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Physicians' motivations to use mobile health monitoring: A cross-country comparison

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Abstract

While mobile device receives increasing attention as a practical tool to remotely check patients' health, little research has shed light on physicians' acceptance of this information and communication technology. This study attempts to fill this research gap by examining how Japanese and Spanish physicians perceive a series of factors associated with mobile diabetes monitoring acceptance, and whether any differences exist in these perceptions between the countries due to different levels of physician scarcity, which is operationalized as the number of physicians available per 10,000 population. The hypotheses were tested by empirical surveys in Japan and Spain. In total, 471 and 497 usable responses were obtained from Japanese and Spanish physicians, respectively. In both countries, physicians were likely to embrace clinical expectations (perceived value) and appreciate the ability to check patients' health remotely (ubiquitous control) as the main benefits of mobile diabetes monitoring. In terms of cross-country comparison, the influence of personal innovativeness on perceived value and ubiquitous control was stronger in Japan (greater physician scarcity), compared with Spain (less physician scarcity).

Keywords: health information technology, mobile health, physicians, technology assessment, telemedicine

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1. Introduction

Following unprecedented growth in information and communication technology (ICT) during the past decade, health-care experts throughout the world have explored the possibilities of utilizing telemedicine (Aas 2003; Holden and Karsh 2009). Telemedicine is defined as health-care service, consultation, and expertise delivered via a telecommunications medium, over any distance (Priyan 2013).

The gradual but steady shift toward telemedicine is a clear response to important overall problems that most industrialized countries have been facing—the increasing elderly population and changing dietary habits. Such an aging population is a likely cause of substantial increases in health-care expenditures, while dietary changes have been causing an increase in chronic diseases, such as diabetes and hypertension (Seto *et al.* 2011). In addition, rural residents often confront limited accessibility to care outside of hospitals, due to the absence of sophisticated outpatient and diagnostic services (Iezzoni *et al.* 2006). Furthermore, there are difficulties in recruiting and retaining personnel in health-care services in general, and in home and elderly care in particular (Koch 2006).

Among the various alternative telemedicine systems, mobile health monitoring has been receiving increasing attention in recent years (Chatterjee *et al.* 2009, Junglas *et al.* 2009, Sneha and Varshney 2013, Wu *et al.* 2011.). A review of the diabetes self-monitoring industry by Chomutare *et al.* (2001) found 101 applications on the online vendor markets, including those for insulin and medication recording, data export and communication, diet recording, and weight management. According to a survey by PricewaterhouseCoopers (PricewaterhouseCoopers 2010), as much as 40% of U.S. adults would pay for a mobile health monitoring service that sends health information directly to their doctor. Even more

importantly, 87% of physicians prefer that their patients be able to track and/or monitor their health at home, particularly their weight, blood sugar levels, and vital signs. Furthermore, 57% of physicians said they would like to use remote devices to monitor their patients outside of the hospital (PricewaterhouseCoopers 2010). Such data implies that mobile-based medical decision support has higher potential, and needs to be explored further in terms of its acceptance and feasibility.

This study examines physicians' motivations to use mobile health monitoring in two ways. First, focusing on a monitoring system for one of the most common causes of death, type 1 diabetes (National Institutes of Health 2009), we elaborate and test an explicative model that consists of the motivations to use mobile diabetes monitoring, including *personal innovativeness in ICT*, *innovation characteristics*, and *usage intention*. Second, the study compares physicians' answers to a questionnaire survey in two industrialized countries, Japan and Spain, where we collected 471 and 497 usable responses, respectively. In doing so, we posit that *physician scarcity*, which is conceptualized as the number of physicians per 10,000 population, moderates the relationships among these constructs. Physician scarcity is expected to drive a serious need for ICT-based health-care monitoring. The results provide some important implications on mobile diabetes monitoring from the physicians' perspectives.

A comparative study across these countries is motivated by two factors. First, both Japan and Spain possess a comprehensive public social security system that fully covers basic health-care costs, with very similar medical expenditure as a percentage of GDP as well as per capita. However, there is an important difference in terms of the relevant medical statistics, such as the number of physicians per 10,000 population or per hospital bed (Table 1). Second, both countries suffer from accelerating aging with a low birth rate, and will reach a very similar societal structure in the near future. Many scholars in demography indicate that

the ratio of effective labourers to effective consumers in Japan and Spain will plunge in 20 years (Lee and Mason 2010). Thus, monitoring chronic disease among the elderly, such as diabetes, would become a serious social and economic issue in both countries in the future. Due to these similarities and differences in medical and societal factors, we believe that our research provides reasonable justification for our hypotheses testing.

<Please insert Table 1 around here>

The remaining part of the manuscript is structured as follows: We first provide a general background on mobile diabetes monitoring. Next, we present our baseline research model with a series of hypothesized relationships among the key constructs, and then formulate our cross-country comparison hypotheses. We then describe the methodology used in this study in detail, and present the hypotheses testing results. On this basis, we draw theoretical and managerial implications. In closing, we recognize important limitations, while suggesting future research directions.

2. Mobile diabetes monitoring

Mobile health monitoring has received much attention from the health-care industry, as consumers are increasingly relying on mobile applications to help them manage their health and fitness (Tode 2013). Compared with other telemedicine tools, mobile health monitoring provides a more personalized and flexible means of control through which physicians can get immediate medical data and achieve continuous control over patients' health. One of the advantages of this monitoring system for patients is the unobtrusive, prolonged ambulatory monitoring, which allows for improved quality of life and faster response in the case of emergencies (Istepanian *et al.* 2004).

One of the more prevalent chronic diseases today is diabetes mellitus, characterized by an abnormal index of blood glucose (hyperglycemia). According to estimates by the World Health Organization, more than 347 million people in the world have diabetes. This

figure is expected to double before 2030, and related deaths will multiply by two between 2005 and 2030 (World Health Organization 2012). In pursuing quality care in diabetes, ICT enhances efficient collaboration between physicians and patients (Krishna and Boren 2008). In particular, an increasing number of specialists view mobile device as an effective tool for diabetes management at a distance (Liang *et al.* 2011, Liu and Ogwu 2012). Hence, mobile diabetes monitoring has received much attention in recent years because it enables the following functions: (a) self-monitoring of blood glucose, weight, physical activity, diet, insulin and medication, and blood pressure; (b) disease-related data export and physician–patient communication; and (c) synchronization with personal health record systems at the hospital’s information hub (Chomutare *et al.* 2001).

The literature on mobile-based medical decision support has been steadily increasing, while important studies on mobile diabetes monitoring have been published in patient care or health-care settings (Chatterjee *et al.* 2009, Junglas *et al.* 2009, Sneha and Varshney 2013, Wu *et al.* 2011). In contrast, much of the research in the medical informatics deals with clinical trials. According to a literature review by Liang *et al.* (2011), 22 clinical trials have been documented between 1990 and 2010. Their meta-analysis concluded that research on type 2 diabetes led to significant reduction of HbA1c, compared with research on type 1 diabetes, with reduced costs ranging from less than 1€ to 10€ per month (e.g., Kollmann *et al.* 2007, Rossi *et al.* 2009). Kollmann *et al.* (2007) conducted a pilot test with 10 type 1 diabetes patients. The patients perceived mobile diabetes monitoring as easy to learn and practical for regular daily use. Similar results were reported by García-Sáez *et al.* (2009), Kim *et al.* (2010), and Peña *et al.* (2009), among others, who collectively reported a high level of patients’ acceptance and favourable attitude toward the system.

These studies crystallize two important research needs. First, past studies focused on patients' points of view, while little attention was paid to physicians' perspectives. Second, cross-country comparison on mobile diabetes monitoring is almost non-existent.

3. Research model

3.1. Overview of the model

Figure 1 shows our research model, which synthesizes a stream of past studies based on diffusion of innovation theory (Agarwal and Prasad 1998, Rogers 1983, Yi *et al.* 2006). According to this theory, there are five elements affecting a new innovative technology that will each partly determine whether adoption or diffusion of a new activity will occur: relative advantage, compatibility, complexity, trialability, and observability (Rogers 1983). This study focuses mainly on relative advantage and compatibility.

The way in which physicians perceive innovation characteristics of mobile diabetes monitoring is largely dependent on their *personal innovativeness in ICT*, which can be defined as the propensity to be in quest of novel ICT. In general, innovation diffusion research has long recognized that highly innovative individuals are active information seekers for new ideas (Lu *et al.* 2005). In our study context, physicians who are prone to seek innovative ICT would be more motivated to use mobile diabetes monitoring. Next, drawing upon the diffusion of innovation theory, Yi *et al.* (2006) proposed three *innovation characteristics* of a new ICT as the direct drivers of usage intention. More specifically, their model examined usefulness (relative advantage in the diffusion of innovation theory), ease of use (complexity), and compatibility as determinants of the innovation's adoption outcomes. Similarly, this study focuses on relative advantage and compatibility of mobile diabetes monitoring. Rogers (1983) defines relative advantage as the degree to which an innovation is perceived as better than the idea it supersedes. We envisage relative advantage of mobile diabetes monitoring as two main factors, *perceived value* and *ubiquitous control*. Here,

perceived value is understood as utility and advantage of the device, while ubiquitous control refers to the ability to check a patient's health regardless of time and place. We view *compatibility* of a new ICT as a measure of the degree to which an innovation is perceived as being compatible with existing capability, values, past experiences, and the needs of potential adopters. The new device must fit not only physicians' clinical routines (Melas *et al.* 2013), but also their medical beliefs that remote control of chronic disease is beneficial (Sanson-Fisher 2004).

<Please insert Figure 1 around here>

These innovation characteristics turn out to be the main causes of *usage intention*. In addition, we posit that innovation characteristics would fully mediate the impact of personal innovativeness on intention to use mobile diabetes monitoring. The rationale behind this mediation hypothesis is that Yi *et al.* (2006) found that the impact of personal innovativeness on intention to use a personal digital assistant was hardly significant in the presence of the innovation characteristics between the two variables. Several past studies corroborate the importance of personal innovativeness in directly determining user perceptions of innovation characteristics (Lu *et al.* 2005, Jeyaraj *et al.* 2006).

In the following sections, we explain our theoretical rationale for each dimension and formulate a series of hypotheses.

3.2. Personal innovativeness in ICT and innovation characteristics

Personal innovativeness has been identified as one of the most important determinants in new technology adoption. Prior research offers similar terms, such as arousal seeking (Mehrabian and Russell 1974) or venturesomeness (Rogers 1983). This study adopts inherent novelty seeking, which is defined as “an individual's inherent innovative personality, predisposition, and cognitive style toward innovations” (Dabholkar and Bagozzi 2002, p. 62). Research on the diffusion of innovation is generally in accord with the proposition that the

predisposition to acquire new information, ideas, and products is generally derived from personal innovativeness. Consumers high in personal innovativeness are more likely to look favourably on ICT, and have a stronger intrinsic motivation to use such products (Dabholkar and Bagozzi 2002). Because mobile diabetes monitoring is considered a new ICT, personal innovativeness could be considered as one of the main drivers for its adoption; that is, the greater the personal innovativeness in ICT, the higher the likelihood to perceive relative advantage and compatibility of mobile diabetes monitoring.

While perceived usefulness has been one of the most widely accepted constructs in information system (IS) adoption research, prior health research indicates the importance of value creation in clinical services. Porter (2009) argued that the central focus of a health-care system must be on increasing value for patients; in other words, the health outcomes achieved per dollar spent. In addition, the management literature provides consistent evidence that ICT may indeed contribute to the improvement of organizational performance, and is often viewed as a tool whose intended purpose is to generate value (Melville *et al.* 2004). Furthermore, research on health-care service suggests that “patients arrive at a perceived value of service through a trade-off between benefits arising from the services received and the costs paid to get the service” (Yoon *et al.* 2007, p. 376). We posit that physicians who are more prone to use innovative ICT would perceive mobile device to be more value-added, and thus see more incentive to adopt that tool (Vlahos and Ferratt 1995). Thus:

H1a. Personal innovativeness in ICT will directly and positively affect perceived value.

H1b. Perceived value will directly and positively affect intention to use mobile diabetes monitoring.

Ubiquity has been pointed out as the most unique property of mobile device (Chen *et al.* 2012). Similar to our proposition related to perceived value, people with more innovative behaviour in ICT adoption are more likely to perceive mobile device as unique due to its

flexibility in time and space. Prior research views ubiquity as the most beneficial attribute of mobile services (Okazaki *et al.* 2009). Watson *et al.* (2002) describe ubiquity as synonymous with omnipresence: “not only that they are everywhere but also that they are, in a sense, ‘nowhere,’ for they become invisible as we no longer notice them” (p. 332). However, perhaps a more commonly accepted notion of ubiquity in the context of mobile services has been the combined flexibility of space and time (Okazaki *et al.* 2009, Kleijnen *et al.* 2007) or time criticality fit in patient care settings (Junglas *et al.* 2009). We contemplate that physicians with a high propensity to adopt innovative ICT are more likely to appreciate this unique feature of mobile device, and thus develop a higher motivation to use mobile diabetes monitoring. More formally:

H2a. Personal innovativeness in ICT will directly and positively affect ubiquitous control.

H2b. Ubiquitous control will directly and positively affect intention to use mobile diabetes monitoring.

Compatibility refers to a notion of “fit” to the intended users’ values, norms, beliefs, and perceived needs (Aubert and Hamel 2001). Users can be considered on the individual or organizational levels. The concept of reinvention, sometimes identified as a distinct feature of innovation (Greenhalgh *et al.* 2004), can also be thought of as an extension of compatibility (Oldenburg and Glanz 2008). In fact, prior research indicates a strong relationship between personal innovativeness and compatibility (Yi *et al.* 2006). Since mobile diabetes monitoring is an innovative form of telemedicine, compatibility holds a key for its adoption. In their seminal work on mobile technology in patient care settings, Junglas *et al.* (2009) found workflow fit, referring to “the fit between the need to streamline the workflow and the perceived technological capabilities to support this need,” to be one of the most important determinants in its utilization. If physicians can adapt, change, and modify the device or system functionality to suit their own clinical needs and context, it will be adopted more

easily. Otherwise, physicians might perceive a new ICT tool as a perceived threat to professional autonomy that would negatively affect their usage intention (Walter and Lopez 2008). Taken together, it seems reasonable to assume:

H3a. Personal innovativeness in ICT will directly and positively affect compatibility.

H3b. Compatibility will directly and positively affect intention to use mobile diabetes monitoring.

3.3. Physician scarcity as a moderator

We conceptualize physician scarcity as a moderator of ICT-based remote health monitoring adoption. For example, due to shortages of primary medical care, if a physician is unable to spend enough time with his or her patients or get in touch with them frequently, the quality of patient care would decrease since physician–patient communication plays a role in patient concern about chronic disease control (Friedman *et al.* 2008). Thus, the frequency of contact and the amount of time spent with physicians may affect the need for ICT-based remote health monitoring. In general, it seems reasonable to assume that the fewer the number of physicians per a given number of patients, the greater the need for remote health monitoring, since the time for a physician to spend with one patient would be smaller and that physician would need an alternative method to reach the patient from a distance; for example, remote health monitoring via smartphone. Therefore, our primary thesis is that the more serious the physician scarcity, the stronger the physicians’ perceived benefits resulting from the use of mobile diabetes monitoring, because the need to remotely provide health-care service is greater.

One of the objective measures for physician scarcity is the physician–patient ratio. According to the World Health Statistics (World Health Organization 2012), the number of physicians per 10,000 population varies considerably across countries. For example, in Japan, France, and the U.S., approximately 20 physicians are available for every 10,000 population,

while in Spain, Portugal, and Ireland, this number exceeds 35 (Table 1). Such a statistic seems to represent the “distance” between a physician and a patient that needs to be resolved by a new ICT device. Specifically, we believe that a mobile monitoring system would help physicians to reduce the existing issues related to physician scarcity by remotely checking their health conditions. ICT-based health monitoring would also be beneficial for health-care organizations in terms of cost reduction.

The above discussion leads us to posit that, in a country with greater physician scarcity, physicians with a high propensity to adopt innovative ICT would perceive greater value and ubiquity of such a device, and they would be more capable of using it. More formally:

H4. The relationship between personal innovativeness in ICT and innovation characteristics will be stronger in a country with greater physician scarcity, when compared to a country with less physician scarcity, in terms of: (a) perceived value, (b) ubiquitous control, and (c) compatibility. Thus:

H5. The relationship between innovation characteristics and intention to use mobile diabetes monitoring will be stronger in a country with greater physician scarcity, when compared to a country with less physician scarcity, in terms of: (a) perceived value, (b) ubiquitous control, and (c) compatibility.

4. Method

This study adopted quantitative research paradigm, in which an online questionnaire survey was employed for the data collection with nationally representative physicians.

4.1. Data collection

The survey participants were recruited by professional research firms in Japan and Spain. In neither country was the sampling method probabilistic. Yet, quota sampling was applied in an attempt to ensure the nationally representative sample, in a sense that the

respondents were collected from all geographical regions, while the quota of physicians per region was weighed by the size of its population. For example, in Japan, the respondents were collected from 47 prefectures. In Spain, the respondents were drawn from 17 autonomous communities. Thus, the sample distribution was not skewed toward certain regions.

The standardized survey procedure was applied in both countries in an attempt to obtain comparable results and minimize data collection bias. The questionnaire was first prepared in English, and then translated into the local language (i.e., Japanese and Spanish). The translated version was then back-translated into English in order to ensure the semantic equivalency. At the beginning of the questionnaire, we asked the medical specialty of the respondents and their level of clinical experience (in years).

We then showed a graphical image of self-monitoring of blood glucose. In addition, we provided a detailed description of the system purpose, functions, and usage procedure. On this basis, we asked whether the respondents had used mobile diabetes monitoring. If the answer was affirmative, we then asked them to rate each item according to their usage experience; otherwise, their assessments were based on the description provided in the questionnaire.

In the next section, we listed questions related to the model constructs explained in the previous section: personal innovativeness, perceived value, ubiquitous control, compatibility, and intention to use mobile diabetes monitoring.

4.2. Measures

Relevant constructs were adapted from previous research in information systems, health care, and consumer behaviour. All constructs were measured by multiple-item scales with a 7-point Likert scale, except perceived value. Personal innovativeness in ICT was measured by a 4-item scale adapted from Dabholkar and Bagozzi (2002). Perceived value was measured by an 8-item semantic differential scale used in Kleijnen *et al.* (2007).

Ubiquitous control was specified as a second-order construct consisting of two first-order constructs: time flexibility (3 items) and spatial flexibility (3 items) proposed by Okazaki *et al.* (2009). Compatibility was measured by a 3-item scale adapted from Wu *et al.* (2007). Usage intention was adapted from Dabholkar and Bagozzi (2002). All questionnaire items are listed in the Appendix.

The end of the questionnaire included some demographic questions, such as age, gender, and geographical area, along with other relevant questions (e.g., usage experience and frequency of Internet and mobile device use).

4.3. Sample characteristics

In total, 471 and 497 usable responses were obtained from Japan and Spain, respectively. For the Japanese sample, approximately 20.6% and 10.4% belonged to general medicine and surgery, respectively. Almost 8% of the sample included physicians who specialized in gastrointestinal medicine. The average clinical experience of the respondents was 19.3 years. Approximately 87% and 13% of the respondents were male and female, respectively, aged 25–65. For the Spanish sample, the majority of the physicians specialized in general medicine (55.6%). The average clinical experience of the respondents was 19 years. Approximately 52.6% and 47.4% of the respondents were male and female, respectively, aged 25–80.

Next, with regard to the *general* Internet usage in their medical routine, approximately 17.2% and 30% of the Japanese and Spanish respondents, respectively, habitually used the Internet for their patient care or other clinical practices. In terms of *mobile* Internet usage, both countries exhibited similar patterns. In terms of personal use, approximately 44% and 42% of the Japanese and Spanish respondents, respectively, accessed the Internet with their mobile device on a daily basis. By contrast, 26.9% and 41.1% did not in Japan and Spain,

respectively. On average, the respondents had been using the Internet with their mobile device for approximately 7 and 2.23 years in Japan and Spain, respectively.

Furthermore, the usage experience and prior knowledge on mobile diabetes monitoring were quite similar in Japan and Spain. As in most of the new technology adoption studies, we had to face the difficulty to obtain data from respondents without prior usage experience. In fact, only .8% and 1% of the respondents had actually used mobile diabetes monitoring in Japan and Spain, respectively. Approximately 26% and 27% of the Japanese and Spanish respondents, respectively, were aware of its existence, purpose, and functions but had not used it. Approximately 73% of the respondents in Japan, and 72% in Spain, had not been well informed.

4.4. Confirmatory factor analysis

Before proceeding with the estimation of the structural model, we performed a full-sample confirmatory factor analysis (CFA) with six latent constructs using AMOS 19.0 (Byrne 2001). Perceived ubiquity was conceptualized as a second-order construct, thus time flexibility and spatial flexibility were added as separate first-order constructs. To take into account the recommendations of such authors as Bagozzi and Yi (1988) and Bollen (1989), multiple indices were used to assess the goodness of fit of the overall model: $\chi^2_{242} = 1883.75$, CFI = .93, TLI = .92, and RMSEA = .084. In a model with “good” fit, the χ^2 statistic should not be significant at the 5% level. However, the literature suggests that this index becomes too sensitive to larger sample sizes (Hair *et al.* 2006). The values of the CFI and TLI indices should be close to 1, although values between .90 and .95 are considered adequate (Bagozzi and Yi 1988, Bollen 1989). The RMSEA index should be close to 0 (Byrne 2001). Thus, all the indices, except the χ^2 statistic, were in an acceptable range. In addition, all items exhibited high standardized loadings on their intended factors. Thus, convergent validity was established. The CFA results are summarized in the Appendix.

Next, the internal consistency of multiple measures was assessed using composite reliability (CR) and average variance extracted (AVE) (Fornell and Larcker 1981). Unlike Cronbach's alpha, which represents a lower bound estimate of internal consistency due to its assumption of equal weightings of items, the CR offers a better estimate of variance shared by the respective indicators, since it uses the item loadings obtained within the nomological network (Hair *et al.* 2006). An even stricter reliability indicator is the AVE, which is the amount of common variance among latent construct indicators (Hair *et al.* 2006). As a benchmark, researchers generally recommend .70 and .50 as an appropriate level for the CR and AVE, respectively, in an exploratory study. All the multiple reflective constructs exceeded these criteria.

Discriminant validity is the extent to which a construct truly differs from neighbouring constructs (Hair *et al.* 2006). This was assessed from the latent constructs correlations matrix, where the square roots of the AVE along the diagonal are reported. The correlations between the constructs are reported in the lower left off-diagonal elements in the matrix. Fornell and Larcker (1981) suggest that average variance shared between a construct and its measures should be greater than the variance shared between the construct and other constructs in the model. Thus, discriminant validity is satisfied when the diagonal elements (square root of AVE) are greater than the off-diagonal elements in the same row and column.

4.5. Invariance structure

Given our comparative purpose for the path strengths between Japan and Spain, we tested for the measurement invariance across the samples, according to the procedure suggested by Steenkamp and Baumgartner (1998). The unrestricted model was used as a baseline model. The resulting goodness-of-fit indices met the widely accepted threshold criteria, except the chi-square value. All loadings to their respective factors were significant, suggesting configural invariance.

The second model tested the invariant factor loadings across the models, restricting factor loadings equal across countries. The chi-square difference between the full metric invariance model and the baseline model was significant ($p < .01$), although the other fit indices, such as CFI, TLI, and RMSEA, were acceptable. Thus, full metric variance was not achieved.

The literature suggests, however, that full metric invariance is rather unrealistic and only partial invariance is required for cross-country model comparison (Netemeyer *et al.* 2006). On this basis, we next tested a series of partial measurement invariance models by sequentially relaxing the factor loadings of the items. Several items—one of spatial flexibility, one of usage intention, and three of perceived value—showed modification indices indicative of non-invariant items across the samples, and thus were released. The resulting model did not differ significantly from the baseline model ($p = .07$). Therefore, we confirmed evidence of partial metric invariance, which enabled us to assess relations in the structural model.

5. Results

5.1. Main paths

The structural paths on the hypothesized relationships between the proposed constructs were examined for the full sample with maximum likelihood method using AMOS 19.0 (Byrne 2001). Most of the indices indicated an adequate model fit, except for the χ^2 statistic. Testing yielded a χ^2 value of 2017.63 with 245 degrees of freedom and a probability of less than .001. However, as we pointed out previously, it has been widely documented that the χ^2 statistic tends to be substantial when the sample size is large (Hair *et al.* 2006). In addition, the difficulty of passing this stringent test has been noted elsewhere (Bollen 1989). Therefore, it was judged that the multiple indices sufficiently justified the adequacy of the

model's fit to the sample data. The resulting fit indices were CFI = .93, TLI = .92, and RMSEA = .086. The structural model results are summarized in Table 2.

<Please insert Table 2 around here>

Our H1a posits that personal innovativeness in ICT directly and positively affects perceived value. Our structural equation modelling results indicate that this path was indeed statistically significant with a solid standardized coefficient ($\beta = .82, p < .01$). Thus, H1a was supported by our data. H1b proposes the direct causal effect of perceived value over usage intention. Our results indicate that this path was modest but statistically significant ($\beta = .18, p < .01$). Thus, H1b was supported.

Similarly, H2a predicts that personal innovativeness in ICT will determine the level of ubiquitous control. This path exhibited the greatest coefficient that was statistically significant ($\beta = .85, p < .01$). Thus, H2a was supported. H2b hypothesizes that ubiquitous control directly and positively influences usage intention. Our results indicate that this relationship was statistically significant ($\beta = .11, p < .05$). Therefore, H2b was also supported.

H3a contemplates a significant causal relationship between personal innovativeness in ICT and compatibility. Our results provide support for this prediction ($\beta = .84, p < .01$), supporting H3a. H3b makes a similar prediction for the relationship between compatibility and usage intention. According to our structural model results, this was indeed the case ($\beta = .57, p < .01$). Hence, H3b was supported.

5.2. Cross-country comparison

To address H4a–c and H5a–c, multigroup analyses were performed using AMOS 19.0 with the maximum likelihood method. First, the multigroup baseline model was estimated across the countries simultaneously, without placing any equality constraints on the hypothesized paths. Their fit indices served as initial points of comparison in addressing

whether the proposed structural relationships would hold in the same way across the two groups. The chi-square value of the unconstrained model was 2572.36 ($p < 0.001$), with 511 degrees of freedom. This is the unconstrained or baseline model as indicated in the first row of Table 3. In the second model, the path between personal innovativeness in ICT and perceived value was constrained to be equal in both Spain and Japan. This is the equal path model. The difference in chi-square values between the constrained and equal path models ($\chi^2_1 = 3.12$) suggests that the direct path between personal innovativeness in ICT and perceived value was marginally greater for the Japanese sample, compared with their Spanish counterpart. This test was repeated for the path between personal innovativeness in ICT and ubiquitous control, and the one between personal innovativeness in ICT and compatibility. As we can see in Table 3, all three paths were greater in Japan than in Spain but the difference in the path between personal innovativeness in ICT and compatibility across countries was not statistically significant. This evidence supports our H4a and b, but not H4c.

<Please insert Table 3 around here>

In testing H5, we obtained only a marginally significant result for the path between perceived value and usage intention. This path was marginally greater for the Japanese sample, compared with the Spanish sample, while the other two paths were not statistically different across the countries. Thus, only H5a was supported; H5b and c were not.

6. Discussion

Our intended contribution of this research was to propose and validate a theoretical model, while comparing the relationships among the constructs across countries. The moderation is based on physician scarcity, which is operationalized as the number of physicians per 10,000 population. To this end, we chose Japan and Spain as the sites of study. Our structural equation modeling results offer some insightful implications.

Theoretically, our study demonstrates the importance of innovation characteristics—namely perceived value (H1a-b), ubiquitous control (H2a-b), and compatibility (H3a-b)—in adopting mobile diabetes monitoring. Our model replaced relative advantage in the original model by Yi *et al.* (2006) with perceived value and ubiquitous control, primarily because of the limited diffusion of this technology. However, our study rather crystallized the importance of relative advantage in the framework of the diffusion of innovation theory. In other words, our results clearly indicate that clinical value and ubiquitous control are the main benefits physicians may perceive (and appreciate) from this new tool. This tendency will be stronger for those high in personal innovativeness in ICT.

Indeed, the paths from personal innovativeness in ICT to these three constructs—perceived value (H1a), ubiquitous control (H2a), and compatibility (H3a)—were solid, indicating strong mediating effects of innovation characteristics between personal innovativeness and usage intention, which seems consistent with the findings of Yi *et al.* (2006). That is, physicians' personal innovativeness per se would not stimulate intention to use a new device. Instead, physicians should be able to not only understand, but also appreciate perceived value, ubiquitous control, and compatibility of the device. First, physicians should see the central focus of health-care systems as value creation for patients (Porter 2009), and the new device could make a significant contribution to that focus. Second, due to their time constraints, physicians should feel a strong urge to improve their patients' health, regardless of their physical location. Third, physicians should be willing to try a new device if it does not significantly alter their clinical routine (Melville *et al.* 2004, Vlahos and Ferratt 1995). Therefore, health-care administrators should provide physicians with opportunities to become aware of these three innovation characteristics associated with mobile diabetes monitoring.

In terms of cross-country comparison, the strength of the path from personal innovativeness in ICT to perceived value (H4a) was greater in Japan than in Spain. This corroborates our theoretical explanation based on physician scarcity. Since the number of physicians per 10,000 population is substantially smaller in Japan, compared with Spain, physicians with a greater propensity to innovate ICT may have perceived greater value in using mobile diabetes monitoring to improve remote patient care. For the same reason, the path from personal innovativeness in ICT to ubiquitous control (H4b) was more accentuated in Japan than in Spain, probably because Japanese physicians are more concerned with their limitations in clinical capacity, and thus are more willing to take advantage of the most important utility in mobile diabetes monitoring—flexibility in time and space. The impact of physician scarcity as a moderator of mobile-based clinical device has not been introduced in the literature, and thus can be considered as an incremental value of this research.

On the other hand, while compatibility was found to be a main consequence of personal innovativeness in ICT, and a strong determinant of usage intention, there was no difference in the path strength across the countries in either path (H4c and H5c). Perhaps this result indicates that compatibility may not be a unique determinant of mobile diabetes monitoring, but a general determinant of *any* ICT-based monitoring.

As for the moderating results for the paths between the three innovation characteristics and usage intention, only the path from perceived value to usage intention was marginally significant (H5a). This seems consistent with our above arguments on the importance of value creation in health care. Given the current limited adoption and usage experience, physicians could imagine a situation when this tool can actually be used, only when they perceive value. Apparently, Japanese physicians are more likely to see value in mobile diabetes monitoring. One possible explanation could lie in the fundamental difference between the health-care system in Japan and Spain.

The Japanese health-care system can be classified as a Bismarck model, whereas the Spanish health-care system is known as a Beveridge model. These models are two polar opposite social welfare systems. The Bismarck model is an insurance-based open framework, where patients can freely choose from a broad range of private doctors and hospitals. Patients consult medical specialists directly and pay for their insurance premiums. In contrast, the Beveridge model is a tax-funded public system, where the government owns hospitals and employs medical specialists. Because it aims at universal coverage through national health systems, the Beveridge model provides much less choice to patients, compared with the Bismarck model. In addition, the Beveridge model is known for generating significant waiting lists to see specialists and thus provoking patient dissatisfaction. Since physicians are employed by the government, their salaries are not linked to productivity; this means there is generally less incentive to achieve greater efficiency (Or *et al.* 2010).

What our findings apparently indicate is that Japanese physicians may see themselves as capable of creating value to health care, due to the more flexible Bismarck model that allows much more freedom in their clinical practice. In contrast, Spanish physicians may not see this value, due to the more restrictive Beveridge model, where their voluntary and additional work to achieve greater efficiency is not linked to any recognition.

7. Limitations

There are three important limitations that must be recognized in attempting to make our discussion more objective. First and foremost, there may be other factors, besides physician scarcity, that could have affected the cross-country differences between Japan and Spain. For example, the physicians from the two countries may have perceived mobile diabetes monitoring differently due to varying levels of technology readiness (World Economic Forum 2013). Second, most of the respondents in both countries had not used the system, thus their responses were based on their limited knowledge and similar online device

experiences. Third, the proportion of male sample was much greater than that of female sample in Japan. This skewed gender balance may have affected the results associated with innovativeness in ICT, since prior research indicates males are more prone to use new technology than females. Finally, some may argue that our study did not include one of the countries with the largest medical expenditures—the U.S. The reason for excluding this country was due to the structural difference of the social security system where private, not public, medical insurance plays a central role. Yet, public interest in mobile diabetes monitoring has been rapidly growing in the U.S., thus a comparative study with Asia and/or Europe may be of interest in our future research.

8. Conclusion

Besides the fact that smartphones have rapidly penetrated worldwide, there are two social concerns for which our study results may be useful. First, both Japan and Spain are similar in size and have large rural populations in addition to huge urban centres. Mobile diabetes monitoring could be an effective tool to functionally “bridge” the clinical needs of rural communities and health-care centres. Second, both countries will soon suffer from an accelerating aging population. This elderly populace will become a serious burden for social security systems that will need a practical solution, and mobile diabetes monitoring could be among the most commonly available alternatives that may not require substantial and substantive installations. However, from the patients’ perspectives, the health-care industry will need to make greater efforts to improve system usability. Easy input methods and clear instructions would help the elderly to learn how to manage such devices.

A logical extension of this study would be to expand our model and include more variables that are directly relevant to health-care services. For example, the notion of ubiquitous control could be improved. Recent research indicates that perceived ubiquity could be a multidimensional construct consisting of immediacy, continuity, portability, and

search ability (Okazaki and Mendez 2013). Our future exploration could examine these indicators to find out which dimension of perceived ubiquity has the most influence on physicians' usage intention. In addition, other economic indicators such as costs per patient, actual usability, and communication frequency could be included in the model so that more specific recommendations could be drawn.

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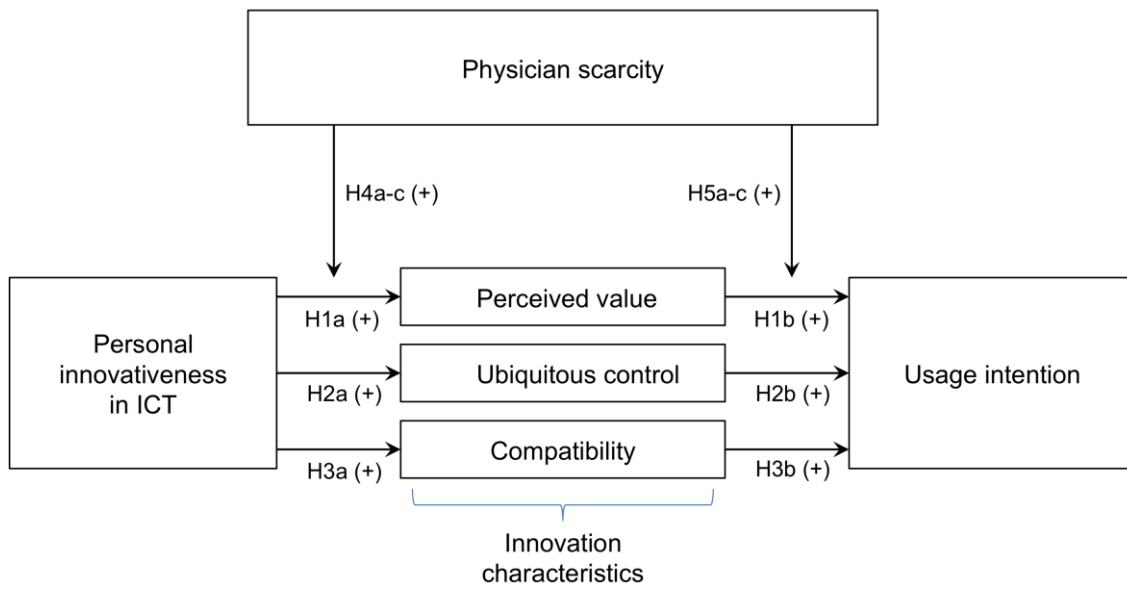


Figure 1. Research model

Table 1. Relevant medical statistics in Japan and Spain.

Variables	Japan	Spain
Number of physicians per 10,000 population	21.4	39.6
Number of hospital beds per 10,000 population	137	32
Number of physicians per hospital bed	.16	1.24
Medical expenditure as % of GDP	9.5%	9.6%
Medical expenditure per capita (US\$)	\$3,754	\$3,032
Pre-diabetes adults in total population ^a	6%	10%
Median age (years old)	45	40
Aged over 60	30%	22%

Source: Social Security Advisory Board 2009, ^a ≥ 25 years old.

Table 2. Structural model results (full sample).

Structural paths			Standardized β	
Personal innovativeness in ICT	→	Perceived value	.82	**
Personal innovativeness in ICT	→	Ubiquitous control	.85	**
Personal innovativeness in ICT	→	Compatibility	.84	**
Perceived value	→	Usage intention	.18	**
Ubiquitous control	→	Usage intention	.11	*
Compatibility	→	Usage intention	.57	**

Note: ** $p < .01$, * $p < .05$

Table 3. Results of multigroup moderation analyses.

Hypotheses	Paths	Path coefficients in unconstrained model	Chi-square statistics test results
			Baseline model $\chi^2_{511} = 2572.36$
H4a	Personal innovativeness in ICT → Perceived value	$\beta(\text{Japan}) = .84$ (SE = .02) $\beta(\text{Spain}) = .79$ (SE = .03)	Constrained Model $\chi^2_{512} = 2575.48$ $\chi^2_1 = 3.12, p = .08$
H4b	Personal innovativeness in ICT → Ubiquitous control	$\beta(\text{Japan}) = .86$ (SE = .03) $\beta(\text{Spain}) = .82$ (SE = .03)	Constrained Model $\chi^2_{512} = 2591.03$ $\chi^2_1 = 18.67, p < .001$
H4c	Personal innovativeness in ICT → Compatibility	$\beta(\text{Japan}) = .97$ (SE = .01) $\beta(\text{Spain}) = .78$ (SE = .04)	Constrained Model $\chi^2_{512} = 2572.41$ $\chi^2_1 = .05, p = .82$
H5a	Perceived value → Usage intention	$\beta(\text{Japan}) = .28$ (SE = .06) $\beta(\text{Spain}) = .14$ (SE = .09)	Constrained Model $\chi^2_{512} = 2574.95$ $\chi^2_1 = 2.59, p = .10$
H5b	Ubiquitous control → Usage intention	$\beta(\text{Japan}) = .23$ (SE = .10) $\beta(\text{Spain}) = .19$ (SE = .06)	Constrained Model $\chi^2_{512} = 2572.37$ $\chi^2_1 = .01, p = .92$
H5c	Compatibility → Usage intention	$\beta(\text{Japan}) = .37$ (SE = .10) $\beta(\text{Spain}) = .57$ (SE = .05)	Constrained Model $\chi^2_{512} = 2574.60$ $\chi^2_1 = 2.24, p = .13$

Note: β = unstandardized coefficients. SE = standard error.