AIS Transactions on Human-Computer Interaction

Volume 7 | Issue 3 Article 5

2015

Understanding Task-Performance Chain Feed-Forward and Feedback Relationships in E-health

Mike Chiasson
University of British Columbia, mike.chiasson@ubc.ca

Helen Kelley
University of Lethbridge, helen.kelley@uleth.ca

Angela Downey
University of Victoria, adowney@uvic.ca

Follow this and additional works at: https://aisel.aisnet.org/thci

Recommended Citation

Chiasson, M., Kelley, H., & Downey, A. (2015). Understanding Task-Performance Chain Feed-Forward and Feedback Relationships in E-health. *AIS Transactions on Human-Computer Interaction, 7*(3), 167-190.
Retrieved from https://aisel.aisnet.org/thci/vol7/iss3/5
DOI:

This material is brought to you by the AIS Journals at AIS Electronic Library (AISeL). It has been accepted for inclusion in AIS Transactions on Human-Computer Interaction by an authorized administrator of AIS Electronic Library (AISeL). For more information, please contact elibrary@aisnet.org.

www.manaraa.com

Transactions on Human – Computer Interaction

Research Paper ISSN: 1944-3900

Understanding Task-Performance Chain Feed-Forward and Feedback Relationships in E-health

Special Issue: HCI in Health and Wellness

Mike Chiasson[1]
University of British Columbia
mike.chiasson@ubc.ca

Helen Kelley
University of Lethbridge
helen.kelley@uleth.ca

Angela Downey
University of Victoria
adowney@uvic.ca

Abstract:

The associations between the use of effective technology and user performance, and the effect of user performance on technology use and task-technology fit (TTF), requires further research (Furneauz, 2012). To address this call for future research, we examined the feed-forward from use and TTF to performance and the feedback from performance to use and TTF by using longitudinal data (n = 156) collected from participants using two custom-built e-health systems that we designed to provide education to develop self-management practices for study participants with newly diagnosed type 2 diabetes. We captured participants' use of the two systems, their perceptions of TTF, and their health performance through biomedical outcomes every three months over a 12month period. Our findings show significant and different feed-forward and feedback relationships. In general, our results also show that system use and a negative TTF-use interaction significantly affected performance through feed-forward, while participant performance significantly affected use and negatively affects TTF through feedback. We discuss the implications for task-performance chain (TPC) research and developing and using e-health systems in chronic care.

Keywords: Task-technology Fit, Task-performance Chain, IT Use, E-health, Diabetes Education, Feed-forward, Feedback, Learning Process, Biomedical Outcomes.

[1] Please address correspondence to the first two authors.

المنارة للاستشارات
www.manaraa.com

1 Introduction

Individuals' use of information technology (IT) and information systems (IS) is one of the defining theoretical concepts and measures of success in IS research and practice (DeLone & McLean, 1992; Petter, DeLone, & McLean, 2008). However, researchers consider IS use and outcomes to be increasingly dependent on a range of contextual influences (Tambe & Hitt, 2012).

In response, IS researchers continue to advance the field's core knowledge of the complex relationship between use and performance through a range of theoretical approaches, which include use research. This stream of research examines various individual and group factors that lead to intentions to use technology and, occasionally, to actual use (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989; Venkatesh, Morris, Davis, & Davis, 2003). Another stream of research examines task-technology fit; specifically, it investigates and explains the performance outcomes of technology use through the fit of information technology to task requirements (Goodhue & Thompson, 1995).

Goodhue and Thompson (1995) theorized an integration of use and fit models into the so-called task-performance chain (TPC). They hypothesized that the fit arising from task, technology and individual characteristics affects performance directly and fit affects performance indirectly through precursors to use and actual use. Then they posited that performance influences subsequent TTF, use, and other antecedents through feedback relationships.

Despite a large amount of research testing the TPC model's implications (c.f. Cane & McCarthy, 2009), several important research areas remain largely unaddressed by task-technology fit (TTF) theory and research. Two specific research areas include the difference between feed-forward and feedback TPCs. Specifically, the nature of the dynamic relationships of feed-forward chain—TTF, use, and performance and the feedback chain—from performance to TTF and use. These two research areas have important implications for TTF theory and practice.

To address these research areas, we propose a feed-forward and feedback framework, based on theory, across TTF, use, and performance by reviewing the TPC and use literatures. For this study, we use feed-forward to mean the effect of current TTF and use on performance and feedback to mean the effect of performance on subsequent TTF and use. We developed and tested two e-health systems built with diabetes clinicians to support individuals with recently diagnosed diabetes. Both systems included educational materials, a participant logbook to record diabetes-related behaviors, lab records, and search features. One system provided synchronous communication tools for participant-clinician interaction; the other provided asynchronous communication tools.

In the following sections of this paper, we discuss how we collected data and designed the e-health systems to produce an objective difference in IT task-technology fit, the use of subjective perceptions of TTF, and their feed-forward and feedback relationships with use and biomedical outcome performance based on participants' blood sugar control. We randomly assigned study participants to two groups: group 1 using the e-health system with synchronous communication tools and group 2 using the e-health system with asynchronous tools. We collected measurement data every three months over a 12-month period for both groups. We examined feed-forward by analyzing the effects of TTF, total use of the technology, and their interaction on performance over multiple three-month periods. We examined feedback through the effect of performance on subsequent technology use and TTF. All results controlled for technology and time. Our findings highlight significant positive associations between use and performance through feed-forward and feedback, a significant negative relationship between a TTF and use interaction during feed-forward, and a negative relationship between performance and TTF during feedback. We also found that group 1 participants using the system with synchronous communication tools had a significantly higher level of performance than group 2 participants using the system with asynchronous communication tools. We consider the important theoretical and practical implications for the TPC model and e-health.

In Section 2, we outline the feed-forward and feedback relationships across technology fit, use, and performance. In Section 3, we discuss the methodology and, in Section 4, we present the results. In Section 5, we explore the practical and theoretical implications of the findings.

www.manaraa.com

2 Literature and Hypothesis Formulation

2.1 Task-Technology Fit Theory

Generally speaking, TTF is a contingency theory that focuses on understanding why and how information technologies that support technology-related task characteristics increase performance (i.e. its so-called "fit" with the task). TTF responds to a need to move beyond studying only individuals' intention to use technology and use to how using technologies that fit the task increase performance (Devaraj & Kohli, 2003; Goodhue & Thompson, 1995).

In modelling and theorizing TTF, Goodhue (1995) and Goodhue and Thompson (1995) propose the TPC and indicate that using technologies that support the steps in a task, in combination with individual characteristics that allow individuals to competently use the technology, will have a positive influence on performance (see Figure 1). They define the resulting task-technology fit (TTF) as "the degree to which a technology assists an individual in performing his or her portfolio of tasks" (Goodhue & Thompson, 1995, p. 206).

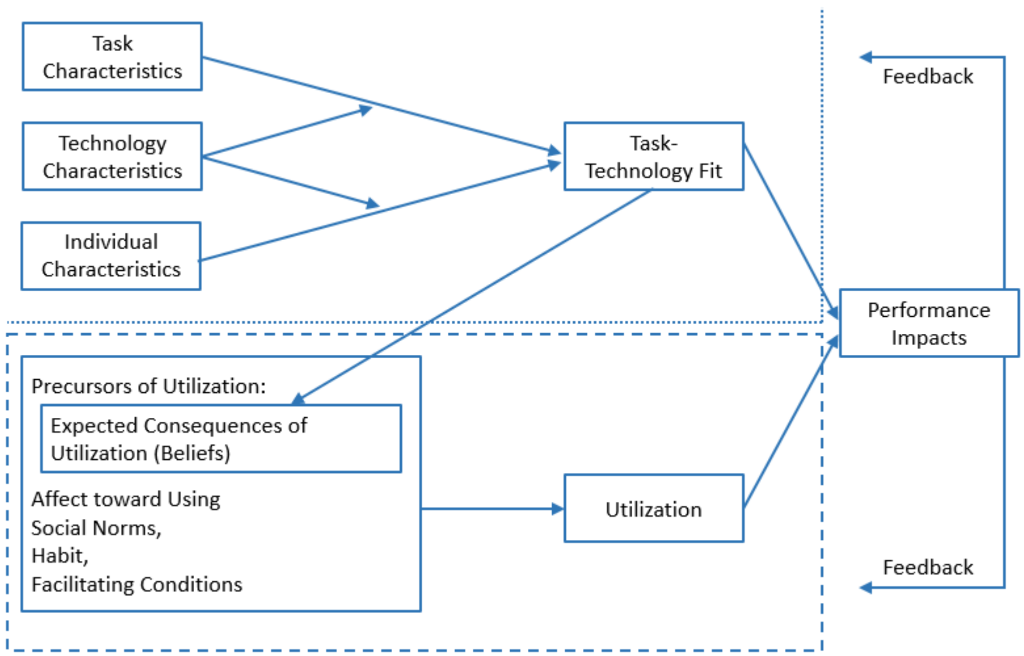

Figure 1. Technology-to-Performance Chain (Goodhue & Thompson, 1995, p. 217)

Since Goodhue and Thompson's (1995) initial theorization of TPC, the IS field's core knowledge and supporting empirical evidence continues to demonstrate the theory's robustness in a variety of contexts and with different types of IT artifacts, including e-health (Willis, El-Gayar, & Deokar, 2009). This extensive body of literature has extended TPC by examining several antecedents and performance outcome variables (see Cane and McCarthy's (2009) meta-analysis). TPC researchers have also used a variety of approaches to measure the fit between task and technology.

We refer to the hypothesized outcome and causal relationships in Goodhue and Thompson's (1995) model as a feed-forward chain relationship from technology, TTF, and technological use to performance. In addition to the feed-forward chain, Goodhue and Thompson also theorize two different possible and influential pathways of feedback from use and performance to subsequent use and TTF. These two influential pathways are: (1) when subsequent use is affected by good or poor performance (adaptation) and (2) when initial fit expectations have been met or unmet by using the technology (experience) (Goodhue & Thompson, 1995, p. 218-219). We address the theoretical development of the feed-forward and feedback relationships in our study and consider them in detail in the following sections.

www.manaraa.com

2.2 TPC (Task-Performance Chain)—Classic Triad—Feed-forward Relationship

Various studies have explored the feed-forward relationships among TTF, use, and performance at one specific point in time (see. Mathieson & Keil, 1998; Teo & Men, 2008). Key to this research stream has been how TTF is measured. Cane and McCarthy (2009) outline six perspectives of fit: fit as moderation, fit as mediation, fit as matching, fit as gestalt, fit as profile deviation, and fit as covariance. These perspectives use either objective measures of fit or subjective evaluations of fit. Objective measures of fit focus on how a technology's characteristics do or do not match task requirements (see Dishaw & Strong, 1998). In these cases, technological variation in fit is either a natural occurrence or is manipulated through experimental methods.

Subjective measures of "fit as matching" examine individuals' reports of the TTF, usually across various dimensions such as information characteristics (see Goodhue & Thompson, 1995) and as a mixture of use and information quality (see Staples & Seddon, 2004). In these cases, self-report is often considered a proxy for the real "fit as matching" (Cane & McCarthy, 2009).

As Figure 1 depicts, Goodhue and Thompson (1995) theorize that the interactions of task, individual, and technology characteristics are antecedents to TTF. For example, if a technology provides different or poor functionality than what is required for the task, one's perception of TTF will decrease (Goodhue & Thompson, 1995, p. 218).

In terms of feed-forward, Goodhue and Thompson (1995) theorize that TTF is a direct antecedent to performance. They postulate that using a technology with high TTF will positively affect performance because greater TTF means the technology more closely meets the task. Various performance outcomes have been explored in the literature to determine this, including increased system use (Lucas & Spitler, 1999; Pinsonneault & Rivard, 1998), improved attitudes towards a system such as ease-of-use (Mathieson & Deil, 1998), increased perception of fit (Fuller & Dennis, 2009), increased performance (Ahearne, Jones, Rapp, & Mathieu, 2008; Goodhue & Thompson, 1995), and perceived performance measured by decision quality and time to task completion (Barrera, Glasgow, McKay, Boles, & Feil, 2002). The performance outcomes depend primarily on the task, the technology, and the context of system use.

Table 1. Summary of Empirical Studies of the TTF and TPC Outcomes

Paper	Research method	TTF measure	Results/recommendations
Ahearne et al. (2001)	Survey: salesperson in Pharmaceutical Industry (n = 137)	Fit assumed – technology fits the selling tasks	• IT use → improves customer service • IT use → improves adaptability • Customer service → improves salesperson's performance • Adaptability → improves salesperson's performance.
Dishaw & Strong (1999)	Survey: program analysts	TTF = task X technology	• TTF → use • Tool Experience → use • Task Requirements → use
Goodhue (1995)	Survey: organizational users (n = 357)	User evaluation of fit	• Users can successfully evaluate TTF • Users' evaluation of TTF could be used as measure of IS success
Goodhue (1997)	Survey	Determinants of task technology-fit	• TTF → performance • TTF → use (not shown)
Goodhue, Klein, & March (2000)	Experiment: undergraduate business students (n = 155)	TTF = manipulate integrated/non-integrated data environment Perceived TTF	• TTF → performance • TTF → user evaluation of TTF • User evaluation of TTF → Performance
Goodhue & Thompson (1995)	Survey: users (n = 662)	Perceived TTF	• TTF → performance • Use → performance • Use and TTF → performance

المنارة للاستشارات
www.manaraa.com

Table 1. Summary of Empirical Studies of the TTF and TPC Outcomes

Goh & Ping (2014)	Experiment with 40 subjects across 8 treatment groups.	Perceived fit	• Fit → attitude toward game • Fit → attitude toward brand • Fit * Interactivity → attitude toward game • Fit * Interactivity → attitude toward game • Attitude toward brand → purchase intention
Junglas & Abraham (2008)	Experiment: 112 subjects	TTF = task and technology manipulations (under fit, ideal fit, and over fit)	• Ideal fit → performance
Junglas, Abraham, & Ives (2009)	Survey: nurses (n = 107)	Perceived TTF	• TTF → use (identification and workflow) • TTF → performance (time criticality, user comfort, and workflow)
Lin & Huang (2009)	Survey: employees in different organizations	Perceived TTF	• Enhance fit by proving a range of functions to match EKR tasks
Mathieson & Keil (1998)	Experiment: undergraduate business students (n = 271)	TTF = manipulate system X task	• TTF high → performance high • TTF low → performance low
McGill & Klobas (2009)	Survey: students who were using WebCT	Perceived TTF	• TTF → perceived learning • TTF → students' grades • Use → perceived impact on learning
Nicholson & Valacich (2008)	Experiment: university students (n = 260)	Fit assumed	• Task, technology, and individual characteristics → learning outcomes – direct and combined influences
Strong, Dishaw, & Bandy (2006)	Survey: business students (n = 220)	TTF = task X technology	• TTF → use • Tool Experience → use • Task Requirements → use

Evidence that supports the relationships of TPC in different contexts have been reported in the extant literature; however, the feed-forward results from TTF and use to performance have been mixed. Therefore, we explore these feed-forward relationships further in our study by hypothesizing the following:

H1: TTF has a positive association with performance.

H2: Technology use has a positive association with performance.

H3: TTF has a positive association with technology use.

Beyond these direct feed-forward effects, we return to the Goodhue and Thompson's (1995) TPC model and their theoretical view of TTF as "the degree to which a technology assists an individual in performing his or her portfolio of tasks" (Goodhue & Thompson, 1995, p. 216). From this, we suggest two possible ways TTF can influence performance via feed-forward and feedback: through TTF's direct effect on performance ("fit as cause"; see Goodhue & Thompson, 1995) and through TTF as a moderator of use on performance ("fit as moderation"). This moderated view suggests that fit (TTF) has little influence on performance if the system isn't used and, conversely, that use without fit (TTF) has little influence on performance.

In addition to this moderation, Goodhue (2006) and Goodhue and Thompson (1995) conjecture that TTF may have a positive or negative influence on performance because, as Lucas and Spitler (1999) explain, individuals with poor performance may use a system more to improve their performance. In addition, mandated use or incorrect use may have little or a negative effect on performance. In all these cases, the effect of TTF on performance is moderated by low and high use, and the effect of use on performance is moderated by low or high TTF. Hence, theoretically, the relationship between use and performance may differ in strength at different levels of TTF, and TTF may have little influence on performance if the system is not used.

With such a heavy influence of research examining the main effect of TTF on performance, the IS literature has been relatively silent on the moderating effect of TTF on use and performance. Teo and Men

المنارة للاستشارات
www.manaraa.com

(2008) point out that the field's understanding of the relationship between task and technology can be further extended by modeling TTF as a moderator rather than as a mediator to facilitate greater use and greater performance separately. In their study, Teo and Men (2008) investigate the moderation effects of certain dimensions of TTF on the task characteristics and use and on the technology characteristics with performance.

Therefore, we propose a theoretical extension that TTF moderates the effect of use, and use moderates the effect of TTF on performance in a feed-forward relationship.

H4: TTF moderates the use-performance association.

2.3 Feedback Relationship

In the original model of TPC, Goodhue and Thompson (1995) theorize two types of feedback: (1) experience feedback from using the technology and its influence on TTF expectations and future use, and (2) adaptation feedback (learning better ways to use technology) and its influence on use and TTF. Goodhue and Thompson (1995) conjecture that, through experience feedback, "the actual experience of utilizing the technology may lead users to conclude that it has a better (or worse) impact on performance than anticipated, changing their expected consequences of utilization and therefore affecting future utilization" (p. 219). Furthermore, from adaptation feedback, "the individual may also learn from experience better ways of utilizing the technology, improving individual-technology fit, and hence overall TTF" (Goodhue, 2006, p. 192). In the first case, TTF will increase or decrease depending on an increase or decrease in performance (experience), while, in the second, use will change and possibly increase to deal with low performance or decrease once performance is high (adaptation). In both cases, feedback effects from performance TTF affect individual evaluation of TTF.

In general, feedback has been largely unexplored in the literature at this time except for Goodhue (1997) and Goodhue et al. (2000). In Goodhue's (1997) longitudinal study (T1 and T2), feedback was measured by the relative level of resources allocated to technology (i.e., less, same, or more), in the future. Goodhue reported that both TTF and performance significantly influenced feedback of allocated resources. Goodhue et al. (2000) suggested that the amount of feedback received by subjects in their experiment might explain why users "are not necessarily accurate reporters of key constructs related to use of IS, specifically that self-reporting is a poor measure of actual utilization" (p. 87). Importantly, they propose that performance feedback impacts individuals' evaluation of objective system's performance.

As far as we know, only one study has examined TTF feedback and adaptation across time. In this study, Fuller and Dennis (2009) show that the initially greater performance of a treatment group with both information processing and communication tools compared to a group with only information processing capabilities decreased across time as the control group adapted its use of the system to overcome technological constraints and performance losses. In another study, Lucus and Spitler (1999) reported how users with poor performance perceived the system as useful to their future work and performance through a negative feedback pathway. As a result, performance can alter future TTF through both positive (i.e., increasing) and negative (i.e., decreasing) feedback influences. We explore a range of possibilities around the hypothesis supported by Lucas and Spitler's (1999) explanation and Goodhue and Thompson's (1995) premise that poor performance can change use toward increased performance and TTF through adaptation.

We need to further theoretically investigate how feedback from performance affects future TTF, use, and performance. Therefore, we propose the following two-tail hypotheses for feedback across time:

H5: Performance has an association with subsequent TTF.

H6: Performance has an association with subsequent technology use.

By proposing both feed-forward and feedback hypotheses, our work contributes to TTF theory and TPC research by exploring how TTF and IT use affect performance and how this performance affects future TTF and subsequent use. In doing this study, we suggest that TTF, use, and performance are co-determined across time through individual experiences with performance and use.

Figure 2 represents these theoretical associations depicting our hypotheses at 1) the technology and individual levels of analysis through a prospective study of the feed-forward and feedback relationships between TTF and its direct and moderating effects on performance and 2) the task-technology level of

للاستشارات المنارة
www.manaraa.com

analysis through the feed-forward and feedback effects of use on performance. In Section 3, we discuss the specific research method and the measures we used to test our theoretically based hypotheses.

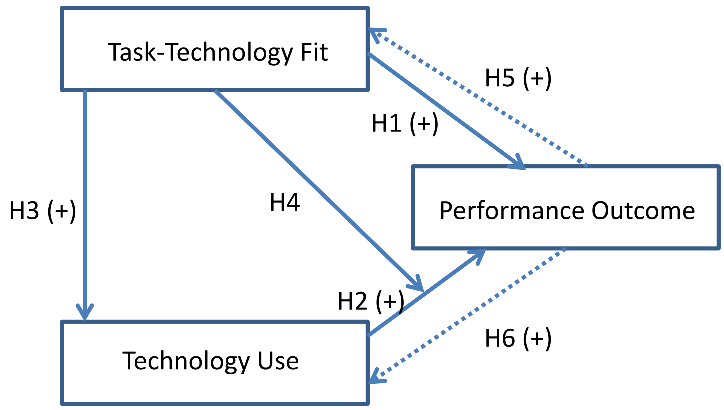

Figure 2. Research Model: Feed-forward to Performance and Feedback from Performance

3 Research Method

We conducted a longitudinal field experiment with a pre- and post-test design to collect data over 12 months to test our hypotheses by using an intention-to-treat approach for clinical-trial analysis[2]. The field experiment involved introducing two e-health systems—one system with both synchronous and asynchronous communication features (system group 1) and another system with only asynchronous communication (system group 2) to improve the education, monitoring, and participant-clinician communication for individuals newly diagnosed with type 2 diabetes from a health region in Canada. We discuss these two systems in detail in Section 3.3.

3.1 Setting

Diabetes is a chronic disease that is exponentially increasing in incidence and prevalence to the point that the economic impact of this growth has been called a “tsunami” (Canadian Diabetes Association, 2009, p. i) in 2009 and now, is labelled an epidemic in the US (Changing Diabetes Barometer, 2012). According to the Canadian Diabetes Association (2009), rising obesity rates, sedentary lifestyles, an aging population, and changes in the ethnic mix of the population are driving this uncontrollable growth of diabetes. In 2012, the estimated worldwide prevalence of diabetes was 371 million adults, 8.3 percent of the world’s population, coupled with a cost of diabetes care of USD$471 billion (Changing Diabetes Barometer, 2013). Shaw, Sicree, and Zimmet (2010) predicted that adults developing diabetes would increase by 20 percent in developed countries and a staggering 69 percent increase in underdeveloped countries between 2010 and 2030. These estimates suggest that the prevalence is growing exponentially worldwide.

The burden of the increasing cost of diabetes throughout the developed world is of concern as health systems grapple with how to maintain education and care in an environment with limited resources and increasing demands. Dedding, van Dorrn, Winkler, and Reis (2011) suggest in a literature review that e-health use could replace, supplement, improve, disturb, or change participation rates in clinics. As the costs of diabetes treatment in the US is estimated to rise to USD$514 billion by 2025, other avenues that might improve the economic impact of dealing with chronic diseases needs investigation (Changing Diabetes Barometer, 2013).

Despite these dire predictions, the promising results of an economic sensitivity analysis showed that improved self-care management practices through education can reduce the direct cost of diabetes by 19 percent and the indirect costs of diabetes by 18 percent (Canadian Diabetes Association, 2009, p. 17). If education and the collective monitoring of participant self-care can lead to improved self-care practice and

[2] The use of intention-to-treat (ITT) analyses is the preferred approach for analyzing most clinical trials and is widely recommended according to the Cochrane Collaboration Group (see http://www.cochrane-net.org/openlearning/html/mod14-4.htm). “Intention-to-treat analysis includes every subject who is randomized according to randomized treatment assignment”; in other words, “once randomized, always analyzed” (Gupta, 2011, p. 111).

المنارة للاستشارات
www.manaraa.com

cost savings, IT could play a crucial role through e-health systems. Several studies report experiences with IT-based interventions across many conditions including diabetes, asthma, congestive heart failure, osteoarthritis, and the human immunodeficiency virus (Bond et al., 2007).

Using IT through e-health systems to support participant–provider communication has the potential to help alleviate the burden of valuable, limited, and expensive face-to-face visits with individuals. The perception is that well-designed e-health systems can help to augment and alleviate the visits of chronic care participants with their key providers/educators and potentially increase the continuity and frequency of communication with existing providers (i.e., physicians, nurses, dieticians), with other assistants (i.e., additional remote medical personnel and other individuals), and with static electronic libraries (i.e., electronic information for participant viewing on their own time). However, while the conceptual arguments are promising, the empirical studies of using IT by itself do not appear to be an automatic panacea for improving chronic care. For example, individuals searching for information have been known to find poor or misleading information (Buettner & Fadem, 2008), which, in extreme cases, can cause self-harm and, in less extreme cases, can increase educational time for providers to correct these misperceptions (Sabel et al., 2005). Increasing participant contact with other individuals may foster Internet-based communities for support (Barrera et al., 2002) and knowledge sharing but may lack health providers' knowledge and expertise to outline a full range of medical and treatment options and their effectiveness (Kaufman et al., 2006). Finally, systems that support continuous communication between individuals and providers may increase self-care learning and management, but providers' and individuals' resource commitment to learn how to use such systems and to effectively triage and manage the ensuing chronic care could be expensive and time-consuming (Kaufman et al., 2006).

3.2 Participants and Design

We conducted our longitudinal field experiment with Our Diabetes (OD)[3] in Canada, a program in a public health organization which, through clinicians, educates and instructs individuals in the basic knowledge about diabetes and self-care activities and in self-managing and monitoring skills to manage diabetes. The clinicians do these activities via initial and subsequent dialogue with the participant in face-to-face meetings or in group education classes at the time of diagnosis and via subsequent visits and telephone calls over three to six months. For the study, we adopted the OD program's self-care management educational goals, the clinical team's planned interactions with clients, and their standardized education process, but extended the time frame and followed participants for 12 months.

We recruited adult participants who were newly diagnosed with type 2 diabetes and referred to the OD program by their physician practitioners for the study. We screened potential participants to ensure that they satisfied the inclusion criteria of the study; specifically, that (1) they had access to a computer connected to the Internet, (2) they were computer literate, (3) they had no other complicating co-morbidities, and (4) they were not involved in another research study. Study participants received no monetary benefits for participating in our study.

After completing the informed consent process, a member of the research team recruited participants for the study on a rolling basis over 18 months. We randomly assigned participants to one of the two e-health systems that were identical except group 1 used synchronous communication and group 2 used asynchronous communication for participant/clinician interactions. Study participants only received information and instructions for their randomly assigned system. Participants' system assignment was not blind to their clinician, and clinicians provided education and support to participants in both system groups.

All individuals who entered the OD program participated in an initial face-to-face assessment session (approximately 60-90 minutes) with a trained clinician, received face-to-face training on their randomly assigned system and its functionalities, and received a training manual that matched their technology group assignment. Both the research assistant, who recruited participants, and the technology trainer used standardized scripts during their interactions with participants. At the beginning of the technology training sessions, we provided participants with a unique username and password for accessing their assigned e-health system, which they accessed via specific Web portals. Participants answered various baseline health questions and received four lab requisition forms for monitoring biomedical outcomes at three-month intervals over 12 months. We obtained initial lab results for each participant. At the end of each three-month interval, participants completed a set of questions asking their perception of TTF and

[3] This name is a pseudonym for the actual program.

www.manaraa.com

self-management outcomes questions (e.g., diabetes self-efficacy, satisfaction, and quality of care) and completed a series of diabetes knowledge questions. The control measures for the individual-level analysis, after testing the effect of the two technologies on performance, were time and technology. We also collected the measures used to test our research model—perceptual TTF, technology use, and biomedical performance—every three months. We describe each measure in Sections 3.3 to 3.7.

Forty-seven participants resulted in a sample size of 156 observations[4], which included baseline and T1-to-T4 measures. Sample attribution between the two groups was similar: between time 0 and time 1 was 21 percent and 28 percent, respectively, growing to 62 percent and 72 percent by time 4.

Table 2 outlines the participants' demographic information. Of the 47 participants, 72.3 percent lived in an urban center, and there were slightly more females than males. Their ages ranged from 35 to 79 years. The baseline HbA1c (standard lab test for assessing diabetes metabolic control) values were not statistically different across the two group systems (t-Test = .727, p = .471).

We conducted a power analysis of the differences across the two system groups, use, and TTF. The results of the three measures on performance (change in the three-month blood sugar control through HbA1c), ignoring the power of a repeated measures design, was 0.95 (treatment, control), 0.98 (use), and 0.91 (TTF). Given these power analysis values, a fairly representative sample of the adult population, and the randomization of participants to the two groups, we are satisfied that the results are strong and general enough to provide insights on the proposed TTF model and on the effects of diabetes and chronic care education and self-care on biomedical outcomes.

Table 2. Participant Demographics

Characteristics	Group 1 (n = 29)	Group 2 (n = 18)
Sex (male / female)	12 / 17	10 / 8
Age (mean / Std. dev.)	54 / 9.3	52 / 8.8
Rural/urban (%)	41.4 / 58.6	5.6 / 94.4
HbA1c baseline (mean / Std. dev.)*	7.2 / 1.8	6.8 / 1.5
*Note: Non-significant mean difference between two groups.		

In Sections 3.3 and 3.4, we describe the e-health systems and tasks and the measures for TTF, performance, and use.

3.3 Technology

TTF theory proposes that particular characteristics of the technologies assist (or do not assist) individuals in task performance (Goodhue, 1995; Goodhue & Thompson, 1995). The characteristics of the two e-health systems are presented in Table 3.

Both of the groups had access to electronic educational material, information processing functionality such as searching the Internet, the ability to track their own learning, the ability to view HbA1c results (the "gold standard" measure of glycaemia, sugar in the blood, over a three-month period), lab and medication updates, the ability to update medication data, information reminders, a message center, and a digital journal that allowed participants to record their blood glucose (BG; measure of glucose/sugar in the blood stream at a specific point), outcomes, and self-care activities (i.e. exercise, diet, alcohol, insulin, and medication). We derived the educational materials and tasks from evidence-based best practices and standards from the clinical practice guidelines based on national standards adopted by the OD program and the health region.

Based on Canadian standards, the electronic journal used color indicators to highlight when the participants' BG values were too low, normal, or too high, and it provided two-week trends in low or high blood glucose results. Clinicians had electronic access to individual participant's electronic BG journal and their historical health data.

[4] Sample attrition occurred over the duration of the longitudinal design. The reasons for the attrition varied: non-availability of participants (e.g., moved to a new location; other complicating medical conditions), or participants' achievement of OD's mandate - development of self-management skills and behaviors, or participants unwilling to continue to participate in study.

المنارة للاستشارات
www.manaraa.com

Clinicians provided participants in both groups with healthcare feedback about type 2 diabetes (either verbally over the phone or electronically through the technology) and how to manage their condition based on their particular biomedical results and personal circumstances. Both groups also interacted with their clinicians during virtual appointments by using asynchronous e-messaging tools, but group 1's system also had access to synchronous private chats during their virtual appointments with clinicians and the ability to interact with other participants in their group using synchronous public chats. This reflects an important dimension of the communication processing functionality required to assist clinicians and study participants receiving advice.

Table 3. Characteristics of Study's E-health Systems

Types of characteristics	**Group 1—synchronous communication tools**	**Group 2—asynchronous communication tools**
Media	Continuous use of e-health technology	
Information processing	Electronic educational materials, Internet search, track your own learning, electronic blood glucose journal, HbA1c results, lab and medication updates, updating oral and injected medications, reminders, message center	
Communication	Virtual appointments using asynchronous e-messaging and synchronous private chats with clinicians	Virtual appointments using asynchronous e-messaging
	E-messaging	
	Asynchronous e-messaging tool Synchronous chat rooms—private and public	Asynchronous e-messaging tool

We developed two additional systems to support the study. We developed one system to support clinicians' interaction with study participants (e.g., e-messaging, chats, and access to individual participant's BG journal) and another to support the research assistant and trainer to administer the study and increase communication with the participants (e.g., establishing participant accounts and initial profiles, posting to message board, e-messaging, reminders, posting lab results, and so forth). We developed both of these systems during a separate research phase using an action research methodology.

3.4 Task

The TPC literature provides evidence that a task's characteristics are important in considering which technological designs will favorably affect performance (Goodhue, 1995; Goodhue & Thompson, 1995). Tasks are "the actions carried out by individuals in turning inputs into outputs" and the task characteristics are "those that might move a user to rely more heavily on certain aspect of the information technology" (Goodhue & Thompson, 1995, p. 216). In our context, a participant with diabetes needs to carry out various tasks and steps to achieve good diabetes control with their blood sugar, which include learning about diabetes generally and their particular condition specifically, learning about the activities and factors which affect their condition, and understanding how these activities affect biomedical outcomes, especially blood sugar control, to acquire an understanding of their medical condition and to develop self-management skills and behaviors. These learning activities and factors include reviewing electronic educational materials, testing their blood, taking insulin or medication (if required), reviewing blood glucose journals, and interacting with their clinician. These tasks actions were anticipated to improve self-care management practices, which are key to the overall management of diabetes (van Vugt, de Wit, Cleijne, & Snoek, 2013), in this study. The learning process in our case also required participants to learn to use the e-health system to carry out the learning tasks. Hence, the need to understand and manage one's diabetes condition may influence an individual's dependence on the e-health's systems functionality for information processing and communication (see Table 3).

The literature provides evidence to support that education should be focused on an understanding of one's diabetes condition (Hornsten, Lundman, Stenlund, & Sandstrom, 2005; Hornsten, Stenlund, Lundman, & Sandstrom, 2008) and education should facilitate the development of self-management skills and knowledge (Canadian Diabetes Association, 2009; Norris, Lau, Smith, Schmid, & Engelgau, 2002). The literature also provides evidence that increased use of education technologies, such as a computer-

www.manaraa.com

based educational program (Lee, Yeh, Liu, & Chen, 2007; Nebel et al., 2002), a blood glucose diary written using a mobile phone and the Internet (Kim & Kim, 2008), telemedicine (Izquierdo et al., 2003; Nebel et al., 2002; Norris et al., 2002), and Web-based intervention (Bond et al., 2007; Kaufman et al., 2006) increases diabetes knowledge and control.

Furthermore, Jackson, Bolen, Brancati, Batts-Turner, and Gar (2006) state that "excellent diabetes care and self-management depends heavily on the flow of timely, accurate information to patients and providers" (p. 105). Although Cooper, Booth, and Gill (2008) suggest that a structured and empowerment-based educational system produced limited benefits in blood glucose control (as measured by HbA1c), Grundy (2012) states that lifestyle intervention, as one of the featured components of diabetes education programs, effectively lowered glycated hemoglobin (HbA1c).

3.5 Task-technology Fit

As we mention in Section 2.2, there are various conceptualizations and measures of TTF in and beyond Goodhue and Thompson's (1995) original approach and their measure of perceptions of system qualities by individuals. These conceptualizations and measures include data quality, data compatibility with the task, information reliability and timeliness, and ease of use (which Mathieson and Keil, 1998 extended further). Others have also explored a range of TTF measures closer to performance, including Ahearne et al. (2008) who focused on specific individual characteristics (knowledge and adaptability) and behaviors (customer service and attention to personal details) in considering the "fit" between IT characteristics (in their case sales force automation) and performance (sales and perception of sales quality by the customers, who were physicians).

An important question according to Goodhue (2006) concerns who should assess a technology's TTF for a particular set of tasks. He suggests that either an "engineering evaluation" approach in which experts with a thorough understanding of the characteristics of the technology, task, and users assess fit or a "user perception evaluation" approach in which users who use the system to complete specific tasks assess it (Goodhue, 2006, p. 194).

In our particular case, the longitudinal design of the study, the complexity of the learning task, the significance of the outcome (e.g., improved health) to each participant, and the health principle of due care required us to assess fit through a combined strategy employing two different levels of interaction in our e-health systems: (1) designed through expert assessment, and (2) participants' perceptions of TTF. Thus, we employed both an objective approach to fit—technology designs based on their expertise and standardized educational practices—and individuals' perception of the relevance of the technology to their task.

As for the technology, clinicians were involved in designing the systems to ensure that the functionality was equivalent to or exceeded OD's standardized best practices in education and care. Clinicians' expert evaluations of the e-health systems' TFF are evident in the following feedback:

> *I believe that the advantages of this study will be invaluable to the clients we serve because today's work environment needs to be flexible...and this is! Today's work environment needs to be based on solid clinical standards...and this is! Today's work environment needs to respond to the questions/concerns/issues that the client has and when the client needs the information... and this does!* (OD Clinical Coordinator)

> *This approach to care is so exciting! It is going to expand our ability to reach more people and improve their care. I see this type of education option growing and expanding to other areas.* (OD Manager).

We also assessed TTF in our study through participants' perception of various characteristics of the technology using a 12-item measure (Sanders, 1984). Specifically, questions we asked about the technology included: the precision of information for the task, the user-friendly format of the system, educational materials' ability to meet needs, the timeliness, accuracy, and value of information content to meet individual needs, and the accuracy of the information. We used a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) to assess each TTF item. Participants answered the TTF items at T0 (baseline), T1, T2, T3, and T4.

We also asked the study participants to evaluate their assigned system for either group 1 or group 2. As an example, one participant said:

www.manaraa.com

…help is just one click away. Whatever questions I have mailed to my coach regarding my health have always been promptly answered, usually within hours. I find it a very convenient, safe, and easy to personally track laboratory test results, medications and blood sugar levels. [The system has] good links to many valuable and informative sites.

3.6 Performance

In our healthcare and diabetes context, we measured participant performance by improved biomedical outcomes captured by a decrease in HbA1c values from baseline. Using a biomedical measure of performance in the TPC literature is novel and unique, but it is common practice in diabetes research and health informatics research. The HbA1c test in particular is considered the “gold standard” measure in diabetes care (Delamater, 2006). HbA1c has been the “most widely accepted outcome measure for evaluating glycemic control in individuals with diabetes” for over 25 years and is “considered to be the most objective and reliable measure of long-term metabolic control” (Delamater, 2006, p. 6). HbA1c provides salient feedback to individuals with diabetes and to healthcare providers (Delamater, 2006). Recent research examples of the use of HbA1c as an outcome measure for specific technologies are diabetes self-management smartphone application (Kirwan, Vandelanotte, Fenning, & Duncan, 2013), telehealthcare programs (Chen et al., 2013), and Web-based self-management programs (see van Vugt et al.’s (2013) systematic review). Therefore, we argue that HbA1c is an appropriate outcome performance measure for our study.

The HbA1c test measures the amount of glycated hemoglobin (hemoglobin with attached glucose molecules to it) in the blood. Higher blood glucose levels lead to increased amount of glucose being attached to hemoglobin proteins. Since hemoglobin is renewed every three months by the body, the measure of glycated hemoglobin (or percentage of hemoglobin with a glucose attached to it) is a good reflection of the average blood glucose of an individual over a three-month period. Normal values may vary between lab assays but are usually less than 6.1 percent for individuals without diabetes. Achieving HbA1c values below 7 percent are considered ideal for individuals recently diagnosed with type 2 diabetes in the OD program. In clinical trials, an absolute change of 0.5 percent in HbA1c (e.g., 7.5 to 7.0) is considered a clinically significant improvement.

We collected HbA1c values at the beginning of the study (baseline) and then every three months for a 12-month period. We calculated the change in HbA1c for feed-forward by subtracting the current period’s HbA1c value from baseline (T0) multiplied by -1 and the previous change in HbA1c from baseline in the previous period for feedback analysis by multiplying it by -1.

3.7 Use

Important to performance is the actual use of the IT, and its measurement is important in connecting TTF and use research together (Goodhue, 2006). Several studies measure use subjectively through questionnaires (Goodhue & Thompson, 1995), and others measure it a dichotomous and implied use variable through experimental groups that have or do not have access to technology (Ahearne et al., 2008). In general, researchers have called for more studies that explore use in objective detail and tease out the various forms of use and their effect on performance (Burton-Jones & Gallivan, 2007; Burton-Jones & Straub, 2006). In our case, we used an objective and continuous measure of system use to inform our study by using a custom-built log system. In our study, we captured all technology continuously through website system logs and accumulated for each three-month period. We used the total use of all the mouse clicks on the different functionalities as the best omnibus measure of the use. In Section 4, we turn to our analysis strategy.

4 Feed-forward and Feedback Analysis

Table 4 outlines the related data analysis models of performance, TTF, and technology use variables for both feed-forward and feedback analyses.

المنارة للاستشارات
www.manaraa.com

Table 4. Data Analysis Models for Feed-forward and Feedback Variables

Feed-forward: *Model for Hypotheses 1, 2, & 4:* $perf_t = TTF_{t-1}$ (H1) + use_t (H2) + $TTF_{t-1} * use_t$ (H4) + tech group (control) + Time (Control) *Model for Hypothesis 3:* $use_t = TTF_{t-1}$ (H3) + tech group (control) + time (control)
Feedback: *Model for Hypothesis 5:* $TTF_t = perf_{t-1}$ (H6) + tech (control) + time (control) *Model for Hypothesis 6:* $use_t = perf_{t-1}$ (H6) + tech (control) + time (control)
Tech = group 1 (synchronous) or group 2 (asynchronous); perf = change in HbA1c from baseline; TTF = task technology fit from study measure at end of each three-month period after baseline; five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree; use = total use of the system for the three-month period; t = time

For all of the hypotheses, we examined the data observations from T2 onward to determine the feed-forward and feedback events because TTF is lagged one period in the feed-forward model and performance is lagged one period in the feedback model.

To analyze the data for feed-forward and feedback, we used SAS's PROC MIXED method with REPEATED statements to handle the repeated measures nature of our data since we collected multiple rows of data from the same individuals. SAS PROC MIXED is also able to effectively handle missing data. In the case of feed-forward, we analyzed hypotheses 1, 2, and 4 using a single model and hypothesis 3 with a separate model. To analyze the data for feedback hypotheses 5 and 6, we also analyzed the data using separate PROC MIXED models to determine the effect of previous performance on subsequent TTF and use.

4.1 Findings

Table 5 presents the descriptive statistics for our various measures of feed-forward and Table 6 presents them for feedback. Of the 47 study participants, 72 percent experienced an improvement in their HbA1c values during the study time.

Table 5. Feed-forward—Means / Standard Deviations for Performance, TTF, and Use

Time	System by group and combined	$Performance_{T1}$ mean / std. dev.	TTF_{T1-1} mean / std. dev.	Use_{T1} mean / std. dev.
1	1 (n = 23)	.487 / 1.064	4.365 / .627	487.26 / 332.63
	2 (n = 13)	.223 / 1.537	4.205 / 1.111	308.38 / 365.86
	Combined (n = 36)	.392 / 1.240	4.307 / .823	422.667 / 350.756
2	1 (n – 17)	1.206 / 1.905	4.392 / .450	303.59 / 253.27
	2 (n = 11)	-.2182 /.579	4.348 / .588	216.91 / 260.06
	Combined (n = 28)	.646 / 1.666	4.375 / .498	269.536 / 254.795
3	1 (n = 15)	1.373 / 2.10	4.228 / .998	215.93 / 260.98
	2 (n = 12)	-.267 / .748	4.465 / .617	279.00 / 347.43
	Combined (n = 27)	.644 / 1.816	4.333 / .844	243.963 / 297.935
4	1 (n = 11)	1.491 / 2.22	4.160 / .718	208.64 / 249.39
	2 (n = 5)	.120 / .444	4.667 / .421	206.00 / 234.46
	Combined (n = 16)	1.063 / 1.938	4.318 / .671	207.813 / 236.904

www.manaraa.com

Table 6. Feedback—Means / Standard Deviations for Performance, Use and TTF

Time	System by group and combined	$Performance_{T-1}$ mean / std. dev.	Use_{T1} mean / std. dev.	TTF_{T1} mean / std. dev.
2	1 (n = 17)	.965 / 1.71	303.59 / 253.27	4.392 / .651
	2 (n = 11)	-.182 / .748	216.91 / 260.06	4.454 / .623
	Combined (n = 28)	.514 / 1.505	269.536 / 254.795	4.417 / .630
3	1 (n = 15)	1.233 / 2.173	215.93 / 260.98	4.117 / 1.033
	2 (n = 12)	-.158 / .558	279.00 / 347.43	4.479 / .600
	Combined (n = 27)	.615 / 1.781	243.963 / 297.935	4.278 / .872
4	1 (n = 11)	1.354 / 2.261	208.64 / 249.39	4.136 / .756
	2 (n = 5)	-.400 / 1.194	206.000 / 234.462	4.483 / .462
	Combined (n = 16)	.806 / 2.119	207.812 / 236.904	4.245 / .682

Tables 7, 8, and 9 present the results of the PROC MIXED with repeated measures for feed-forward.

Table 7. Results on Feed-forward for Technology, Previous TTF, Use and Previous TTF x Use on Performance[5]

H	Model	F Values	P values	B coefficients
H1	TTFt-1 (H1)	0.03	.8705	-0.056
H2	+ Uset (H2)	7.15	.005	+0.013
H4	+ TTFt-1* uset (H4)	5.05	.031	-0.002
Covariate	+ Time (control)	0.35	.705	
Covariate	+ Tech group (control)	9.01	.005	+1.126

These results show that the effect of previous TTF (TTF_t-1) on performance (H1) was insignificant (F = 0.03, p=.870) and that the effect of current use (use_t) on performance (H2) was significant and positive as expected (F = 7.15, p=.005). Hence, while H1 was not supported, H2 was supported.

Moreover, the effect of the interaction of previous TTF and current use on performance (H4) was significant (F = 5.05, p=.031). We theorized that TTF would moderate the association of current use for the three-month period on performance, which was supported (see Figure 3). Specifically, the strongest positive association of use on performance occurred for participants who reported low levels of perceived TTF. In contrast, the weakest association for use and performance occurred for participants who reported high levels of perceived TTF.

Finally, the covariate for the effect of system groups on performance was significant and positive (F = 9.01, p=.005), which indicates that individuals assigned to system group 1 had better biomedical performance than the individuals assigned to system group 2. Table 8 shows the feed-forward results from TTFt-1 to use_t for H3.

Table 8. Results on Feed-forward from previous TTF on Use

H	Model	F Values	P values	B coefficients
H3	TTF_{t-1}	0.00	.9810	1.166
	+ Tech (control)	0.02	.8803	+10.19
	+ Time (control)	0.27	.7671	

[5] Because using biomedical outcomes such as HbA1c appears to be novel in the IS literature, we examined the correlation coefficients among other self-management behaviors and knowledge outcomes (e.g., diabetes self-efficacy, satisfaction, care quality, self-care and knowledge scores) and performance (HbA1c and change in performance) to assess the possibility of confounds. These results showed that HbA1c and change in HbA1c from baseline were not auto-correlated with other self-management behaviors and knowledge outcomes, which suggests that these variables were not confounding our results.

المنارة للاستشارات
www.manaraa.com

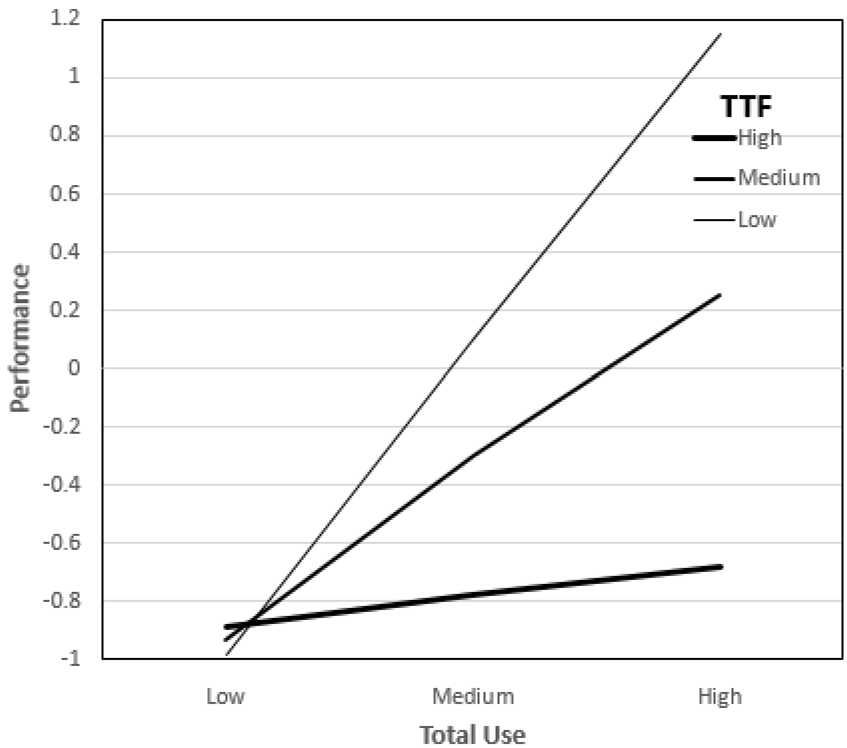

Figure 3. TTF Moderation of Use and Performance Association

The result from Table 8 show that the effect of previous TTF (TTFt-1) on current Use (use_t) in H5 was insignificant (F = 0.00, p=.9810), which suggests that TTF does not affect use.

For testing the feedback relationship, we report the PROC MIXED with repeated measures results of previous performance ($perf_{t-1}$) on subsequent TTF (TTF_t) and on subsequent total use (use_t) for the following period (see Tables 9 and 10) (see model in Table 3).

Table 9. Results on Feedback from Previous Performance on Subsequent TTF

H	Model	F values	P values	B coefficients
H5	$Perf_{t-1}$	7.34	.010	-0.143
	+ Tech (control)	0.06	.812	-0.045
	+ Time (control)	0.27	.7624	

The results show that the effect of previous performance ($perf_{t-1}$) on TTF_t (H5) was significant and negative (F = 7.34, p=.0108). Therefore, the perception of TTF declined as performance improved. Both technology (F = 0.06, p=.812) and time (F = 0.27, p=.7624) were insignificant.

Lastly, the results show that the effect of previous performance ($perf_{t-1}$) on use (use_t) (H6) was significant and positive (F = 6.92, p=.0125). Both technology (F = 0.76, p=.3915) and time (F = 0.40, p=.6761) were insignificant.

Table 10. Results on Feedback from Previous Performance on Use

H	Model	F values	P values	B coefficients
H6	$Perf_{t-1}$	6.92	.0125	50.88
	+ Tech (control)	0.76	.3915	-59.64
	+ Time (control)	0.40	.6761	

www.manaraa.com

5 Discussion

Our results both confirm, clarify, and extend the relationships among technology, TTF, use, and performance through both feed-forward and feedback relationships (Goodhue, 1995; Goodhue & Thompson, 1995) by illustrating how controlled differences in technology design affect performance, how changes in use and TTF-use interactions affect performance through feed-forward, and how performance affects TTF and use through feedback. From our longitudinal study results, we provide evidence of the dynamic relationships of TTF to use and performance over time, of the differences between the feed-forward and feedback relationships, and of the associations among task, performance, and use over time. We suggest various theoretical implications for TTF and practical implications for e-health technology design, e-health use and performance, and diabetes self-care management practices. Figure 4 depicts various emergent and cyclical relationships across TTF, use, and performance, which we discuss below.

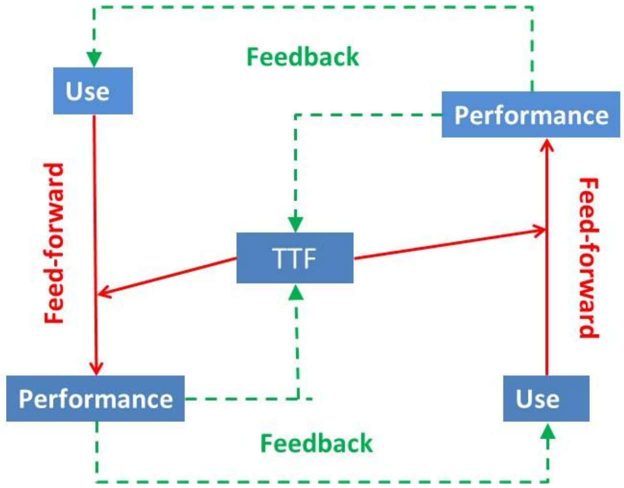

Figure 4. Theoretical Extended TPC Model: TTF and Use Feed-forward to Performance, and Feedback from Performance to TTF and Use

Our descriptive data (Tables 4 and 5) suggest that our e-health systems and the tasks of diabetes control result in with high levels of perceived TTF, use, and performance, which confirms the real and perceived importance of carefully designed technology in addressing the important tasks of chronic care.

In terms of feed-forward, our data (Table 7) support two of our four feed-forward hypotheses: that higher use of the technology increases performance (H2) and that an increased use-TTF interaction negatively affects biomedical performance (H4). We expected the positive association of increased use with performance when a well-designed system fits the task and the technology is used to achieve those tasks.

We can explain the negative interaction of TTF and use on subsequent performance through feed-forward by using a combination of adaptation and experience feedback. In terms of adaptation, lower individual assessment of TTF may have produced a more strategic use of the technology through the adapted use of it during feed-forward, which then prompted improved biomedical (blood sugar control) performance. Conversely, higher perceptions of TTF may have produced less strategic adaptation of use, which, preserved or decreased performance.

In addition to adaptation, experience feedback from individuals with aggravated blood sugar levels at the outset (i.e., lower performance) may have started with a lower perception of the technology's ability to address these problems (low TTF), which then motivated strategic use and the use of educational materials and system functionalities to learn and develop strategies to improve their diabetes care and performance. Conversely, better blood sugar control at the outset without a need to decrease HbA1c (performance) may have resulted in a greater perceived fit of the technology with this easier task and a small change in performance.

Moving beyond individual-level results, our feedback analysis also shows that group 1's system had significantly better results on biomedical performance than group 2's system, which illustrates an objective fit of the communication capabilities across participants and clinicians in group 1 and which further supports the task of learning about diabetes self-care.

المنارة للاستشارات
www.manaraa.com

In terms of feed-forward from TTF to use (Table 8), we found H3 to be insignificant, which suggests that varying levels of TTF do not prompt different levels of system use. Instead, through the negative relationship of the TTF-use interaction on performance, higher levels of use combined with lower levels of TTF had a positive effect on performance. This suggests that not only use but also the targeted use of the technology from low expectations about the technology drive performance (more on this next).

In terms of feedback, Table 9 confirms H5 by showing that higher performance significantly affected TTF but, like feed-forward, in a negative direction. We can explain this negative result in a similar way as Lucas and Spitler (1999) and Goodhue and Thompson (1995): that is, through experience feedback, those with high performance may have found that, once they reached their target HbA1c levels, they had low expectations about the technology meeting the future challenges beyond diagnosis and their early learning about diabetes, and so TTF decreased as performance increased. This result suggests that high performance begat decreased TTF. Conversely, those with poor performance may have continued to believe in the technology's ability to support future performance. We confirmed both of these results with some follow-up interviews in which participants indicated they wanted increased functionality of their assigned e-health system as their knowledge of controlling type 2 diabetes grew beyond the mandate of the OD program and the system's functionality.

Table 10 confirms H6 by showing that higher performance significantly affected subsequent use. As such, this confirms the expected result that increased performance increases future use that and decreased performance decreases future use.

In summary, our results show that group 1's e-health system increased use of both systems that the interaction of lower TTF with increased use increased performance through feed-forward, and that increased performance increased use and decreased TTF through feedback.

5.1 Practical Implications

The results suggest several practical implications for designing and implementing e-health systems. First, involving clinicians and participants in ensuring that the e-health system fits the learning needs of the individual and satisfies the ethical standard of due care is essential.

Second, given our descriptive statistics, the learning activities of the e-health system must incorporate more than the static presentation of information and search capabilities: it should also incorporate information-processing capabilities such as Internet searching, evaluation, the tracking of individual learning, and the use of self-care journals with trend analyses to evaluate self-care actions and outcomes. These capabilities provide opportunities for individuals to process and incorporate the general diabetes information into their own medical situation and to self-assess their health-related outcomes from adapting and adopting self-management skills and behaviors.

Third, our result for group 1's system indicate that e-health systems that allow individuals to interact and engage their clinician/health care provider via both synchronous/asynchronous channels and/or virtual appointments is important. As Bartelt and Dennis (2014) suggest, when one selects communication capabilities, they need to assess the social structures associated with the different communication tools used during the individual/clinician interaction. For example, a private chat or instant messaging (synchronous) may fit the learning task better when an immediate response is needed to understand aggravated blood glucose levels, whereas email (asynchronous) may fit the learning task of reinforcing the individual's understanding and development of self-management skills and behaviors.

Finally, our individual-level results suggest that learning occurs with individuals who are motivated by a lack of fit, by those who use the technology strategically to address this lack of fit, and by those who develop the self-management skills and behaviors who eventually move beyond the technological capabilities. As the HCI literature outlines, following a "made-for-the-medium" (Agarwal & Venkatesh, 2002; Goh & Ping, 2014) approach is instrumental in tailoring an e-health system to fit individuals' needs.

Our study results also have important practical implications for healthcare programs and clinicians wishing to support participant learning and self-care management in chronic care. As we state in Section 3.1, the costs of diabetes education and care are increasing exponentially around the world, and healthcare organizations have limited resources available. Our study suggests that participants can acquire diabetes knowledge and develop self-care management skills and behaviors by using an online e-health system. Well-designed e-health systems that prompt and manage initially low expectations of fit and allow individuals to adapt its use to their situation to increase performance have the potential to supplement,

المنارة للاستشارات
www.manaraa.com

replace, and improve the delivery of diabetes education. As a result, diabetes education programs may be able to limit or reduce the expense of face-to-face delivery through self-management programs (Jones, Berard, MacNeill, & Whitham, 2013).

5.2 Limitations and Conclusions

Before outlining the paper's contributions, we highlight several limitations and opportunities for future research. Typical of longitudinal and experimental studies in a natural setting, we needed to make various assumptions about how to best measure and analyze the data, such as the change in HbA1c as a measure of performance, total use across functionality, and the use of particular statistical methods to analyze our data and compare it with theory. We have tried to address these concerns by explaining our measurement and analysis approach in detail, including particular analytical assumptions. Future studies could employ other measures and statistical approaches including multi-level mixed modelling to consider between-group comparisons and to further extend and replicate our results.

The fact that we demonstrate significance given a small individual sample size and subject attrition could be seen as a strength of our study. To address the statistical problem of the individual sample size, however, we used repeated measures, which resulted in a sample size that is higher than some medical Internet studies (sample size ranges from 15 to 73; see van Vugt et al.'s (2013) systematic review) and lower than other standard medical studies (sample size ranges from 255 to 958; see van Vugt et al.'s (2013) systematic review). As a consequence, there may be other statistically and clinically important relationships between the variables in our study that we did not detect with our modest sample size. Despite this, we did find several significant results across feed-forward and feedback, and, although our sample includes a modest and diverse set of individuals, our results may be carefully generalizable to other chronic care participants and other TTF settings. More studies with a greater number of participants with diabetes, other chronic care conditions, or other TTF tasks and performance outcomes would provide further evidence to confirm our findings.

We also studied a specific population of individuals living in a particular time and place and with a specific condition (i.e., diabetes) immediately after diagnosis. As with any field experiment like this, care will need to be taken in generalizing and applying the results wholeheartedly to other IT research and practical settings through additional replication studies. Further investigation with other chronic conditions and with other populations of individuals is required.

Despite these limitations, we believe that our study provides several important practical and theoretical contributions. Practically speaking, we address an important area of concern—the growing problem of handling the increasing prevalence and incidence of chronic disease and the cost of its associated care (Canadian Diabetes Association, 2009). Specifically, the future of participant care is considered to be a growing epidemic in terms of resource cost and medical illness unless we can take steps soon to mitigate the consequences of diabetes (Canadian Diabetes Association, 2009).

Our study results suggest that using electronic materials for education, combined with asynchronous and synchronous interaction with clinicians and using a journal for self-care activities and monitoring, helps in supporting the development of good chronic self-care in which not only the technology but also the socio-technical structures and practices required to support chronic care are created (Farmer, Gibson, Tarassenko, & Neil, 2005). We have done what many have suggested, which is to study long-term care interventions lasting at least one year and to develop rigorous methods for evaluating differences and similarities in clinical outcomes across treatments (Jackson et al., 2006). As van Vugt et al. (2013) suggest in their systematic review of Web-based self-management systems, we have helped "to successfully improve patient health behaviors and health related outcomes" (p. e279).

In doing so, we have employed and extended TPC to guide our study and to analyze our findings, and we contribute to important questions about TTF, its relationship to performance and use, and the feedback relationships identified but largely untested in the literature. We also found that variation in participants' TTF assessment of IT is an important part of the theory, with and beyond objective differences in technology fit, which needs to be accounted for in research and practice. In addition, we found that TTF's relationship to performance depends on its interaction with use, which confirms TTF's moderating effect on performance.

The negative relationship of TTF-use to performance and the positive relationship from performance back to TTF indicates that decreases in TTF from high performance indicate both a response to the difficulties of achieving performance through the technology combined with high and optimistic TTF at the outset

www.manaraa.com

before initial use. We can also further explain the negative association of TTF and performance through the limits encountered once a desirable HbA1c is achieved and when participants turn towards their future needs to maintain this care beyond the OD program and the use of this particular e-health technology.

Finally, our results demonstrate that IS can have material effects—in this case, on participant's self-management behaviors and health outcomes (i.e., the embedded socio-technical realization of IT artifacts as Orlikowski and Iacono (2001) suggest) and the social structural aspect of TTF as Bartelt and Dennis (2014) suggest). This result addresses a long-standing quest for the dependent variable in information systems research (DeLone & McLean, 1992, 2003). We address this quest by mixing research rigor in an important, real, and specific context—newly diagnosed individuals needing to learn about diabetes care. Thus, through the theoretical and practical work, we illustrate how using a custom-designed IT can support the individual appropriation of IT towards individual-level fit and performance across time and include practical implications designing and developing e-health systems for chronic care.

Acknowledgements

Thank you to The Lawson Foundation and the Advanced Institute of Management (AIM) research foundation in the UK for providing the funding for this longitudinal research project. We greatly appreciate the support we received from the OD program and its clinicians, staff members, and managers. Their support and efforts played a key role in the development of the e-health system and in providing the services and interactions with clients during the planning and execution of this longitudinal study. We also want to thank the panel of reviewers for their valuable comments, recommendations, and suggestions.

المنارة للاستشارات
www.manaraa.com

References

Agarwal, R., & Venkatesh, V. (2002). Assessing a firm's Web presence: A heuristic evaluation procedure for the measurement of usability. *Information Systems Research*, *13*(2), 168-186.

Ahearne, M., Jones, E., Rapp, A., & Mathieu, J. (2008). High touch through high tech: The impact of salesperson technology usage on sales performance via mediating mechanisms. *Management Science*, *54*(4), 671-685.

Barrera, M., Glasgow, R. E., McKay, H., Boles, S., & Feil, E. (2002). Do Internet-based support interventions change perceptions of social support? An experimental trial of approaches for supporting diabetes self-management. *American Journal of Community Psychology*, *30*(5), 637-654.

Bartelt, V. A., & Dennis, A. R. (2014). The impact of automaticity and the structuration of communication of virtual team behaviour and performance. *Management Information Systems Quarterly*, *38*(2), 521-538.

Bond, G., Burr, R., Wolf, F., Price, M., McCurry, S., & Teri, L. (2007). The effects of a Web-based intervention on the physical outcomes associated with diabetes among adults age 60 and older: A randomized trial. *Diabetes Technology & Therapeutics*, *9*(1), 52-59.

Buettner, K., & Fadem, S.Z. (2008). The Internet as a tool for the renal community. *Advances in Chronic Kidney Disease*, *15*(1), 73-82.

Burton-Jones, A., & Gallivan M. J. (2007). Towards a deeper understanding of system usage in organizations: A multilevel perspective. *MIS Quarterly*, *31*(4), 657-679.

Burton-Jones, A., & Straub D. (2006). Reconceptualizing system usage: An approach and empirical test. *Information Systems Research*, *17*(3), 228-246.

Canadian Diabetes Association. (2009). *An economic tsunami—the cost of diabetes in Canada*. Toronto, ON: Canadian Diabetes Association. Retrieved from http://www.diabetes.ca/documents/get-involved/FINAL_Economic_Report.pdf.

Cane, S., & McCarthy, R. (2009). Analyzing the factors that affect information systems use: A task-technology fit meta-analysis. *Journal of Computer Information Systems*, *50*(1), 108-123.

Chen, L., Chuang, L., Chang, C., Wang, C., Wang, I., Chung, Y., Peng, H.-Y., Chen, H.-C., Hsu, Y.-L., Lin, Y.-S., Chen, H.-J., Chang, T.-C., Jiang, Y.-D., Lee, H.-C., Tan, C.-T., Chang, H.-L., & Lai, F. (2013). Evaluating self-management behaviors of diabetic patients in a telehealthcare program: Longitudinal study over 18 months. *Journal of Medical Internet Research*, *15*(12), e266.

Changing Diabetes Barometer. (2012). Changing diabetes in the US. Retrieved from http://www.changingdiabetesbarometer.com/docs/CDB_USA_GP_FINAL.pdf

Changing Diabetes Barometer. (2013). Diabetes—a chronic disease. Retrieved from http://www.changingdiabetesbarometer.com/about-diabetes.aspx

Cooper, H., Booth, K., & Gill, G. (2008). A trial of empowerment-based education in type 2 diabetes—global rather than glycemic benefits. *Diabetes Research and Clinical Practice*, *82*(2), 165-171.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982-1003.

Dedding, C., van Dorrn, R., Winkler, L., & Reis, R. (2011). How will e-health affect patient participating in the clinic? A review of e-health studies and the current evidence for changes in the relationship between medical professionals and patients. *Social Science & Medicine*, *72*, 49e-53.

Delamater, A. M. (2006). Clinical use of hemoglobin A1c to improve diabetes management. *Clinical Diabetes*, *24*(1), 6-8.

المنارة للاستشارات
www.manaraa.com

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information Systems Research*, *3*(1), 60-95.

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, *19*(4), 9-30.

Devaraj, S., & Kohli, R. (2003). Performance impacts of information technology: Is actual usage the missing link? *Management Science*, *49*(3), 273–289.

Dishaw, M. T., & Strong, D. M. (1998). Supporting software maintenance with software engineering tools: A computed task—technology fit analysis. *Journal of Systems and Software, 44*(2), 107-120.

Dishaw, M. T., & Strong, D. M. (1999). Extending the technology acceptance model with task–technology fit constructs. *Information & Management*, *36*(1), 9-21.

Farmer, A., Gibson, O., Tarassenko, L., & Neil, A. (2005). A systematic review of telemedicine intervention to support blood glucose self-monitoring in diabetes. *Diabetes Medicine*, *11*(10), 1372-1378.

Furneauz, B. (2012). Task-technology fit theory: A survey and synopsis of the literature. In Y. K. Dwivedi, M. R. Wade, & S. L. Schneberger (Eds.), *Information systems theory: Explaining and predicting our digital society* (Vol. 1, pp. 87-106). New York: Springer-Verlag.

Fuller, R. M., & Dennis, A. R. (2009). Does fit matter? The impact of task-technology fit and appropriation on team performance in repeated tasks. *Information Systems Research*, *20*(1), 2-17.

Goh, K., & Ping, J. W. (2014). Engaging consumers with advergames: An experimental evaluation of interactivity, fit and expectancy. *Journal of the Association of Information Systems*, *15*(7), 388-421.

Goodhue, D. L. (1995). Understanding user evaluations of information systems. *Management Science*, *41*(12), 1827-1844.

Goodhue, D. L. (1997). The model underlying the measurement of the impacts of the IIC on the end-users. *Journal of the American Society of Information Science*, *48*(5), 449-453.

Goodhue, D. L. (2006). Task-technology fit: a critical (but often missing!) construct in models of information systems and performance. In Y. Zhang & D. F. Galletta (Eds), *Human-Computer Interaction and Management: Foundations* (pp. 184-204). New York: M.E. Sharpe.

Goodhue, D. L., Klein, B. D., & March, S. (2000). User evaluations of IS as surrogates for objective performance. *Information & Management*, *38*(2), 87-101.

Goodhue, D. L., & Thompson, R L. (1995). Task-technology fit and individual performance. *MIS Quarterly*, *19*(2), 213-236.

Grundy, S. M. (2012). Pre-diabetes, metabolic syndrome, and cardiovascular risk. *Journal of the American College of Cardiology*, *59*(7), 635-643.

Gupta, S. K. (2011). Intention-to-treat concept: A review. *Perspectives in Clinical Research*, *2*(3), 109-112.

Hornsten, A., Lundman, B., Stenlund, H., & Sandstrom, H. (2005). Metabolic improvement after intervention focusing on personal understanding in Type 2 diabetes. *Diabetes Research and Clinical Practice*, *68*(1), 65-74.

Hornsten, A., Stenlund, H., Lundman, B., & Sandstrom, H. (2008). Improvements in HbA1c remain after 5 years—a follow up of an educational intervention focusing on patients' personal understanding of type 2 diabetes. *Diabetes Research and Clinical Practice*, *81*(1), 50-55.

Izquierdo, R. E., Knudson, P. E., Meyer S., Kearns, J., Ploutz-Snyder, R., & Weinstock, R. S. (2003). A comparison of diabetes education administered through telemedicine versus in person. *Diabetes Care*, *26*(4), 1002-1007.

المنارة للاستشارات
www.manaraa.com

Jackson, C., Bolen, S., Brancati, F., Batts-Turner, M., & Gar, T. (2006). A systematic review of interactive computer-assisted technology in diabetes care. *Journal of General Internal Medicine*, *21*(2), 105-110.

Jones, H., Berard, L. D., MacNeill, G., Whitham, D., & Yu, C. (2013). Canadian diabetes association 2013 clinical practice guidelines for the prevention and management of diabetes in Canada: Self-management education. *Canadian Journal of Diabetes*, *37*, S26-S30.

Junglas, I., & Abraham, C. W. (2008). Task-technology fit for mobile locatable information systems. *Decision Support Systems*, *45*(4), 1046-1057.

Junglas, I., Abraham, C., & Ives, B. (2009). Mobile technology at the frontlines of patient care: Understanding fit and human drives in utilization decisions and performance. *Decision Support Systems*, *46*, 634-647.

Kaufman, D. R, Pevzner, J., Hilliman, C., Weinstock, R. S., Teresi, J., Shea, S., & Starren, J. (2006). Redesigning a telehealth diabetes management program for a digital divide seniors population. *Home Health Care Management and Practice*, *18*(3), 223-234.

Kim, S. I., & Kim, H. S. (2008). Effectiveness of mobile and internet intervention in patients with obese type 2 diabetes. *International Journal of Medical Informatics*, *77*(6), 399-404.

Kirwan, M., Vandelanotte, C., Fenning, A., & Duncan, M. (2013). Diabetes self-management smartphone application for adults with type 1 diabetes: Randomized controlled trial. *Journal of Medical Internet Research*, *15*(11), e235.

Lee, T. I., Yeh, Y. T., Liu, C. T., & Chen, P. L. (2007). Development and evaluation of a patient-oriented education system for diabetes management. *International Journal of Medical Informatics*, *76*(1), 655-663.

Lin, T. C., & Huang, C. C. (2009). Understanding the determinants of EKR usage from social, technological and personal perspectives. *Journal of Information Science*, *35*(2), 165-179.

Lucas, H. C., & Spitler, V. K. (1999). Technology use and performance: A field study of broker workstations. *Decision Sciences*, *30*(2), 291-311.

Mathieson, K., & Keil, M. (1998). Beyond the interface: Ease of use and task/technology fit. *Information & Management*, *34*(4), 221-230.

McGill, T. J., & Klobas, J. E. (2009). A task-technology fit view of learning management system impact. *Computers & Education*, *52*(2), 496-508.

Nebel, I. T., Bluher, M., Starcke U., Muller, U. A., Haak, T., & Paschke R. (2002). Evaluation of a computer based interactive diabetes education program designed to train the estimation of the energy or carbohydrate contents of foods. *Patient Education and Counseling*, *46*(1), 55-59.

Nicholson, J., & Valacich, J. S. (2008). Examining the effects of technology attributes on learning: A contingency perspective. *Journal of Information Technology Education*, *7*, 185-204.

Norris, S. L., Lau, J., Smith, J., Schmid, C. H., & Engelgau, M. M. (2002). Self-management education for adults with type 2 diabetes: A meta-analysis of the effect of glycemic control. *Diabetes Care*, *25*(7), 1159-1171.

Orlikowski. W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the “IT” in IT research—a call to theorizing the IT artifact. *Information Systems Research*, *12*(2), 121-134.

Petter, S., DeLone, W., & McLean, E. (2008). Measuring information systems success: Models, dimensions, measures, and interrelationships. *European Journal of Information Systems*, *17*(3), 236-263.

Pinsonneault, A., & Rivard, S. (1998). Information technology and the nature of managerial work: From the productivity paradox to the Icarus paradox? *MIS Quarterly*, *22*(3), 287–311.

Sabel, M., Strecher, V., Schwartz, J., Wang, T., Karimipour, D., Orringer, J., Johnson, T., & Bichakjian, C. (2005). Patterns of Internet use and impact on patients with melanoma. *Journal of the American Academy of Dermatology*, *52*(5), 779-785.

المنارة للاستشارات
www.manaraa.com

Sanders, G.L. (1984). MIS/DSS success measure. *Systems, Objectives and Solutions*, *4*, 29-34.

Shaw, J. E., Sicree, R. A., & Zimmet, P. Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice*, *87*(1), 4-14.

Staples, D. S., & Seddon, P. (2004). Testing the technology-to-performance chain model. *Journal of Organizational and End User Computing*, *16*(4), 17–36.

Strong, D. M., Dishaw, M. T., & Bandy, B. D. (2006). Extending task technology fit with computer self-efficacy. *ACM SIGMIS*, *37*(2-3), 96-107.

Tambe, P., & Hitt, L.M. (2012). The productivity of information technology investments: New evidence from IT labor data. *Information Systems Research*, *23*(), 599–617.

Teo, T. S. H., & Men, B. (2008). Knowledge portals in Chinese consulting firms: A task–technology fit perspective. *European Journal of Information Systems*, *17*(6), 557-574.

van Vugt, M., de Wit, M., Cleijne, W., & Snoek, F. (2013). Use of behavioral change techniques in Web-based self-management programs for type 2 diabetes patients: Systematic review. *Journal of Medical Internet Research*, *15*(12), e279.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. (2003). User acceptance of information technology: A unified view. *MIS Quarterly*, *27*(3), 425-478.

Willis, M. J., El-Gayar, O. F., & Deokar, A. V. (2009). Evaluating task-technology fits and user performance for an electronic health record system. In *Proceedings of the American Conference on Information Systems.*

www.manaraa.com

About the Authors

Mike W. Chiasson is current a Professor at the University of British Columbia, in the Faculty of Management, and an Advanced Institute for Management Research (AIM) fellow. Before joining UBC, He was professor at Lancaster University's Management School, an Associate Professor in the Haskayne School of Business, University of Calgary, and a postdoctoral fellow at the Institute for Health Promotion Research at the University of British Columbia. His research examines how the social and organizational context affects and is effected by IS development and implementation. His work mixes both quantitative and qualitative data, with typically a strong emphasis on "participant" observation, resulting in various contributions to social theory (ANT, Habermas, pragmatism, structuration theory, entrepreneurial opportunities), action research, research methods and ethics. His research has appeared in such journals as *MIS Quarterly*, the *Journal of Business Venturing*, the *Journal of the Association of Information Systems*, the *Information Systems Journal*, the *Journal of Information Technology*, *European Journal of Information Systems*, *Information and Organization*, and several medical and medical informatics journals.

Helen Kelley is an Associate Professor of Information Systems in the Faculty of Management at the University of Lethbridge. Her research focuses on the individual user of information and enterprise resource planning technologies, viewed from social cognitive and attributional perspectives. Her current interests investigate understanding what management of organizations can do to enhance individual acceptance and learning about information systems technologies plus e-health. Her research has been published in *Information Systems Research*, *Journal of the Association of Information Systems*, *Database for Advances in Information Systems*, and others.

Angela Downey is an Associate Professor of Accounting in the Faculty of Business at the University of Victoria. Her research interests are centered in the health environment. She has published and presented extensively on the role of measurement in health promotion and prevention. She is involved in research using her economic and costing models to measure the impact of changes in health care system delivery including the development and adoption of evidence-based best clinical practice. She has published in the *Journal of the Association for Information Systems*, *Worldviews on Evidence-Based Nursing*, and the *Journal of Accounting Ethics*, among others.

Copyright © 2015 by the Association for Information Systems. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and full citation on the first page. Copyright for components of this work owned by others than the Association for Information Systems must be honored. Abstracting with credit is permitted. To copy otherwise, to republish, to post on servers, or to redistribute to lists requires prior specific permission and/or fee. Request permission to publish from: AIS Administrative Office, P.O. Box 2712 Atlanta, GA, 30301-2712 Attn: Reprints or via e-mail from publications@aisnet.org.

المنارة للاستشارات
www.manaraa.com