5-15-2012

INDIVIDUAL INFUSION OF M-HEALTH TECHNOLOGIES: DETERMINANTS AND OUTCOMES

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Abstract

Despite substantial research on IT implementation in the IS field, the healthcare industry has historically been considered a technological laggard and lacks direction on how to successfully infuse new technological innovations within individuals work practices. Theoretically, mobile-health (m-health) technologies, if infused in work practices can potentially enhance the quality of healthcare delivery. The question remains as to whether practitioners' performance significantly improves and individual knowledge is enhanced through the infusion of these technologies. While a significant amount of extant literature focuses on initial technology adoption and acceptance, there remains a dearth of literature in the IS field focusing on the long term utilisation and associated benefits.

This paper addresses this gap in extant literature through the development and testing of a conceptual model, exploring determinants of individual infusion of m-health technologies and their subsequent outcomes. This study reveals (a) key enablers of successful mobile infusion in a healthcare context and that successful infusion is determined by the characteristics of the: 1. technology 2. user and 3. task, (b) Infusion of mobile technologies leads to improvements in preventative care, greater decision making and reduced medical errors and, (c) Individuals perceive that knowledge is presented rather than created through mobile technologies.

Keywords: Infusion, Mobile Technology, Individual Performance, Knowledge Creation

1. INTRODUCTION AND THEORETICAL BACKGROUND

In healthcare, organisations continually strive to improve patient care (Mohr et al., 2008). Information Technology (IT) is perceived as being an enabler of more efficient and effective healthcare delivery (Green et al., 2007). Yet, despite substantial research on IT implementation in the Information Systems (IS) field, the healthcare industry remains a technological laggard (Burke and Menachemi, 2004) with a dearth of research focusing on how to infuse IT technologies into an individuals' work practices in order to realise substantial benefits. The underlying premise behind this 'lag' is that information technologies are often under-utilised following adoption (Jasperson et al., 2005). For instance, a study conducted in the Geneva University Hospital (Tschopp et al., 2002) with mobile handheld devices found that usage of the devices declined after the initial phase of implementation. It is therefore important to investigate post-adoption use of any technological innovation to fully appreciate long term success of IT technologies (Stafford et al., 2010).

Cooper and Zmud (1990) identify six stages of IT implementation. Analysis of the literature pertaining to implementation of mobile technologies (Table 1) reveals that extant research predominately focuses on the first 5 stages. Stage 6 - namely, infusion - remains one of the least studied facets of IT post adoption, not only in the mobile literature but also in the generic IS literature (Ng and Kim 2009; Tennant et al., 2011). Infusion is a distinctive feature in the Cooper and Zmud (1990) model, which reflects the extent to which an IT technology is fully embedded in an individual's work system (Fadel, 2007).

Organisations worldwide invest heavily in the implementation of technological innovations. Engagements in Swedish e-health initiatives cost the healthcare sector approximately €700 million annually (Ministry of Health and Social Affairs, 2010). If such technological innovations are not infused within an individual's work practice, technology will ultimately fail, as individuals do not realise the full potential of a technological innovation through comprehensive and integrated use. Consequently, such technological innovations may deliver only limited benefits. These limited benefits, according to Sousa and Goodhue (2003), may not compensate for what is usually a costly and difficult implementation process.

Stage of IT Implementation	**Definition**	**Literature on mobile technology implementation**
(1) Initiation	Scanning of organisational opportunities and IT solutions	Zhou et al., (2003); Frolick and Chen (2004); Hsieh (2007)
(2) Adoption	Negotiations to achieve organisational backing for the implementation of IT	Yap and Hii (2009); Gebauer et al., (2010); Wu et al., (2011)
(3) Adaptation	The development, installation and maintenance of new technology, and the development of new organizational procedures	Ney et al., (2004); Sutherland and van den Heuvel (2006); Schmitz et al., (2010)
(4) Acceptance	Inducing members of organisations to commit to use the IT	Wu and Wang (2005); López-Nicolás et al., (2008) ; Lou et al., (2010)
(5) Routinisation	Encouraging continued use of IT as a normal activity	Thong et al., (2006); Hung et al., (2007), Kim and Oh (2011)
(6) Infusion	Realising the full potential of IT through comprehensive and integrated use	O' Connor et al., (2011)

Table 1: Studies on mobile implementation at different stages

1.1 Infusion of m-health technologies

The application of mobile technologies within healthcare, namely mobile-health or m-Health, has revolutionised the delivery of healthcare services as mobile technologies support the provision and capture of patient-related information at the point-of-care (Burley et al., 2005). In this study an m-

health technology refers to "any mobile handheld device and applications which run on that device to support the user" (O' Connor et al., 2011).

The documented potential of m-health technologies is widely purported. These include how effectively and efficiently a healthcare practitioner delivers healthcare services through m-health technologies (O' Connor et al., 2011). Another potential benefit of IT implementation is knowledge creation (Nonaka et al. 2000). Knowledge creation is defined as the capability to improve continuously, and create new knowledge by expanding the existing knowledge base (Nonaka et al. 2000) of individuals. Yet, there remains a dearth of research as to whether such benefits are fully realised. Theoretically, for such benefits to be realised, m-health technologies must be embedded and fully utilised (i.e. infused) as part of individuals' work practices (Cooper and Zmud, 1990).

A review of the infusion literature reveals that infusion has primarily been studied at the level of the organisation, with less attention focussed towards the individual level (Peijian and Lihua, 2007). Research on individual level infusion is important as individuals are the primary users of the IS which underpins many organisations (Tennant et al., 2011). Although understanding infusion at the organisational level is important, the researchers perceive that it is first necessary to understand individual infusion, as individual infusion is a prerequisite to organisational infusion (Sundaram et al., 2007).

The remainder of this paper is structured as follows. A preliminary model of determinants and outcomes is developed in section 2 to address the gap in the literature relating to m-health technology infusion. This conceptual model, which draws upon and extends extant literature, is operationalised using a case study approach (section 3). Section 4 presents the findings leading to a revised conceptual model, propositions and hypotheses. Section 5 presents the key implications for theory and practice of this study and discusses the potential for future research within individual m-health infusion.

2. Conceptual Model Development

In developing a conceptual model to explore determinants and outcomes of m-health infusion, pertaining to individuals, the researchers identified and analysed a number of existing models pertaining to infusion (e.g. Sousa and Goodhue, 2003; Kishore and McLean, 2007; Ramamurthy et al., 2008; Wu and Subramaniam, 2009). However analysis of existing infusion models revealed their unsuitability for investigating individual infusion, with such models primarily focused on infusion of technologies at an organisational level. For example, organisational readiness, external pressure and additional organisation factors were often examined in infusion studies (Ramamurthy et al., 2008; Wu and Subramaniam, 2009).

In developing a model (Figure 1) for investigating individual infusion and the associated outcomes, the researchers reviewed the IS literature regarding implementation and diffusion in order to identify appropriate constructs with theoretical value in constructing a conceptual model to explore individual m-health infusion. The appropriate constructs and the association between these will be discussed in detail in the following section.

2.1 Conceptual Model and Construct Definition

An analysis of the m-health infusion literature revealed four key technology characteristics which have an impact on m-health infusion (Table 2). Adapted from Agarwal and Venkatesh (2002), technology characteristics refer to specific features, functionality, or usability of a technology that can affect its infusion by target users. These characteristics have been shown to influence other phases of IT implementation but have received little attention in the infusion literature.

Technology Characteristics	Adapted Definitions	Relevance to m-health infusion	Limitation
Perceived System Quality	Represents individuals' perceptions of interaction with m-health technology (hardware and software) over time. (O'Connor et al., 2011)	Research argues that poor graphical user interface design and bad process design of mobile systems result in unnecessary medical errors. Systems perceived to be of poor quality are less likely utilised by user.	Additional evidence is required to investigate the relationship between system quality and technology trust.
Perceived Content Quality	Represents individual's perception that the content stored within or accessed through an m-health technology is fit for use. (O'Connor et al., 2011)	Users rely on the content accessible through the IS in effectively performing their work. If this is inadequate then individuals will not infuse the IT technology.	Additional evidence is required to investigate the relationship between content quality and technology trust.
Technology Trust	The degree to which an individual perceives that an m-health technology infrastructure is capable of facilitating tasks based on expectations of technology predictability, functionality and utility. (McKnight et al., 2002)	Research argues that users may be reluctant to use some IT technologies because they may fear it will not perform reliably. If it is not used then it cannot be infused.	Majority of research only deals with trust relating to the individual and not the technology. Lack of empirical research on the association between technology trust and m-health infusion.
Perceived Risk in Technology	Perceived possibility of loss or harm to patients whereby individuals believe it is unsafe to use an m-health technology in a healthcare context. (McKnight et al., 2002)	Research argues that perceived risk in technology can have a negative effect when using IT technologies.	Lack of empirical evidence on the association between perceived risk in technology and m-health infusion.

Table 2: Technology Characteristics impacting individual infusion of m-health technologies

Infusion distinguishes itself from the routinization phase of the Cooper and Zmud (1990) model by moving beyond continued use of IT to realising the full potential of IT through comprehensive and integrated use. Comprehensive and integrative use is expressed in terms of post-adoptive behaviours proposed by Hsieh and Zmud (2006). It is important to note that post-adoptive behaviours vary at different post-adoption stages of IT implementation. From a review of the literature, Hsieh and Zmud (2006) mapped IS implementation stages and post-adoptive usage behaviours and found that integrative use and exploratory use are post-adoptive behaviours depicted by individuals at an infusion phase. Integrative use refers to the configuration of workflow linkages among a set of work tasks (Saga and Zmud, 1994) from utilising m-health technologies. Exploratory use captures active examination of new uses of the m-health technology post implementation by enabling users to find novel uses of the IS within their work environment (Saeed and Abdinnour-Helm, 2006). Therefore, in order to investigate determinants and outcomes of m-health infusion a conceptual model (Figure 1) was derived from the literature base and explored through a case study.

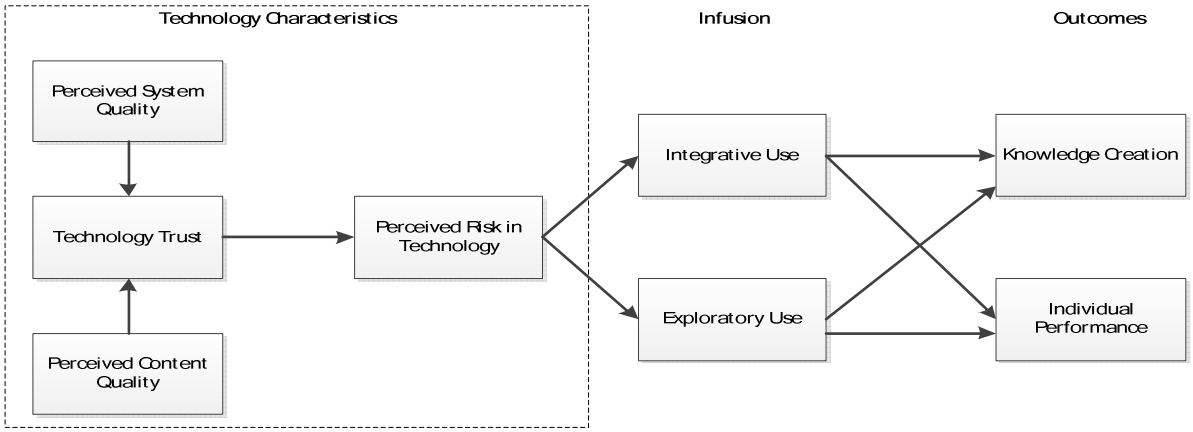

Figure 1: Preliminary conceptual model of determinants and outcomes of m-health infusion

3. Research Methodology

The objective of this research is to explore the infusion of m-health technologies among medical practitioners and the resultant impact of infusion on knowledge creation and individual performance. The case study approach is one of the most commonly used research methods in the IS field (Benbasat et al., 1987; Darke et al., 1998). It aims to obtain an in-depth understanding of the phenomenon and its context (Cavaye, 1996). Case studies enable researchers to investigate pre-defined phenomena without explicit control or manipulation of any variables (Yin, 1994; Cavaye, 1996; Darke et al., 1998). Marshall and Rossman (1989) indicate that when the state of knowledge in a field is at an early stage of investigation, a need exists for the research purpose to focus on 'discovery' and 'theory building', and be 'exploratory' in nature. Galliers (1992) states that for a theory building / theory-testing approach, a case study is a valid research method.

The case study approach enables the researcher to investigate and capture the reality of the phenomenon (Yin, 1994). The NHS case was chosen as it represents a critical case with regard to understanding determinants and outcomes of infusion of mobile technologies in a healthcare environment. Data was gathered over a one month period in October 2011. University Hospital Birmingham NHS Foundation Trust (UHBFT) is one of the most-consistently highest performing trusts in the NHS and has been rated "excellent" for quality of clinical and non-clinical services by the Healthcare Commission. UHBFT first began using "tablet technology" some ten years ago and currently has over 500 tablets in operation within the Trust. Over ten hours of interviews were conducted onsite with a broad spectrum of medical practitioners ranging from clinical lead in pharmacology, nurses, PICS (Prescribing Information and Communication System) training personnel to pharmacist technicians interviewed.

Content analysis was undertaken using the three grounded theory coding techniques (open, axial and selective) proposed by Strauss and Corbin (1990) and exemplified by the research of Urquhart (2001). This approach is consistent with a post-positivist epistemology (cf. Charmaz, 2000). This approach necessitates the researchers to be immersed in the data (Glaser and Strauss, 1967) and to draw on existing theoretical knowledge without imposing a theory (Strauss and Corbin, 1990; Urquhart, 2001). Such techniques were therefore deemed relevant for this study. The first step (open coding) involved the data being examined 'line by line' to ascertain the main ideas. These were then grouped by logical headings to reveal categories and sub-categories/properties. The next step (axial coding) is the process of determining hypotheses regarding the relationships between a category and its subcategories. Finally, selective coding was undertaken to identify the relationships between categories using hypothesised conditions, context, strategies and consequences.

4. Findings and Discussions

This section presents the findings of this study and discusses its implications for the a priori conceptual model. Findings reveal that the conceptual model developed from extant literature is limited in explaining infusion of m-health technologies by individuals and by extension individual performance. Therefore, a revised model is derived and presented (Figure 2).

Extant literature characterised the factors which impact upon m-health infusion as being technological characteristics. Analysis revealed that in addition to technology, the dimensions of which are refined as a result of the analysis process, two additional categories; 1. Task characteristics and 2. User characteristics must be considered when explaining individuals' infusion of m-health technologies. The resultant impact upon individual performance from the use of m-health technologies is then discussed. The three categories will now be explored, leading to the emergence of the revised model.

4.1 Emergent Categories

Two additional categories emerged from the coding process including task characteristics and user characteristics. Table 3 provides an overview of our findings in terms of the emergent determinants and their associated category.

Technology Characteristics

Medical practitioners indicate that system quality dimensions such as availability, technology maturity and portability of m-health technologies are pertinent for individual infusion. Having the technology available to users when they require it is essential. This point is reflected by a pharmacology consultant who stated "*I think as I have said the critical thing is to make sure there is enough technology"*. Saturating the organisation with m-health technologies makes them readily available to the end user. Increasing the availability of m-health technologies within the health care setting makes it more likely that individual users will use the technology when delivering health care services to patients at the point-of-care. Therefore, individual users are well equipped to utilise and embed m-health technologies within their work practices. Furthermore, as stated by a pharmacology consultant *"there is little than .07% of downtime running PICS (Prescribing Information and Communication Systems) over the last 8 years"*. This stability and maturity indicates that the *"systems are working and that they are safe"* and thus, are important for individual infusion. However, comments from the medical practitioners indicate that the ergonomics associated with m-health is a concern. M-health technologies must be designed to accommodate an individual's work practices. Some people (junior doctors, pharmacists and nurses) feel that the device itself is *"too unwieldy - it is too heavy"* and this is having a negative impact on existing users with complaints of having "*problems with their neck and shoulders"*. As a result, portability is a key issue affecting infusion of m-health technologies.

Perceived risk in the technology was found to have no significant impact on infusion. Many people acknowledge that some risks exist in the system when initially implemented as *"risks are inherent within any system"*. However, due to the maturity and stability of the current m-health technology, many healthcare practitioners consider it safe and don't perceive any technology risk associated with m-health infusion. To such an extent that one pharmacy technician would still consider infusing the technology if some risk exists: *"I don't think that should stop us going through and pushing on with technology"*.

User Characteristics

Various medical practitioners interviewed indicate that content quality dimensions such as traceability – considered as *"Big Brother like"* - is important for individual infusion. Attitudes towards this 'Big Brother Surveillance' ranged from *"it scares me"* (nurse) to *"I think when you are looking after people you got to be a bit 'Big Brother' – you got to be tight"* (dietician). Comments from one nurse indicate that the "*only thing that makes me as diligent as I am of using it, is a scare tactic – and that is I know that somewhere in some office everything I do is being looked at and it is very, very Big Brother like*".

Users who have been using m-health technologies for over one year gain habits towards using m-health technologies. These habits can have an influence on infusion of m-health technologies. For example, a pharmacy technician stated "*I would say they tend to use the tab based system*", *"if they know one particular way of getting and doing something... they will continue to use it in that way."* Inevitably, usage habits are formed for systems that have been in operation for some time. As habitual routines are derived by the user it was deemed that habit would be a dimension of user characteristics. Furthermore, an individual's competency towards computing influences infusion of m-health technologies. For example, to explore the m-health technology, according to one nurse, *"depends on your proficiency with IT and how you want to interact with it"*. This finding is consistent with extant literature and is therefore pertinent when exploring individual infusion.

Although initially perceived to be an initial technology characteristic technology trust emerged to be important for individual infusion. However in the revised model technology trust is now a dimension of user characteristics. One interviewee (registrar in medicine) indicated that without trust in the mobile technologies individuals will *"lose confidence in the system and not work with it"*.

Task Characteristics

When discussing content quality time criticality emerged as a dimension which influences infusion. Timeliness of content is considered to be clinically pertinent when infusing m-health technologies into an individual's work practice. Findings revealed a desire of users to obtain content from m-health technologies when completing a task. Therefore, it was deemed that time criticality was pertinent and is now considered a dimension of task characteristics. Findings exemplify that the type of task carried out by individuals has an impact on infusion. One nurse stated that "*every time they give someone a drink we need to go and find a tablet PICS, log on, wait for it to get on, and then put in 50mls of drink, log off, put the computer back, and then go on to finish off the bed bath and then start on the new one – the next patient."* Clinical work is characterised by a complex mixture of routine and unexpected events thus, clinical work is highly mobile. Therefore, the mobility must also be investigated when examining infusion. Medical practitioners cannot complete a task without having first received data/information from a mutual practitioner. For example, pharmacists cannot dispense any drugs without receiving information on the patient from the nurse/doctor on the type of drug. Therefore, task interdependence influences infusion.

Category	**Category Definition**	**Emergent Dimension**
Task Characteristics	Refer to the nature of the tasks users must execute (Trice and Treacy, 1986).	Time Criticality Interdependence Mobility
User Characteristics	Individuals' traits and perceptions from utilising IT over a period of time.	Habit Self-Efficacy Technology Trust
Technology Characteristics	Technology characteristics refer to specific features, functionality, or usability of a technology that can affect its infusion by target users (adapted from Agarwal and Venkatesh, 2002).	Availability Maturity Portability

Table 3: Definitions for new categories and dimensions derived from the findings

4.2 Extent of Infusion

This section will discuss integrative and exploratory use (infusion). Analysis revealed that individual users utilise the m-health technology at various levels of sophistication. As a result, the revised model will now merge integrative and exploratory use into 'extent of infusion'. The following section will discuss our findings relating to infusion.

Results indicate that integrative use is dominant at the infusion phase of m-health technology implementation. Medical practitioners use the m-health technology to organise their daily tasks based on the content in PICS. "*The 'b' indicates that the patient needs a blister pack when he/she is being*

discharged. So it is really helpful for us in the dispensary. So if we know that a patient needs a blister pack on discharge we probably won't do a lot of OSD (One Stop Dispensing) on the ward". Furthermore, tasks can be coordinated based upon the time in which they are scheduled. Nurses interviewed start their "*drug round which is a scheduled time on PICS"*. Individuals using m-health technologies can have access to content, independent of their location. As a result, it is easier for medical practitioners to organise their tasks.

Unlike integrative use, exploratory use of m-health technologies is limited. The underlying rationale for this is that the m-health technologies are "*locked down"* and when individuals log into the systems they have certain *"right privileges"*. This role based approach only provides individual users access to certain features which corresponds to their tasks. However, because the system is locked down limited exploring can be done with the system. Exploring the system is a time-consuming activity, therefore, one junior doctor stated that he would not explore the system because most of the time he is "*under a lot of time pressure"*. However, there were instances of some users exploring the system. One pharmacist *"went and explored using the training domain"* because this system is not locked down. Others explore the help functionality available to the end user.

Findings on integrative and exploratory use argue that users utilise the m-health technology at various levels of sophistication and as a result, this mediates the relationship between the determinants and the consequent outcomes. Thus, this relationship is represented in the revised model (Figure 2) as extent of infusion.

4.3 Individual Performance

This section will discuss the outcomes of m-health infusion. Analysis revealed that individual performance is significantly improved through the infusion of m-health technologies. However, findings revealed that infusion of m-health technologies did not enhance individual's knowledge. The following section will discuss our findings relating to these outcomes.

Several categories of benefits emerged from the analysis associated with individual performance through infusion of m-health technologies. Incorporated within PICS is a Clinical Decision Support (CDS). Having this functionality, in addition to relevant patient data, at the point-of-care helps in the decision making process. As a result, medical practitioners do not have to spend a lot of time researching before making a decision. This time then is used to deliver healthcare services to more patients. M-health technologies "*saves significant time which obviously helps us to see more patients"*. Furthermore, if a drug is prescribed by a medical practitioner and there is some danger to the patient a warning notification is presented to the user. Some medical practitioners conducting internal research within the hospital found that on average, *"probably several thousand hard stopped warnings occur every year"*. If medical practitioners do not override these notifications many people believed that, as a result, there would be a reduction in medical errors. It was advised by a pharmacy technician, however, that "*IT electronic system do reduce errors but this is not the panacea – it doesn't eradicate errors"*. Finally, medical practitioners believed that preventive care was improved when they were prompted by reminders concerning the patient. Medical practitioners are notified when patient data is operating outside of normal ranges. This improves the delivery of healthcare services to the patient as medical practitioner can respond rapidly to a dangerous situation. This was illustrated by one nurse who stated that it a "*patient starts to deteriorate you get flag up warnings which doctors have to acknowledge. If the patient gets really sick then the outreach nurses get an email sent to their blackberries saying that a patient has got sick"*. Furthermore, tests, drug administration and vital sign checks are scheduled and completed on time due to prompts notified to the individual user once they log in. These reminders are an effective way to ensure that routine clinical care is carried out on time.

Exploring knowledge creation through individual infusion of m-health technologies was one key finding from the data analysis. The majority of interviewees said that knowledge was not created but

in fact presented to the end user - *"I don't know whether we can create knowledge but we can present knowledge to people"*. Knowledge can be created by medical practitioners; however, not necessarily through m-health technologies. This is depicted by a pharmacy technician who mentioned *"If people have a thirst for knowledge or a quest for knowledge then I think they will find it. They will go and read a book. I am not sure if they would get it entirely from the PICS system"*. When describing knowledge many people referred to the concept of learning. A nurse revealed *"I can learn about new drug interactions that I hadn't known about recently"*.

Therefore, individual performance in the revised conceptual model will encompass the concept of learning. Individual performance is viewed in terms of efficiency and effectiveness. Efficiency is defined as "the degree to which a given activity or program undertaken by medical practitioners lead to a more efficient workflow" whereas effectiveness is defined as "the degree to which a given activity or program undertaken by medical practitioner improves clinical care and practitioner learning" (O'Connor et al., 2011).

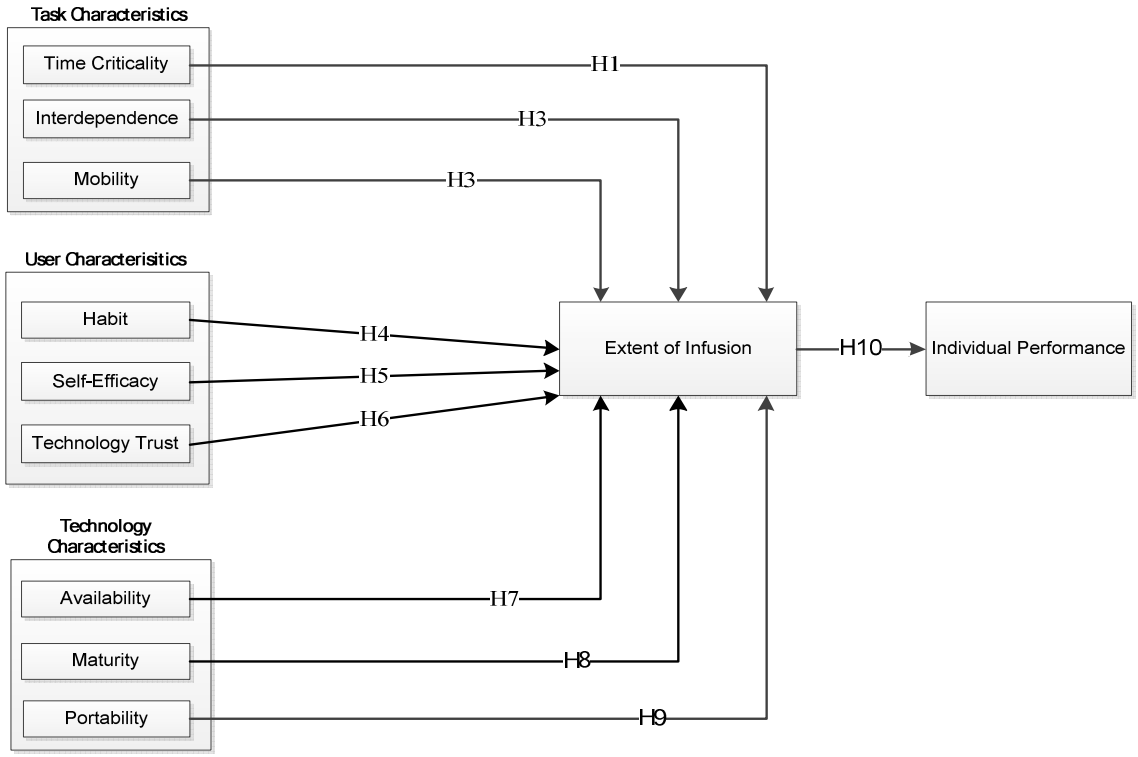

Figure 2- Revised Conceptual Model: Individual Mobile Health Infusion (IMHI)

Therefore, our findings now enable us to present a revised conceptual model (Figure 2) consisting of three propositions and ten hypotheses. These propositions and hypotheses are now presented for future empirical testing and validation.

Proposition 1: Extent of Infusion is affected by task characteristics
H1: Extent of Infusion is affected by time criticality
H2: Extent of Infusion is affected by task interdependence
H3: Extent of Infusion is affected by mobility

Proposition 2: Extent of Infusion is affected by user characteristics
H4: Extent of Infusion is affected by habit
H5: Extent of Infusion is affected by self-efficacy
H6: Extent of Infusion is affected by technology trust
Proposition 3: Extent of Infusion is affected by technology characteristics
H7: Extent of Infusion is affected by availability
H8: Extent of Infusion is affected by maturity
H9: Extent of Infusion is affected by ergonomics

Finally, it is also hypothesised - H10: Individual performance is affected by extent of infusion.

5. Conclusion

Mobile technologies have been increasingly incorporated into medical practitioners' work practices. Yet actual infusion of such technologies has tended to lag, and the potential benefits of m-health technologies have not been fully realised. This paper develops a model to explain an individual's infusion of m-health technologies and has implications for both theory and practice. This study identifies three categories (task characteristics, user characteristics and technology characteristics) and their associated dimensions in explaining infusion of m-health technologies. The findings enhance the extant literature on infusion through the identification of the dimensions which determine individual's infusion of m-health technologies. The study provides empirical evidence of the impact which infusion of m-health technologies have on practitioners' performance. Furthermore, in terms of knowledge creation it was established that users of m-health technologies believe that knowledge is not created by the individual through m-health infusion. This study has potentially significant implications for organisations looking to invest in m-health technologies and for those seeking to understand how a practitioner's performance can be improved through infusion. However, the conceptual model is derived from the analysis of data from a single-case study. As with all single-case study research the conclusions and findings arrived at in this study may not be generalisable. Further research is now required to investigate the derived propositions and hypotheses as the generalisability of the findings in this study are limited by method and sample size. A survey will be conducted where structural equation modelling will be utilised for data analysis and hypotheses testing in order to determine the reliability of the derived constructs and their associated dimensions.

Acknowledgement: This research was partially funded by Business Information Systems, Conference Travel Support Scheme, University College Cork, Health Information Systems Research Centre (HISRC), and by the Science Foundation Ireland (SFI) SFI"11/RFP.1/CMS/3338.

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