Innovations in medical technology – The influence of personal and product characteristics on physicians' acceptance of the Artificial Pancreas

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ABSTRACT

Although the literature provides abundant theories and approaches to the understanding of technology acceptance, it is unclear what factors drive certain professional user groups to accept technological novelties. In light of the planned market introduction of an artificial pancreas used in diabetes treatment, this research paper deals with the examination of possible extrinsic and intrinsic factors influencing physicians' intention to prescribe the technology of the artificial pancreas in their working environment. Building on key findings of several theoretical paradigms, the author developed a conceptual framework and tested it in the context of Dutch, German and Austrian healthcare. Using multiple regression analysing answers of 50 physicians, the model explained 39% of the physicians' intention to use the artificial pancreas with a good model fit. Hereby the author found out, that while innovativeness and complexity do not significantly influence a physician's intention to use the artificial pancreas, perceived usefulness significantly explained 38.4% of the variance of intention to use. With these results, this study provides important initial insights into the understanding of market acceptance from one main stakeholder group for the Dutch company Inreda Diabetics B.V. who is responsible for the development of the artificial pancreas. Furthermore, it provides further ideas for understanding circumstances that contribute to the acceptance of new technological innovations.

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1. INTRODUCTION

Many questions can be asked to understand how people react to the innovation of new technologies, the health care industry being no exception. Medical innovations, such as new types of technologies incorporated in mechanic or electronic devices, used for treatment of patients, sprang up in the last decade and leveraged health systems to be competitive (Alagöz, Ziefle, Wilkowska & Valdez, 2011; Cain & Mittman, 2002). Those innovations not only promote the development of technological lifecycles (Lettl, Herstatt & Gemuenden, 2006), but also ease the burden resulting from diseases patients are suffering from, making them live longer, better-quality lives (Fuchs & Sox Jr., 2001). However, it is usually the attending physician, who decides for the type of treatment a certain patient receives. This often is described as a principal-agent relationship, where the patient becomes the treatment receiving principal, and the physician the treatment prescribing agent (Phelps, 1995). In this process, "the doctor possesses the knowledge needed for making a treatment decision regarding the patient's illness and for assessing the expected effectiveness of health care interventions in improving the patient's health status" (Gafni, Charles & Whelan, 1998, p. 347). Hence, to receive the treatment of a certain new medical innovation as a patient, her physician must be willing to introduce the technology and prescribe it to his patients. The arising problem is, that to be willing to prescribe this type of treatment to his patients, the physician has to accept the technology first. It is unlikely, that a physician resistant to a particular technology will make use of it (Lapointe & Rivard, 2005).

Much research has been done on the general acceptance of technologies and innovations, however, it is mostly unknown how physicians react to new medical technical innovations and what are the factors driving them to accept or reject those. (Menon, Lee & Eldenburg, 2000). This is a problem for companies active in the medical field bringing new technological inventions to the market, not knowing if their technology is going to be accepted and therefore used in treatments by physicians or not. The current status quo hence can be supported by crucial marketing research on technology acceptance of physicians based on the understanding of medical and business theories.

The author therefore wants to investigate what it is, that makes physicians accept and adopt new technologies to eventually field them in his work with his patients. There might be physicians focussing merely on the characteristics of the technology itself, while others might follow peer pressure or are guided by cognitive or situational factors. These differences between intrinsic and extrinsic factors of acceptance will be the focus of this research and eventually formulate the research question:

"To what extent do intrinsic and extrinsic factors influence the possible adoption of medical technological innovations by physicians"

The most prevailing and used theories to understand the acceptance and adoption of technology and innovations are those of the technology acceptance model (TAM) of Davis (1989) and the work on the adoption and diffusion of innovations by Rogers (1995). While the former looks at acceptance defined by the individual's behavioural intention, the latter considers the success or failure of acceptance more from a viewpoint that examines the characteristics of an innovation. However, these models are of general nature and can be applied to any user. They are not specifically targeted at physicians and as a means to measure their acceptance and adoption of innovations in particular. Study results have shown, that physicians differ from other users in regard to IT acceptance (Paul & McDaniel Jr., 2004). Herein Ziefle and Wilkowska (2010) argue that a distinct differentiation has to be made between the acceptance of regular IT and medical technologies and devices. First, while regular IT acceptance is often based on a fun factor, medical technology acceptance is driven by, sometimes critical, health states and vital medical reasons. Second, next to their very nature of being important for patients' safety and wellbeing, medical technology touches on "taboo-areas", that are intertwined with illnesses and diseases which has an intricate impact on the acceptance.

To adapt the theory of technology acceptance to a medical setting, the author chose to examine the case of the planned market introduction of the so-called artificial pancreas by the Dutch located company Inreda Diabetic BV (henceforth Inreda). The artificial pancreas is used in the treatment of diabetes mellitus (henceforth diabetes) and is based on existing technology such as the insulin pump. The interested and selective reader will find more detailed information about the characteristics of diabetes and the artificial pancreas in the appendix.

As diabetes is a disease with extensive implications and according to recent statistics of the International Diabetes Federation (IDF, 2013), in 2013 the global prevalence of diabetes was 382m and is projected to head for 592m by 2035, making it the most abundant non-communicable disease worldwide (Business Insights, 2011), this topic provides a highly interesting research opportunity to understand the behaviour and decision-making processes of physicians when it comes to the acceptance of medical technical innovations.

This paper provides practical relevance on several measures. First, it provides Inreda with underlying information on their planned market penetration of the artificial pancreas according to the possible acceptance or rejection of one of the product's main stakeholder group, which are physicians. It helps them to formulate their strategic marketing position before bringing their product to the market. Furthermore, it provides general information for other companies in the industry as well as for physicians as primary users of the artificial pancreas on how their peers react to new innovations. On the theoretical level, this research contributes to the understanding of user acceptance of innovations. In detail, it examines, how different intrinsic and extrinsic factors motivate professionals to either accept or reject a new technical innovation.

The remainder of this paper is structured as follows. First, a summary and the theoretical background of the existing work of acceptance of technology and innovation will be given. Following, the variables used for the research will be defined including the dependent variable of interest and the antecedents introduced in the theory section. The next part provides a research model as well as the authors a priori expectations of the relationships of those variables presented in the form testable hypotheses. After that, the research methodology will be described as well as the operationalization of the variables. Finally, the author will discuss the major findings and eventually close the paper with the consideration of scientific and pragmatic implications, the limitations of the study and present a final conclusion.

2. THEORIES OF INNOVATION AND TECHNOLOGY ACCEPTANCE

Studies have shown, that the adoption of clinical information systems of physicians has been slow (Lowenhaupt, 2004; HIMSS, 2002) and an understanding and approach to the process of acceptance is urgently needed (Walter & Succi

Lopez, 2008). Though innovations in the provision of health care can lead to more convenient, more effective, and less expensive treatments for patients, doctors have to accept those innovations and technologies and recommend them to patients and colleagues (Herzlinger, 2009).

All of this writing, several very distinguished models have been used to understand and examine the acceptance of innovations and technologies (Davis, 1993; Kottemann & Davis, 1991; Lee & Kim, 1995). Especially the research on information systems and technology has been influenced by intention-based models, which stem from cognitive psychology (López-Nicolás, Molina-Castillo & Bouwman, 2008). Fishbein and Ajzen (1975) with their discussion on the theory of reasoned action (TRA) and Ajzen (1991) with his work on the theory of planned behaviour (TPB) contributed to the underlying framework of psychological decision-making. Based on these theories to specify causal linkages, the more pragmatic approaches of TAM, its successor the extended TAM (TAM2) (Venkatesh, 2000) as well as the UTAUT model (Venkatesh, Morris, Davis & Davis, 2003) were developed. These frameworks still build the mainstay among the research and studies of technology and innovation acceptance (Holden & Karsh, 2010; Ma & Liu, 2004; Agarwal & Prasad, 1999). The TAM suggests that an intention to accept technology is determined directly by *attitude*, *perceived usefulness*, and *perceived ease of use* (Davis, Bagozzi & Warshaw, 1989). Davis et al. (1989) define perceived usefulness as an individual's perception that the application of a certain technology or innovation will outperform existing practices and perceived ease of use as an individual's perception that the application of that new technology or innovation will be relatively pain- and effortless. The user's attitude factor stems from the notion of the TRA, that a user's behavioural intention to use or reject a technology is based on his subjective norm and his general attitude and behaviour. This variable was dropped in a later revision of the model as it showed low validity as a mediator between the beliefs and behavioural intention (Davis, 1993)

However, the TAM framework is susceptible to various concerns about the appropriateness and comprehensiveness in various contexts and being too parsimonious and tautological (Bouwman, van den Hooff, van den Wijngaert & van Dijk, 2005). Furthermore, it lacks the ability to explain for social influences and user intentions. In their work from 2000, Venkatesh and Davis developed a theoretical extension of the TAM to cope with the lack of explanations of the strong determinant of usage intentions, perceived usefulness. These include additional theoretical constructs encompassing social influence processes and cognitive instrumental processes such as *job relevance*, which is described as an "individual's perception regarding the degree to which the target system is applicable to his or her job" (Venkatesh & Davis, 2000, p. 191).

Rogers (1995) provided another important paradigm in understanding technological and innovation acceptance in his seminal work on innovation diffusion theory. Based on sociology research, the theory looks at the diffusion of innovation as a type of communication process in which information about new technologies or inventions are transferred between members of a social system (Glanz, Rimer & Viswanath, 2008). Hereby, the rate of adoption and the success of acceptance are merely guided by the characteristics and attributes of the particular innovation. Those attributes and characteristics introduced by Rogers (1995) were defined as follows:

Relative advantage is the degree to which an innovation is perceived as better as the idea it supersedes. (Rogers, 1995, p. 212)

Compatibility is the degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters. (Rogers, 1995, p. 224)

Complexity is the degree to which an innovation is perceived as difficult to understand and to use. (Rogers, 1995, p. 242)

Trialabilty is the degree to which an innovation may be experimented with on a limited basis. (Rogers, 1995, p. 243)

Observability is the degree to which the results of an innovation are visible to others. (Rogers, 1995, p. 244)

The notion that the rate of adoption is partially determined by these perceived attributes and characteristics of an innovation gave reason to study various innovations according to this theory. Moore and Benbasat (1991) used this set of characteristics and adapted it to be applicable especially to the information technology context. They proposed two further attributes, which are:

Image, which is the degree to which use of an innovation is perceived to enhance one's image or status in one's social status. (Moore & Benbasat, 1991, p. 195)

Voluntariness of use, which is the degree to which use of an innovation is perceived as being voluntary, or of free will. (Moore & Benbasat, 1991, p. 195)

Though widely comprehensive, these models often face critiques of being too generic and linear (Wolfe, 1994) and lacking empirical validity. Much more attention within the diffusion process needs to be addressed to the underlying capacity of individuals to absorb new knowledge (Fiol, 1996). Fitzgerald, Ferlie, Wood & Hawkins (2002) suggest that the theory of innovation diffusion has to be understood not as a uniform pattern but influenced by different factors such as the credibility of evidence and the interlocking of situational contexts and different stakeholders and actors engaged in the diffusion process.

Another variable found in recent studies, which were also based on the innovation diffusion theory, is that of *personal innovativeness in the domain of IT* (PIIT) suggested by Yi, Jackson, Park & Probst (2006) This variable describes the individual's willingness to try out any new IT and can be put in context with other innovation characteristics to measure the acceptance of those innovations. Furthermore, as physicians tend to hold the suggestions and opinions of their colleagues and peers in high regard, it is proposed that the notion of *subjective norm* is an important determinant of intention to accept and use an innovation (Yi et al., 2006). As a social force, it is impinging on an individual that faces the option to adopt or reject a new technology (Venkatesh & Davis, 2000). Another variable worth explaining is that of *perceived risk* introduced and defined by Ostlund (1974) as the degree to which product performance and/or psychosocial risks are attributed to a product (Holak & Lehmann, 1990). Further variables have been identified as the *cost of the innovation* such as purchase and switching costs, and *uncertainty* towards the innovation, such as standardization and the expected length of life cycle (Gatignon & Robertson, 1993).

Bagozzi and Lee (1991), in their research on innovation, noted that these merely extrinsic factors leave out the more cognitive and intrinsic factors of motivation to resist or accept an innovation. They introduce the reflection of *self-efficacy*, which is the confidence one has to be able to do what it takes to adopt an innovation. Other influences on an intrinsic level have been

presented by Agarwal and Prasad (1999) who have researched the individual differences in regard to the acceptance of technologic innovations. Considering the attitude of an individual they focussed on the *tenure in workforce, the level of education, prior and similar experiences,* and *participation in training.* In their earlier work on antecedents and consequents of user perceptions towards innovations (Agarwal & Prasad, 1997), they introduced the notion of *awareness*, which is defined as a positive general attitude towards the innovation.

Table 1 provides an overview of prior research towards technology acceptance using one or more of the variables quoted above in an integrative way.

Table 1. Review of prior research on technology acceptance

Prior studies and frameworks	Independent variables	Dependent variable
Ostlund (1974)	Perceived risk	Adopters' perception of the technology
Davis et al. (1989)	Attitude, Perceived usefulness, Perceived ease of use	Behavioural Intention to use
Bagozzi and Lee (1991)	Self-efficacy	Intentions to perform a personal act
Moore and Benbasat (1991)	Image, Voluntariness of use	Adopters' perception of the technology
Gatignon and Robertson (1993)	Cost, Uncertainty	Intent to innovate
Rogers (1995)	Relative advantage, Compatibility, Complexity, Trialability, Observability	Rate of diffusion
Agarwal and Prasad (1997)	Awareness	Adoption decision
Agarwal and Prasad (1999)	Tenure in workforce, Level of education, Prior and similar experiences, Participation in training	Behavioural intentions
Venkatesh and Davis (2000)	Subjective norm, Job relevance	Intention to use
Yi et al. (2006)	Innovativeness in the domain of IT, Subjective norm	Behavioural Intention

3. RESEARCH MODEL AND HYPOTHESES

The research model underlying this study is shown in figure 1. Its independent variables are conceptually based on the research streams of the TAM (Davis, 1989), Rogers' innovation diffusion theory (1995) and the initial work of Midgley and Dowling (1978) on the concept of innovativeness. However, to the author's best knowledge, there are no studies that combine these approaches into one integrative stream of research.

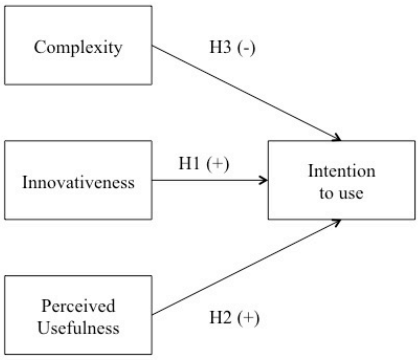

Figure 1. Research Model

In Rogers' theory, innovation adoption is explained as the process of uncertainty reduction and information gathering (Agarwal & Prasad, 1998). Within this theory, an important outcome is an individual's decision whether to accept or reject the innovation. Rogers (1995) solely describes the perceived characteristics of using an innovation, compared to primary characteristics, such as actual cost price (Moore and Benbasat, 1991). Focussing on primary characteristics in innovation adoption research can lead to vacuous outcomes, resulting from inconsistencies in previous research incorporating primary characteristics only (Downs & Mohr, 1976). The author therefore intended to integrate the perceived characteristics of Rogers (1995) as part of his research model. However, in a study and meta-analysis on innovation characteristics, Tornatzky and Klein (1982) found that only three of Rogers' characteristics are consistently related to adoption. These characteristics are relative advantage, complexity and compatibility. In the light of the research context, the author chose to include complexity as one main characteristic of the innovation into the research model. This is because an examination of innovation complexity is of particular interest, considering the technological nature of the innovation in a rather complex context. Relative advantage is closely related to the construct of perceived usefulness, which was coined in the TAM of Davis (1989). He argues that perceived usefulness and job relevance from his extension of the TAM (Venkatesh & Davis, 2000) as a cognitive instrumental process are a significant construct to describe how perceived usefulness judgments are formed by people partially by cognitively comparing what a technology is capable of doing with what they need to get their job done. The notion that innovations typically are developed with a certain purpose in mind and that their virtue to fulfil the intended task better than their predecessors is inevitable, makes this concept highly interesting for this research. This understanding is especially true for the context of the artificial pancreas, which is said to supersede and possessing the potential to substitute existing technologies, such as the insulin pump (Hovorka, 2008). The author therefore argues for essentiality of this concept to integrate it into the research model. Compatibility however is omitted to having a balance between intrinsic and extrinsic predictors of innovation adoption. While innovativeness is an intrinsic factor, perceived usefulness, complexity and compatibility are rather extrinsic, underlining the notion that physicians are rather rational and pragmatic in their decision-making processes than intuitive and emotional (Kaplan, Greenfield, Gandek, Rogers & Ware Jr., 1996; Chau & Hu, 2002). Innovativeness (Midgley & Dowling, 1978; Flynn & Goldsmith, 1993) is important to the study of individual behaviour towards innovation, especially in the area of Marketing (Rogers, 1995). Considering the context of the study, the concept is especially interesting to examine and the author wants to find out, if more innovative physicians possess the ability to conceive potential benefits of the artificial pancreas already in an early stage of development (Moore, 1999), thus resulting in their level of usage intention.

The model used in this research therefore integrates intrinsic and extrinsic key variables of widely used and accepted theories of innovation acceptance and suggests several relationships that were not examined in prior studies. Recent studies have shown, that both, personality and intrinsic dimensions as well as system

specific or extrinsic dimensions are of major importance when adopting new technology (Godoe & Johansen, 2012).

The author chose behavioural intention to use as the dependent variable, as it displays the more objective and rational probability of an individual to make use of the technology or not. Ajzen and Fishbein (1977) argue, that a person's attitude towards an innovation can influence the general pattern of the response to this innovation but not necessarily predicts any given action. An individual's intention therefore is a function of his attitude and has a major influence on the actual behaviour. Furthermore, the intentional aspect backs up the current status quo of the pre-market status of the artificial pancreas, which is also utilized in the survey. In this context, it is worthwhile mentioning, that the character of the dependent variable should be translated to the willingness of the physician to prescribe the artificial pancreas to patients in terms of usage intentions. Considering the physician as the end user in this research, he has an important role in the decision-making process of the prescription of the artificial pancreas to patients (Renard, 2010). For the sake of simplicity, henceforth the notion of intention to use as the dependent variable will be kept in this paper.

3.1 Innovativeness

There are only a few concepts in behavioural sciences that have as much immediate relevance to consumer behaviour as innovativeness (Hirschmann, 1980). Rogers and Shoemaker (1971) have provided one major conceptualization of this term when describing it as the degree to which an individual is relatively earlier in adopting an innovation than other members of a specific social system. Hereby, they describe the term innovation as "an idea, practice, or object perceived new by the individual" (p. 19). This notion is highly applicable to the research focus of this paper, considering the newness of the artificial pancreas to the physician as an individual. In this case, the physician as the innovation adopter is the consumer of the product (Atuahene-Gima, 1995.) In a more recent theory, Parasuraman and Colby (2001) define innovativeness as a tendency to be a technology pioneer and thought leader. It therefore investigates to what degree individuals perceive themselves as being at the very front of technology adoption. Despite several varying perspectives on innovativeness dealt with in the literature (Song & Montoya-Weiss, 1998; Ettlie & Rubenstein, 1987; Kleinschmidt, 1991; Colarelli, 1998) there is a single consistency in innovativeness, which is modelled as the discontinuity in marketing and/or technological aspects (Garcia & Calantone, 2001). Rogers and Shoemaker (1971) argue, that although there may be variations in the perceptions of the newness of a product among consumers, it is this diversity of perceived novelty, which is closely tied to the cognitive origin of the initial innovativeness. Furthermore, reinforcing the idea of this research, Midgley and Dowling's theory on innovation (1978) can be taken as a basis, considering that innovativeness is a personality construct, possessed to a greater or lesser extent by all individuals. It is normally distributed within a population of any type of consumers and generalizable across all types of products. Another notion, based on the innovation diffusion theory of Rogers (1995) is that earlier adopters are more technically competent than others (Yi et al., 2006), suggesting a direct influence on the willingness to make use of an innovation or to reject it. Therefore, the author hypothesizes:

H1: Innovativeness has a positive effect on behavioural intention to use

3.2 Perceived Usefulness

The research on perceived usefulness is based on the notion that using a particular system can enhance an individual's job performance (Davis, 1989). This leads to the "user's believe in an existence of a positive use-performance relationship" (Davis, 1090, p. 320). Likewise, it is argued, that any system that does not help people achieving higher performance in their jobs is not very likely to receive favourable attention despite careful implementation efforts (Robey, 1979). The relationship between perceived usefulness and innovation and technology acceptance has been widely researched and tested in the literature (Adams, Nelson & Todd, 1992; Mathieson, 1991; Thompson & Higgins, 1991) and yield consistently variance for reasons why users determine to use specific systems. The linkages between those constructs, which are also reflected in the relationships of perceived usefulness and perceived ease of use, have been verified in diverse information systems theories (Karahanna & Straub, 1998). These research streams have been very important for explaining beliefs about innovations that lead users to positive initial attitudes towards technological systems and eventual intentions to use those technologies. Consequently, the author hypothesizes:

H2: Perceived Usefulness has a positive effect on behavioural intention to use

3.3 Complexity

Complexity as the third construct derived from Rogers' seminal work on innovation diffusion theory (1995) is similar in its definition to the notion of perceived ease of use by Davis' TAM (1989) and recurs in several studies as a significant antecedent of adoption behaviour and intention to use (Adams et al., 1992; Rogers, 1995; Davis, 1989; Davis et al., 1989). In his work on product complexity and innovations, Hobday (1998) named the quantity of tailored components and sub-systems, the hierarchical order in which they are integrated and the degree of technological novelty as important indicators of complexity. Additionally, it influences behavioural intention directly through an individual's attitudes (Yarbrough & Smith, 2007).

Complexity can also take on the understanding of a user-friendly system. In his study of technology adoption among nurses, Lee (2004) observed that too complex systems might result in focusing too much on understanding and mastering the technology and loosing attention for the patient's needs and wants, making too complex products less desirable.

As systems that are perceived to be easier to use and that show less complex characteristics are more prone to adoption, the author hypothesizes:

H3: Complexity has a negative influence on behavioural intention to use

4. METHODOLOGY

4.1 Study subject and sample

This paper deals with the acceptance of new technologies and innovations. Its focus is on medical application innovations and highlights the circumstance of the approaching market penetration of an artificial pancreas developed by the Dutch inhabited company Inreda. While other studies of the Bachelor project that are dealing with the artificial pancreas examine the acceptance of patients, nurses and the financial reimbursement, the aim of this particular study is to provide Inreda with a prediction about how the stakeholder group physicians will accept their new technology.

To test the physicians' acceptance of the artificial pancreas described in the model in figure 1, a survey was constructed. It was distributed to 134 Dutch, 194 Austrian, and 237 German (565 total) physicians, specialised in endocrinology or diabetology, as these countries build the first starting points for the product placement of the artificial pancreas. The contact data were acquired mostly via desk research activities including

search engines such as Google. For the German and Austrian contacts the research turned out to be more straightforward as the author was able to find a database containing several hundreds of endocrinologists and diabetologists (www.diabsite.de for German and www.arztverzeichnis.at for Austrian physicians). As Dutch physicians mostly practise in a hospital environment, the contact data gathered from www.zorgkaartnederland.nl partially had to be determined via phone calls.

In total, 565 surveys were delivered. Including a reminder sent one week later, 66 surveys were returned resulting in a response rate of 11.7 per cent. 16 returned surveys were discarded because of missing responses, resulting in an effective sample size of 50. There are several possible explanations for this low response rate, compared to earlier studies in the medical technology research (Chismar & Wiley-Patton, 2003; Chau & Hu, 2001; Yi et al., 2006). First, according to the rather rigid timetable of this thesis' deadlines, the author sent out the survey after ascension holidays, where lot of medical practices usually are closed. Second, including the reminder, physicians only had about 2 weeks to fill in the questionnaire, which is a rather short timeframe. Finally, most physicians are very busy and might be frustrated being faced with this amount of questions in one survey.

The mean age of respondents after deleting one invalid answer was 46.7 ranging from 28 to 64 and a standard deviation of 10.8. The gender distribution was divided into 27 male and 23 female respondents. The nearly equal distribution might seem a little odd, though reflecting reality. In 2012, the percentage of women in human medicine in Germany was found to be 48.5% (Institut für Arbeitsmarkt und Berufsforschung, 2012). 7 respondents answered that they have already taken part in a clinical trial involving the artificial pancreas. However, 2 of them are partners of Inreda and got to know the product from their testing activities. Leaving these 2 out, the percentage of possibly biased answers is still 10%. Having a figure as low as possible here is important to have an unbiased outcome, as physicians already familiar with the artificial pancreas might not subjectively consider it as an innovation anymore. More than half of the respondents (26) are working in their job for more than 15 years. Out of 50 respondents, from those physicians practicing in the Netherlands, 32 reside in the Netherlands and 1 in Belgium. From the German-speaking physicians, 12 reside in Germany and 5 in Austria. These descriptives provide no reason for considering biases in this research, as they are nearly evenly distributed among age and gender, which are considered to be main descriptives. Only residence and work-affiliation are slightly imbalanced. Physicians in the Netherlands might react to medical innovations differently from German physicians according to a different cultural mindset, and older physicians might be more resistant to younger ones, but a reasoning for that lies beyond the scope of this paper.

4.2 Measures

The survey was constructed to operationalize the variables introduced in the theory section and the constructs of the model. The author made use of existing questionnaires used to test the acceptance and adoption of innovation and adapted it to test the acceptance of medical technological innovations as in this case the artificial pancreas. As a template, the research of Chismar and Wiley-Patton (2003) was used, where the authors tailored the original items of the extended TAM to items that were intended to measure physicians' acceptance of new technologies. The items in this research are measured on a 7-point Likert scale, ranging from 1 to 7. These numbers are translated to "strongly disagree" and "strongly agree" respectively. As the sample included physicians from the Netherlands, Germany and Austria, the surveys were also translated to Dutch and German to increase respondents' comprehension as compared with delivering the survey in English. All translated items can be found in the appendix.

4.2.1 Item requirements

In the light of the short timeframe available for this research project, the author and other fellow students working on research of the artificial pancreas have decided to make exclusively use of close-ended questions. This is because these types of questions provide a greater uniformity of responses and are more easily processed than open-ended questions (Babbie, 2010). Furthermore, they can be easily transferred into a computer format, which in this case is SPSS. Another advantage of close-ended questions is that there is no chance for answers by respondents that are essentially irrelevant to the researcher's intent, as possibilities for misunderstanding normally are endless and no researcher is immune towards that (Polivka & Rothgeb, 1993). This is of particular interest in this research area, as the author is generally not deeply involved in medical technical operations and products.

4.2.2 Item selection

Table 2 provides a detailed overview of constructs used, their definition and corresponding items, as well as reliability measures. As developing own sound scales is a difficult and time-consuming process (Schmitt & Klimoski, 1991), only existing constructs and items were used for this questionnaire. They were checked for validity in terms of high Cronbach's alpha and tailored to the context of the artificial pancreas. This was because some wordings of items might have been ambiguous if asked without adapting it beforehand. For example, descriptions such as "the system", used in theories from Venkatesh (2000; 2003) had to be replaced by the notion of "the artificial pancreas".

However, there are some more crucial changes that had to be made to the original items, to appropriately tailor them to the context of the artificial pancreas. First, and apparent in most constructs, is the fact that the artificial pancreas is not yet available to any consumer and therefore not applicable to the context of possible experiences from using it. Hence, all items that incorporated any notion of actual technology usage were adapted to the expectation of a certain outcome of the usage. Respondents therefore were able to answer the questions adequately while not having the need to actually having used it by now. Second, in the earlier stages of the researchers' item and construct selection, somewhat more constructs were proposed for testing. For example, initially several items of the construct of costs were included in the questionnaire dealing with financial expenses as well as personal efforts needed to use the artificial pancreas. This construct was omitted from the survey, due to a strong overlap with the notion of perceived usefulness of the TAM (Davis, 1989). Also for the independent variable, the outcome, which is intention to use, the items were changed in the process of the operationalization. Existing theories (Venkatesh & Davis, 2000; Taylor & Todd, 1995; Davis et al., 1989) used two scales to measure this construct. However, the difference between these two questions in this research context was vanishingly low and merely a matter of question formulation. Initially, the author planned to use only one of these scales, but decided to switch for both in the final questionnaire to achieve higher reliability.

By using and slightly adapting existent and tested items only, chances of asking unclear or ambiguous questions were

basically ruled out and the reliability of the items could more easily be established. There were also no double-barrelled questions used in the questionnaire to not leaving respondents in the situation of not being able to give an answer. The researchers further made clear, that respondents are competent to answer by defining the sample to be physicians active in the field of diabetes and at least 18 years or older. In a highly specialized and not very broad topic this is very important to not end up with too many invalid responses. One issue of this research is time, as the physicians only have about two weeks to fill in the survey. Therefore, the author depends on the willingness of respondents to answer. To promote willingness, the time needed to apprehend and fill in the survey was kept at a minimum possible and tested to be about ten to fifteen minutes. Physicians usually do not have a lot of spare time, making this a very important issue to have a sufficient response rate. After gathering items for all constructs described in existing theories, the researchers checked for overlapping and redundancies between the questions' intents. Though items in questionnaires should tend to be short, the complexity of the research focus justifies a few somewhat longer questions. To further minimise irritation and misinterpretation, negative items were omitted from the questionnaire. The author carefully only selected items from existing questionnaires that allow measuring the concept of this research.

Table 2 gives a comprehensive overview of the constructs reviewed from the theory and the corresponding adaptation to the context of the artificial pancreas.

Table 2. Construct and Item Description and Operationalization

Construct	Definition	Original Item	Author and Cronbach's alpha	Adapted item
Innovativeness	The degree, to which an individual is relatively earlier in adopting an innovation than other members of a specific social system	1. Other people come to you for advice on new technologies 2. In general, you are among the first in your circle of friends to acquire new technology when it appears 3. You can usually figure out new high-tech products and services without help from others 4. You keep up with the latest technological developments in your areas of interest 5. You find you have fewer problems than other people in making technology work for you	Godoe and Johansen (2012), Cronbach's alpha: Minimum 0.74	INN_01: Other people come to you for advice on new technologies INN_02: In general, you are among the first in your circle of friends to acquire new technology when it appears INN_03: You can usually figure out new high-tech products and services without help from others INN_04: You keep up with the latest technological developments in your areas of interest INN_05: You find you have fewer problems than other people in making technology work for you
Perceived usefulness	An individual's perception that the application of a certain technology or innovation will outperform existing practices	1. Using the system improves my performance in my job 2. Using the system in my job increases my productivity 3. Using the system enhances effectiveness in my job 4. I find the system to be useful in my job	Venkatesh (2000), Cronbach's alpha: Minimum 0.87	VN_01: I expect that using the artificial pancreas improves my performance in my job VN_02: I expect that using the artificial pancreas in my job increases my productivity VN_03: I expect that using the artificial pancreas enhances effectiveness in my job VN_04: I expect that the artificial pancreas will be useful in my job
		5. (. . .) enables me to accomplish tasks more quickly 6. Using (. . .) makes it easier to do my job	Godoe and Johansen (2012), Cronbach's alpha: Minimum 0.90	VN_05: I expect that using the artificial pancreas in my job would enable me to accomplish tasks more quickly VN_06: I expect that using the artificial pancreas would make it easier to do my job
Complexity	The degree to which a system is perceived as relatively difficult to understand and use	1. Using the system takes too much time from my normal duties 2. Working with the system is so complicated, it is difficult to understand what is going on 3. Using the system involves too much time doing mechanical operations 4. It takes too long to learn how to use the system to make it worth the effort	Venkatesh (2003) based on Thompson et al. (1991), Cronbach's alpha: Minimum 0.73	ING_01: I expect that using the artificial pancreas takes too much time from my normal duties ING_02: I expect that working with the artificial pancreas is so complicated, it is difficult to understand what is going on ING_03: I expect that using the artificial pancreas involves too much time doing mechanical operations ING_04: I expect that it takes too long to learn how to use the artificial pancreas to make it worth the effort
Intention to use	An individuals intention to use a particular device or technology	1. Assuming I have access to the system, I intend to use it 2. Assuming I have access to the system, I predict that I would use it	Venkatesh and Davis (2000), Cronbach's alpha: Minimum 0.82	ITU_01: Assuming I have access to an artificial pancreas, I intend to prescribe it ITU_02: Assuming I have access to an artificial pancreas, I predict I would prescribe it

4.2.3 Questionnaire construction

Within this research, the author intended to make use of a self-administered questionnaire instead of interviews. Interviews may face biases resulting from the interviewer-respondent interaction and are difficult to conduct when the units of observation are geographically dispersed (Bradburn & Sudman, 1979; Kwong See & Ryan, 1999). The survey is conducted via mail, which fosters the ease of administration and the professional appearance of the questionnaire. Another important consideration for mail surveys is that questionnaires can be completed at the respondent's convenience and are generally perceived as more anonymous than other methods (Synodinos, 2003). For the digital creation of the survey, the online tool "Limesurvey" was used, which design is plain but clear. The author made sure, that the questionnaire is not squeezed-together to not discourage or confuse the respondents. As for the scales, an explanation of the orientation and the meaning of each number are given in the introduction text of the item as well as on top of the scale. In the chosen format of the questionnaire, the respondent simply has to tick a box underneath the scale of each item and it was made sure that the answer categories are mutually exclusive.

4.3 Data collection

Before the actual delivery of the questionnaire, its validity and suitability was internally tested by students, PhD's and a physician. After this pre-test, the survey was delivered by the Limesurvey incorporated email function to the selected respondents. In this mail, the recipients were able to find a formal invitation followed by a detailed description of the questionnaire occasion, its owners and the description of the artificial pancreas itself. The product description was supported by several illustrations.

The survey software Limesurvey is easily and intuitively to understand and to be operated by both, questionnaire creators and respondents. It provides respondents with the option to pause the filling in and to resume it later. This function comes in especially handy for physicians, who cannot completely plan

their daily tasks and might only have a couple of minutes between the treatment of several patients.

However, the researcher faced a low response rate, so that after one week a reminder was sent out, to generate at least enough responses to make the actual testing of the proposed model feasible. The reminder contained a friendly email, which once again shortly described the questionnaire's purpose and asked the recipient for support in conducting this research.

4.4 Analysis

For the analysis, the statistics package Microsoft SPSS was used. The data gathered from the Limesurvey questionnaire could automatically be transferred into the predictive statistics software SPSS to perform a multiple regression analysis, which is appropriate for testing the proposed research model with several not-interconnecting predictors and an outcome variable (Friedrich, 1982). Next to general descriptive statistics such as means, standard deviations and correlations of the variables, the analysis will help to answer the research question, and give insight about whether innovativeness, perceived usefulness and complexity have a direct influence on physicians intention to use the artificial pancreas as suggested by the author.

As for the sake of the simplicity of the author's research model the predictor variables are assumed to be completely uncorrelated, the order of variable entry has very little effect on the parameters calculated, and the method of regression was chosen to be a forced entry, which is also argued to be the only appropriate method for theory testing (Studenmund & Cassidy, 1987).

5. RESULTS

5.1 Descriptives

This analysis incorporated questionnaire answers of 50 respondents. The author made use of SPSS to calculate several general descriptives of the scales used. The author used means and standard deviations to show the average spread of values of the variables used in this research. Furthermore, a Pearson's correlation calculation was performed to measure how well the data sets are related. It is noticeable, that only the correlation between perceived usefulness and intention to use show a somewhat meaningful value, while all other correlations tend towards zero, describing a rather not existent relationship. In result, the relationship between the three independent variables is weak and only significant for perceived usefulness and complexity with r equalling 0.346 (z=2.59, P= 0.14, N=50). Table 3 gives an overview of the correlation between the data and the descriptives.

Table 3. Correlation Matrix and Construct Level Statistics

	Sample Size N	Mean	Standard Deviation	Intention to use	Innovativeness	Perceived Usefulness	Complexity
Intention to use	50	5.3600	1.08816	1.000	0.109	0.620**	-0.156
Innovativeness	50	4.7150	1.05343	0.109	1.000	0.163	-0.059
Perceived Usefulness	50	3.8686	0.94710	0.620**	0.163	1.000	-0.346**
Complexity	50	3.2450	1.08620	-0.156	-0.059	-0.346**	1.000

*** Correlation is significant at the 0.01 level (1-tailed)*

5.2 Validity

A factor analysis was used to test the convergent and discriminant validity and to determine the dimensionality of the scales used (Gliem & Gliem, 2003). Validity is considered to be satisfactory when items load high on their respective component (about 0.7 or higher) and low on other components (about 0.4 or lower) (Chismar & Wiley-Patton, 2003). For this, the author made use of a principal component analysis with oblimin rotation. According to Stevens (2002) as cited by Field (2009), for a sample size of 50, which is exactly the sample size of this study, a loading factor of 0.722 can be considered significant.

It revealed, that the items of the outcome variable intention to use evenly loaded on two factors, which are intention to use and perceived usefulness. Though surprising, theory provides several explanations for this conspicuousness. The technology readiness index (TRI) as suggested by Parasuraman (2000) refers to "people's propensity to embrace and use new technologies for accomplishing goals (…) at work" (p. 308). However, recent research on innovativeness as a predictor on perceived usefulness, which in turn can be seen as an antecedent of intention to use, showed that there is a significant negative impact (Walczuch, Lemmink & Streukens, 2007). An explanation for this can be, that innovative people are more critical towards technology, as they are usually aware of new innovations and developments and have a rather high expectation of technologies fulfilling highest demands and standards (Walczuch et al., 2007). The construct of Intention to use was therefore omitted from the factor analysis.

The same was true for one item of the construct of innovativeness as it showed a very low loading factor of 0.143 only. All other constructs and items were found to be consistent valid. Perceived usefulness showed loadings of a minimum of 0.707 and a maximum of 0.873. According to Stevens (2002), this item would be considered insignificant and subject to leave out. However, the author decided to keep this scale, due to its crucial relevance for the research. After omitting one item from the test, Innovativeness showed a minimum loading of 0.762 with a marginal loading of 0.190 on Complexity, which is acceptable at that level. The maximum loading factor for Innovativeness was 0.837. Complexity's highest loading factor was 0.833 with a marginal loading on Innovativeness of 0.210, which is also reasonable considering the causal connectivity of those constructs. The lowest value came to 0.774.

Table 4 summarizes the results of the factor analysis, suggesting that the measurement in overall provides strong convergent and discriminant validity for the context of this study.

Table 4. Factor Structure Matrix of Loadings and Cross-loadings

	1	2	3
Perceived Usefulness			
VN_01	0.873		
VN_02	0.836		0.209
VN_03	0.794	0.128	
VN_04	0.794	0.166	-0.120
VN_05	0.748	-0.163	-0.215
VN_06	0.707	-0.208	
Innovativeness			
INN_02		0.837	
INN_03		0.820	
INN_04		0.806	-0.174
INN_05	0.116	0.762	0.190

Complexity		
ING_01	0.210	0.833
ING_02	-0.212	0.799
ING_03		0.782
ING_04	-0.138	0.774

Principal components analysis with oblimin rotation was performed

Also, the sampling adequacy was tested using a KMO test, showing a value of 0.750. Kaiser (1974) recommends a level of at least 0.5 and a value between 0.7 and 0.8 as good (Hutcheson and Sofroniou, 1999). Furthermore Bartlett's test of sphericity indicated a significant difference with $p<0.001$ and a chi-square value of approximately 370 with 91 degrees of freedom. With these values the author was confident, that the sample size is adequate for factor analysis. A possible bias of multicollinearity, when there is a strong correlation between the predictors, was checked using measures of correlation matrix analysis and variance inflation (VIF) analysis. For the former, the author checked all values in the correlation matrix and found none to be higher than 0.8, which is the threshold (Field, 2009). Also all VIF values are slightly above 1 only, which is a level at which there is no need to worry about multicollinearity (Cornell & Myers, 1987; Bowerman & O'Connell, 1990).

5.3 Reliability

Although the scales used have been validated extensively by prior research, the author tested the adapted scales for internal resistance reliability within the context of the acceptance of the artificial pancreas by physicians. Table 5 shows the reliability measures using Cronbach's alpha values. All these values are rather high, considering a minimum level of 0.700 argued for by Nunally and Bernstein (1994).

Table 5. Model Reliability Indices

Construct	Cronbach's alpha
Intention to use	0,922
Innovativeness	0.824
Perceived Usefulness	0.887
Complexity	0.827

5.4 Model testing

To address the research question and test the model of physicians' acceptance of medical technology innovations, linear multiple regression was used. This analysis aimed at explaining the intention to use influenced by innovativeness of the responding individual, and the perceived usefulness and complexity of the technology. An R^2 value of 0.388 testifies that the effects of the predictors explained almost 39% of the variance of intention to use. Continuing this means, that about 61% is related to other unknown, or untested variables.

A theorized perceived usefulness was found to have a significant positive influence on physicians' intention to use the artificial pancreas ($p<0.001$). Its R^2 value explains 38.4% of the variance of usage intention. However, the hypothesized influence of innovativeness and complexity was not significant and the corresponding hypotheses had to be rejected. For the former, R^2 explains 1.2% of the variance of intention to use only and 2.4% for the latter respectively. Furthermore, the B value of complexity even suggests that the hypothesis is headed in the wrong direction. According to the outcome, complexity is suggested to have a positive influence on intention to use, while the hypothesis theorized a negative relation. However, as this outcome is not significant, any direction for these variables can be neglected. Table 7 gives the reader an overview of the regression results.

Table 6. Results Structural Model explaining Intention To Use

	B	Std. Error	R Square	Beta	t-value	Significance
Constant	2.252	0.928	0.388		2.426	0.019
Innovativeness	0.009	0.121	0.012	0.009	0.075	0.940
Perceived Usefulness	0.737	0.143	0.384	0.641	5.155	0.000
Complexity	0.066	0.123	0.024	0.066	0.538	0.593

6. DISCUSSION

6.1 Summary of findings

In this research, the author intended to integrate several streams of research and to define their relations between some of their key constructs to test physicians' acceptance of new medical technology applications. With two of three hypotheses rejected, the model explains 38.8% of the variance of usage intentions. It is worthwhile to have a closer look at the coefficients of the analysis here. Most striking is the very low gradient B of complexity as a predictor of intention to use. Within the multiple regression analysis this gradient was found to be positive, suggesting a positive relationship in reality, though negatively related as described by Pearson's correlation coefficient analysis in table 3. Critical thinking would lead to the conclusion that the more complex and difficult a technology is to understand and use, the more reluctant possible users are to actually adopt it. This is also described by Rogers (1995), who states that the less complex an innovation is, the more rapidly it will be adopted compared to innovations "that require the adopter to develop new skills and understandings" (p. 15). However, various research (Hu, Chau, Sheng & Tam, 1999; Lee, Kim, Rhee & Trimi, 2006; Liu & Ma, 2005) found the relationship between perceived ease of use, which is similar in its nature to complexity, and intention to use to be insignificant across various contexts. Hu et al. (1999) argue for physicians to have a higher degree of competence and intellectual and cognitive capacity as a reason for that, making the variable of complexity not sufficient or not critical for the explanation of intention to use a new technology within this professional user group. Furthermore, Chau and Hu (2002) argue that physicians often have a strong staff support of nurses and assistant physicians for operating medical equipment, which allows them to neglect certain aspects of mastering technology and are able to comprehend them quicker than the average population.

This might be another reason for the significance and the rather high B value of perceived usefulness as a predictor of intention to use while explaining 38.4% of the variance of intention to use. For example, Keil, Beranek and Konsynski (1995) argue that in the decision-making process of whether or not to use a certain technology, for physicians, usefulness is a more important aspect than ease of use or complexity. Other studies

even revealed higher explanation of the variance in intention to use by perceived usefulness, such as in the longitudinal studies on the extended TAM of Venkatesh and Davis (2000), where Perceived Usefulness explained 60% of intention to use. This is in line with this research paper, although it showed a lower explanation of 38.4%.

Finally, the lack of support for the hypothesized influence of innovativeness on intention to use might come in surprisingly to the reader. Following from the theory, the author hypothesized physicians showing a higher level of personal innovativeness to be more keen to adapt new medical technology. This inference stems from the notion of Rogers' (1995) information diffusion theory, which suggests that individuals who show a stronger peculiarity in innovativeness are more favourably inclined towards trying out new technologies and possess greater ability to deal with uncertainty and risk. Denis, Hébert, Langley, Lozeau and Trottier (2002) suggest that one reason for the somewhat reverse expectation is that in general, innovations that have a clear and proven relative advantage in effectiveness, as measured by perceived usefulness, are rather adopted through their characteristics than through the individuals' personal characteristics. A further study of Heisler, Bouknight, Hayward, Smith and Kerr (2002) showed that physicians base their usage intention of medical appliances on their urge to act in the patients' interest and improve patients' self-management, an aspect that can be supported by the artificial pancreas.

In sum, this study provided statistical evidence for a relationship between the extrinsic factor of perceived usefulness on intention to use, while the other extrinsic factor complexity and the intrinsic factor innovativeness were found to not be significant as a predictor of intention to use.

6.2 Evaluation and limitations

This research holds several limitations that should be noted. First of all, this study did not test the actual usage of the technology discussed, but instead usage intentions were assessed. Although the scales used were adapted considering this issue, this might be a bias towards the answers given by the respondents. Second, this study incorporated a single-design study resulting in findings and implications examining a particular technology only and might be different in perception outcomes for other medical innovations. Next to that, the sample size was rather small, though internal statistics proved the appropriateness of the size towards the research analysis. Third, the scope of this paper as a basis assessment criterion of this Bachelor thesis limits this research to a certain user group, professionally and geographically, distributed over the countries Germany, Austria and the Netherlands. However, in practical terms this is appropriate, as Inreda is firstly interested in results of these countries only. Fourth, the administrative issue of survey translation from English to German and Dutch was prone to possible misunderstanding or different comprehension of scales due to mistakes in translation. Another issue is that the components, though the components used in this research are considered to be mutually exclusive, are not collectively exhaustive and studies suggest that external influences must not be ignored in appropriate technology acceptance measurements (Burton-Jones & Hubona, 2006; James, Pirim & Boswell, 2006; Yi et al., 2006). Finally, a phone-call between the author and a German physician revealed the assertion, that physicians can not base their possible acceptance of new medical technical innovations on intrinsic and personality factors and extrinsic factors or technology characteristics but solely on the issue of financial reimbursement through insurances. This might result in a general bias, that physicians will base their attitude towards the artificial pancreas as a foregone conclusion on financial aspects only instead of considering the characteristics of the innovation or their own capabilities and perceptions. However, this might only be true for general medical circumstances in Germany and can not be examined within the scope of this study.

6.3 Recommendations and implications for further research

6.3.1 Practical

This research has some important implications as well. It provides substantial marketing research insights for Inreda on their way to introduce the artificial pancreas in the Dutch, German and Austrian market. The results show, where to focus on, and which aspects need to be tackled in second instance only. For example, it is worthwhile thinking about focusing rather on emphasizing benefits of the new technology in terms of perceived usefulness than attaching lengthy descriptions, application examples and manuals. Given the outcomes of this research, Inreda rather has to build up the strengths of their technology and market this adequately and ingeniously to possible users than to identify those individuals who provide a higher propensity to try out new technologies and to involve them in the introduction process of the innovation.

6.3.2 Theoretical

Beyond a practical scope, this study provides a leverage point for further research. From a theory development, the author has established and found empirical support for the influence of extrinsic factors as in this research the technology characteristic perceived usefulness based on the TAM on intention to use. However, these findings were not in line with components of innovation diffusion theory and the understanding of the technology readiness index. The rejection of two hypotheses raises some intriguing implications on the construction of the research model, which is striking, due to the rather simple nature of the model used within this research. A suggestion therefore is to research for antecedents of the predictors used in this analysis. Also, as stated before, it would be worthwhile to investigate possible mediating factors and examine individual differences between components that are auxiliary in explaining the variance in beliefs and perceptions to a large extent. A further fruitful research opportunity builds the fact that complexity tends to increase the intention to use, according to the outcomes of this study. An application of this research methodology to other fields of profession or regional clusters can deliver interesting insights. A final suggestion that does not need a new conceptualization or approach to the theory is to run this study for a longer time with a higher sample size. It is also conceivable, to do a comparing analysis after the market introduction of the artificial pancreas.

7. CONCLUSION

With the introduction of the artificial pancreas, Inreda is going to set a milestone in diabetes treatment, like the epinephrine autoinjector or the insulin pump did before. Getting a grasp of the likelihood of acceptance of this innovation therefore is of crucial economic nature for the organization. This research delivered insights into the factors influencing the acceptance of physicians and proposing a new framework seizing on widely accepted and tested components of the last decades. The author assessed empirical evidence for integrating streams from the most accepted and prevalent theories, providing Inreda with substantial information about underlying factors of technology acceptance and suggestions for actively and successfully accompanying and moderating the adoption process of their artificial pancreas by physicians.

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10. APPENDIX

10.1 Background information on diabetes

The disease diabetes mellitus is specified into several subtypes, of which there are a few major types, namely type -1, accounting for approximately 5-10%, type-2, accounting for approximately 90-95% of the diagnosed diabetes population, and gestational diabetes. While the form of gestational diabetes is most often of temporary nature, type-1 and type-2 diabetes are usually chronic down to the present day. Hereby, people diagnosed with the former type suffer from an autoimmune attack against the pancreatic islet beta cells, which produce insulin, making frequent insulin injections to replace the regular pancreatic release of insulin the only means of treatment, whereas the latter type shows a cell resistance towards insulin, preventing circulating insulin from accessing the cells and adjusting the level of glucose in the body (Alberti and Zimmet, 1998). To compensate the resistance towards insulin and the resulting high level of glucose in the blood, the pancreas secretes increased levels of insulin. This pre-diabetic state is a gradual process, continuing for up to 10 years. Pre-diabetic patients suffer an increased risk of stroke and cardiovascular disorders and have to adapt appropriate changes in lifestyle and diet to evade developing Type-2 diabetes (Business Insights, 2011) As a treatment of diabetes type-2, oral anti-diabetic drugs (OADs) are the main type of treatment. Most patients also require insulin treatment in later stages of the disease, which is typically used in combination with OADs.

Insulin dependent patients, namely those suffering from diabetes type 1 are required to strictly monitor their administration of insulin and match it with their diet and daily exercise intensity. Dosage failures will lead to severe complications and life dangers. The spectrum of insulin application means includes specific pens, which inject a certain amount of insulin subcutaneous as well as insulin pumps (Healthchecksystems.com, 2012)

These facts and issues can lead to a tremendous decrease of the level of ease of living and convenience of the daily lives of diabetes patients. Fortunately, research and development in the field of technological advances in so-called continuous subcutaneous insulin infusion (CSII) and continuous glucose monitoring (CGM) have taken big steps forward since the beginning of the new millennium. (Gonder-Frederick, Shepard and Peterson; 2011).

A more recent technology, the artificial pancreas, takes the capabilities of both these technologies and combines them in a close-loop and state-of-the-art appliance. (Klein, 2009) This artificial pancreas is essentially an electro-mechanical device, carried close to the body, that includes three main elements which are insulin delivery, a continuous glucose sensing, and an algorithm-based controller, that, similar to the beta cell, monitors and calculates the right amount of insulin needed at the right time (Kowalski, 2009; Hovorka, 2006) It seems obvious, that the application of this device can imply a great relief for patients suffering from diabetes and make their daily life more convenient. According to recent research, at this moment in time, the artificial pancreas, though no panacea, is said to be the most promising and convenient way of treatment for diabetes type 1 patients (Weinziemer, Steil, Swan, Dziura, Kurtz and Tamborlane, 2008)

10.2 Item translations

The following table 7 provides an overview of all items used for the research on the artificial pancreas by the author of this paper and his study colleagues, researching different aspects on the planned market introduction by Inreda.

Table 7. Construct and item translation to Dutch and German

Construct (Dutch/German)	Coding	Dutch Item	German Item
NL: Bereidheid tot aanschaf van de kunstmatige alvleesklier DE: Kaufbereitschaft EN: Buyer Readiness	BR_01	Ik heb wat gehoord of gelezen over de kunstmatige alvleesklier alvorens deze enquête in te vullen	Ich habe von der künstlichen Bauchspeicheldrüse gehört oder gelesen, bevor ich diesen Fragenbogen ausgefüllt habe.
	BR_02	De kunstmatige alvleesklier is zichtbaar in mijn beroepspraktijk	Die künstliche Bauchspeicheldrüse ist in meinem professionellen Umfeld präsent.
	BR_03	Ik heb actief gezocht naar informatie over de kunstmatige alvleesklier	Ich habe mich bemüht weitere Informationen über die künstliche Bauchspeicheldrüse zu erhalten, nachdem ich von ihr erfahren habe.
	BR_04	Ik wil meer weten of leren over de kunstmatige alvleesklier	Ich möchte mehr über die künstliche Bauchspeicheldrüse erfahren und lernen.
	BR_05	Ik ben van plan de kunstmatige alvleesklier te vergelijken met andere behandelingen	Ich gedenke die künstliche Bauchspeicheldrüse mit anderen Behandlungsmethoden zu vergleichen.
NL: Optimisme DE: Optimismus EN: Optimism	OPT_01	Technologie geeft mensen meer controle over hun dagelijkse leven	Technologie gibt Menschen mehr Kontrolle im Alltag.
	OPT_02	Producten en diensten die de nieuwst beschikbare technologie gebruiken zijn gemakkelijker om te gebruiken.	Produkte und Dienstleistungen, die auf der neuesten Technologie basieren, sind deutlich komfortabler zu nutzen.
	OPT_03	U heeft een voorkeur om de meest geavanceerde technologie die beschikbaar is te gebruiken.	Ich bevorzuge es modernste Technologien zu nutzen.
	OPT_04	Technologie maakt u efficiënter in uw beroep.	Technologien erlauben es mir, effizienter in meinem Beruf zu sein.
	OPT_05	Technologie geeft u meer bewegings vrijheid.	Technologien geben mir mehr Mobilität.
	OPT_06	U bent ervan overtuigd dat apparaten doen wat u ze heeft geïnstrueerd.	Ich bin zuversichtlich, dass Maschinen das befolgen was ich ihnen vorgebe.
NL: Innovativiteit DE: Innovativität EN: Innovativeness	INN_01	Andere mensen komen bij u advies inwinnen over nieuwe technologieën.	Mitmenschen fragen mich nach Ratschlägen zu neuen Technologien.
	INN_02	In het algemeen bent u de eerste in uw vriendenkring die nieuwe technologie aanschaft wanneer het beschikbaar is.	Generell bin ich einer der Ersten in meinem Bekanntenkreis der neue Technologien besitzt sobald sie verfügbar sind.
	INN_03	Normaliter begrijpt u nieuwe high-tech producten en diensten zonder de hulp van anderen.	Gewöhnlicherweise kann ich neue Hightech-Produkte und Dienstleistungen ohne die Hilfe von anderen verstehen.

Construct (Dutch/German)	Coding	Dutch Item	German Item
	INN_04	U blijft op de hoogte van de laatste technologische ontwikkelingen in uw werkveld.	Ich bin über die neuesten technologischen Entwicklungen in Gebieten, die mich interessieren, auf dem Laufenden.
	INN_05	U heeft over het algemeen minder problemen dan andere mensen om u een technologie eigen te maken.	Ich habe weniger Probleme als andere Menschen mit technischen Geräten umzugehen.
NL: Ongemak DE: Unannehmlichkeiten EN: Discomfort	ONG_01	Technische instructies zijn niet behulpzaam omdat ze geen uitleg geven in voor u begrijpelijke taal	Technik-Hotlines sind für mich nicht hilfreich, da sie Dinge nicht in leicht verständlicher Sprache erklären.
	ONG_02	Soms denkt u dat technische systemen niet ontworpen zijn voor gewone mensen.	Manchmal denke ich, dass technologische Systeme nicht für den Durchschnittsmenschen gemacht sind.
	ONG_03	Naar mijn mening, bestaat er niet zoiets als een handleiding voor een high-tech product of dienst dat is geschreven in eenvoudig Nederlands.	Es gibt keine Anleitung für Hightech-Produkte oder Dienstleistungen, die in deutlicher Sprache verfasst ist.
	ONG_04	Wanneer je een technisch product of dienst koopt, heb je liever het basis model dan een model met veel extra functies	Wenn ich ein Hightech-Produkt oder eine Dienstleistung kaufe, bevorzuge ich eher das Basismodell als eines mit viel Ausstattung.
	ONG_05	Voorzichtigheid is geboden wanneer belangrijke menselijke taken vervangen worden door nieuwe technologie.	Achtsamkeit ist von Nöten, da neue Technologien, die die manuelle Arbeit von Menschen ersetzen, defekt sein können.
	ONG_06	Veel nieuwe technologische ontwikkelingen hebben gezondheids- of veiligheidsproblemen die niet ontdekt worden tot na gebruik.	Viele neue Technologien haben Gesundheits- oder Sicherheitsrisiken, die nicht erforscht sind bevor sie genutzt werden.
	ONG_07	Technologie lijkt altijd te mislukken op het slechtst mogelijke moment.	Dem Anschein nach versagen Technologien immer im ungünstigsten Augenblick.
NL: Onzekerheid DE: Unsicherheit EN: Insecurity	ONZ_01	Revolutionaire nieuwe technologie is vaak minder veilig dan critici me doen geloven.	Kritiken lassen Menschen glauben, dass revolutionäre neue Technologien deutlich unsicherer sind als sie eigentlich sind.
	ONZ_02	Een machine of een computer zal een taak minder betrouwbaar uitvoeren dan een persoon.	Eine Maschine oder ein Computer ist deutlich unzuverlässiger in der Bewältigung einer Aufgabe als ein Mensch.
	ONZ_03	Het kan riskant zijn om te vroeg naar een nieuwe technologie om te schakelen.	Es kann riskant sein zu schnell zu einer revolutionären neuen Technologie zu wechseln.
	ONZ_04	Als je producten koopt die erg high-tech zijn, kan het gebeuren dat je geen reserve onderdelen of service kan vinden.	Wenn ich ein Hightech-Produkt erwerbe, laufe ich Gefahr keine Ersatzteile zu finden oder Service zu erhalten.
	ONZ_05	Nieuwe technologieën lijken altijd mensen te benadelen doordat deze hun vaardigheden overbodig maken	Technologische Innovationen schaden immer einer Menge Menschen, da sie deren Fähigkeiten hinfällig machen.
NL: Verwachte Nut DE: Wahrgenommener Nutzen EN: Perceived Usefulness	VN_01	Ik verwacht dat het gebruik van de kunstmatige alvleesklier de prestaties in mijn werk zal verbeteren	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse meine Leistungsfähigkeit im Beruf erhöht.
	VN_02	Ik verwacht dat het gebruik van de kunstmatige alvleesklier de productiviteit in mijn werk zal verbeteren	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse meine Produktivität im Beruf erhöht.
	VN_03	Ik verwacht dat het gebruik van de kunstmatige alvleesklier de effectiviteit in mijn werk zal verbeteren	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse meine Effektivität im Beruf erhöht.
	VN_04	Ik verwacht dat het gebruik van de kunstmatige alvleesklier nuttig zal zijn in mijn werk	Ich erwarte, dass die künstliche Bauchspeicheldrüse nützlich in meinem Job sein wird.
	VN_05	Ik verwacht dat het gebruik van de kunstmatige alvleesklier me zal helpen om bepaalde taken in mijn werk sneller te volbrengen	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse es mir ermöglicht, Aufgaben schneller zu erledigen.
	VN_06	Ik verwacht dat het gebruik van de kunstmatige alvleesklier het makkelijker maakt om mijn werk uit te oefenen	Ich erwarte, dass mir die Nutzung der künstlichen Bauchspeicheldrüse die Ausführung meiner Arbeit erleichtert.
NL: Compatibiliteit DE: Kompatibilität EN: Compatibility	COM_01	Ik verwacht dat het gebruik van de kunstmatige alvleesklier aansluit bij alle aspecten van mijn werk	Die Nutzung der künstlichen Bauchspeicheldrüse ist kompatibel mit sämtlichen Aspekten meiner Arbeit.
	COM_02	Ik denk dat het gebruik van de kunstmatige alvleesklier goed past bij de manier waarop ik graag werk	Ich denke, dass die Nutzung der künstlichen Bauchspeicheldrüse gut in die Art und Weise, wie ich arbeite, passt.
	COM_03	Ik verwacht dat het gebruik van de kunstmatige alvleesklier past bij mijn werkstijl	Ich denke, dass die Nutzung der künstlichen Bauchspeicheldrüse gut zu meinem Arbeitsstil passt.
NL: Ingewikkeldheid DE: Komplexität EN: Complexity	ING_01	Ik verwacht dat het gebruik van de kunstmatige alvleesklier te veel tijd wegneemt van mijn normale taken	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse zu viel Zeit von meiner regulären Arbeitszeit beansprucht.
	ING_02	Ik verwacht dat het werken met de kunstmatige alvleesklier zo ingewikkeld is dat het moeilijk is om te begrijpen is wat er precies gaande is	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse derart kompliziert ist, dass es schwierig wird die Anwendung zu verstehen.
	ING_03	Ik verwacht dat het gebruik van de kunstmatige alvleesklier te veel tijd kost in de vorm van de uit te voeren handelingen	Ich erwarte, dass die Nutzung der künstlichen Bauchspeicheldrüse zu viel Zeit für mechanische Vorgänge beansprucht.
	ING_04	Ik verwacht dat het te lang zal duren om te leren hoe de kunstmatige alvleesklier gebruikt dient te worden om het de moeite waard te maken	Ich erwarte, dass das Erlernen der Nutzung der künstlichen Bauchspeicheldrüse zu viel Zeit benötigt, sodass der Nutzen verringert wird.
NL: Subjectieve Norm DE: Subjektive Norm EN: Subjective Norm	SN_01	Ik denk dat mensen die mijn gedrag beïnvloeden vinden dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten.	Ich denke, dass Menschen, die mein Verhalten beeinflussen, meinen, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.
	SN_02	Ik denk dat mensen die belangrijk voor mij zijn vinden dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten.	Ich denke, dass Menschen, die mir wichtig sind, meinen, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.

Construct (Dutch/German)	Coding	Dutch Item	German Item
NL: Sociale Influenties DE: Sozialer Einfluss EN: Social Influences	SI_01	Mijn collega artsen vinden waarschijnlijk dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten	Meine Kollegen denken, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.
	SI_02	Over het algemeen wil ik doen wat mijn collega artsen vinden dat ik zou moeten doen	Im Großen und Ganzen möchte ich das tun, was meine Kollegen denken das ich tun sollte.
	SI_03	Mijn leidinggevenden vinden waarschijnlijk dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten	Meine Vorgesetzten denken, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.
	SI_04	Over het algemeen wil ik doen wat mijn leidinggevenden vinden dat ik zou moeten doen	Im Großen und Ganzen möchte ich das tun, was meine Vorgesetzten denken das ich tun sollte.
	SI_05	Mijn ondergeschikten vinden waarschijnlijk dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten	Meine Untergebenen denken, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.
	SI_06	Over het algemeen wil ik doen wat mijn ondergeschikten vinden dat ik zou moeten doen	Im Großen und Ganzen möchte ich das tun, was meine Untergebenen denken das ich tun sollte.
	SI_07	Mijn patiënten vinden waarschijnlijk dat ik de kunstmatige alvleesklier zou moeten voorschrijven aan mijn patiënten	Meine Patienten denken, dass ich die künstliche Bauchspeicheldrüse verschreiben sollte.
	SI_08	Over het algemeen wil ik doen wat mijn patiënten vinden dat ik zou moeten doen	Im Großen und Ganzen möchte ich das tun, was meine Patienten denken das ich tun sollte.
NL: Bedoeling tot Gebruik DE: Nutzungsabsicht EN: Intention to Use	ITU_01	Er van uitgaande dat ik toegang zou hebben tot een kunstmatige alvleesklier, ben ik van plan om het voor te schrijven	Vorausgesetzt ich habe Zugang zur künstlichen Bauchspeicheldrüse, plane ich diese einzusetzen.
	ITU_02	Er van uitgaande dat ik toegang zou hebben tot een kunstmatige alvleesklier, voorspel ik dat ik het zou voorschrijven	Vorausgesetzt ich habe Zugang zur künstlichen Bauchspeicheldrüse, nehme ich an, dass ich diese nutzen würde.
NL: Demografische Vragen	AGE	Wat is uw leeftijd?	Alter
DE: Demographische Fragen	GEN	Wat is uw geslacht?	Geschlecht
EN: Demographical Questions	EDU	Wat is uw hoogst genoten opleiding waarvan u een diploma heeft behaald?	Höchster erzielter Abschluss
	NAT	In welk land bent u woonachtig?	In welchem Land sind Sie derzeit wohnhaft?
	BER	Hoeveel jaren werkt u in uw huidige beroep?	Wie lange sind Sie bereits in Ihrem jetzigen Beruf tätig?
	KLITEST	Heeft u deelgenomen aan een klinische test van de kunstmatige alvleesklier?	Haben Sie bereits an einer klinischen Teststudie der künstlichen Bauchspeicheldrüse teilgenommen?
	TYPHOS	In wat voor type ziekenhuis bent u werkzaam?	In welcher Art von Krankenhaus sind Sie zur Zeit tätig?
	COMMAP	Door middel van welk communicatie kanaal wordt u normaliter op de hoogte gebracht van nieuwe (medische) technologieën zoals de kunstmatige alvleesklier?	Wie erfahren Sie im regelfall von den neuesten (medizinischen) Technologien, wie zB. der künstlichen Bauspeicheldrüse?