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ABSTRACT

The development of connected objects (COs) offers a new perspective on both e-health and the economy; however, the factors leading to the adoption of e-health and COs remain somewhat misunderstood. Using a sequential combination of qualitative and quantitative research methods, this study investigates the factors affecting the adoption of COs in e-health. After conducting semi-structured interviews, a research model was developed and tested on a sample of 226 professionals in an online survey. The findings of this mixed methods study indicate that perceived convenience and social influence mainly affect adoption. Five other factors were also found to contribute to CO adoption: compatibility, object interoperability, object integration, result demonstrability and reputation. This study contributes to the understanding of CO adoption in e-health and provides useful insight into how to successfully launch connected devices.

Keywords: *e-health, adoption, connected objects, mixed methods approach, perceived convenience.*

RÉSUMÉ

Les objets connectés offrent une perspective nouvelle pour l'e-santé et l'économie. Cependant, les facteurs d'adoption de l'e-santé ou des objets connectés restent peu étudiés et compris. Cette recherche aborde les facteurs d'adoption des objets connectés dans l'e-santé en s'appuyant sur la combinaison successive de méthodes de recherche qualitative et quantitative. A partir d'entrevues semi-dirigées, un modèle de recherche est développé et testé auprès de 226 professionnels de la santé (par enquête en ligne). Les résultats de cette méthodologie mixte indiquent les rôles primordiaux de l'influence sociale et la commodité perçue dans l'adoption. Cinq autres facteurs contribuent, dans une mesure moindre à l'adoption : la compatibilité, l'interopérabilité, l'intégration, la capacité de démonstration des résultats et la réputation. Cette recherche offre une contribution importante et propose de nouvelles avenues pour assurer le lancement d'objets connectés dans l'e-santé.

Mots-clés : *e-santé, adoption, objets connectés, approche mixte, commodité perçue.*

1. INTRODUCTION

Health-related issues have become critical in most countries, and the implementation of healthcare-related information systems remains difficult. Healthcare effectiveness and delivery is a critical issue worldwide. It is thus crucial to engage resources in the development, implementation and use of e-health technologies (Miller, 2015). E-health refers to all services, systems and activities related to patient health and supported by technology. It includes all the digital content linked to patient health (Xerfi-Percepta, 2014). The practice of e-health is expanding dynamically (Botella *et al.,* 2009; Kaltenbach, 2014; San Nicolas Roca *et al.,* 2014), and early findings suggest that e-health can improve the effectiveness of patient management, enhance precision in drug administration, and reduce patient and physician travel time through telemedicine.

The development of connected objects (COs) and mobile e-health applications is increasing rapidly. According to a 2013 French survey (Financial Times, 2015), the proportion of the population currently using health devices associated with CO stands at 17%, and this percentage should increase exponentially in the next few years. On a worldwide basis, CO used in human health could have an economic impact of $170 billion to $1.6 trillion per year 2015 (McKinsey, 2015). Examples of their advantages are to monitor and maintain human health and wellness, disease management, increased fitness and higher productivity. COs, which are devices attached to or inside the human body, link digital and physical entities and enable a whole new class of applications and services (Miorandi *et al.,* 2012). The CO capabilities make it much more manageable to handle some critical health conditions outside of general health facilities (Wilson *et al.,* 2004). Connected applications or objects in e-health include connected products taking body measurements (pulse, body temperature, blood pressure), assisting with fall detection (assistance for the elderly), athletic care (vital sign monitoring) and/or monitoring of hospitalized patients. However, despite the alleged advantages of IT investments in healthcare, many physicians do not widely use connected applications in their clinical practices (Chismar and Wiley-Patton, 2003). Among the possible causes mitigating COs' adoption is their specific singularity in the health sector, especially because of their intrusive and sensitive properties involving ethical, security and privacy issues (Hossain *et al.,* 2015).

In general, much remains to be learned about the factors influencing the adoption of COs in e-health, particularly by professionals (Miorandi *et al.,* 2012). Scholarly research on the factors affecting the adoption of COs is growing (Shim *et al.,* 2007; Hossain and Prybutok, 2008; Dutot, 2015) but tends to focus on end-user adoption almost exclusively (Bahtiyar and Çağlayan, 2014). Furthermore, the involvement of academics is still limited despite the high potential impact of contributions in the development of the field (Atzori *et al.,* 2010; Zorzi *et al.,* 2010). Upon reviewing the literature on the subject, we notice that user technology acceptance has been the subject of thorough research by information system researchers and practitioners (Alavi and Carlson, 1992; Brancheau *et al.,* 1996; Davis *et al.,* 1989; Hu *et al.,* 1999; Holden and Karsh, 2010, Lapointe and Rivard, 2005). However, few studies have evaluated technology adoption models in the healthcare environment (Lapointe and Rivard, 2007; Chismar and Wiley-Patton, 2003; Holden and Karsh, 2010). Given the difficulty in implementing IT-related systems in this field, it is deemed appropriate to conduct a more in-depth study, based on a richer model of technology acceptance.

This study emerges as a response to the call for more empirical validation of well-researched theories/models in different settings (Jawahar and Harindran, 2016; Hu *et al.,* 1999). Its purpose is to improve the general understanding of CO use in e-health and contribute to the successful development of technologies in the health sector as recommended by Miller (2015). This research answers the following question: *What are the antecedents of the adoption of CO by health professionals*?

Following the introduction, the paper then presents the conceptual foundations and initial qualitative research model used in the mixed method approach (Venkatesh *et al.,* 2013) on which this research is based. The third part presents the qualitative study, the first step in testing the initial conceptual model, meant to elicit new variables and validate the initial research propositions. The fourth part examines the quantitative part of the mixed method approach, to confirm the introduction and importance of variables. Results indicate that perceived convenience and social influence mainly affect the intention to use COs, while the antecedent factors are compatibility, object interoperability and integration, result demonstrability and reputation. The fifth part is the discussion, followed by the conclusion.

2. CONCEPTUAL FOUNDATIONS

This part defines our main concepts, highlights the main contributions to technological adoption, examines technological adoption in e-health and finally presents the initial conceptual model to be tested.

2.1. Terminology and context of COs

In this paper, we refer to Miorandi *et al.* (2012: 1497-1498) and define connected objects as "*(1) the resulting global network interconnecting smart objects by means of extended Internet technologies, (2) the set of supporting technologies necessary to realize such a vision (including e.g., RFIDs, sensor/actuators, machine-to-machine communication devices, etc.) and (3) the ensemble of applications and services leveraging such technologies to open new business and market opportunities*" (Atzori *et al.,* 2010). For the authors, COs are built on three pillars, all related to the ability of smart objects to: "(1) be identifiable (anything identifies itself), (2) communicate (anything communicates) and (3) interact (anything interacts) – either among themselves, building networks of interconnected objects, or with end-users or other entities in the network" (Miorandi *et al.,* 2012: 1498). There are very few studies on the adoption of COs. Previous works have focused on the adoption of similar technologies such as mobile services (Shim *et al.,* 2007), mobile technology (Isaac *et al.,* 2006), radio frequency identification (RFID) (Hossain and Pryutok, 2008), and near field communication (NFC) (Dutot, 2015). The results from Shim *et al.* (2007) acknowledged a positive reaction to the adoption of connected technologies (a connected fridge) in cases of technology convergence. If perceived usefulness and perceived ease of use are crucial in terms of technology adoption, invasion of privacy would be a limiting factor of adoption (such as the use of personal data). Finally, Dutot (2015) studied the adoption of NFC technology in the French context. His results showed the importance of security and social influence on the adoption of connected technology.

2.2. Technology adoption in e-health

2.2.1. Technology adoption in the e-health context

Academic contributions regarding the mechanisms involved in technology adoption have grown rapidly over the past 30 years. Following Rogers' Innovation Diffusion Theory, a precursor of the adoption model was developed by Davis (1989), namely the Technology Acceptance Model (TAM). This model was mainly inspired by the Theory of Reasoned Action (Fishbein and Ajzen, 1975) and served as the basis for further studies on the subject. Other theories and models followed such as TAM2 and TAM3, the Theory of Planned Behavior (TPB) (Ajzen, 1985), the Unified Theory of Acceptance and the Use of Technology (UTAUT) (Venkatesh *et al.,* 2003).

More and more researchers have been studying the use of technology in a decision-making context over the years (Hu *et al.,* 1999; Bhattacherjee and Premkumar, 2004; Venkatesh, 2000). Jawahar and Harindran (2016) stated that significant research on users' reaction to information systems established that the success of implementation efforts of new IS depends on the acceptance of employees and has to integrate the different contexts (Davis *et al.,* 1989; and Knights and Murray, 1992). Cornell *et al.* (2011) advocated that to successfully measure the organizational context, research has to focus on the individuals' decision to use technology; however, none of the models used in the health care context has been developed for that specific context (Holden and Karsh, 2010). Indeed, the diversity of healthcare environments, e.g., ambulatory care, telemedicine, emergency room, clinical information system, electronic health record, makes it particularly difficult to aspire to a universal model. These diversities should be integrated into new research on technology acceptance in order to find additional drivers of use.

In an attempt to explain the potential lack of specificities of technology adoption models to the healthcare context, we examined theories and models in various fields and selected those that seemed most appropriate for the healthcare context and the adoption of new technology. Our literature review and model got insights from the TAM (Davis, 1989), UTAUT (Venkatesh *et al.,* 2003), TAM3 (Venkatesh and Bala, 2008), ICTAM (An, 2005), e-Ham (Jung, 2008), Dünnebeil *et al.*, 2012), and indirectly from RFID (Hossain and Pryutok, 2008) (see Table 1).

2.2.2. From literature to the initial research model

With TAM as a starting point, studies in the healthcare context field have also sought to understand the factors related to the adoption of technology. Hu *et al.* (1999) studied adoption among physicians and concluded that TAM was ill-suited for physicians, requiring enhanced models. This same conclusion drove Chismar and Wiley-Patton (2003) to work on an extended TAM2, to understand physicians' intention to adopt Internet-based health applications. Finally, Paré *et al.* (2014) or Hendrix *et al.* (2013) also completed the TAM to make it more suitable to the healthcare context, suggesting as well that a more specific model is needed.

TAM3 was developed by Venkatesh and Bala (2008). Their model distinguishes concepts and their influence. The authors show the direct and positive link between result demonstrability and perceived usefulness as well as the positive link between

Reference models	Dimensions of the original model	Dimensions used in the e-health context	Dimensions used in the connected object context	Dimensions used in the current research
TAM (Davis, 1989)	PU	■	■	■
	PEOU	■	■	■
	Attitude	■	■	
UTAUT (Venkatesh *et al.*, 2003)	Performance expectancy	■		■
	Effort expectancy	■		
	Social influence	■	■	■
	Facilitating conditions	■		■
	Intention to use	■		■
TAM3 (Venkatesh and Bala, 2008)	Subjective norms			■
	Image			
	Job relevance			
	Output quality			■
	Result demonstrability			■
	Computer self-efficacy			
	Computer playfulness			■
	Perceived enjoyment			■
	External control			
	Objective usability			
ICTAM (An, 2005)	Perceived playfulness	■		■
	TAM3 components	■		
eHAM (Jung, 2008)	TAM3 components	■		
	Credibility	■		■
	Accessibility	■		
	Perceived risk	■	■	■
Dünnebeil (2012)	Security	■	■	■
	Documentation	■		
	Knowledge of e-health	■		
	Standardization	■		

Table 1: Dimensions used in the initial qualitative research model

perceived usefulness and behavioral intention; however they do not identify a significant or direct link between output quality and perceived usefulness. In the healthcare context, Jung (2008) acknowledged the need to develop specific moderators and determinants. The author developed the e-health Acceptance Model (e-HAM). His model recognized the strong connection between both result demonstrability and output quality on perceived usefulness. Safari Mehr and Albadvi (2008) proposed and tested a comprehensive model incorporating ten criteria drawn from previous models (attitude, compatibility, normative factors, computer self-efficacy, computer anxiety, perceived usefulness, perceived ease of use, perceived behavioral control, behavioral intention and actual usage).

Hossain and Prybutok (2008) measured RFID adoption among consumers. The authors studied various factors including perceived convenience, which includes perceived usefulness and perceived ease of use. Perceived convenience is defined as '*the extent to which a consumer believes that using [a technology] is comfortable, free of effort and is fit for performing a task*' (2008: 317-318). Perceived convenience is viewed as a more comprehensive concept than ease of use and perceived usefulness in terms of the intention to use a CO in the healthcare context. The results of Hossain and Prybutok show that perceived convenience, perceived culture and perceived security affect an individual's intention to use RFID technology in a positive way.

The UTAUT model (Venkatesh *et al.,* 2003) presents four factors affecting the intention to use a technology directly and positively: (1) performance expectancy, i.e., the degree to which a person believes that using technology will optimize his performance; (2) effort expectancy, i.e., the level of effort expected to adapt to the use of technology; (3) social influence, i.e., the level of importance an individual places on others believing that he or she should use a technology; and (4) facilitating conditions, i.e., the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system. The UTAUT does not contain a separate determinant for compatibility as it is combined with facilitating conditions. In this research, we follow the proposal of Schaper and Pervan (2007) and define the compatibility construct as "*the degree to which an innovation is perceived as being consistent with the existing practices, values, needs and experiences of the healthcare professional*" (2007:738-739). Kijsanayotin *et al.* (2009) also used the UTAUT model as a theoretical foundation to understand the factors of adoption of information technology in Thai health centers. Study results showed that intention to use is highly dependent on performance expectation and expected effort, social influence and context of use, in decreasing order of importance. Moreover, use of technology is directly influenced by the intention to use, facilitating conditions and previous experience. Previous experience is predominant in this model, and these results suggest that the UTAUT model could be useful as a basis for research in the health field. These results are in keeping with the recent study by Venugopa *et al. (*2018), which cross-validated the UTAUT model for the adoption of e-health records. The authors once again acknowledged the direct and positive roles of social influence, facilitating conditions and behavioral intention. Sequist *et al. (*2007) and Mitchell (1997) highlighted the positive correlation between perceived usefulness and IT use by health professionals. The concept of perceived convenience introduced by Hossain and Prybutok (2008), along with perceived culture and perceived security, have been shown to affect an individual's intention to use RFID technology. It is expected that the same relationship applies to CO in the healthcare context.

Based on this research, the following propositions were made to define the initial conceptual model (Figure 1):

Perceived convenience has been found to be related to the intention to use a CO, in this case RFID (Hossain and Prybutok, 2008). It is viewed as a more comprehensive concept than ease of use and perceived usefulness. Compatibility has been included in earlier research and found to support the use of a system (Venkatesh *et* *al.,* 2003; Safari Mehr and Albadvi, 2008; Schaper and Pervan, 2007; Taylor and Todd, 1995, Rogers, 1995). Since perceived convenience is modeled as an intervening variable between compatibility and intention to use, compatibility is expected to be related to perceived convenience. Thus, the following proposition:

P1: There is a positive link between the compatibility and perceived convenience of a CO.

Output quality is a potential significant predictor of perceived convenience. Chismar and Wiley-Patton (2003) and Venkatesh and Bala (2008) obtained mixed results in terms of the relationship between output quality and perceived usefulness. Perceived convenience being a more comprehensive concept, it is proposed that output quality is related to perceived convenience. Thus, the following proposition:

P2: There is a positive link between the output quality and perceived convenience of a CO.

In addition to contributing to perceived convenience directly, output quality also contributes to the result demonstrability (Venkatesh and Bala, 2008; An, 2005; Jung, 2008). Output quality being a system performance characteristic, it should help increase the result demonstrability of COs specifically. Thus, the following proposition:

P3: There is a positive link between the output quality and result demonstrability of a CO.

Result demonstrability is also a potential predictor of perceived convenience. Research has shown that result demonstrability is related to various facets of perceived convenience (Venkatesh and Bala, 2008; Jung, 2008; Chismar and Wiley-Patton, 2003). Its importance is highlighted by the fact that result demonstrability could act as an intervening variable between output quality and perceived convenience, emphasizing a specific consequence of output quality. Thus, the following proposition:

P4: There is a positive link between the result demonstrability and perceived convenience of a CO.

Intention to use has been thoroughly studied in various predictive behavioral models in various fields including the health field (Gagnon *et al.,* 2014, Kijsanayotin *et al.,* 2009; Venkatesh *et al.,* 2003). Several predictive factors were identified to explain its variations, including a more recent one, perceived convenience (Hossain and Prybutok, 2008). It should be positively related to the intention to use a CO. Thus, the following proposition:

P5: There is a positive link between the perceived convenience and intention to use a CO.

The original work of Venkatesh *et al.* (2003) acknowledges the links between social influence and intention to use. Perceived pressures from colleagues and the workplace push individuals to adopt a specific behavior. A positive link between social influence and intention to use has often been observed (Dutot, 2015; Lombardo, 2011, Venkatesh and Bala, 2008). A similar link is expected in the context of COs. Thus, the following proposition:

P6: There is a positive link between social influence and the intention to use a CO.

A positive link between facilitating conditions and intention to use has been observed in various information system contexts (Venugopa *et al.,* 2018; Lassoued and Hofaidhllaoui, 2013; Carrr *et al.,* 2010). Conditions facilitating the technical use of a system have been considered necessary for a long time. Following the proposal made by Venkatesh *et al.* (2003), we expect the same influence in the context of COs. Thus, the following proposition:

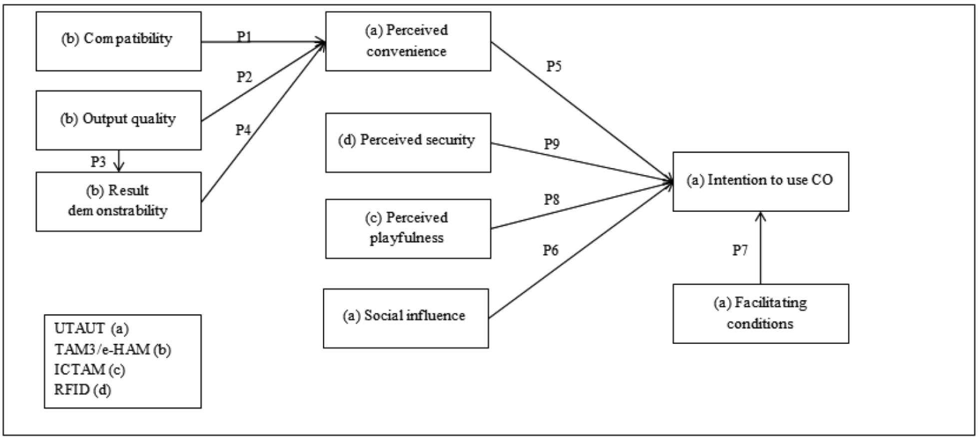

Figure 1: Initial conceptual model

P7: There is a positive link between the facilitating conditions and intention to use a CO.

Following the development and testing of the ICTAM (information and communication technology acceptance model), An (2005) completed the development of technology acceptance models. Starting with TAM3, he used the works of Moon and Kim (2001) and Chung and Tan (2004) to integrate the concept of technology's playful nature (called perceived playfulness) and relate it to the acceptance of technology. Perceived playfulness refers to "*the extent to which the individual perceives that his or her attention is focused on the interaction with the web; is curious during the interaction; and finds the interaction intrinsically enjoyable or interesting*" (Moon and Kim, 2001: 219). Thus, the following proposition:

P8: There is a positive link between the perceived playfulness and intention to use a CO.

Finally, Dünnebeil *et al.* (2012) investigated the factors influencing the adoption of e-health systems and added new factors including security. Security had a significant and direct influence on the intention to use e-health. Kim *et al.* (2008) had a more global view of the concept of security. They used the term "perceived security protection" to describe the consumers' perception that the vendor will fulfil security requirements such as authentication, integrity and encryption. Perceived security could be a valuable improvement to the model. Thus, the following proposition:

P9: There is a positive link between the perceived security and intention to use a CO.

3. QUALITATIVE STUDY

In order to test and validate our conceptual model, we followed a mixed methods approach. It consisted of a sequence of qualitative and quantitative research methods. In doing so, we were better able to understand the phenomenon (Jick, 1979, Reichardt and Rallis, 1994). The results of the qualitative study provided a solid empirical base that was tested and validated by the subsequent quantitative study (what Venkatesh *et al.,* 2013 considered developmental). This methodology has been proven to improve the strength of results when looking to better understand and explain social phenomena or a complex context (Cao *et al.,* 2006).

3.1. Methodology for the qualitative study

The first research method used was a qualitative study, namely individual semi-structured interviews probing informants' opinions concerning a specific theme. This approach helps to understand the reason for adoption (more specifically, in trying to explore the potential factors of adoption) and presents real strengths in the analysis of a research subject and identification of causal inferences (Yin, 2003). We used a convenience sample and, as the subject is relatively new, retained the criteria for precursor users developed by Bates *et al. (*2007) and Chau and Hui (1998), i.e., a person "*with leading capacity of opinion and a high social status*".

Relying on professional networks and opinion groups, the saturation of the convenient sample was deemed satisfactory at the eighth interview. The interviews lasted 30 to 60 minutes and were conducted in person or by phone (the complete guide is presented in the appendix). The respondents first had to present themselves and their level of knowledge of COs and e-health. Then, they had to explain how they adopted or intended to adopt the device. To do so, we used a funnel approach going from general questions about adoption to specific items (20 questions were prepared). As such, the respondents could describe their opinions regarding factors related to the adoption of COs in their professional activity, their main challenges and benefits. At the end of the interview, the researcher showed the initial conceptual model to the interviewee for elicitation purposes. The goal was to (1) validate or not the concepts mentioned by the respondents, (2) exchange ideas about the conceptualization – the order and links between the antecedents, and finally, when applicable, (3) discuss new factors proposed by the respondents, which could be added to the initial model proposed.

The respondents included five general practitioners and three specialists (pediatrics, endocrinology and hepatology). They were between 28 and 65 years old (mean: 44 years old). Half of them had their own office while the other four worked in a hospital or private clinic.

3.2. Data analysis and discussion

The transcripts were first analyzed using a closed coding process to predefine the analysis grid. We followed the methodology developed by Buber *et al. (*2004). The grid helped to validate or further refine the elements developed by the conceptual framework. At first, two authors coded and analyzed the interviews. A four-step process was used: (1) analysis of the content based on the topics (e-healthcare, CO and adoption), (2) overview of the categories (regrouping content from the different interviews into similar construct), (3) explanation (highlighting differences and similarities in perception) and (4) evaluation (identifying add-ons to the model). Then, a third researcher controlled the coding and analysis to ensure the validity of the results. Differences in coding were analyzed and discussed by the three researchers until a consensus was reached. Overall, the qualitative data was interpreted to assess whether the proposed research model was validated by respondents.

3.2.1. Validation of the conceptual model

The first factor, mentioned by all respondents, is 'convenience'. For these professionals, connected objects allow them to improve their day-to-day business activities as it "*saves time because we do not have to transcribe the measures; before, [we] had to manually enter in the patient's medical record*." Moreover, it helps to "*avoid input errors that could take place*," which is compatible with their values. Thus, proposition 1 is validated (Table 2).

The second factor mentioned by respondents while discussing convenience was the speed involved in using COs. Indeed, they expressed words such as ("*faster action taken*", "*I perform ancillary tasks simultaneously"*), allowing their patients to self-regulate (which could be considered "*self-regulation*"). These observations result from professionals' self-experimentation. Thus, proposition 2 is validated.

The concepts of output quality and result demonstrability were expressed as important since they strengthen the communication between the doctor and patient. Indeed, given the simplicity and fluidity of CO use ("*my patients are more informed now than before and they ask me questions about their health*"), professionals can provide patients with more details about their health; however, only two out of eight professionals mentioned these concepts spontaneously during the interview, while six others did so after seeing the model. Thus, proposition 3 is partially validated.

There are mixed results in terms of the link between result demonstrability and perceived convenience. Indeed, out of the eight respondents who were active on the web (who used social networks, blogs or personal websites), only two regularly shared their experiences with their staff and / or close professional colleagues ("*I am part of a virtual community of professionals where I explain to my colleagues how I'm using the CO and the perception of my patients*"). Four others agreed (after seeing the model) that being able to present results can be helpful and saw the benefits of it ("*I see the benefits in using this device, and my patients as well"*) Thus, we consider proposition 4 to be partially validated.

Overall, the professionals all agreed that COs improve their personal and professional life (eight out of eight). Indeed, they seemed to trust the measures (results) generated by the device or application they used and considered its performance to be *"reliable overall*". Notably, however, all participants mentioned "*the need to first test [its] performance over a certain period of time*.» Thus, we consider proposition 5 to be validated.

The sixth proposition addresses social influence. It refers to the way in which the adoption of COs by users/respondents can be influenced by others. As the participants interviewed were often early adopters, they were, by default, the first in their professional or close circle to use these tools ("*I couldn't talk to anyone about the device because none of my colleagues were using it yet*"). Therefore, they most likely motivated those around them to use the CO instead of the other way around. It appeared as though the respondents were influenced by information gathered as part of their exploration or exchanges with the industry ("*I've read academic articles stating the growing influence of COs in our field, I wanted to test it with some of my patients to see if it was as good as it seemed*"; "*some colleagues of mine were starting to use some COs and they explained to me how much easier their work had become*"). Thus, proposition 6 is validated.

The seventh factor concerns the facilitating conditions (technical support or experimentation prior to use) of the CO. This concept was less represented in the sample; none of the respondents had to use external assistance when using the CO yet ("*Up to now, I didn't experience troubles with the technology. And if it ever happens,* *I know what to do*"); however, two respondents mentioned that they could call the seller if necessary, and two had previously called customer service to obtain more information ("*I had to call the supplier to check about a specific functionality and their answer was very professional*"). They also acknowledged that they were more technology savvy than the rest of their colleagues, so they would use these devices more easily than others (*"I've always being open to new technologies and see myself as a geek"*). Even though only 2 respondents out of 8 validated the link, the proposition was kept given the small sample size. Thus, proposition 7 is partially validated.

Regarding perceived playfulness, all respondents expressed a strong willingness to test and use the CO. Some stated that it was "*fun to try a technical innovation*" whereas others mentioned the "*aesthetics of the product*". They acknowledged the fact that being playful helped the perception of it and the potential use of the CO. Some even said that they started to use them for fun ("*I wanted to see if it was as fun as it looked, […], and it was even better than expected*"). Thus, proposition 8 is validated.

Finally, respondents were unanimous regarding the importance of security. They acknowledged their "*natural confidence"* toward the protection of data in the CO they use *("I am not afraid to use it and recommend it to my patients"*) as well as their trust in their supplier ("*I've chosen the best on the market*"). Five of them, although aware of possible security issues, did not understand what "*interest a third party could have in stealing this data*" (consistent with the findings of Bousnina, 2010) but nonetheless acknowledged a

Concept and link	Number of respondents mentioning the concept before seeing the model	Number of respondents validating the concept after seeing the model	Validation
P1: Compatibility to perceived convenience	5	8	Validated
P2: Output quality to perceived convenience	6	8	Validated
P3: Output quality to result demonstrability	2	6	Partially validated
P4: Result demonstrability to perceived convenience	2	6	Partially validated
P5: Perceived convenience to intention to use CO	8	8	Validated
P6: Social influence to intention to use CO	6	8	Validated
P7: Facilitating conditions to intention to use CO	2	2	Partially validated
P8: Perceived playfulness to intention to use CO	8	8	Validated
P9: Perceived security to intention to use CO	8	8	Validated

Table 2: Overview of qualitative study and propositions (n=8)

"*potential risk*". Therefore, proposition 9 is also validated.

As stated here, all propositions made for the initial conceptual model, except for three of them, were fully validated by the respondents, and three others were only partially validated (see Table 2 for an overview). We decided to keep the construct of result demonstrability in our final model as respondents were at early stage of adoption and the technology was quite new, meaning that they could not present the results to a lot of people yet. The same reasoning was applied to facilitating conditions. Moreover, literature showed a significant influence of both constructs in the adoption process (Venkatesh and Bala, 2008).

3.2.2. Additions to the model

After seeing the initial conceptual model, the professionals proposed to enhance three constructs (perceived security, perceived convenience and social influence) by adding five variables: certification of the object, confidentiality, interoperability and integration of the CO, and reputation of the CO brand.

The first construct to be modified was perceived security. Respondents wanted the model to be more specific in terms of antecedents. They proposed to add two new variables. The first one is the certification of the object. By certification, the professionals meant a label or symbol certifying the quality of the device. Certification should be undertaken by a governmental authority to validate the "*precise measurements taken with a [reported] calibrated degree of error*". By doing this, it would ensure the protection and security of the patients' personal data ("*the device collects personal information and so we must ensure security […]. Knowing that it has been checked by authorities would be reassuring*"). Thus, the following proposition:

P10: There is a positive link between the certification and perceived security of a CO.

The second variable related to security is the level of confidentiality. Most respondents did not want to share all the results with their patients ("*as a professional, we need to control and select what information we share with our patients*"), or wanted to make sure that their patients could not save all their personal data because they felt that they "*had no control over the* [subsequent] *use of this data* [by a third party] *post-transmission*." They recognized that being able to manage the level of confidentiality would increase their level of perceived security and therefore improve their intention to use COs. Thus, the following proposition:

P11: There is a positive link between the certification and perceived security of a CO.

The second construct to be improved in terms of antecedents was perceived convenience. The respondents proposed to specify two technical capabilities. As a first technical capacity, the professionals mentioned the need for interoperability with other existing digital tools ("*the device itself is great, but knowing that it also operates with other devices or apps makes me want to use it more*"). Interoperability is systems' ability to provide and receive information and services from other systems or platforms and to use these services to operate effectively together (TOGAF, 2016). Thus, the following proposition:

P12: There is a positive link between the object interoperability and perceived convenience of a CO.

The second technical capacity to be added as an antecedent to perceived convenience is object integration. It is an automatic link that allows data to be seamlessly exchanged between connected devices and computers or other COs (similar to the findings of Krees *et al.,* 2015). COs have become commonplace today, and the respondents thought that this criterion should be added to the model ("*to me, the fact that the data is synchronized between my device and laptop is very useful*", "…*every connected object has a synchronization function*"). Thus, the following proposition:

P13: There is a positive link between the object integration and perceived convenience of a CO.

Finally, the fifth variable to be added is the reputation of the CO supplier/brand. Participants acknowledged the fact that for a new product, they preferred choosing a well-known brand. It should at least be mentioned in the newspapers ("*I knew the brand, so it helped me to choose*", "*knowing the supplier is better*"). They also said that often they were the first ones in their network to use such technologies, and therefore they could not rely on the advice of others ("*I couldn't ask any of my colleagues about it*"; "*I read the general comments about the product and supplier online*"). Thus, the following proposition:

P14: There is a positive link between reputation and social influence.

4. QUANTITATIVE STUDY

The following section details the research model and validation of the hypotheses. First, we explain the survey design and data collection, and then we present the results of the analyses (construct validity, reliability, and discriminant validity) that led to the structural model.

4.1. Research model and hypotheses

The qualitative survey confirmed the factors influencing adoption that had been reported in literature. It also led to the addition of five new constructs in the final model, which became the foundation for the development of the final research model for the quantitative study (see Figure 2 – new factors in bold).

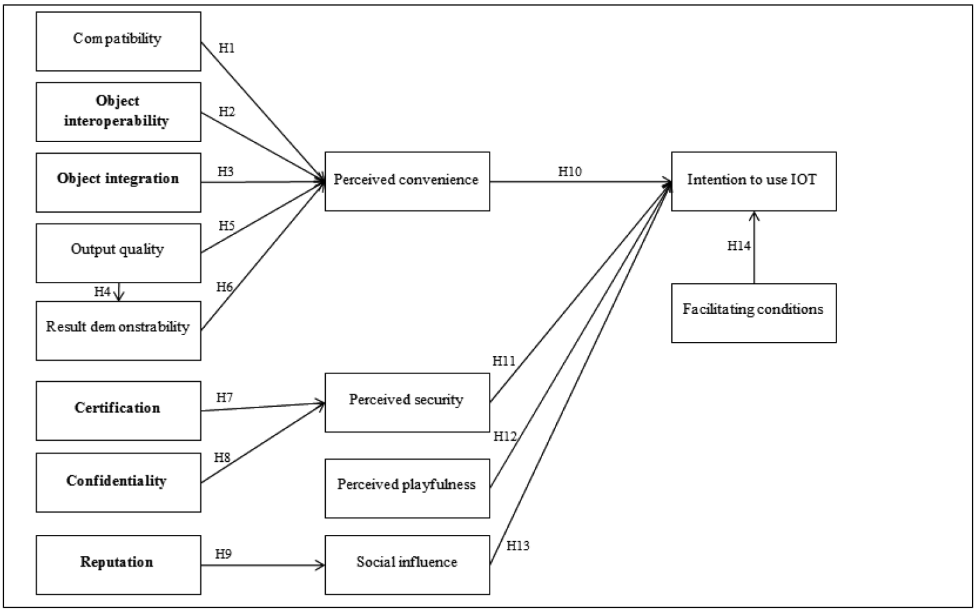

Figure 2: Final research model

In order to present hypotheses and develop the survey, we reviewed the literature and used the concepts presented. Thus, from the UTAUT model (Venkatesh *et al.,* 2003), we used the concepts of intention to use, perceived convenience (Hossain and Prybutok, 2008), social influence (Lombardo, 2011) and facilitating conditions. From TAM3 and e-Ham (Venkatesh and Bala, 2008; Jung, 2008), we looked for the conceptualization of the three determinants of perceived convenience. The first determinant is compatibility, as defined by Rogers (1995) and Schaper and Persan (2007). For the second and third determinants (i.e. output quality and result demonstrability), we referred to Chismar and Wiley-Patton (2003) and Venkatesh and Bala (2008). As stated in the literature review, we used Moon and Kim's work (2001) to conceptualize and measure perceived playfulness, while security was based on Hossain and Prybutok (2008).

The compatibility of a system has been observed to be related to perceived convenience (Safari Mehr and Albadvi, 2008; Schaper and Pervan, 2007; Taylor and Todd, 1995; Rogers, 1995). The qualitative study confirms the pertinence of the variable, meaning that the use of the CO is suitable to support the business activities of the individual. The same relationship is expected to apply to COs. Thus, the following hypothesis:

H1: There is a positive link between the compatibility and perceived convenience of a CO.

Object interoperability has been identified in the qualitative part of this research as a significant characteristic of a CO and a possible predictor of perceived convenience since it can be used in complementarity with other devices and on various platforms with no human intervention. Interoperability makes using the device more interesting or beneficial. We do not expect there to be a direct link between interoperability and intention to use. Thus, the following hypothesis:

H2: There is a positive link between the object interoperability and perceived convenience of a CO.

Object integration has been identified in the qualitative part of this research as a significant characteristic of a CO and a possible predictor of perceived convenience. Object integration allows automatic synchronization among devices. The relationship is similar to the one observed by Krees *et al.* (2015). It is expected to be an important antecedent of perceived convenience. Thus, the following hypothesis:

H3: There is a positive link between the object integration and perceived convenience of a CO.

The output quality of a system has been observed to be related to result demonstrability (Venkatesh and Bala, 2008; An, 2005; Jung, 2008). The same relationship is expected to apply to COs. In healthcare, it is important to be able to show the reliability and validity of a device as well as the potential benefits before using it in professional practice. Demonstrability should contribute to the perceived convenience of the CO. Thus, the following hypothesis:

H4: There is a positive link between the output quality and result demonstrability of a CO.

The output quality of a system has also been observed to be related to perceived convenience (Venkatesh and Bala, 2008; An, 2005). The CO is expected to show technical performance and provide relevant and comprehensible information. The same relationship that has been observed in other environments should contribute to the perceived convenience of COs in the health field. Thus, the following hypothesis:

H5: There is a positive link between the output quality and perceived convenience of a CO.

The result demonstrability of a system has been observed to be related to perceived convenience (Venkatesh and Bala, 2008; An, 2005; Jung, 2008). It is expected that the result demonstrability of COs leads to the perceived convenience of COs. Thus, the following hypothesis:

H6: There is a positive link between the result demonstrability and perceived convenience of a CO.

The certification of a system has been observed to be related to perceived security (Jung, 2008). It has been identified in the qualitative part of this research as indicative of the quality of a CO, which can lead to higher perceived security. Perceived security means that the users are clearly identified, possible intrusions in the system are minimal and data can be backed up and restored if needed. Given that the certification of a CO in the health field is very important, it should be related to perceived security. Thus, the following hypothesis:

H7: There is a positive link between the certification and perceived security of a CO.

The data confidentiality of a system has been observed to be related to perceived security (Jung, 2008; Shim *et al.,* 2007; Hossain and Prybutok, 2008). Data confidentiality means that the data is only accessible to authorized persons and is not shared with others. It has been identified in the qualitative part of this research as a significant characteristic of a CO and a possible predictor of perceived security. Thus, the following hypothesis:

H8: There is a positive link between data confidentiality and the perceived security of a CO.

Brand reputation has been observed to be related to social influence (Jung, 2008). It is important for the respondents and their colleagues to know the brand or company offering the CO. It has been identified in the qualitative part of this research as a significant characteristic of a CO and a possible predictor of social influence. Thus, the following hypothesis:

H9: There is a positive link between the brand reputation of a CO and social influence.

The perceived convenience of a system has been observed to be related to intention to use in earlier research (Hossain and Prybutok, 2008). When applied to healthcare, it means that the CO provides more convenient, accessible and timely information about the patient's health. Thus, the following hypothesis:

H10: There is a positive link between the perceived convenience and intention to use a CO.

The perceived security of a system (Dünnebeil *et al.*, 2012; Kim *et al.,* 2008; Hossain and Prybutok, 2008; Malhotra *et al.,* 2004) has been observed to be related to intention to use. Secure information is expected to be an important predictor of intention to use a CO in healthcare. Thus, the following hypothesis:

H11: There is a positive link between the perceived security and intention to use a CO.

The perceived playfulness of a system has been observed to be related to the intention to use a system (An, 2005; Chung and Tan, 2004; Moon and Kim, 2001). Although patient health is (certainly) not a game, enjoying using a CO for patient health seems to be a positive aspect that could lead to the intention to use a CO in healthcare as it is for other service fields. The same relationship is expected to apply to our context. Thus, the following hypothesis:

H12: There is a positive link between perceived playfulness and the intention to use a CO.

Social influence has been observed to be related to intention to use. This was observed for systems (Lombardo, 2011; Venkatesh *et al.,* 2003; Venkatesh and Bala, 2008; Thakur, 2013) and COs (Dutot, 2015). The same relationship is expected to apply to COs. Thus the following hypothesis:

H13: There is a positive link between social influence and the intention to use a CO.

The facilitating conditions of a system have been observed to be related to intention to use (Venkatesh *et al.,* 2003; Lassoued and Hofaidhllaoui, 2013; Carr *et al.,* 2010). The same relationship is expected to apply to COs. Thus, the following hypothesis:

H14: There is a positive link between the facilitating conditions and intention to use a CO.

4.2. Methodology for the quantitative study

4.2.1. Survey design

After the initial questionnaire was designed, the authors conducted a pre-test to avoid "*vagueness or fuzziness, which could ultimately affect both the reliability and validity*" of the study (Chen and Chang, 2013: 616). The pre-test was performed with 53 healthcare professionals (including the eight professionals interviewed in the qualitative study). After modifying the wording of some questions to enhance clarity, the final survey was launched. The survey was composed of ten subsections, with the first nine focusing on the main constructs of the model (see Table 3 for the list of constructs and items). The last subsection concerned demographic characteristics (Tarran, 2010). Overall, there were 41 questions (37 regarding the constructs and 4 regarding demographic characteristics).

4.2.2. Measures

The survey included 13 constructs that are antecedents to the intention to use the CO in the health industry. Most of the measures used in the survey were based on literature and were selected for their previously confirmed reliability and validity as well as their relevance to the research model and field of study. Some were created by the authors. Although the certification, confidentiality and interoperability measures were created by the researchers, they were also based on previous studies of these concepts (certification – 4 items; confidentiality – 3 items; and interoperability – 6 items), then pre-tested, and validated through the reliability and validity analyses described in the following section. Compatibility was defined using items from Jung (2008) (4 items). We followed Venkatesh and Bala (2008) and Chismar and Wiley-Patton (2003) to define result demonstrability (3 items). Output quality was assessed using 3 items inspired by Venkatesh (2000) and Jung (2008). The reputation measure was created by the authors, but was adapted from Jung (2008) who studied e-reputation (3 items). Perceived security was based on Hossain and Prybutok (2008) (4 items), and the perceived convenience items were created based on Hossain and Prybutok (2008) and Jung (2008) (3 items). Social influence was measured using Venkatesh *et al.* (2003) (4 items). Perceived playfulness was assessed using Moon and Kim (2001) and Venkatesh *et al. (*2003) (4 items). For all the remaining constructs (intention to use the CO – 3 items; and facilitating conditions – 3 items), we used the UTAUT scales as defined by Venkatesh *et al. (*2003) and adapted the questions to specifically address the CO in an e-health context. We finally pre-tested them all and tested them for reliability and validity (see subsection 5.2.2.).

All items were measured using Likert-type scales ranging from 1 (strongly disagree) to 5 (strongly agree) and were formatted as closed-ended questions with the same scale for all questions relative to the constructs. In doing so, the risks of misunderstanding and/or measurement error are reduced (Vehovar and Lozar Manfreda, 2008).

Table 3: Structure of the questionnaire

Construct	Item	Statement
Compatibility	COM1	Using a connected object suits the daily activities (well-being) of my patients
	COM2	Using a connected object is compatible with my business activities
	COM3	Using a connected object is compatible with the lifestyle of my patients
	COM4	Using a connected object is compatible with my values
Object interoperability	OIB1	Recognition of a connected object by other devices should be automatic
	OIB2	A connected object should not require any configuration
	OIB3	Data exchange between other devices and the connected object should not require a third party
Object integration	OIT1	A connected object must be able to exchange data with a computer
	OIT2	A connected object must be able to exchange data with a mobile phone
	OIT3	A connected object must be able to exchange data with other connected objects
Output quality	OQ1	The connected object I am using shows good performance (charging time, autonomy)
	OQ2	The connected object provides relevant information
	OQ3	The connected object provides understandable information
Certification	CER1	A connected object should be certified before being marketed
	CER2	I would chose a connected object with certification over one without
	CER3	I do not trust a connected object with no certification
	CER4	I think that only a connected object with certification shows quality
Confidentiality	CD1	I want the data to be accessible only to the people I choose
	CD2	I prefer not to share the data, even anonymously
	CD3	I wish to be alerted when the data is being used externally
Reputation	REP1	I prefer buying a connected object from a recognized brand
	REP2	I prefer using a connected object from a brand or company that I know
	REP3	I prefer using a connected object that a colleague knows or recommends
Perceived convenience	PC1	A connected object helps me obtain more convenient information about my patient's health
	PC2	A connected object makes health information more accessible
	PC3	A connected object helps me get information about my patient's health faster
Result demonstrability	RD1	I will have no difficulties attesting to the benefits of a connected object to others
	RD2	The benefits of connected objects are obvious to me
	RD3	I share results of the connected object on a regular basis (on social networks or blogs, for example)

Construct	Item	Statement
Perceived security	PS1	Secure applications are important when using a connected object
	PS2	Being able to identify and authenticate the user is important
	PS3	Being protected against intrusion is important
	PS4	Backing up and restoring data are important
Perceived playfulness	PP1	I enjoy using connected objects
	PP2	Time flies when using a connected object
	PP3	Using a connected object is fun
	PP4	I feel pleasure when using a connected object
Social influence	SI1	I am more inclined to use a connected object that other professionals also use
	SI2	Close colleagues approve the use of a connected object
	SI3	My relative's opinion impacts my use of a connected object
	SI4	Professionals around me think that using a connected object is a good idea
Facilitating conditions	FC1	I know how to use a connected object
	FC2	Connected objects are compatible with other systems I use
	FC3	When required, I can call technical support
Intention to use	IU1	I believe I will use a connected object regularly in the future
	IU2	I would strongly recommend using a connected object to other colleagues
	IU3	I think that using a connected object can have a positive influence on my patient's health and well-being
General questions	Connected object	Which of the following connected object are you using (multiple-choice answer): watch, mobile application (e-Health application), wristband, cardio frequency, other (personal glycemic control, etc.)
	Frequency of use	How often are you using the connected object as part of your professional relations with patients: (1) several times a day, (2) once a day, (3) several times a week, (4) once a week, (5) several times a month, (6) once a month

4.2.3. Data collection

Data collection began in June 2015 and lasted 6 weeks. Only health professionals using a CO in their relations with their patients were targeted. We first went on LinkedIn to find professional groups on COs in the healthcare industry, wearable technology professionals and e-health (e.g.: Wearable, IOT, health trackers – 3,743 members; Internet of Things Convention Europa – 340 members, Rhenatic, cluster du Numérique – 176 members). We then identified several virtual e-health communities. On these platforms, we asked if professionals would participate in a study related to factors of CO adoption in e-health. We also attended e-health events and got in touch with professionals. Finally, we asked respondents from the qualitative study to send the survey to their network. Overall, 594 email addresses were obtained.

An online survey was used because it is recognized as an essential tool for current research (Vehovar and Lozar Manfreda, 2008), but also because it presented several advantages over other forms of data collection (such as a mailed survey). Online surveys are considered a faster, simpler and cheaper means of gathering data (Bethlehem and Biffignandi, 2012).

Answers were collected using the Sphinx online© platform and by sending the link or posting the link to the questionnaire on forums and blogs, since according to Vehovar and Lozar Manfreda (2008), the diversity of platforms decreases the risk of sample selection bias. As each question had to be completed for the questionnaire to be accepted by the online survey system, we controlled for one variable: use of a CO in the doctor-patient relationship.

The questionnaire was completed online by 238 respondents out of 594 professionals contacted. The final number of usable questionnaires was 226, after the removal of 12 questionnaires from respondents who had never used a CO (9) or who had not fully completed the questionnaire (3), resulting in a final response rate of 38%. This final number of respondents satisfied the Soper (2014) and Westland (2010) minimum sample size requirements in SEM studies, given the total number of respondents, the number of latent variables (14) and the number of observed variables (47), with a probability level of .05 and an anticipated size effect of .3. Westland's minimum sample size criterion for this type of study (208 respondents) was met.

4.2.4. Descriptive statistics analysis

The population of respondents was divided almost equally among men (56.2%) and women (43.8%), and 88.3% were younger than 45 years old, which is consistent with the IFOP (2013) profile of CO users. Table 4 presents the sample characteristics and CO use.

	Characteristics	Frequency	%
Gender	Male	127	56.2%
	Female	99	43.8%
Age	22-24	34	15.1%
	25-34	123	54.6%
	35-44	42	18.5%
	45-54	19	8.4%
	55-64	6	2.5%
	More than 65	2	0.8%
Connected objects	Watch	70	31%
	Mobile app	210	93%
	Wristband	72	31.8%
	Cardio frequency	56	24.7%
	Other (personal glycemic control)	22	9.7%
Frequency of use	Several times a day	146	64.6%
	Once a day	12	5.3%
	Several times a week	54	23.8%
	Once a week	5	1.7%
	Several times a month	7	3.1%
	Once a month	2	0.8%

Table 4: Respondents' characteristics and CO use

4.3. Results

4.3.1. Choice of statistical analysis for path models

In this study, we used structural equation modeling (SEM) to assess the research model, and preferred a PLS approach over a covariance-based (CB-SEM) method, such as LISREL. PLS is considered an appropriate type of measurement model when the research context involves defining conceptual variables and implies formative conceptualization (Sartstedt *et al.,* 2016). For a small sample size such as the one in this study, previous research also stated that PLS is a better solution (Rigdon, 2016), and in the case of complex research models, PLS is preferable over other methods (Wold *et al.*, 2001).

The approach used in the analysis followed Anderson and Gerbing (1988), and more recently (O'Rourke and Hatcher, 2013). First, the construct validity was assessed, allowing for the re-specification of the measurement model. Then, the structural model was used to test the research hypotheses. SPSS 22 and SmartPLS 3 software were used to perform the analyses. Finally, we presented the nomological validity of the research.

4.3.2. Assessment of construct reliability and validity

First, the construct validity of the fourteen dimensions of the research model was assessed by performing a principal components analysis (PCA) and confirmatory factor analyses (CFA). These analyses examine reliability, convergent validity and discriminant validity, thus measuring and validating the internal consistency of the measures. Observable variables that measure a reflective construct must be unidimensional to be considered unique values (Gefen *et al.,* 2000). The reliability and convergent validity of the constructs are typically satisfied by retaining variables with alphas that exceed the recommended value of 0.7, that exceed the value of 0.7 for composite reliability (for an exploratory study, 0.6 can be accepted; Hair *et al.,* 2011) and that exceed 0.5 for AVEs (Gefen *et al.,* 2000; Chen and Chang, 2013). Data normality was also considered sufficient after skewness, kurtosis and Kolmogorov-Smirnov normality tests were applied. The results led to the conclusion of data normality.

Based on the results, the measurement model was refined by deleting items that did not sufficiently load on their associated dimension ($\lambda<0.5$). As such, 1 of the 3 items assessing facilitating conditions (FC3) was deleted, as well as 1 of the 3 items for object integration (OIT1), 1 of the 4 items for perceived playfulness (PP2), 1 of the 4 items for perceived security (PS4), 1 of the 3 items for result demonstrability (RD3), and 2 of the 4 items measuring social influence (SI1 and SI3).

Table 5 lists the standardized item loadings, average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha values for the final items and constructs (the complete table of cross-loadings is presented in Appendix 2). Notably, the AVEs, CR and alphas exceed the recommended values, showing good convergent validity and reliability.

The final property to verify before applying the structural model was discriminant validity, which illustrates the extent to which each construct in the research model is unique and different from the others (Campbell and Fiske, 1959). The shared variance between a construct and other constructs must be smaller than the square root of the AVE (see Table 6). All fourteen constructs met this criterion, thus showing good discriminant validity (Fornell and Larcker, 1981). Then we controlled the HTMT (heterotrait-monotrait

Construct	Item	Mean	S-D	Standardized loading	AVE	CR	Cronbach alpha
Certification (CER)	CER1	4.230	.79	.797	.605	.859	.779
	CER2	4.160	.84	.835			
	CER3	3.610	.93	.822			
	CER4	3.630	1.09	.643			
Confidentiality (CD)	CD1	4.420	.84	.650	.538	.775	.763
	CD2	3.470	1.10	.703			
	CD3	4.690	.57	.835			
Compatibility (COM)	COM1	3.770	.95	.856	.539	.821	.711
	COM2	4.430	.81	.615			
	COM3	3.710	.96	.776			
	COM4	3.360	.92	.665			
Object interoperability (OIB)	OIB1	3.890	.96	.791	.599	.818	.769
	OIB2	4.320	.75	.757			
	OIB3	4.370	.69	.774			
Object integration (OIT)	OIT2	3.630	.78	.912	.795	.886	.745
	OIT3	3.960	1.13	.872			
Result demonstrability (RD)	RD1	4.010	.83	.941	.878	.935	.862
	RD2	3.860	1.01	.934			
Output quality (OQ)	OQ1	3.690	.89	.800	.640	.842	.719
	OQ2	3.850	.75	.840			
	OQ3	4.020	.67	.758			
Reputation (REP)	REP1	3.410	1.14	.778	.589	.810	.788
	REP2	3.820	1.12	.530			
	REP3	3.920	.91	.863			
Perceived security (PS)	PS1	4.410	.87	.860	.673	.860	.759
	PS2	4.260	.99	.778			
	PS3	4.580	.66	.821			
Perceived convenience (PC)	PC1	3.990	.76	.853	.650	.847	.731
	PC2	3.940	.86	.855			
	PC3	4.220	.71	.701			
Social influence (SI)	SI2	3.250	.75	.770	.722	.837	.734
	SI4	3.290	.66	.922			
Perceived playfulness (PP)	PP1	3.900	.91	.801	.733	.892	.817
	PP3	3.870	.82	.873			
	PP4	3.860	.88	.892			
Facilitating conditions (FC)	FC1	4.370	.67	.745	.647	.772	.727
	FC2	4.390	.69	.899			
Intention to use CO (IU)	IU1	3.870	1.03	.822	.755	.902	.838
	IU2	4.070	.89	.888			
	IU3	3.880	.92	.895			

Table 5: Assessment of construct validity

Table 6: Discriminant validity of constructs

Construct	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Perceived playfulness	.86													
2. Certification	-.03	.78												
3. Perceived convenience	.52*	-.10	.81											
4. Compatibility	.54*	.03	.53*	.73										
5. Facilitating conditions	.07	-.16	-.01	.10	.80									
6. Confidentiality	.20	.27	-.12	.08	-.02	.73								
7. Object integration	.02	.07	-.12	.06	.09	.21	.89							
8. Intention to use CO	.44*	.05	.55*	.60**	.01	.05	.17	.87						
9. Object interoperability	.17	-.02	.18	.16	.22	.14	.52*	.29	.77					
10. Output quality	.50*	.12	.48*	.65**	.03	.04	-.04	.45	.05	.80				
11. Reputation	.29	.14	.12	.11	-.06	.15	.17	.07	.16	.19	.76			
12. Result demonstrability	.52*	-.02	.53*	.59**	.10	.12	.13	.83***	.26	.47	.12	.93		
13. Social influence	.34	.06	.27	.30	-.12	.20	.19	.40	.16	.34	.23	.43	.85	
14. Perceived security	.20	.44*	-.09	.11	-.14	.50*	.05	-.00	-.05	.14	.10	.02	.12	.82

Nota. Diagonal: (average variance extracted)$^{1/2}$ = $(\Sigma\lambda_i^2/n)^{1/2}$
Sub-diagonals: correlation = (shared variance)$^{1/2}$
Significant correlations: *: p<0.05), **: p<0.01, *** p<0.001

ratio). In order to prove the discriminant validity of the model and reflective constructs, the HTMT value must be well below .85, which is the most conservative HTMT value (Hair *et al.,* 2014). As this was the case for all HTMT values (see Appendix 3), we can therefore conclude that discriminant validity was established. We also checked for HTMT inference criteria. To do so, we performed the bootstrapping routine and controlled the upper confidence interval limit. Results showed that all values were well below the 1 value (Hair *et al.,* 2014). Thereby, we found that HTMT inference criteria indicated that all HTMT values were significantly different from 1. These two complementary analyses allowed us to establish the discriminant validity of the model. We finally checked for possible multicollinearity and verified the variance inflation factor (VIF). All values were less than 5 (Hair *et al.,* 2011), meaning that there was no multicollinearity between the constructs.

4.3.3. Assessment of the structural model

The research hypotheses were tested by assessing the direction, strength and level of significance of the path coefficients (betas) as estimated by PLS (shown in Figure 3) through a bootstrap analysis. As PLS-SEM does not presume that the data is normally distributed, using this technique enables the estimated coefficients to be tested for their significance. The fact that the variables in the model explained a significant amount of variance (36.1%), thus providing overall support for the research model and the adoption theories that it represented is of primary interest. Furthermore, analysis of the research model showed that 10 of the 14 hypotheses were confirmed, as summarized in Table 7.

4.3.4. Nomological validity of the research

Nomological validity is a form of construct validity (Peter, 1981) that results from a stream of solid theoretical developments (Cronbach and Meel, 1955). Nomological validity refers to "the degree to which the measure of the construct relates to measures of other constructs in a manner that is consistent with theory" (Houston, 2004). It is starting to be more frequent in organizational research, and IS in particular, but has

Figure 3: Test of the research model

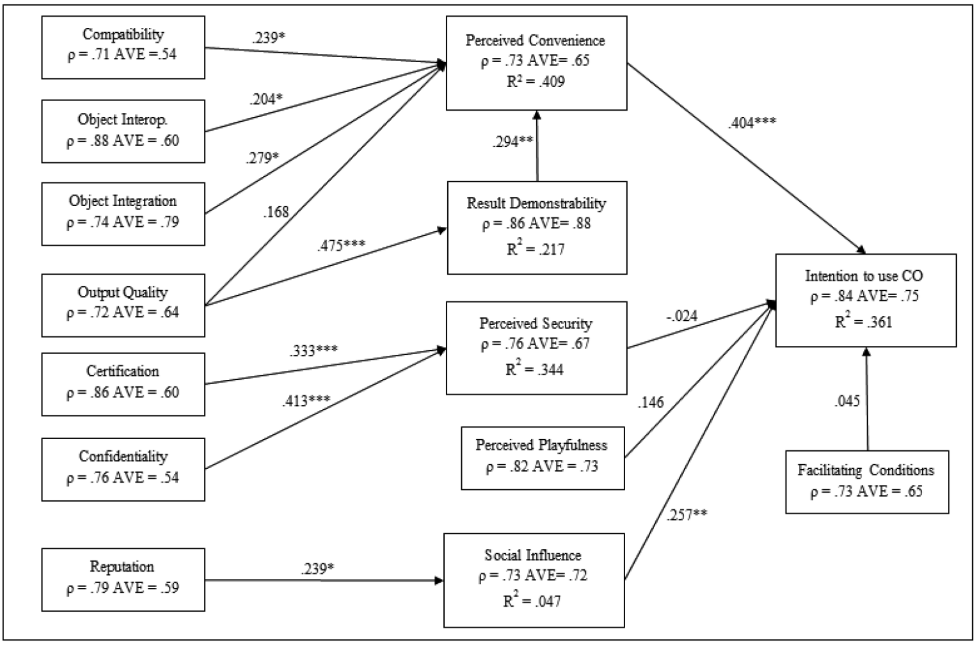

Table 7: Summary of hypotheses testing

Hypothesized relationship	Path coefficient	T-value	Validation
H1: Compatibility → Perceived convenience	.239*	2.303	Accepted
H2: Object interoperability → Perceived convenience	.204*	2.274	Accepted
H3: Object integration → Perceived convenience	.279*	2.090	Accepted
H4: Output quality → Perceived convenience	.168	1.463	Rejected
H5: Output quality → Result demonstrability	.475***	4.894	Accepted
H6: Result demonstrability → Perceived convenience	.294***	2.746	Accepted
H7: Certification → Perceived security	.333***	3.516	Accepted
H8: Confidentiality → Perceived security	.413***	4.195	Accepted
H9: Reputation → Social influence	.239*	2.026	Accepted
H10: Perceived convenience → Intention to use CO	.404***	4.396	Accepted
H11: Perceived security → Intention to use CO	-.024	.300	Rejected
H12: Perceived playfulness → Intention to use CO	.146	1.478	Rejected
H13: Social influence → Intention to use CO	.257**	2.523	Accepted
H14: Facilitating conditions → Intention to use CO	.045	.487	Rejected

*: p < .05 **: p < .01 ***: p < .001

been assessed in different ways by researchers (Liu *et al.,* 2012). While nomological validity can be assessed quite directly for a specific construct as a part of a nomological network, it is more complex to apply to a network of new constructs. To answer the *research question*, the nomological validity of the research had to be assessed within a specific context and according to several constraints: a new technology, a new environment (e-health), a new research method (mixed methods) and several constructs.

In this research, nomological validity was verified by following the three-step construct validation process (adapted from O'Leary-Kelly and Vokurka, 1998 by Houston, 2004). First, the theoretical specification of the constructs was established by specifying the domain (Table 1) and nomological network (Figures 1, 2). The most valid predictive models of user acceptance theories were selected, and only the items relevant to the research were kept while those unrelated to the research object (such as attitude, effort expectancy, image, job relevance computer self-efficacy, external control, accessibility and documentation) were removed from the initial scales. Multiple interviews were conducted to validate and improve the initial model. Then, the ability of the indicators to measure the constructs by testing the reliability, unidimensionality, content validity, convergent and discriminant validity, was tested and met the acceptability criteria. The suitability of the measures within a theoretically specified network of constructs was then evaluated by analyzing their validity within the nomological network; this analysis is presented in the discussion part that follows. The accepted hypotheses (rejected null hypotheses) are explained by referring to the supportive literature, giving ground to the nomological validity of the research. The rejected hypotheses are also insightful since they inform about elements of the theory that could have played a significant role in explaining the dependent variable but did not. Finally, the proportion of variance explained by the model was 36% and considered satisfactory.

5. DISCUSSION

5.1. Discussion of findings

This study, consisting of both an exploratory and confirmatory part, led to several important findings regarding the factors affecting the adoption of connected objects (COs) by professionals in e-health.

First, perceived convenience is positively related to the intention to use a CO in e-health. This finding implies that the higher the perceived convenience of connected devices is, the greater the professional intention to use the technology is, supporting Hossain and Prybutok's findings (2008). This result was first expressed in the qualitative study, when respondents mentioned looking for something simple, easy to use and resulting in better performance of their tasks. The quantitative survey confirmed this relationship (.409, $p<0.001$).

This paper, however, goes further as it reinforces the importance of four factors as direct determinants of perceived convenience in a new context of study and from a professional perspective: compatibility, object interoperability, object integration and result demonstrability. While compatibility and result demonstrability were already presented in literature as possible determinants, object interoperability and object integration are new determinants presented as part of this study. Output quality, an indirect determinant, does not seem to have a direct influence on perceived convenience, as presented by Venkatesh and Bala (2008) in their inaugural work on TAM3.

Regarding the antecedents of perceived convenience, the first factor is the degree of compatibility of the CO with the user's activities, which is significantly linked with perceived convenience (H1). This relationship indicates that the more practical and useful the CO is in a person's professional and personal life, the more convenient it is perceived and the more likely it will be used. This result supports the proposal of Ajzen and Fishbein (1980). The second factor, with the most important influence on perceived convenience, is result demonstrability (H6). The extent to which professionals can clearly identify the benefits of the connected device seems to be a key convenience factor and important to the device's use, as suggested by Rogers (1995). What is quite intriguing though is that output quality is not sufficient for a user to increase his or her perceived convenience of the CO (H4). Previous research obtained mixed results. When Venkatesh (2000), An (2005) or Jung (2008) pointed out the positive relation between the two concepts, Venkatesh and Bala (2008) showed the opposite. In this research, our results follow the later conclusion; however, one must notice the indirect influence of output quality on perceived convenience through result demonstrability (H5). Thus, it may be insufficient for a user to obtain quality output if there are no results shown from his practice. This is in keeping with the trend from authority-based to evidence-based medicine in healthcare research where results must be statistically demonstrated before concluding in the effectiveness of a device or treatment (Bland and Peacock, 2000). Perceived convenience depends on how the output is used to obtain results and the way in which these results can be shown and shared in professional circles.

The second and third antecedent factors of perceived convenience are new. First, the interoperability of the device (object interoperability) is positively linked (H2) to perceived convenience. It indicates that a device should not require a specific configuration, should be simple to connect (no help from a third party required) and should be connected automatically. Hypothesis 3 indicates a positive correlation between integration of the device and perceived convenience. This confirms what the qualitative survey highlighted, namely that the CO should be automatically synced with other devices (e.g., other objects, laptops, and computers), otherwise the perceived use of the product may be altered. These two new factors highlight the importance of the technological adaptability of the device and the fact that adding a new device should not be made at the expense of the quality of use. These features should be implemented on any connected object by default as they appear to influence factors in the adoption process.

The second element to discuss relates to security. Contrary to earlier findings relative to connected devices in other contexts (Dutot, 2015), perceived security does not influence the professional's intention to use a CO (H11). Data showed that the respondents believed that the CO used was secure, which is reflected in its high construct mean (4.42/5) and negative skewness. As noted by the respondents, they may not have perceived why their device security could be threatened or may not have been afraid of a security breach. Despite this attitude, professionals seemed rational in establishing a relationship between certification, confidentiality and security, expressing that more certification and more confidentiality led to more security (as supported by H7 and H8). However, some respondents may have considered security to be important and related to intention of use, but their opinions may have been counterbalanced by other respondents who were not afraid of a security breach and therefore intended to use the connected device anyway. In any case, COs definitely store and transmit highly sensitive information. A security breach would leave unprotected sensitive patients personal data. In terms of risk, this is a case of low probability – high consequence scenario. How are the data protected? Are they encrypted? Who has access to the data? Where are they stored? What is their market value for a hacker? What are the potential financial and personal consequences of a security breach for the patient, for the hospital? This finding (no significant relationship) related to security calls for further investigation.

Lack of a significant link between perceived playfulness and the intention to use the CO is highlighted through H12. It contrasts with the results from An (2005) and the ICTAM. This may be explained by the respondent profile and the purpose of the CO use in their setting. Indeed, respondents are healthcare professionals who tend to use devices in a professional way. The level of playfulness was intended to measure the degree to which devices attract patients and the perception of pleasure attached to the object. As the participants used the CO in their day-to-day activities, perhaps the device playfulness was not essential as long as the device was effective. It may also be that, following the initial lure of the device, the feeling of playfulness sentiment was quickly replaced by the usefulness and practicality of the device for health-related professional use. Playfulness may be a positive characteristic in other environments, such as gaming or recreation, but in this case, it does not appear to be necessary.

Social influence is positively related to the intention to use a CO (H13). This result is consistent with previous studies on technology (Venkatesh *et al.,* 2003), but confirms its importance in a brand new context. It also highlights the fact that recognition by peers is crucial for almost every new product and that companies may target social influencers (such as opinion leaders, bloggers or leaders) to increase adoption. Based on the qualitative interviews, the reputation variable was added to the model as an antecedent to social influence. Results show a positive link between the two (H9), meaning that a seller's reputation and the characteristics of the product also contribute to the importance of social influence on the intention to use. This result, new in this e-health context, may be explained by the novelty of COs that are not widely distributed and used versus those that are. When buying this type of product, health professionals rely on information that help them make informed decisions, such as brand reputation or the brand recognition level or perceptions.

Finally, no significant relationship is found between facilitating conditions and the intention to use a CO (H14). Venkatesh *et al. (*2003) contend that an individual's intention to use a technology increases when third parties also use it; however, the results of this study do not support that claim. As expressed in the qualitative study, the users may have remained in the discovery mode without requiring any additional technical support yet. On the other hand, and this seems to be a more realistic possibility, the quality of the device may have been so high and the product so easy to use that the users did not require any particular facilitating condition. This possibility is reflected in the high variable mean (4.38/5).

5.2. Implications for research and practice

This study has several implications for further research and practice. Previous studies have explored the adoption of technology, connected objects and information systems in the health industry, but little research has been conducted on CO adoption in the e-health industry. Thus, this is one of the few studies, if any, that has addressed this important issue.

The findings contribute to the academic field in four different ways. The first contribution is to the health field and involves the identification of additional factors of adoption. Results respond to Holden and Karsh's request (2010) when they stated that the healthcare context should use models specifically developed for it. Although results show that not every item significantly influences the intention of use, they acknowledge the fact that there is a need for more constructs in the e-health context, including compatibility, reputation, or result demonstrability, to explain technology adoption more efficiently. Second, this study adds to the literature on CO adoption by exploring it in a new context (health) and presenting new drivers. It highlights the fact that general models of adoption may not be suitable and that there is a real need for adaptive models, in other words, a combination of different existing models or the creation of new ones. Third, this study contributes to the knowledge of technology adoption by testing theoretical constructs. As suggested by prior researchers, there is a persistent call for more empirical validation of well-known theories in new settings (Jawahar and Harindran, 2016). By enhancing models such as UTAUT, ICTAM and e-HAM, this study opens the way to context-related research. Lastly, this explorative study contributes to the use of a mixed methods approach in the IS field, which helps develop a deeper understanding of a specific phenomenon (Venkatesh *et al.,* 2013). Using interviews as a qualitative approach was useful in refining the conceptual model, exploring the factors of adoption and generating five new constructs. Quantitative research was then used to test and validate the resulting factors. In doing so, the antecedents of antecedent factors could be identified and tested.

This work also has important practical contributions, as the findings may be useful for professionals and CO developers regarding the adoption of COs in e-health. More precisely, the results highlight the importance of convenience and social influence. Companies should target influencers and professional leaders to promote their products (professional conferences, associations, etc.) and develop products with regard to their interoperability with other devices and compatibility with users' daily activities. The reputation of the company should also be taken into account. Finally, although security issues were not significant predictors of intention to use a CO in this study, this does not indicate that they are not important in their own right. Due to the low incidence of security breaches, they may not be observed in this type of research; however, researchers can continue to insist on the importance of privacy and confidentiality of the data gathered by these devices in e-health and other service sectors. Security breaches may not have occurred to the respondents yet, but they can have critical material and financial consequences on the targeted organizations, professionals and patients.

5.2.1. Limitations

The findings must be interpreted in the context of the limitations of this research. A first limitation is the need to refine the predicting variables in order to better understand their effects on attitude formation and the adoption decision. Another limitation is the use of a convenience sample. In this study, we focused on professionals who use a CO in their relation with their patients. Although our approach is appropriate for an exploratory study, its results are preliminary. While the qualitative part of the mixed methods approach opened the way to the inclusion of new factors in the acceptance model, it initiated the need for an additional nomological validation phase that will need to be conducted to further validate the final model. Thus, a replication of the study would provide greater empirical support for its findings. Future studies can also extend the model by incorporating constructs that increase its predictive power. The strong support for the final model suggests that it delivers a useful starting point for further research in terms of the adoption of COs in e-health.

6. CONCLUSION

E-health has been recognized as a key factor for economic success in developed countries such as the EU and USA in the coming years; connected objects are likely to be the next industrial revolution for most industries as well as key factors of change in the health field. This study aimed to identify the factors affecting the adoption of COs in the e-health context. It extends current knowledge regarding the factors of adoption of CO technology in the health sector. By using a mixed methods approach, this study answers an important call for research in the IS field. In particular, it identifies several factors that contribute to the intention to use the connected objects. These factors include perceived convenience, social influence, compatibility, object interoperability, object integration, output quality, result demonstrability and reputation. Finally, this study provides important suggestions for the successful adoption of COs by professionals in the e-health sector.

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APPENDIX

APPENDIX 1: INTERVIEW GUIDE

Step 1: General and specific questions

Please present yourself (profession, age, digital knowledge, etc.)

- Which connected objects related to your current activity do you regularly use?
- How often do you use them (per day, week)?
- How do they benefit your work?

What are their advantages compared to your previous practice? What are their disadvantages?

- What overall perception do you have of connected objects?

Back in time: Looking back at when you first decided to use a CO

- What is the first object that you decided to use? Why that one (colleagues, personal desire, patients' requests, etc.)?
- Which criteria where crucial in your decision (compatibility, testing, curiosity, utility, game)?
- Tracing the factual process step by step, what ultimately made you decide to test / use a connected object? What was the main break before this first use?
- Do you still have some issues regarding the use of connected objects in your business?

Trust

1. The product and its performance

- How much do you trust the reliability of the data?
- Are you presenting the data to your patients?
- What kind of spontaneous trust do you give to new connected objects that come out on the market?
- Do you need to test them or have them tested before using them?

2. Security and data protection

- How much do you trust the security of the data transiting through the CO?
- Do you think that the data is collected and stored securely? If not, do you use a particular protocol to address this risk?
- Do you think there may be a high risk of leakage or unsolicited recovery of data at any given time between the measurement phase and storage phase?

Social influence

- Do other colleagues around you use connected objects? If so, did they start before or after you? Did you talk to each other before or after your first use? Which criteria convinced you the most? Which ones didn't?
- Are you presenting the results to other colleagues?

- Have you read articles or comments left by other professionals in your sector? On which media did you gather information (ads, articles, blogs, tests, professional conferences, specialized press, others)?

Do you have anything else to add?

Step 2: Presentation of the model and discussion

Take a look at the following graph (Figure 1) and tell us what you think about it. What do you think about the link between the constructs? Do you think that there is anything missing? If so, how would you integrate them in the figure?

APPENDIX 2

Cross-loadings (1. Perceived playfulness; 2. Certification; 3. Perceived convenience; 4. Compatibility; 5. Facilitating conditions; 6. Confidentiality; 7. Object integration; 8. Intention of use; 9. Object interoperability; 10. Output quality; 11. Reputation; 12. Result demonstrability; 13. Social influence and 14. Perceived security)

Construct	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
CD1	.328	.126	.112	.315	-.069	**.650**	.255	.259	.246	.182	.170	.287	.187	.346
CD2	.009	.292	-.149	-.102	-.027	**.703**	.041	-.028	-.087	-.022	.012	-.015	.097	.339
CD3	.047	.194	-.205	-.021	.036	**.835**	.164	-.085	.155	-.052	.150	.013	.161	.419
CER1	-.094	**.797**	-.035	.016	-.051	.272	.059	.001	.048	.093	.104	-.056	.012	.356
CER2	-.058	**.835**	-.150	.022	-.074	.163	.076	.025	-.075	.041	.137	-.061	-.038	.370
CER3	-.053	**.822**	-.184	-.038	-.193	.263	.072	.044	-.070	.031	-.017	-.027	.097	.378
CER4	.135	**.643**	.096	.141	-.212	.148	.003	.127	.027	.275	.252	.105	.156	.277
COM1	.426	.048	.532	**.856**	.042	-.038	.027	.529	.128	.577	.051	.515	.244	.024
COM2	.464	-.066	.311	**.614**	.055	.097	.053	.394	.211	.452	.085	.354	.114	.114
COM3	.404	.106	.326	**.776**	.129	.175	.071	.406	.121	.467	.044	.404	.267	.195
COM4	.310	.002	.355	**.665**	.105	.070	.063	.436	.054	.418	.160	.434	.263	.042
FC1	.035	-.038	.024	.011	**.545**	.127	-.031	.001	.171	.037	-.059	.107	.093	-.102
FC2	.077	-.166	-.021	.107	**.999**	-.030	.101	.020	.220	.033	-.064	.103	-.135	-.145
OIT2	.027	.072	-.117	.078	.104	.212	**.912**	.175	.362	-.048	.116	142	.189	.026
OIT3	.013	.054	-.098	.038	.065	.159	**.872**	.142	.600	-.026	.209	.104	.148	.079
OIB1	.110	-.091	.165	.064	.054	.099	.412	.192	**.791**	-.003	.114	.221	.194	-.163
OIB2	.168	.068	.126	.188	.128	.253	.412	.254	**.757**	.172	.131	.215	.211	.100
OIB3	.141	-.020	.135	.161	.360	.005	.400	.254	**.774**	-.033	.146	.187	-.023	-.021
IU1	.259	.033	.473	.455	.054	-.027	.096	**.822**	.201	.354	.034	.589	.324	-.045
IU2	.518	.062	.466	.603	.018	.064	.212	**.888**	.273	.443	.050	.721	.306	.038
IU3	.375	.051	.498	.526	-.016	.096	.155	**.895**	.294	.379	.110	.846	.429	-.011
REP1	.148	.196	.057	.053	-.098	.072	.178	.051	.029	.147	**.793**	.080	.188	.095
REP2	.188	.301	-.090	.029	-.087	.257	.193	-.042	.108	.038	**.667**	-.005	.068	.128
REP3	.325	-.016	.184	.133	-.003	.126	.095	.099	.225	.196	**.833**	.149	.227	.064
OQ1	.452	.014	.414	.529	-.016	.072	-.091	.424	-.091	**.800**	.039	.420	.229	.140
OQ2	.349	.166	.376	.576	.032	-.006	-.008	.373	.103	**.840**	.134	.389	.244	.117
OQ3	.417	.133	.376	.472	.075	.030	.007	.273	.131	**.758**	.320	.322	.360	.075
PC1	.384	-.083	**.853**	.462	-.008	-.185	-.181	.519	.147	.391	.084	.487	.216	-.166
PC2	.435	-.156	**.855**	.478	-.027	-.059	-.034	.462	.096	.471	.062	.471	.320	-.075
PC3	.471	.011	**.701**	.352	-.012	-.021	-.063	.327	.228	.306	.167	.300	.098	.063
PP1	**.801**	-.012	.412	.540	.030	.167	.070	.381	.187	.507	.143	.472	.259	.203
PP3	**.873**	-.012	.455	.442	.020	.199	.026	.419	.143	.380	.299	.451	.356	.169
PP4	**.892**	-.072	.473	.393	.166	.144	-.048	.329	.120	.419	.327	.410	.266	.151
PS1	.155	.366	-.071	.000	-.112	.539	.011	-.019	-.055	.132	.103	.039	.148	**.860**
PS2	.242	.357	-.030	.290	-.161	.310	.086	.067	.026	.201	.114	.077	.122	**.778**
PS3	.121	.382	-.120	.029	-.096	.357	.056	-.051	-.087	.019	.046	-.052	.023	**.821**
RD1	.486	.015	.511	.575	.131	.084	.141	.820	.246	.457	.180	**.941**	.389	-.042
RD2	.494	-.058	.483	.529	.066	.148	.119	.739	.259	.432	.054	**.934**	.423	.094
SI2	.315	-.059	.366	.277	-.075	.250	.101	.252	.121	.305	.145	.281	**.770**	.120
SI4	.291	.126	.156	.255	-.130	.130	.204	.415	.160	.291	.244	.431	**.922**	.098

APPENDIX 3: HETEROTRAIT-MONOTRAIT RATIO

Construct	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Perceived playfulness														
2. Certification	.14													
3. Perceived convenience	.69	.24												
4. Compatibility	.71	.17	.72											
5. Facilitating conditions	.09	.18	.04	.14										
6. Confidentiality	.31	.42	.32	.36	.17									
7. Object integration	.07	.12	.15	.09	.11	.32								
8. Intention of use	.53	.09	.69	.78	.07	.24	.22							
9. Object interoperability	.24	.16	.28	.27	.35	.38	.76	.40						
10. Output quality	.66	.22	.67	.61	.13	.19	.07	.57	.21					
11. Reputation	.38	.35	.26	.19	.11	.31	.28	.11	.24	.28				
12. Result demonstrability	.62	.10	.65	.74	.16	.25	.17	.67	.35	.59	.14			
13. Social influence	.48	.17	.44	.46	.22	.37	.26	.53	.32	.52	.29	.56		
14. Perceived security	.26	.58	.17	.26	.20	.75	.09	.10	.19	.19	.17	.09	.18	