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30TH BLED ECONFERENCE: DIGITAL TRANSFORMATION – FROM CONNECTING THINGS TO TRANSFORMING OUR LIVES (JUNE 18 – 21, 2017, BLED, SLOVENIA)
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Behaviour Intentions to Use RFID Subcutaneous Microchips: A Cross-sectional Slovenian Perspective

BORUT WERBER, ALENKA BAGGIA & ANJA ŽNIDARŠIČ

Abstract This paper presents the second iteration results of a study investigating the possibility of radio frequency identification device subcutaneous microchip (RFID-SM) usage as a substitute for personal identification, healthcare issues, shopping or payments, and home usage. Our aim was to investigate the readiness to use SM-RFID in everyday life. In the study, we used an extended Technology Acceptance Model (TAM) to verify the main concerns regarding the use of RFID-SM among Slovenian people. The survey responses were gathered from October until December 2016. After evaluating the model, it can be concluded that the fit of the model is good and the significant path of dependence are similar as in the first study from 2014. Similar to previous results, the Health Concerns have a negative effect on the Perceived Trust and Perceived Usefulness of SM-RFID adoption. On the other hand, the Perceived Trust and Perceived Usefulness have a positive effect on the Behaviour Intention to use SM-RFID.

Keywords: • RFID • subcutaneous microchip • implant • adoption • everyday life •

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1 Introduction

In the era of the Internet of things (IoT) the information and communication technology (ICT) is used to support everyday tasks of people (e.g. Baquero, Cabrera & De Sousa, 2016). The number of different smart or magnetic stripe cards, keys and various other devices for personal identification, financial transactions, unlocking of doors, etc. has become unmanageable. When near field communication (NFC) became available on mobile phones, some cards were offered as a mobile service. To increase security, most of the magnetic cards were equipped or replaced with radio frequency identification device (RFID) microchip and NFC possibility. RFID microchips can be used for shopping, health care services, logistics, car industry and domestic usage.

During the research on diverse types of personal identification, questions about a unified type of identification arose. People are no longer willing to operate with the diversity of identification cards and passwords needed to efficiently manage their professional and personal life. Recent studies have shown that the RFID technology is secure enough to be used for personal identification and some attempts were made to use RFID subcutaneous microchip implants (RFID-SM) (Bergmann et al., 2012; Gasson & Koops, 2013; Madrid, Korsvold, Rochat & Abarca, 2012; Soares dos Santos et al., 2013).

Body-implantable devices for non-medical purposes are emerging as a hot topic that has the potential to permeate throughout society (Catherwood, Finlay & McLaughlin, 2016). According to Graafstra (interviewed by Michael, 2016), the attitude of consumers has changed from being unaware about the possible usage of RFID implants to general acceptance of RFID implants as a kind of jewellery. In recent years, people are becoming aware that the RFID-SM present a plausible future (Michael, Michael & Perakslis, 2015). Heffernan, Vetere & Chang (2017) even introduce a new concept called "insertables". Nevertheless, some researchers still explore the potential negative impact of enforced microchipping (Bradley-Munn, Michael & Michael, 2016), while others look for highly positive effects of RFID implants. Namely, implantation of RFID microchips in tumours may provide a new method for cancer treatment (Lai, Chan & Singh, 2016).

The literature review showed several attempts to research the readiness of RFID-SM adoption from the provider's viewpoint (e.g. hospital management, doctors) (Cao, Jones & Sheng, 2014; Hossain & Quaddus, 2015), while only a few of them dealt with the end-users (e.g. patients) (Katz & Rice, 2009). In addition, most of the studies are focused only on RFID-SM usage for the healthcare purposes.

This research is a continuation of the research conducted in 2014 (Werber & Žnidaršič, 2015), when readiness of potential RFID-SM users to adopt the microchips in their everyday life was researched. There are two reasons of survey repetition and upgrade:

- The attitudes towards technology acceptance change rapidly, so we wanted to compare the new results with the results from 2014,

- The study was extended from Slovenia to some other countries (e.g. Poland, Croatia).
-

In this paper, the responses gathered in Slovenia are presented, to enable a consistent comparison with the results gathered in 2014 (Werber & Žnidaršič, 2015).

Similar to Chong, Liu, Luo & Keng-Boon (2015), the basic Technology Acceptance Model (TAM) was extended with three additional external variables which enabled us to include all of our research questions. Health Concerns (HC) were included in the model according to the results of previous studies on RFID adoption (Foster & Jaeger, 2007; Katz & Rice, 2009; Rotter, Daskala & Compano, 2008), Perceived Trust (PT) has similar to HC gained a lot of attention in the research community (Garbarino & Johnson, 1999; Smith, 2008; Suh & Han, 2002; Tung, Chang & Chou, 2008; Wu & Chen, 2005). Furthermore, age was included as a predictor variable of Behaviour Intention to Use (BIU) since younger people are more prone to adopt new technologies (Burton-Jones & Hubona, 2006; Morris & Venkatesh, 2000).

2 RFID microchip

With the development of technology and robotic production, the capacity of microchip has multiplied while the size of it was minimised. The biggest challenge today is not the size of a microchip (0,05mm x 0,05mm). The problem is the size of the antenna that should be at least 1mm long to get reliable results (Burke & Rutherglen, 2010). Depending on power needed for operating, RFID microchips are categorised into three types: passive, active and semi-passive. While passive devices don't need any internal power, the active do and their life time depends on battery capacity, usually not longer than one year (Ruiz-Garcia, Lunadei, Barreiro & Robla, 2009). Semi-passive devices present a combination of both other types.

While data stored in a passive NFC RFID-SM microchip can be read with the help of electromagnetic field produced by a reader device, the sensor (temperature sensor, PH sensor, etc.) needs a power supply (Badia-Melis et al., 2014). To overcome this problem, the researchers are trying to develop rechargeable implanted batteries that produce electricity with the chemical reaction of body fluids – glucose bio-batteries (Yazdi et al., 2017).

We can find the application of RFID microchip in manufacturing, supply chain management (Yee-Loong Chong et al., 2015), logistic, automotive industry, livestock production (Iyasere, Edwards, Bateson, Mitchell & Guy, 2017), food production and public sector (Dwivedi, Kapoor, Williams & Williams, 2013). RFID microchip is used in shops, passports, proximity cards, automated toll-payment transponders, ignition keys, contactless credit-cards, smart bracelets, smart finger rings, smart watches, etc. (Juels, 2006).

In healthcare we can use RFID for resource management (Fisher & Monahan, 2008). There are also RFID systems for tracking patients and personnel (Baker, 2016; Fosso Wamba, Anand & Carter, 2013). Besides, the high number of health care errors (up to 98,000 per year) causing death can be reduced when using RFID system for monitoring patients (Baker, 2016).

There were several attempts of using RFID-SM in vivo. The first human with active RFID-SM implant was Professor Kevin Warwick in 1998. He was able to programme doors to open and lights to switch on when he approaches the RFID reader. He removed the chip after nine days in order to avoid possible health complications due to the battery lifetime. In 2002 the Jacobs family members were implanted by Very chip (Ip, Michael & Michael, 2008). One of first recorded commercial use of RFID-SM was in 2004 in the Baja Beach Club in Barcelona, Spain, and Rotterdam (Ip et al., 2008; Michael & Michael, 2010). An RFID-SM with a unique code for identification of very important persons (VIP) was used to enable electronic payment and access to VIP areas of the club. The name of the person was displayed publicly on screens upon their entrance to the club. In 2005, three employees of the U.S. Company Citywatcher.com were implanted with microchips for access control application. In the same year, the Very Chip was used for medical reasons to identify patients for the first time in the USA. Volunteers were chipped in hand or arm with local anaesthetics. The system was able to recognize 16 digit identification code to identify and gain an insight into patient medical record data (Michael & Michael, 2013). The author of the book RFID toys (Graafstra, 2006), Amal Graafstra's initial motivation to get a chip implant was for the convenience of eliminating keys (Ip et al., 2008). In 2013 first commercial company called Dangerous Things was established and started to sale the first RFID-SM for home use (Michael, 2016).

The presented study considered the usage of the passive NFC RFID-SM of size 2mm x 12mm, similar to the glass-coated used for animals' identification. There are more than 5 million house pets with such chips, which enable identification of the pet's owner (Juels, 2006).

3 Research approach

3.1 Data collection

The study about attitudes toward RFID-SM among Slovenians was performed from April to December 2016. The link to the web questionnaire was sent via email to members of researchers' social networks and it was posted on the faculty web page.

3.2 Questionnaire and research hypotheses

The research model includes all three basic concepts of TAM (Morris & Venkatesh, 2000; Ronteltap, Fischer & Tobi, 2011): Perceived Ease of Use (PEU), Perceived Usefulness (PU), and Behaviour Intention to Use (BIU). The basic concepts are combined with two external factors (Werber, Baggia & Žnidaršič, 2016): Perceived Trust (PT) and Health Concerns (HC). Furthermore, two manifest variables are included: age and painful procedure; first with hypothesized direct impact on BIU, and the second on HC.

PU has seven items which are in accordance with items proposed by proposed by Davis (1989) in the original TAM model. Five of them were adopted from (Katz & Rice, 2009), and two additional items on storing information about organ donation and a general statement on saving lives in different medical conditions were added. PEU and PT items were adopted based on Davis (1989) and Smith (2008), respectively. PT refers to an individual's trust that the state, banks and healthcare systems will be able to ensure the security and protection of gathered personal data. Items composing HC construct were prepared based on extensive literature review of medical research papers (e.g. Foster & Jaeger, 2007; Katz & Rice, 2009; Rotter, Daskala & Compano, 2008) and they measure possible threats of RFID-SM usage. BIU reflects four different possible types of the RFID-SM usage (healthcare purposes, for identification purposes, for shopping and payment, and for everyday home usage) as pointed out in the interviews. The exact items wording can be found in Table 1.

AS noted above, each model component was measured by several items (Table 1). The items of HC, PT, the last item of PU, and PEU were measured on a 5-point Likert-type scale of agreement; the first six items for PU were measured on a 5-point Likert-type scale of acceptability, while the items of BIU were measured as dichotomous variable (yes/no).

Research hypotheses are presented in Figure 1. We proposed ten hypotheses. Nine of them were adopted from the 2014 study, and one new was added. We assumed that perceived experience on implantation procedure ("implanting RFID-SM is a painful procedure") has a positive impact on HC. The predicted relationships among concepts included in the model are presented with arrows, where a plus sign (+) represents positive impact and a minus sign (-) negative impact.

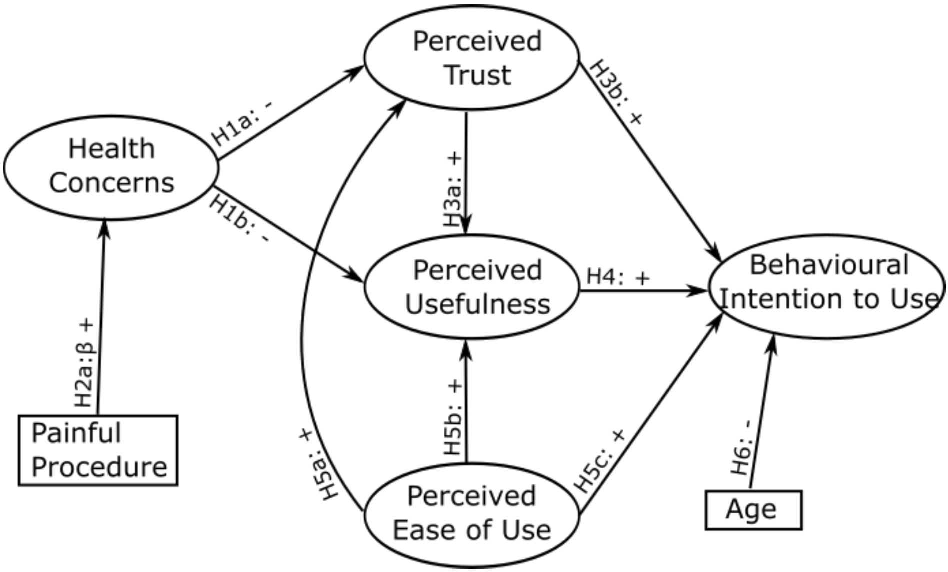

Figure 1: Research hypotheses

3.3 Data analyses

The proposed hypotheses in the research model were analysed with structural equation modelling (SEM). In this paper, presented results were obtained based on the analyses of 291 respondents, who provided at least partial responses on the variables included in the model (252 responses were complete). There is no general recommendation on minimal sample size required for SEM. Hair et al. (2006) suggested the sample size between 150 and 400, while Loehlin's rule of thumb (Siddiqui, 2013) suggests that the sample size should be at least 50 more than eight times the number of measured items in the model. Since our model consists of 25 measured variables, the minimal sample size should be 250, which indicates that the analysed sample size of 291 respondents is sufficient to achieve the statistical power necessary for SEM with three or more measured items per latent variable. To use all, also partial information obtained from the respondents, multiple imputations was used when analysing the data in order to improve the validity of the results (Mackinnon, 2010).

The research model was evaluated in two steps. First, measurement model was investigated, followed by the analyses of the structural model (Kline, 2011). To confirm, that the constructs are correctly defined, first data screening and confirmatory factor analysis (CFA) was performed, followed by SEM. Our hypotheses assume several relationships between variables which could be analysed with several multiple regressions, but SEM was employed for its ability to analyse relationships between latent and observed variables simultaneously (Teo, 2011). Several statistics were calculated before SEM, and the detailed results are omitted due to limitation of the paper length.

Here, we will only list the performed analyses to justify the corrections of the data analyses and results presented.

To assess whether the data are approximately normal and therefore appropriate for CFA and SEM, the absolute values of skewness and kurtosis were calculated. The Cronbach's alpha coefficients were calculated for each of the five constructs in our research model to determine the extent of the internal reliability. The construct validity of each scale was assessed using CFA, and it was evaluated via the convergent validity and the discriminant validity. The convergent validity was examined based on three concepts (Fornell & Larcker, 1981; Koufteros, 1999): a) estimates of the standardized factor loadings which should exceed 0.5 (or even 0.7), b) composite reliability (CR) for each latent variable which should exceed 0.7, and c) average variance extracted (AVE) measuring the amount of the common variance between the indicators and their construct in relation to the amount of variance attributable to measurement error for each latent variable, which should exceed 0.5. In order to investigate the discriminant validity of the measurement model, the square root of AVE of each latent variable was compared to the correlations between the latent variables.

In the final step, to evaluate the impact of proposed relationships among constructs in the research model, SEM was used. Since there are endogenous (dependent) binary variables in the model, the robust weighted least squares mean and variance-adjusted (WLSMV) estimation in the lavaan R-package was used (Rosseel, 2014).

In order to assess the fit of the measurement model and the structural model, the overall fit was examined based on various sets of commonly-used fit indices: $\chi 2$/df which should be lower than 3 (Teo & Zhou, 2014); indices TLI and CFI which should be at least 0.9 in order to indicate adequate model fit (Koufteros, 1999). The root mean square error of approximation (RMSEA) should be below 0.06 (Teo & Zhou, 2014) or at least below 0.08 as proposed by (MacCallum, Browne & Sugawara, 1996).

Results of the SEM analyisis are presented in the Results section. The values of standardized path coefficients (β) and corresponding z-values reflect the relationships among the latent variables in terms of the magnitude and statistical significance. For every endogenous latent variable the coefficient of determination (R2) is also calculated, which should be above 0.1 (Escobar-Rodriguez & Monge-Lozano, 2012) to confirm the predictive capability of the model.

4 Findings and results

4.1 Sample characteristics

The sample consists of 59% of women and 41% of men. Among the respondents, 33% are in primary school, secondary school or at the university. More than half of the respondents (54%) are employed, 6% are unemployed, while 7% are retired. The age of the respondents ranges from 11 to 79 years, with an average age of 35.7 years and SD = 15.0 years.

4.2 Descriptive statistics of the questionnaire items under study

Table 1 presents descriptive statistics (mean (M) and standard deviation (SD)) of 24 variables included in the research model.

On average, respondents agree the most with the statement that subcutaneous microchips can integrate multiple functions at the same time (M = 4.02). If we examine the four items of HC closely, we can see that respondents are worried due to treats of possible allergies (M = 3.27), and an impact on the nervous system (M = 3.14). On the other hand, they are less concerned due to possibility of microchip movements in their bodies (M = 2.97) and due to effects on emotional behaviour (M = 2.95).

Items of BIU were measured as dichotomous variables. In Table 1 the percentages of the respondents who positively answered on the individual question are presented. The highest proportion of the respondents (43%) would insert an RFID-SM for health care purposes and the smallest proportion of the respondents (20%) would have microchips for shopping and payment in a way that microchip would replace debit cards, credit cards, and profit cards.

The means were calculated also for four components. Mean values are above 3 for three components: 3.08 for HC, 3.76 for PEU, and 3.46 for PU, which indicates that the overall response could be classified as positive. The mean of PT is equal to 2.71, which indicates that perceived trust on security issues provided by state, banks, and healthcare system is somehow low.

Table 1: Descriptive statistic of the questionnaire items

Model comp.	Questionnaire items	*N*=291	
		Mean	*SD*
Health Concerns (HC)	Subcutaneous microchips can be threatening to my health because of the possibility of movement in my body. **(HC1)**	2.97	1.187
	Subcutaneous microchips may affect my emotional behaviour (control of human behaviour, etc.). **(HC2)**	2.95	1.265
	Subcutaneous microchips can be threatening to my health because of possible allergies. **(HC3)**	3.27	1.196
	Subcutaneous microchips can be threatening to my health because of their impact on the nervous system. **(HC4)**	3.14	1.206
Perceived Trust (PT))	The state will ensure the security and the protection of human rights (security of identity documents, passport, identity theft, tracking via GPS, no records should be archived without the consent of the person observed). **(PT1)**	2.57	1.271
	Banks will provide security (payment, discretion of operation, transactions, etc.). **(PT2)**	2.70	1.297
	The healthcare system will provide security (personal data, medical data, information on treatments, organ donation, etc.). **(PT3)**	2.84	1.29
Perceived Usefulness (PU)	Subcutaneous microchips could be used:		
	for monitoring the health of the user, e.g. pulse or blood pressure. **(PU1)**	3.60	1.127
	for warning about potential health problems or complications (e.g. diabetes). **(PU2)**	3.73	1.09
	for storing medical info for accident or emergency. **(PU3)**	3.64	1.097
	for personalized health info. **(PU4)**	3.21	1.198
	for storing information about organ donation. **(PU5)**	3.21	1.2
	Users of the subcutaneous microchips should have lower health insurance premiums. **(PU6)**	3.03	1.246
	Subcutaneous microchips may save your life (e.g. unconsciousness, cardiac pacemaker, sugar detector, insulin dispenser, etc.). **(PU7)**	3.81	1.066
Perceived Ease of Use (PEU)	Subcutaneous microchips are always available. **(PEU1)**	3.53	1.117
	Subcutaneous microchips cannot be lost. **(PEU2)**	3.79	1.068
	Subcutaneous microchips cannot be stolen (high-security protection). **(PEU3)**	3.18	1.317
	Subcutaneous microchips can integrate multiple functions at the same time. **(PEU4)**	4.02	0.888

Painful Procedure	Implanting RFID-SM is a painful procedure.	2.89	1.167
	Would you insert a subcutaneous microchip:	**Percentage of positive responses**	
Behaviour Intention to Use (BIU)	for healthcare purposes (identification, storage of medical data, information on organ donation, etc.)?	43%	
	for identification purposes (ID card, passport, driving licence, etc.)?	28%	
	for shopping and payment (debit cards, credit cards, profit cards, etc.)?	20%	
	for everyday home usage (unlocking house or apartment, car, computer, mobile phone, etc.)?	23%	
	if you were assured that GPS positioning and tracking were not possible?	29%	

4.3 Results of the SEM

First, measurement model was evaluated. The item PEU3 on RFID-SM security protection was removed from the PEU construct, and consequently from the model, due to combination of its standard loading slightly above 0.5 (0.515) and its variance which was twice as big as for other construct items. Standardized factor loadings for items in the (final) model exceed a threshold of 0.5 for convergent validity, 19 of them exceed also stricter threshold of 0.7. The AVE for all five constructs reach and exceeds a threshold of 0.5 for convergent validity (HC 0.53, PT 0.74, PEU 0.50, PU 0.54, BIU 0.85).

In our measurement model, the obtained value of $\chi2/df = 1.465$ ($\chi2 = 291.502$, df = 199) is lower than 3, and both TLI = 0.89 and CFI = 0.90 are close to 0.9. The RMSEA is equal to 0.040, and the upper bound of RMSEA 90% confidence interval (0.030, 0.050) is lower than 0.06. According to the set of the calculated fit indices, it could be concluded that measurement model fits the sample data reasonably well. Therefore, the fit of the structural model could be evaluated.

The goodness-of-fit of the SEM was evaluated with the same set of indices as for the measurement model. The results show that the model has a good fit: $\chi2/df = 2.154$ ($\chi2 = 523.343$, df = 266), TLI = 0.88, CFI = 0.89, and RMSEA = 0.063 with its 90% confidence interval (0.056, 0.070).

The results of the structural model are presented with standardized path coefficients (β) (and corresponding z-values), which reflect the strength of the relationships among the latent variables (Figure 2).

For every endogenous latent variable also the coefficient of determination (R2) is presented. The predictive capability of the model is satisfactory because all coefficients of determination (R2) are above 0.1. The smallest R2 is for HC and it is equal to 0.246, R2 for PT is 0.278, for PU is equal to 0.514, and the highest value of R2 is for BIU (0.578).

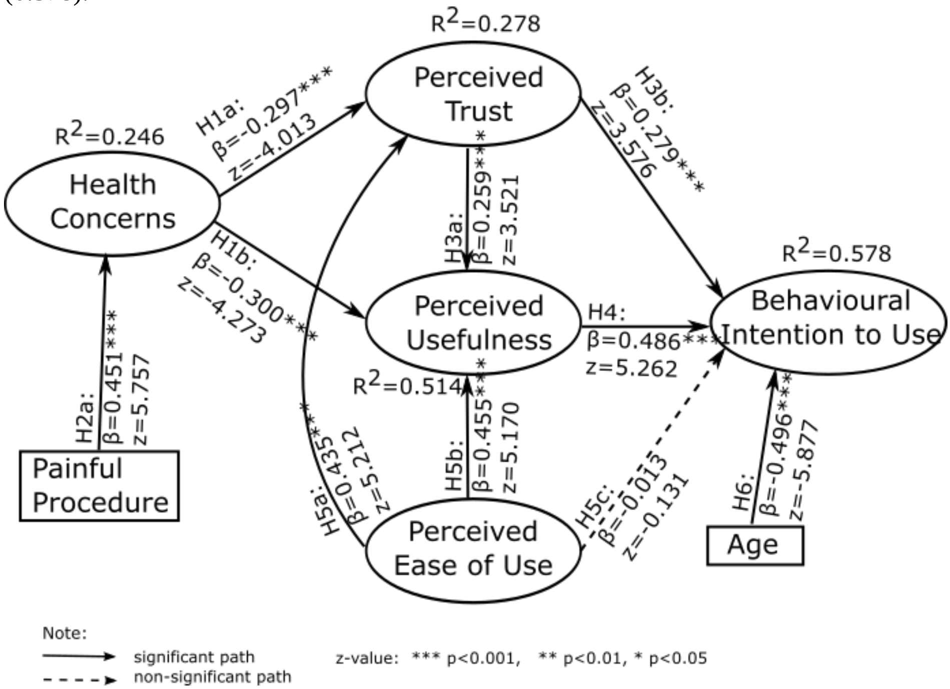

Figure 2: The results for structural model

Table 2 presents overview of the results for ten proposed research hypotheses regarding their acceptance or rejections.

Table 2: Overview of the results for ten proposed research hypotheses

Hypothesis	**Supported**
H1a: Health Concerns has negative impact on Perceived Trust.	Supported
H1b: Health Concerns has negative impact on Perceived Usefulness.	Supported
H2a: Painful Procedure has positive impact on Health Concerns.	Supported
H3a: Perceived Trust has positive impact on Perceived Usefulness.	Supported
H3b: Perceived Trust has positive impact on Behaviour Intention to Use.	Supported
H4: Perceived Usefulness has positive impact on Behaviour Intention to Use.	Supported
H5a: Perceived Ease of Use has positive impact on Perceived Trust.	Supported
H5b: Perceived Ease of Use has positive impact on Perceived Trust.	Supported
H5c: Perceived Ease of Use has positive impact on Behaviour Intention to Use.	Not supported
H6: Age has positive impact on Behaviour Intention to Use.	Supported

We can see from Figure 2 and Table 2 that based on the values of the standardized path coefficients and the corresponding z-values nine out of ten hypotheses were supported. Details are discussed below.

Basic TAM model proposes three positive relationships among constructs. Two of them were supported, while one was rejected. The positive effects of PU on BIU (hypotheses H4) and positive effects of PEU on PU (hypothesis H5b) were supported. Hypothesis H5c regarding positive effect of PEU on BIU could not be supported. This is in accordance with the finding of the research from 2014, where this relationship has also not been confirmed. That result shows that ease of use is not an important predictor of BIU. If the respondents find the microchips useful, then they would implant them regardless their availability and handiness.

The impacts of Age on BIU and of the Painful Procedure on HC are the strongest in the model. The variables PU and BIU have three significant predictors that can explain 51% and 58% of its total variance, respectively.
HC have a negative effect on both PT and PU (hypotheses H1a and H1b), where the impact is slightly stronger to the PT. PT has a positive impact on PU (H3a) as well as direct effect on BIU (H3b). As expected, Age has a strong direct negative impact on BIU (hypothesis H6).

5 Conclusion

Since most of the research has studied the willingness to adopt RFID-SM technology from the viewpoint of providers (e.g. Hospital management), and only a few studies dealt with end-user willingness to adopt RFID-SM, we decided to research this gap in 2014.

Due to the high frequency of technological advances, we have repeated and extended our study in 2016. The latter results are presented in this research paper.

The research topic is rather delicate. There are ethical questions whether or not should we put something unnatural under our skin. Hundreds of deaf people with hearing implants will surely not reject interventions in their bodies to enable their hearing. The same goes for patients with cardiac pacemakers and diabetes patients. There are thousands of orthopaedic patients with different implants. In the first research, back in 2014, no statistically significant correlations between the attitude towards earrings, piercing and tattoos and willingness to use RFID-SM existed. Although we would expect that the people willing to puncture their skin just to change their appearance, would also be prone to RFID-SM if they find the advantages of such system inspiring.

Most of the researched items showed a slightly more positive attitude towards the RFID-SM than two years ago. In addition, people are less concerned, since all items on Perceived Trust have higher average values. In addition, the recent results again showed that Perceived Ease of Use does not have a statistically significant influence on the Behaviour Intention to Use. The fact the implantation of RFID-SM is a painful procedure, positively influences the concept of Health Concerns. Although the Perceived Trust has slightly raised, Health Concerns are still evaluated as significant predictor of Perceived Trust and Perceived Usefulness. The result showed that the attitude towards the RFID-SM implantation is still negative. The respondents probably do not realize that most of the medical implants work the same way as an RFID-SM.

According to the results, most of the issues on RFID-SM adoption perceived by the end users are slowly losing their importance. Due to different reasons, public has become more open to the possibility of using the RFID-SM for different purposes. Therefore, more studies on the safety of RFID-SM should be conducted. New, preferably less invasive ways to enable a unified personal identification should be proposed.

This paper presents only the results of the survey conducted in Slovenia, therefore, our further research will include the results of the surveys gathered in other European countries to establish whether similarities in the attitudes toward RFID-SM adoption exists. A general extended TAM model for the intention to use the RFID-SM will be generated, where also an impact of privacy rights and privacy threats on Perceived Trust and indirectly on Behaviour Intention to Use will be examined.

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