To examine the ability of the proposed hedonic TAM to explain the adoption of insideables. This analysis allows us to determine the intensity and level of significance with which the latent variables generate behavioral intentions.
2. RO2: To establish the threshold that must be reached in each of the input latent variables, if it exists, to ensure a certain degree of behavioral intention. In other words, while reaching that threshold in the analyzed input variable does not guarantee behavioral intention, having the score achieved fall below the threshold ensures rejection of the insertable tech.

To fulfil RO1, structural equation modeling using partial least squares (PLS-SEM) is used, which is common in this type of work [40]. From a logical point of view, RO1 establishes whether the explanatory factors are sufficient to induce behavioral intention. However, because PLS-SEM is a correlational method, it does not allow us to establish whether any of the input factors are necessary [41]. A necessary determinant must be present to achieve an outcome, but its presence is not sufficient to achieve that outcome. Without the necessary conditions, there is guaranteed failure that cannot be compensated for by other determinants of the outcome. Therefore, to fulfil RO2, we used the necessary condition analysis (NCA) developed in [41–43]. Notice that the way in which we have formulated the research questions requires implementing PLS-SEM sequentially, and subsequently, the NCA, as recommended by Richter et al. in [40].

2. Theoretical Framework

2.1. Previous Considerations

The objective of using embeddable technology is to fulfil its function and provide a pleasant emotional experience [24]. This has been reflected in various qualitative studies. For example, in the study [16], a participant stated that the use of an insertable tool allowed potential clients to scan it with their devices to access a website informing them about the offered services and it is an "original way to promote my work". Another participant described the experience of having a magnet in their hand as follows: "I can feel the rhythm in my finger, I can feel the bass, I can feel the hi-hats".

Given that users may seek both functional benefits and emotional experiences from using embeddables, a study that aims to explain their acceptance must include both motivations [24]. In line with the suggestion in [24], this study uses the HTAM proposed by van der Heijden (2004) as a framework to explain insideable acceptance. In addition, we have added the subjective norm as an explanatory factor for the TAM2 [26]. The proposed model is illustrated in Figure 1.

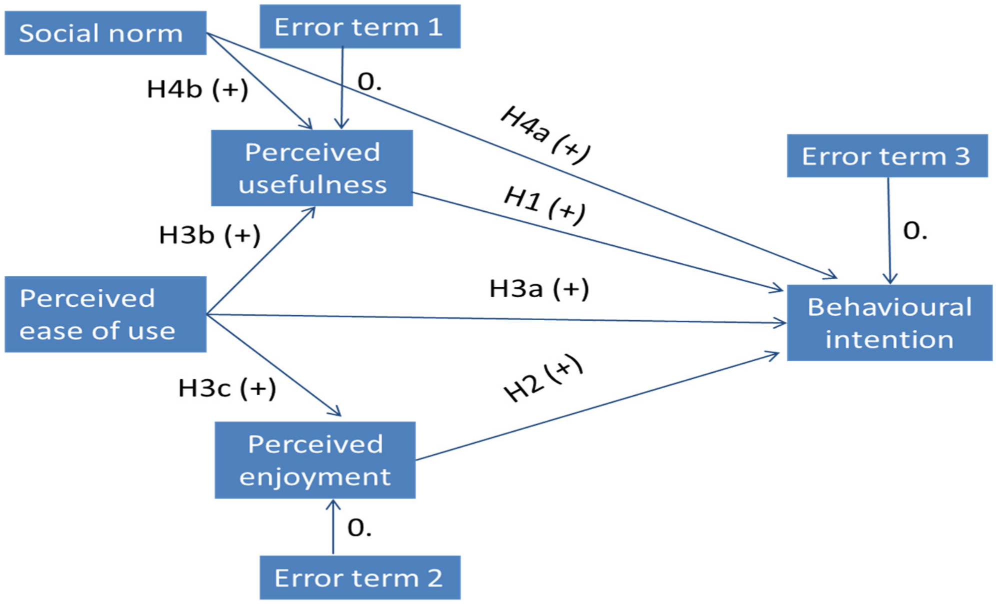

Figure 1. Theoretical framework of our study.

The HTAM [39] has served as inspiration and a theoretical basis for a large body of research on the acceptance of information systems in which hedonic motivation is relevant. With the inspiration of the HTAM or modifications on the basis that it provides, the acceptance of webpages [39], video games and online games [44,45], Apple products [46], and social media apps [47] has been evaluated.

The outcome explained in this work is behavioral intention (BI), which can be defined as the readiness of an individual to perform a given behavior [48]. This outcome can be answered under equal conditions among potential respondents, unlike in actual use, since insideables are a market that is in its infancy [3], and a large number of potential users may not have access to the devices and/or may need to be helped in their implementation. People living in rural areas have more difficulty receiving help from professionals who can insert them into their body [4]. Similarly, behavioral intention is a common outcome in hedonic technological acceptance models [39,44,45].

The approach that we follow in the justification of the model will lead, as is usual in these cases, to the formulation of a set of statistical hypotheses that can be evaluated using conventional correlational instruments. In this work, we used PLS-SEM, which is common in statistical acceptance evaluations [40]. This analysis will allow us to accomplish RO1, but it will not give us information about whether the presence of these factors is a sine qua non condition for producing behavioral intention, which is the object of RO2. For this purpose, we conduct a necessity condition analysis later in an exploratory manner. Thus, we do not hypothesize the necessary conditions of the latent variables explaining behavioral intentions; rather, we discuss the possible reasons for the results obtained with the NCA.

2.2. Hypothesis Development

2.2.1. Perceived Usefulness

We can define perceived usefulness (PU) as the individual's perception of the extent to which the use of a given technology improves performance [25]. It is the most relevant construct in analyses of utilitarian systems, although it often loses relevance in systems that are also used for hedonic reasons [39,45].

Implantable technologies for nonmedical instrumental purposes are often applied to control and access places, to computers, and to parking lots to make payments, as well as to share information [17]. That is, implantable devices are substitutes for ID cards and avoid people having to remember passwords and PINs, which potentially avoids problems arising from theft and hacking [20,49] and can be an alternative to other instruments with those issues such as biometric identification technologies described in [49]. Various companies have implemented these systems [20]. In [4,16,17], we find appreciation from users who point out that their main motivation for using implantables is limited to this sphere.

Implantables are also seen by some users as tools that stimulate creativity through their use [16] and during the process of their design and implementation [21]. As some avant-garde artists rely on these instruments for creation, they must be considered instruments that favor their work [19]. The most well-known case within the so-called cyborg art is that of Neil Harbisson, an avant-garde artist with congenital color blindness who has an antenna implanted in his head that allows him to capture sounds of more color than the human eye can see [50]. The magnets of Moon Ribas or certain devices made ad hoc, such as the ears of Manel de Aguas, generate new senses, such as the ability to capture seismic movements or changes in weather, being used by these artists in their creations [50].

However, the use of implantable techs poses potential risks that, if realized, can be detrimental to users and their daily activities. On the one hand, there is a risk of infection and rejection of the materials [7,51]. Similarly, they can cause discomfort and even pain [22]. The general consensus is that although in extreme cases, such as magnetic implants, the risk can be severe [51], in most cases, the health risk of these types of devices is comparable to that of tattooing and piercing practices [4,51]. Therefore, hygiene measures similar to those of these practices are usually sufficient to use the implantables safely.

Theoretically, due to the electronic nature of most of these devices, there are concerns regarding privacy and excessive surveillance due to its use [52]. However, this danger must be mitigated by the fact that RFID and NFC have limited coverage, store minimal information [8], and have poor connectivity with other devices [16]. Nonetheless, if these risks materialize, users' effectiveness in their daily tasks will decrease.

As Table 1 shows, in research that is conducted from a quantitative perspective, performance expectancy is often a factor that significantly influences intention to use. Thus, regarding RO1, we propose the following hypothesis:

Hypothesis 1 (H1): *Perceived usefulness positively influences behavioral intention toward insideables.*

2.2.2. Perceived Enjoyment

Perceived enjoyment (PENJ) can be defined as the perception that an information system is enjoyable in its own right, apart from any anticipated performance consequences [39]. The hedonistic motivation toward a product seeks emotional, enjoyable, and experiential benefits such as indulging in fun, entertainment, novelty, fantasy, or sensory stimulation [53].

According to qualitative studies [4,16,17], a significant motivation for a substantial portion of wearable technology users is recreational and hedonistic, with little or no perspective on improving daily tasks. The immediate goal of adopting insertable technologies may be body hacking or the exploration of new sensations [17], serving as a means to reaffirm self-esteem and individualistic assertions [1,7]. Examples of these motivations could be user testimonies regarding the reasons for their usage, such as "*not overly functional. . . I'll admit it's a bit of a statement to be honest, why get a piercing? I love technology, it's neat*" or "*I've loved piercings all my life. A friend of mine mentioned that she'd read in Wired that people were getting magnets and were able to pick up some sort of electromagnetic sense around live electronics and detect live wires, and that sounded really appealing*" [4].

Indeed, although the adoption of wearables to enhance existing senses or create new ones may provide professional motivation for certain artists, aspects related to sensations and pleasure are always present. Thus, Moon Ribas stated, "When I closed my eyes, I'd imagine that I travelled deep through the layers of the Earth. Throughout the years, I was able to reach deeper. It's like having branches and roots under my feet that allowed me to experience the Earth through those branches. I was able to experience the constant movement of the Earth. I know how our planet moves. Overall, it made me realize how little we know about our planet. It's a living organism, but it's just that it's so massive that it's difficult to grasp. It's a profound feeling, really" [54].

As far as Neil Harbisson is concerned, he indicates the antenna implanted in his head, "Not many people go for a walk in the supermarket for fun, but I do. I have an electronic eye that converts light into sound to enable me to 'hear' colour—so the cleaning product aisle is very exciting. The rows of rainbow-colored bottles sound like a symphony to me" [55].

Table 1 shows that there are various quantitative studies on the adoption of insertable technology that consider hedonic motivation [3,33] or the maximization of positive emotions and the minimization of negative emotions [31,32] as relevant factors. However, in the literature, loyalty is less common than performance expectancy. Thus, we posit the following hypothesis:

Hypothesis 2 (H2): *Perceived enjoyment positively influences behavioral intention to use insideables.*

2.2.3. Perceived Ease of Use

Following [25], perceived ease of use (PEoU) can be defined as the perception that a system can be used without much effort. It is a construct commonly considered in research on technological acceptance and is often more relevant in explaining the adoption of certain hedonic information systems than perceived usefulness, as the attainment of rewarding sensations is more relevant than the achievement of measurable objectives [39,56].

The most common implantables on the market, NFC chips, RFID chips, and magnets, in principle, do not require any active action on the part of the user for it function [4]; therefore, we can assume that effort expectancy is not an issue. However, several factors make them more difficult to use than wearables.

A relevant barrier to the use of implantables is that they must be inserted into the body [11], and their insertion is not usually performed by a healthcare professional [17]. One of the main reasons is that healthcare professionals are reluctant to access these types of devices if their purpose is not strictly medical [22], and certain practitioners of DIY practice find this challenge a motivation for the use of these technologies [21]. At least in the early stages, the use of these technologies requires medical supervision because of the risk of rejection and infection [7].

Another problem faced by devices such as NFC and RFID chips is that, in practice, they have little connectivity and compatibility with other devices and operating systems, such as Android [16,17]. Thus, achieving interconnection between implantable devices and other devices can be complicated. Therefore, interpersonal communication throughout insertable technologies is in many cases hard. In [4], for example, one respondent indicated that "for someone who didn't have any technical skills I would consider it would be quite difficult"; another surveyed person, a software developer, echoed these difficulties: "it's one of those things where it's a surprisingly large amount to get set up and get it working". The durability of the devices and the limitations of the materials with which they are fabricated or the small amount of data must also be outlined [57].

In addition, once these devices are implanted, users require training and familiarization to fully utilize their functionalities [10]. This can lead to challenges in controlling the devices and issues related to comfort [24,51]. Likewise, these devices can disrupt various aspects of daily life, such as radiofrequency emitters, which can cause interference. Therefore, a participant in the study [16] noted that "If you are in a magnetic resonance image machine, the only thing that will happen is that you get a slight attenuation of the picture, it's just more blurry".

Of course, a more user-friendly use of implants should lead to greater behavioral intention, which has been reported in the literature on the acceptance of implantable technologies in the studies listed in Table 1. However, the HTAM [39] and TAM [25] also postulated that

PEoU should influence perceived usefulness. Failure of the implant when it is used for instrumental purposes will result in a decrease in the perceived usefulness of this device. The less challenging the use of technological innovation, the greater the task performance it provides [26]. Thus, in [16], participants described "getting the NFC chip reader to read the content on the chip takes much longer than just reading the paper boarding pass or the boarding pass on your screen on the phone"; in other words, the NFC chip avoids the problem of forgetting your boarding pass, but it creates new potential drawbacks.

Moreover, greater ease of use has a significant impact on perceived enjoyment as positive sensations are more likely to be experienced. Several authors have found that systems perceived as easy to use are more likely to be perceived as enjoyable [39,45–47]. Considering the above, we propose the following:

Hypothesis 3a (H3a): *Perceived ease of use positively influences behavioral intention to use implantables.*

Hypothesis 3b (H3b): *Perceived ease of use positively influences the perceived usefulness of implantables.*

Hypothesis 3c (H3c): *Perceived ease of use positively influences the perceived enjoyment of using implantables.*

2.2.4. Subjective Norm

Subjective norm (SN) is a construct commonly considered in technological acceptance models and can be defined as an individual's perceived social pressure or expectation to engage in a particular behavior [26]. In fact, in most of the reviewed studies on the acceptance of implantables, the subjective norm is considered a possible explanatory factor of behavioral intention and is usually significant (see Table 1).

In the use of implantable technologies, there is a mainstream point of view considering that practices such as body hacking are "weird" [18]. While the use of these technologies for medical purposes is commonly accepted, their use in enhancing capabilities raises ethical controversies [6,8] that have been tested as relevant in empirical analyses. Thus, Ahadzadeh et al. [38] observed that ethical perceptions such as moral equity diminish the influence of perfectionism on behavioral intention to adopt brain implants. Reinares-Lara et al. [35] observed that the personal and social perceptions of what is fair, acceptable, and appropriate influence the impact of the constructs of the CAN model on behavioral intention to use neural implants.

Social resistance also comes from monotheistic religions, such as Christianity or Islam, which understand that the human body is created in the image and likeness of God, so practices such as body hacking can be interpreted as sacrileges [58]. Thus, ref [18] documents that some users of implantable technologies have been targets of abuse from religious groups believing that they are carrying the so-called mark of the beast based on an interpretation of Bible passages. Thus, individuals with more liberal ideologies and less intense religiosity are more likely to accept manipulation of the human body than those with conservative ideologies [7].

Identification with certain countercultural groups, such as certain radical feminist movements and DIY collectives devoted to body hacking or biohacking, may be an incentive for the adoption of implantable technologies, as they are part of their cultural capital [21,51]. Additionally, groups of young people see body modification practices such as piercings and tattoos more normally than older people, so they tend to accept implantable technologies to a greater extent [16].

However, being less sensitive to social norms and tending toward individualistic behaviors can facilitate the adoption of implantable technologies [1]. Therefore, ref [4] identifies as a significant motivator for insertable adoption behaviors the development of self-expression to show identity and an expression of individuality in such a way that body modifications are a signal of being "special".

The fact that theoretically data in insertable devices may be vulnerable to hacking [20] or that it may allow for user surveillance can fuel conspiracy theories that, from a societal norm perspective, discourage the use of insertable technologies [8]. The findings in [30,31] revealing that concerns about privacy and personal security significantly negatively impact the use of insideables may support this assertion.

Although many countries have health regulations regarding aspects related to the implementation of insertables such as the administration of anesthetic substances, these devices often lack health regulations in many countries [8], thus resulting in a lack of explicit authorization from health authorities [51]. Consequently, surgeons are hesitant to perform the insertion, deeming it unnecessary [22], and as a result, these devices are typically implanted in tattoo centers [8] or by the users themselves [51]. This concern may be exacerbated by the pace of evolution of nanotechnologies, which outpaces regulatory measures on data protection [59]. This lack of regulation may lead to general social resistance [8] on the one hand. On the other hand, the fact that this absence of regulation deems insertable technologies a clandestine area aligns with the philosophy of certain underground groups such as the DIYers [51].

In the TAM extensions TAM2 and TAM3 [26,60], the influence of subjective norms on behavioral intentions is emphasized. Likewise, these models postulate that social influence also affects perceived usefulness. This influence is most pronounced when the social group's impact is internalized and becomes ingrained in an individual's belief system. In such cases, if a specific technology is viewed positively by the group, the individual perceives it as useful. Thus, we postulate the following:

Hypothesis 4a (H4a): *Perceiving favorable subjective norms for the use of insideables has a positive impact on behavioral intention.*

Hypothesis 4b (H4b): *Perceiving a favorable subjective norm influence on the use of insideables has a positive impact on perceived usefulness.*

Table 1. Studies supporting the impact of perceived usefulness, perceived enjoyment, perceived ease of use, and subjective norm influence on behavioral intention toward insertable tech.

Latent Variable	Theoretical Ground	Studies
Perceived usefulness	TAM	[29–31]
	UTAUT	[3,33]
	CAN	[5,34,35]
	MES	Refs. [2,28] find that egoism and utilitarianism influence positively behavioral intention and [38] reports that utilitarianism moderates positively the impact of perfectionism on intention to use.
Perceived enjoyment/positive and negative emotions	TAM	[29,32,60]
	UTAUT	[3,33]
	CAN	[5,34,35]
Perceived ease of use	TAM	[31,33]
	UTAUT	[33]
	CAN	[5,35]
Social norm	TAM	[31]
	UTAUT	[3,33]
	CAN	[5,34,35]
	MES	Refs. [2,28,36] find that moral equity and relativism influence positively behavioral intention. Ahadzadeh et al. [38] find that a moral equity against insertables moderates perfectionism in terms of intention to use.

3. Materials and Methods

3.1. Materials

In this study, we used a sample of 1563 university students from seven different countries (Chile, China, Denmark, Japan, Mexico, Spain, and the U.S.) which was previously used in [2,3,28,37] that were published during years 2020 and 2021. The survey asked participants about their perceptions regarding the use of insideables and wearables. In our case, we were only interested in the use of insideables. Both regarding the use of insideables and wearables, the questionnaire has 36 questions, of which only 16 are utilized in this study.

The responses came from people below 30 years of age to ensure that the population comprised digital natives [61]. Younger individuals are typically more receptive to insertable devices since they are more accustomed to practices such as piercings. Thus, they may be more comfortable with the concept of nonmedical devices implanted in the body [8]. Another aspect that may contribute to differential acceptance among the youth is that as individuals still growing, they have a greater need to express their individuality [1]. Similarly, the younger population might exhibit a stronger inclination toward insertables due to their increased familiarity with and acceptance of various technological advancements within a digitized society [8].

Therefore, it is easier to find respondents with some awareness of insertable technology. Similarly, the survey was provided online, which facilitated the response of digital natives; therefore, the response rate is expected to be greater than that of other demographic groups [62].

In addition, members of the university community have knowledge that is supposedly superior to that of average citizens; therefore, it is expected that they will have well-founded opinions. In addition, it is expected that students will provide their responses from heterogeneous perspectives and sensitivities, both because of the different branches of knowledge that university studies encompass [62] and because the sample encompasses members of the university community from seven countries with different cultural backgrounds.

In order to avoid, as far as possible, cultural biases, ref [3] indicates that the sample should come from seven countries. To guarantee a broad and balanced international perspective and to make sure that no country would have an undue influence on the results, a country quota of between 200 and 300 responses was established. The quota was met in all countries except the U.S., where data collection laws and university regulations made it impossible [3]. Concretely, the distribution of responses by country ranged from 229 (China) to 300 (Japan). The responses from the U.S. were only 53.

In regard to the questionnaire, ten experts in the field of ethics and technology from the Ethicomp international research network reviewed and enhanced the face and content validity of the questionnaire [2]. The questionnaire was adapted to the five languages of the participants' countries. To guarantee the quality of the adaptation of the measurement scales to each language, a sequential linguistic validation process was followed, organized by the stages suggested in [63].

Table 2 presents the complete profiles of the respondents.

With regard to sex distribution, the sample consisted of 827 females (52.91%) and 736 males (47.09%). Among the university students, the respondents had an average age of approximately 20 years (mean = 21.05 years and standard deviation = 2.63 years). Thus, more than half of the respondents were under 20 years old and only 14.65% were 24 years old or older.

In terms of experience with wearable and insideable technologies, 20% of the respondents reported using or having used wearables. In contrast, experience with the use of insideables, which may or may not be for medical reasons, was limited to 9%.

From the perspective of sample representativeness, with $N = 1563$, which is a subset of the total population of university students, the sample size leads to a margin of error of approximately $\pm 3\%$ [64]. The use of a higher education population to carry out these kinds of studies, linked to the acceptance of new information technologies, has several advantages.

Table 2. Sample profile.

Sex	Do You Use Wearables? (Smartwatches, Smartglasses, etc.)
Female: 827 (52.91%) Male: 736 (47.09%)	Yes 1260 (80.61%) No 303 (19.39%)
Age	Do you use insideables? (maybe for medical or nonmedical reasons)
≥18 and ≤20: 790 (50.54%) ≥21 and ≤23: 544 (34.80%) ≥24: 229 (14.65%) Mean = 21.05; SD = 2.63	Yes: 1420 (90.85%) No: 143 (9.15%)
The response comes from. . .	
Chile: 244 (15.61%) China: 229 (14.65%) Denmark: 210 (13.44%) Japan: 300 (19.19%)	Mexico: 241 (15.42%) Spain: 286 (18.30%) The USA: 53 (3.39%)

3.2. Measurement of Variables

The questions used to measure both the explained variable, behavioral intention (BI), and the explanatory variables, perceived usefulness (PU), perceived ease of use (PEoU), subjective norm (SN), and perceived enjoyment (PENJ), are based on those used commonly in the TAM, TAM2, and TAM3 family (Venkatesh & Davis [26], Venkatesh & Bala [59]) and the HTAM (Van der Heijden [39]). The questions used and sources that inspired them are listed in Table 3. It should be noted that all questions were answered on an 11-point Likert scale ranging from 0 ('strongly disagree') to 10 ('strongly agree'), with a neutral position corresponding to a score of 5.

Table 3. Items of the scales used in the study.

Latent Variable	Items	Source
Behavioral intention (BI)	BI1: I will intend to employ insertable techs. BI2: I think that I will adopt insertable tech	Venkatesh and Davis [26] and Van der Heijden [39]
Perceived usefulness (PU)	PU1: Insideables allows daily more comfortable. PU2: Insideables will increase the likelihood of achieving my goals. PU3: Insideables will help me complete my tasks more quickly. PU4: Using insideables will boost my productivity.	Venkatesh and Davis [26] and Van der Heijden [39]
Perceived enjoyment (PENJ)	PENJ1: Insertable technologies are enjoyable. PENJ2: Insertable technologies are pleasant. PENJ3: Insertable technologies are amazing.	Van der Heijden [39]
Perceived ease of use (PEoU)	PEoU1: The use of insideables will be comfortable for me. PEoU 2: How to use insideables is clear and understandable. PEoU 3: Learning the use insideables will be straightforward for me. PEoU 4: Being an expert in insertable tech will be easy for me.	Van der Heijden [39]
Social norm (SN)	SN1: People who are important to me will think I should use insideables. SN2: People who influence me will think I should use insideables. SN3: People whose opinions I value will prefer that I use insideables.	Venkatesh and Davis [26]

This scale, which is broader compared to the more common 4, 5, or 7-point scales, is recommended by various authors for several reasons. On the one hand, most people are capable of capturing more nuances than those allowed by 4, 5, or 6-point scales. On the other hand, the 11-point Likert scale has greater sensitivity and is closer to an interval level of scaling and normality. Additionally, a 0-to-10 range is easily comprehended by most people [65].

3.3. Data Analysis

The instruments used to assess the explanatory and predictive capacity of the presented model and the existence of necessary conditions use a sequential approach involving PLS-SEM and the NCA, which allows us to analyze the data from a complementary perspective that provides more insightful results than the mere use of conventional structural equation modeling [40]. With PLS-SEM, we can analyze the likelihood that the proposed explanatory variables can be understood as sufficient conditions; that is, PLS-SEM allows us to establish statements of the type "variable X has a positive impact on Y" or "Y increases/decreases with X". This allows us to fulfil RO1 and evaluate the hypotheses proposed in Section 2.2. However, this approach does not allow us to establish whether a given construct can be considered a necessary condition for producing behavioral intention, i.e., statements of the type "the presence of X is necessary to produce Y" or "Y cannot be achieved without X" [4]. Thus, in RO2, which aims to investigate the presence of "necessary" constructs to generate intention, we use the NCA, which is a methodology developed in [4,42], especially for this purpose.

Although the sample size is large and covariance-based structural equation modelling (CB-SEM) may be appropriate, the use of PLS-SEM has the advantage of not requiring strict assumptions about the normality of the data [66] and is always a preferable option if it is also intended to evaluate the capacity of the proposed conceptual model [67]. Similarly, the use of the NCA does not require any specific hypotheses about data behavior and may perform effectively with samples of any size [43].

PLS-SEM and the NCA were fully performed using SmartPLS 4.0. The procedure used to perform the analysis with both techniques to complement their results was carried out following the steps outlined in [40]. Therefore, we first implemented PLS-SEM using the following steps:

1. Scale reliability was evaluated through an assessment of internal consistency and discriminant capacity. Internal consistency was measured using Cronbach's alpha (C-α), convergent reliability (CR), average variance extracted (AVE), factor loadings, and confirmatory factor analysis (CFA). To finalize the determination of the items listed in Table 3 for consideration, we ensured that the outer model indicators did not exhibit excessive variance inflation factors (VIFs) in the latent variables they are part of, which we set at >5.

The discriminant validity of the scales was assessed using both the Fornell–Larcker criterion [68] and heterotrait–monotrait ratios [69].

2. We fitted the paths of the model displayed in Figure 1 by running consistent partial least-squares percentile bootstrapping with 5,000 subsamples with replacement. At this stage, we calculated the net impact of these factors and evaluated their statistical significance. We also examined goodness-of-fit indicators such as R^2, standardized root mean square error (SRMR), and normed fit index (NFI). Additionally, we ensured that the inner model did not exhibit multicollinearity issues by analyzing the VIF measure of the input variables.
3. We evaluated the predictive capability of the model using Stone and Greisser's Q^2 and a cross-validated predictive ability test (CVPAT) [70].

Subsequently, we performed the NCA. The subsequent use of the NCA with respect to PLS-SEM is recommended in [40] as a complementary analysis. Furthermore, its subsequent use is also a consequence of its aim to address the second research question, and the analysis of the first question requires the use of PLS-SEM.

The objective of the NCA is not to preselect the input factors that may significantly impact the output variable but to establish whether one or more of them present a minimum threshold necessary for the existence of behavioral intention. It may happen that an input variable presents such a threshold but once surpassed, its contribution to behavioral intention is not significant. Conversely, it may occur that a variable significantly impacts the output factor but does not require a threshold attainment for the existence of behavioral intention, as unfavorable values in that variable can be compensated by favorable values in others.

Then, the NCA was implemented according to [40,65].

1. We measured the constructs by using the latent variable scores used in the regressions performed by using PLS-SEM.
2. We analyzed the scatter plots of bivariate representations of the explained variable (behavioral intention, Y-axis) with respect to the explanatory factors (X-axis). These methods allow for the identification of outliers in the sample and their removal. In any case, we considered the values of the difference between Y and X that were 3.5 times the standard deviation of the difference in these variables to be outliers. The scatter plots allowed us to visualize the ceiling envelopment-free disposal hull (CE-FDH) and ceiling regression-free disposal hull (CR-FDH), which were obtained by smoothing CE-FDH.
3. After removing outliers (if they existed), we determined the size of the necessity effect (d). These effects can be classified as small ($0 < d < 0.1$), medium ($0.1 \leq d < 0.3$), large ($0.3 \leq d < 0.5$), or very large ($\geq$0.5). We also stated statistical significance. According to [43], values of $d > 0.1$ with a p value <0.05 are considered relevant for practical purposes. We obtained two estimates of d: that from CE-FDH, whose value can be considered optimistic, and that obtained from CR-FDH.
4. We presented bottleneck tables to enable bottleneck analysis. Bottleneck analysis involves an analysis of necessity in terms of degree: "level a of input Xa is necessary for level BIa of BI" [43].

Note that the NCA runs in an exploratory manner. In Section 2, we formulated hypotheses that can be tested via statistical analysis, but not statements such as "a minimum level of variable X is necessary to produce BI" or "without an evaluation Xa of variable X, a degree BIa of BI is never reached".

4. Results

4.1. Descriptive Statistics and Results of PLS-SEM Analysis

The average scores and standard deviations of the items are presented in Table 4. It should be noted that all items were answered on an 11-point Likert scale ranging from 0 to 10; thus, the neutral or indifferent evaluation was 5.

Table 4. Descriptive statistics and scale reliability measures.

Latent Variable	Item	Mean	SD	Loading	C-α	CR	AVE
Behavioral intention	BI1	3.66	3.13	0.979	0.96	0.96	0.92
(BI)	BI2	3.70	3.09	0.98			
Perceived usefulness	PU1	4.71	3.12	0.928	0.94	0.94	0.84
(PU)	PU2	4.44	3.09	0.953			
	PU4	4.92	3.10	0.936			
Perceived enjoyment	PENJ2	4.07	2.99	0.969	0.96	0.96	0.88
(PENJ)	PENJ3	4.32	3.08	0.966			
Perceived ease of use	PEoU1	4.91	3.00	0.941	0.94	0.94	0.83
(PEoU)	PEoU2	4.61	2.97	0.947			
	PEoU4	4.57	2.96	0.933			
Subjective norm	SN1	3.15	2.89	0.974	0.97	0.97	0.91
(SN)	SN3	3.16	2.84	0.975			

Notes: "SD" stands for standard deviation, "loading" for factor loading, "C-α" stands for Cronbach's alpha, "CR" for convergent reliability, and "AVE" for average variance extracted.

The mainstream behavioral intention is against the use of insideables, as the averages of both items were slightly above 3.5 out of 10, i.e., we can interpret that the adoption rate is about 35%. The PU and PEoU items had an average of 4.5 or greater, but for no item did the average exceed 5. Finally, while the number of perceived enjoyment items barely exceeded four, the three items related to subjective norms barely exceeded three out of ten.

The results in Table 4 suggest that all of the scales are internally consistent, as Cronbach's alpha and CR > 0.7, AVE > 0.5, and factor loadings > 0.702 for all items. It should be noted that in a preliminary stage, we eliminated the indicators PU3 of PU, PENJ1 of PENJ, PEoU3 of PEoU, and SN2 of SN since they presented excessive VIFs. Their removal allowed the indicators in the outer model to not have a VIF > 5.

The CFA conducted on the measurement model yielded satisfactory results. Specifically, the usual indicators to measure the quality fit are RMSEA = 0.056, SRMR = 0.016, NFI = 0.986, TLI = 0.984, and CFI = 0.988.

Table 5 shows that the scales also present discriminant capability because in all cases, HTMT < 0.85 and the squared AVEs of the latent variables are always above their Pearson's correlation.

Table 5. Discriminant validity matrix.

	BI	**PU**	**PENJ**	**PEoU**	**SN**
BI	**0.96**	*0.83*	*0.81*	*0.68*	*0.76*
PU	0.82	**0.91**	*0.80*	*0.69*	*0.68*
PENJ	0.81	0.80	**0.94**	*0.74*	*0.73*
PEoU	0.68	0.68	0.74	**0.92**	*0.63*
SN	0.76	0.68	0.73	0.62	**0.95**

Note: The square root of the average variance extracted appears on the principal diagonal. Below the main diagonal, Pearson's correlations were found (in bold numbers), and the HTMT ratios were above the principal diagonal (in italics).

Regarding the overall quality of the fit of the model in Figures 1 and 2, we can see that SRMR < 0.1 and NFI is practically 0.9, and so, the model can be judged as good [71]. The coefficient of determination suggests that the behavioral intention fit is close to 75% (R^2 = 73.4%), so it can be characterized as good, whereas that of PU (R^2 = 53.3%) and PENJ (R^2 = 49.5%), which are practically 50%, can be categorized as medium [64].

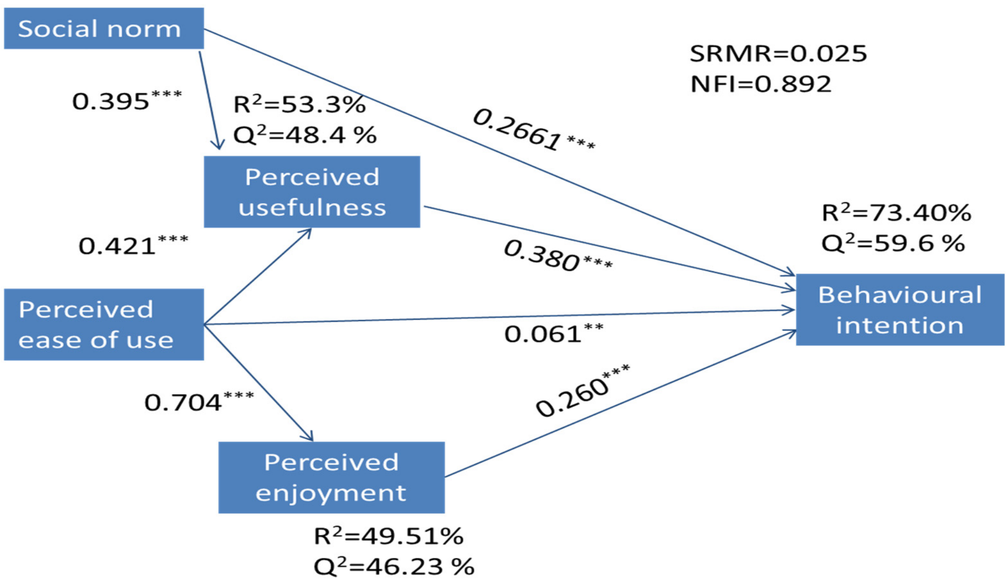

Figure 2. Results of fitting the model in Figure 1. Note: With "***" and "**", we denote the significance at the 0.01% and 1% levels, respectively.

Table 6 presents the values of the path coefficients (β) and their significance. In all cases, the hypotheses are supported by the signs of the coefficients, which are always positive and their *p*-value (*p*) < 0.01. The influence of perceived usefulness on behavioral intention is quantified as β = 0.380 ($p < 0.001$). Perceived enjoyment impacted behavioral intention, with β = 0.260 ($p < 0.001$). The impact of PEOU on the latent variables that influence risk is quantified as β = 0.061 ($p = 0.008$) for BI, β = 0.421 ($p < 0.001$) for PU, and β = 0.704 ($p < 0.001$) for PENJ. Finally, while the impact of subjective norms on intention to use is quantified as β = 0.266 ($p < 0.001$), the impact on PU is fitted as β = 0.395 ($p < 0.001$).

Table 6. Path coefficients for the inner model.

Relation	β	VIF	SD	*p* Value	Decision
PU-> BI	0.380	2.591	0.030	<0.001	Supported
PENJ-> BI	0.260	3.151	0.035	<0.001	Supported
PEoU-> BI	0.061	2.199	0.023	0.008	Supported
PEoU-> PU	0.421	1.567	0.028	<0.001	Supported
PEoU-> PENJ	0.704	1	0.017	<0.001	Supported
SN-> BI	0.266	2.156	0.028	<0.001	Supported
SN-> PU	0.395	1.567	0.026	<0.001	Supported

Table 6 also displays the VIFs of the input factors in the inner model. Their values reveal that no explanatory latent variable presents collinearity issues in explaining the output factors of the model.

Table 7 shows that latent variables have a $Q^2 > 0$ and so we can accept that the model has predictive capacity. The results of the CVPAT analysis indicate that the proposed model outperforms the predictions based on simple consideration of the average values of the BI, PU, and PENJ items, which is the so-called "indicator average". However, we must recognize that our model yields significantly worse predictions compared to the parsimonious linear model benchmark.

Table 7. Measures of the predictive power of the model.

		CVPAT: Indicator Average		CVPAT: Linear Model	
	Q^2	ALD	*p* Value	ALD	*p* Value
BI	59.6%	−5.539	<0.001	0.083	0.031
PU	48.42%	−4.507	<0.001	0.057	0.018
PENJ	46.23%	−4.266	<0.001	1.041	<0.001
Overall		−4.733	<0.001	0.346	<0.001

Note: ALD represents the average loss difference between the proposed model and the benchmark model.

4.2. Results of Necessity Condition Analysis

First, we quantified the values of the constructs analyzed using their factor loadings [40]. From these, we built a first approximation of the scatter plots, which allowed us to visualize whether there were outliers in the bivariate relationships between behavioral intention and the latent variables. This analysis is supported by the rule of 3.5 times the standard deviation of the difference between BI and the variable on the *X*-axis. In the relationship between BI and PU, we detected one outlier. In the relationship between BI and PENJ, there were six outliers; between BI and PEoU, six; and between BI and SN, four. Thus, the scatter plot of BI-PU was constructed with 1562 observations, that of BI against PENJ with 1556 observations, and that of BI with SN and PEoU with 1559 surveys. The final scatter plots are shown in Figure 3.

The size effects are shown in Table 8, both if we take the CE-FDH focus as a reference and if we consider CR-FDH. We can observe that those of PU, PENJ, and PEoU are intermediate because they are within $0.1 \leq d < 0.3$ and are significant ($p < 0.001$). Nevertheless, those associated with PU are notably greater than those associated with PENJ and PEoU, which are almost identical in importance. Subjective norm, although manifested as a variable with a greater impact on BI from a statistical point of view, has a negligible necessity effect size (*d* was clearly less than 0.1) and, therefore, cannot be considered a "necessary" variable for accepting insertable tech.

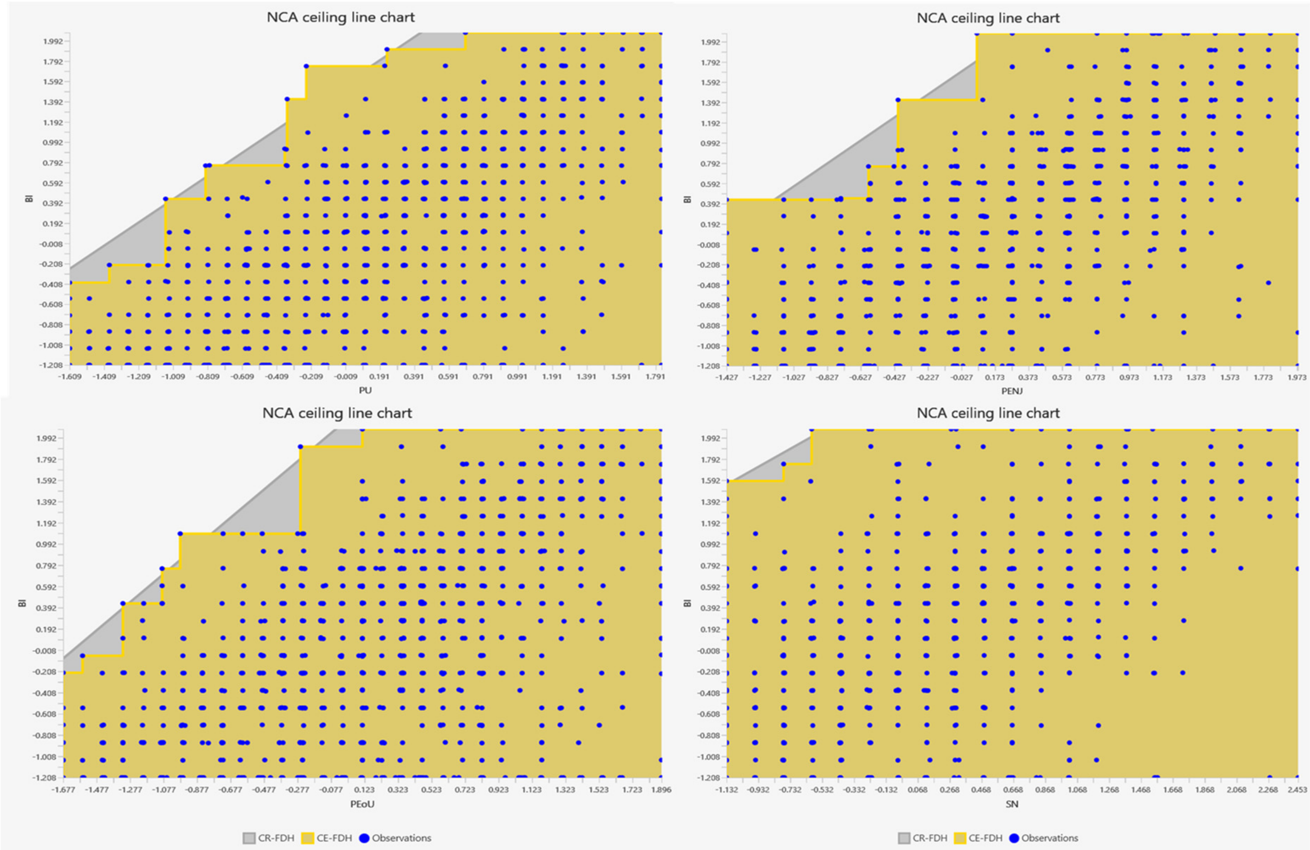

Figure 3. Scatter plots of the relations between behavioral intention with perceived usefulness, perceived enjoyment, perceived ease of use, and subjective norm. Note: From top to bottom and from left to right, we display the scatter plots of BI with PU, PENJ, PEoU, and SN.

Table 8. Size effects of explanatory constructs.

	CE-FDH		**CR-FDH**	
	Size Effect	***p* Value**	**Size Effect**	***p* Value**
PU	0.232	<0.001	0.211	<0.001
PENJ	0.172	<0.001	0.152	<0.001
PEoU	0.177	<0.001	0.150	<0.001
SN	0.020	<0.001	0.014	<0.001

Table 9 presents the bottleneck tables, both of which are associated with CE-FDH and CR-FDH, allowing us to evaluate the minimum value that the explanatory variables must reach for a certain level of acceptance of cyborg technology to occur. According to the bottleneck table constructed for CE-FDH, to be within 50% of BI, perceived usefulness must be 21%, PEoU must be 17.7%, and perceived enjoyment must be at the 26.5% percentile. For BI percentiles that are already higher, above 70% and 80%, it is a sine qua non condition where PENJ is located again at the 35% percentile, PU at the 36% percentile, and PEoU between the 20% and 35% percentiles. In all of these cases, the subjective norm is not a necessary variable; it can be a sufficient condition only if PU, PENJ, and PEoU reach the threshold value to produce percentiles between 50% and 80%. At the highest BI values (90% percentile or higher), all variables are necessary. Thus, to obtain the maximum possible behavioral intention, it is necessary that PU reaches at least 75%, perceived enjoyment reaches 48%, PEoU reaches 46%, and subjective norm reaches 36%.

Table 9. Bottlenecks for CE-FDH and CR-FDH.

	CE-FDH				CR-FDH			
BI	**PU**	**PENJ**	**PEoU**	**SN**	**PU**	**PENJ**	**PEoU**	**SN**
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	14.75	0.00	0.00	0.00	12.87	0.00	0.00	0.00
40	19.36	0.00	12.61	0.00	15.47	0.00	10.66	0.00
50	23.78	26.51	17.74	0.00	21.31	18.26	15.92	0.00
60	25.47	34.70	19.17	0.00	25.73	26.06	19.17	0.00
70	36.06	34.70	19.17	0.00	34.18	34.11	24.56	0.00
80	36.06	34.70	36.00	0.00	40.03	39.31	30.08	0.00
90	55.88	47.50	36.00	28.59	55.30	47.50	35.61	28.27
100	75.24	47.50	46.33	35.93	62.96	64.07	42.63	38.92

Note: quantities are presented as percentages.

5. Discussion

5.1. General Considerations

This study had two research objectives (ROs). The first (RO1) analyzed the suitability of the extension of the technology acceptance model (TAM) [25] for information systems with hedonic objectives [39] in the evaluation of the acceptance of insertable technologies for nonmedical uses. With respect to this model, which uses perceived usefulness, enjoyment, and ease of use as explanatory variables of behavioral intention toward the use of the assessed technology, we added subjective norm as an explanatory factor, as proposed in the TAM2 [26].

The hypotheses raised in RO1 were tested using PLS-SEM. We found that the model fit was good ($R^2 > 70\%$) and that the model had a good predictive ability. We observed that for Stone–Geisser's $Q^2 > 0$ and in the cross-validated predictive ability test [70], our model improved upon the benchmark consisting of predicting behavioral intention through its average, but not the parsimonious linear model. Likewise, all constructs evaluated had a positive and significant impact on behavioral intention.

The results obtained using PLS-SEM must be interpreted from the perspective of the logic of sufficiency. Thus, we can affirm that performance expectancy has a positive influence on behavioral intention, or that greater perceived enjoyment generates more intense acceptance of insertables. However, the RO1 results do not allow us to determine whether one or more of the explanatory variables are necessary to produce acceptance or only accompany and accentuate the impact of the truly essential variables [41], which is the objective of RO2.

RO2 was implemented by running a necessary condition analysis (NCA) [41,42]. This permits us to state whether the assessed explanatory latent variables must be present to some degree to induce the intention to use insertable technology. We checked that PU, PENJ, and PEoU have significant necessity size effects; that is, they are necessary to some extent to induce behavioral intentions. While the greatest effect came from perceived usefulness, perceived enjoyment and perceived ease of use had similar effect sizes.

We observed that the explanatory variable with the greatest influence on behavioral intention was perceived usefulness, that is, the perceived ability of insideables to improve user performance in everyday tasks. Although it is common for this variable to be the most relevant in the acceptance of information technologies when its purpose is instrumental, this is not necessarily the case if its use is hedonic [39,44]. However, qualitative studies [4,16,17] indicate that more than 50% of participants use insertables for convenience reasons. Its significance is congruent with the mainstream literature on insertable technology acceptance, as indicated in Table 1 [2,3,5,29,30]. Furthermore, we found that performance expectancy was a necessary variable for generating intention to use, which seems reasonable. If an insertable produces negative usefulness (e.g., physical rejection), it is reasonable that its use is avoided regardless of whether the score in the rest of the constructs is very high. Perceived usefulness was the variable with the greatest necessity effect size among those evaluated.

PLS-SEM analysis indicated that perceived enjoyment had a significant influence on behavioral intention. This result is supported by the literature, which reports that when information technology has hedonic and enjoyable uses, the impact of PENJ on its acceptance is significant [39,44,46,47]. In the literature on the adoption of cyborg technology, a positive relationship between perceived enjoyment and intention to use has also been noted, as indicated in Table 1. Thus, these results align with the findings of [29,60] using the TAM approach and [3,33] using the UTAUT theory. The results obtained are also in line with the qualitative studies [16,17] which observe a non-negligible proportion of adopters whose motivations are based on hedonic motives such as the extension of their capabilities through the acquisition of new senses, and who judge wearing insertables as "*amazing*" or as a "*wonderful experience*".

In addition, the NCA revealed that perceived enjoyment is a necessary condition for the acceptance of insideables, although its effect size was lower than that of perceived usefulness. This aspect is consistent with the intuition that even if the goal of adopting insertable technology is purely utilitarian, it is necessary that, at least, enjoyment is not negatively valued and that its use does not involve suffering and negative sensations. In this case, the user uses alternative technologies that meet the same needs.

We observed that the direct influence of perceived ease of use on behavioral intention is significant, which is consistent with the results obtained in the evaluation of insertable tech [5,31,33] in the field of insideable tech. However, its absolute value (0.066) is of little relevance, which contradicts [39], who observes that the impact of perceived ease of use on behavioral intention toward the technology evaluated has a value higher than that of performance expectancy. However, this effect is not shared by all technologies with a hedonic component. Casullo et al. [46] and Akdim et al. [47] reported that PEoU had a significant impact on behavioral intention and satisfaction but it was smaller than that of perceived usefulness. Even studies on the acceptance of insertables, such as [3,29,30], report a perceived ease-of-use effect that is not significant, although positive.

With respect to the NCA, we verified that achieving a certain degree of perceived ease of use is a necessary condition for acceptance. It is true that for certain groups of people who are likely to use insertable technology, such as DIYers or early adopters, because insideables are a technology that has not yet been domesticated and because its use has failed, the need for effort to use that technology may be a positive stimulus. However, it is logical to suppose that there must be a threshold for perceived ease of use above which the technology is perceived as impossible to use and therefore rejected.

The "lateral" influence of PEoU on perceived usefulness is consistent with the appreciation that the less challenging the use of a technological innovation is, the greater the task performance it provides [26]. Likewise, the positive influence of PEoU on enjoyment is congruent with other results in the context of hedonic information systems [39,46,47].

The estimation of the impact of subjective norms on behavioral intention suggests that it is the second variable with the greatest relevance in its explanation. Unlike other technologies, implantable devices generate social controversy for cultural and privacy risk perceptions and for religious [8] and ethical reasons [6] which can inhibit their use by certain people because they do not perceive that using this type of technology is well understood. However, various countercultural groups, such as DIYers, grinders, certain feminists, and cyber activists, openly express their support for the use of this type of device [19,50,51], so they can influence their sympathizers. The significance of subjective norm in explaining acceptance is consistent with the reviewed literature on implantables, as shown in Table 1 [3,31,33,34].

On the other hand, we observed that although subjective norms have a greater statistical impact than enjoyment and PEoU on BI, it is not a necessary variable for generating acceptance of cyborg technology. The fact that this is an underground practice allows us to intuit that a relevant proportion of users are attracted to the use of implantable technology precisely for this reason. Thus, in the qualitative study [17], approximately 5% of respondents were attracted by the clandestine nature of wearing a hidden device in the body.

5.2. Theoretical and Practical Implications

From a theoretical point of view, we have shown that the hedonic TAM [39], with the addition of a subjective norm, as TAM2 does, can provide an adequate analytical framework to understand acceptance in the current state of implantable technologies. The proposed model can explain 75% of the intention to use insertable technology in the sample. Although insertable technology is not a purely hedonic technology, such as video games, many users have an essentially hedonic motivation in their use.

The fact that the hedonic TAM tested in this study is not rejected and, at the same time, is a relatively parsimonious model provides new evidence of its utility in explaining behavioral intention toward information technologies with a certain hedonic component.

As [40,43] noted, the combined use of PLS-SEM and the NCA allows us to obtain a more insightful explanation in the field of acceptance of new technologies—in this case, insideables. We verified that for a certain degree of acceptance, it is necessary to reach a certain level of usefulness, usability, and enjoyment. Social normalization of the use of insideables does not seem to be a sine qua non condition for adoption. Thus, the statement "a more intense perception that subjective norm is favorable to use encourages behavioral intention toward insideables" must be satisfied by the fact that "it is only true if certain levels are reached in utility, usability, and enjoyment perception".

The scores obtained for perceived usefulness, perceived ease of use, and enjoyment are low, which explains the low spread of insertable technology and the fact that it is currently far from being in a mass customization phase [21]. Although these technologies have the potential to enhance human capabilities such as intelligence [11] or physical strength [36], their current instrumental uses are limited to the identification, access, and sharing of not a great amount of data [16,17], and as instruments that stimulate senses and creativity, which is useful in the case of avant-garde artists [19,50].

The generalization of these technologies requires an increase in the range of features that these technological devices provide in practice. Perceived usefulness not only positively influences behavioral intention but is also a necessary condition for overcoming a perceived utility threshold without which this technology will have low acceptance even if its usability is high or social perception is very good. Likewise, an increase in features leads to an increase in potential users to whom these technological devices provide enjoyment.

Another aspect highlighted by the literature and observed in the responses of the analyzed survey is the low usability of the technology. These devices have low battery life, short range, and low compatibility with operating systems and other devices [17,72]. Additionally, continuous monitoring is required in the early stages because of the risk of material rejection and the possibility of infection [7]. Perception of a certain threshold for ease of use is a necessary condition for eliciting the intention to use insertable technology.

6. Conclusions

This study examined the perceptions of a sample of university students from seven countries regarding the adoption of nonmedical implantables. Widespread reluctance toward their use was observed, which was likely limited to individuals with an affinity for underground collectives or transhumanist ideals. The analysis was performed with the exception of the TAM model [39], in which perceived enjoyment status was similar to perceived usefulness. Subjective norms were also incorporated into the analysis.

PLS-SEM revealed that the extension of the TAM proposed in this study is reliable. Likewise, all variables had a significant positive influence on behavioral intention. The most impactful variable was perceived usefulness, which was also the variable with the greatest necessity size effect. It is also remarkable that the subjective norm, which was the second most influential factor, was not a necessary condition. However, perceived ease of use, which had a very low path coefficient in the PLS-SEM adjustment, had a significant necessity effect size of a magnitude practically identical to that of perceived enjoyment.

This study has several limitations, as it was conducted exclusively with individuals under the age of 30 within a university setting in seven different countries that include different types of culture: Catholic countries, such as Spain or Chile; Calvinist countries, such as Denmark; or Confucian countries, such as Japan, but not others, such as Islamic or Hindu countries. Consequently, the findings regarding behavioral intent toward implantables may be influenced, on the one hand, by the participants' educational background and economic status. It is important to note that the target population in this study, digital natives, is generally more familiarized to such technologies [16,33] and also more receptive to practices whose objective may be self-reaffirmation [1], such as piercing or tattooing [8]. Cultural aspects are highly relevant for understanding behavioral intention toward devices such as wearable devices [23] and implantable devices [33]. Furthermore, the implications of this research work may not be broadly applicable in the medium- or long-term because of the anticipated significant advancements in implantable technology, including materials, portability, reliability, and overall features, as projected by [72].

On the other hand, the used scales such as perceived enjoyment, as is commonplace, inquire about the perception of relatively vague concepts like "pleasure" or "enjoyment" without specifying the reasons behind them. It should be the respondent who imagines or knows the personal reasons that may encourage or discourage such sensations in their case. This vagueness could potentially create certain difficulties for some participants in expressing their opinions in the proposed questionnaire.

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Institutional Review Board Statement: With regard to ethics approval, (1) all participants were given detailed written information about the study and procedure; (2) no data directly or indirectly related to the subjects' health were collected and, thus, the Declaration of Helsinki was not generally mentioned when the subjects were informed; (3) anonymity of the collected data was ensured at all times; and (4) no permission was obtained from a board or committee for ethics approval, as it was not needed as per applicable institutional and national guidelines and regulations; (5) voluntary completion of the questionnaire was taken as consent for the data to be used in research; informed consent of the participants was implied through survey completion.

Informed Consent Statement: All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Universitat Rovira i Virgili (CEIPSA-2022-PR-0005).

Data Availability Statement: The survey supporting this study can be obtained upon request to any author.

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