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Factors Influencing Adoption of Mobile Computing

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INTRODUCTION

The emergence of mobile computing combined with the increased popularity of the Internet is changing our daily lives. The increasing use of small portable computers, wireless networks and satellites unfolds the new technology of mobile computing, which allows transmission of data to computers that are *not* physically linked to a network. As a result, people can communicate "on the move."

Mobile devices with new input and output methods and form factors are dramatically different from traditional desktop computers (Rodden et al., 1998). These technological changes make increasing demands on both the quality of user interface and the functionality of mobile devices (Johnson, 1998). The questions for this research are: What factors influence users' adoption of mobile computing? How does the design of mobile devices and interface affect user adoption, and to what degree do specific factors such as trust and enjoyment (in using mobile devices) play a role in adoption?

We first review literatures on technology adoption and the various design dimensions of mobile devices, and then propose a model for adoption of mobile computing.

TECHNOLOGY ADOPTION MODELS

In reviewing the Information Systems literature on IT adoption, we found the Technology Acceptance Model (TAM) proposed by Davis (1989) to be most relevant for this study. TAM was derived from the Theory of Reasoned Action (TRA) proposed by Fishbein and Ajzen (1975). According to Davis (1989), perceived usefulness and perceived ease of use are the two determinants that influence people's attitude toward IT usage intention and actual IT usage. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" and perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p.320). Davis and his colleagues (Davis, 1989; Davis et al., 1989; Davis et al., 1992) demonstrated that perceived usefulness had a strong direct effect on usage intentions whereas perceived ease of use affected usage intentions indirectly via perceived usefulness. They also demonstrated that TAM had a higher explanatory power than TRA for predicting (word processing) software usage (Davis et al., 1989).

In an extension to TAM, Davis and his colleagues examined the impact of enjoyment on usage intentions (Davis et al., 1992). They reported two studies concerning the relative effects of usefulness and enjoyment on intentions to use and usage of computers. As expected, they found usefulness had a strong effect on usage intentions. In addition, they found enjoyment had a significant effect on intentions. A positive interaction between usefulness and enjoyment was also observed.

Based on these results, Davis and his colleagues argued that further research is needed to examine the role of additional constructs such as availability of a particular software program, ease of learning, social normative influence, system design characteristics, system familiarity or experience, top management support, user involvement, task characteristics, etc.

Originally evaluated with email, word processing and graphics applications, TAM has been extended to other applications such as voice-mail (Adams et al., 1992), spreadsheets (Mathieson, 1991), DBMS (Szajna, 1994), GSS (Chin and Gopal, 1995) and adaptive technology for the physically-challenged (Goette, 1995). Various constructs such as cultural differences (Straub, 1994) and gender differences (Gefen and Straub, 1997) have also been suggested.

In this research, our goal is to extend the TAM model to study human-computer factors leading to the adoption of mobile computing. In the following sections, we will review and summarize systems and user characteristics that will affect adoption of mobile computing. In addition, we will identify additional constructs that are important to this research.

DESIGN DIMENSIONS OF MOBILE DEVICES: INPUT, OUTPUT, NAVIGATION AND BANDWIDTH

The application context of mobile devices must reflect limitations in interaction due to screen size, keypad, limited navigation, dropped connections, imprecise localization, lack of buffering, limited graphical content, etc. According to a research by Jones et al. (1999), the effectiveness in completing a task will drop by 50% when small screen other than large screen devices are used. This screen size limitation causes input limitations to the users.

Input procedures must be kept to a minimum in mobile computing. There are numerous input styles available. The use of miniature keyboards is a common device in wireless computing. However, it is not suitable for fieldwork environments, where the user is typically standing whilst operating other devices, since both hands are required for keyboard input and placement of the keyboard may be a problem (Kristoffersen and Ljungberg, 1999). Pen-based interfaces on wireless devices provide a more ergonomic solution. Soft keyboard is a popular device that provides more flexibility to users. It is becoming a mainstream technology as small mobile computers such as the Palm Pilot and touch screens of all sizes increase in popularity and affordability. Furthermore, some forms of handwriting recognition for entering data have been introduced to provide a natural substitute for other input devices. Such inputs offer ease of use to users. In circumstances such as driving, visual concentration cannot be switched to the wireless devices. Speech interface, then, has its advantages: being natural, easy to learn, hands-free, and eyes-free (Graham and Carter, 1999).

The output limitations of wireless devices are mainly caused by limitations in screen size. The interface design of wireless devices requires consideration of how people see, think and understand information. Besides using short messages and simple graphics for output display, many other problems are common with input display. Therefore, some audio "display" systems are being researched, such as non-speech sound systems, which utilize non-speech sound to increase usability without the need for more screen space (Brewster et al., 1998).

There are two kinds of navigational information: navigational breadth, which shows available options on the same hierarchy level; and navigational depth, which shows the current location in the hier-

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archy tree (Nielsen, 1998). Cockburn and Jones (1996) emphasized four navigation guidelines to make web sites easy to use: simple and natural dialogue to help users find information easily and quickly; ability to speak the user's language, which increases the usability of web sites without unnecessary confusion in navigation; minimize memory load since users' short-term memory is limited; consistency, which ease navigation. These four guidelines also apply to the navigation of mobile devices. Navigation is mainly based on menus. Menu systems must meet the challenge of providing sufficient breadth and depth of the available options to users. Information must not be hidden away too deeply beneath many layers. To improve navigation, Marsden and Jones (1998) suggest that better categorizations, less key-press actions, and better visualizations can ease the usage of wireless computing. Scrolling is another concern for navigation. Scrolling provides the opportunity to display a greater number of options. Although users may accept scrolling as a necessary feature of mobile devices (i.e., to overcome the problem of limited screen size), scrolling up and down (or sideways if the device allows) is cumbersome. Scrolling beyond two pages causes even more trouble for the user. Therefore, scrolling should be kept to the minimum, if it is necessary at all (Jones et al., 1999).

Limitations of bandwidth create frustrations, or give pressure to users who are transferring huge amount of information and who pay by the seconds. Currently, the limitations of bandwidth only allow the transmission of 160 characters for expressive messaging to mobile platforms, and typically in low-resolution monochrome. In the future, bandwidth limitations will be addressed through 3G solutions of mobile technology.

TRUST

Trust in mobile computing is affected by two main components: mobile technology and mobile vendor (Siau and Shen, forthcoming). Security and usability (i.e., ease of use and usefulness) of mobile devices influence trust, which then influence users' intention to use a mobile device. Unlike wired networks, wireless communications suffer in bandwidth, stability of connection, and predictability in functions. As noted by Siau and Shen, the insecurity and instability of mobile communications undermine user trust in mobile technology.

Privacy policies of the mobile vendor also influence trust. The stricter the privacy policies and adherence to these policies, the greater the degree of trust exhibited by users. Other factors that influence trust in the context of mobile computing are familiarity, reputation and integrity of the mobile vendor. Ratnasingham and Kumar (2000) identified three levels of trust — competence trust, predictability trust, and goodwill trust. In this case, competence trust refers to mobile vendors' skills and technical knowledge in providing mobile services. Predictability trust refers to trust in mobile vendors' consistent behaviors that provide cues and knowledge for users (including, potential users) to make predictions and judgments due to past experiences. Goodwill trust refers to trust in mobile vendors' care, concern, honesty, and benevolence. Familiarity with a mobile vendor increases one's confidence in the quality of services provided, thus increasing competence trust. Reputation of the vendor increases predictability trust. Integrity, on the other hand, refers to honesty and benevolence of the mobile vendor. Hence, it is related to goodwill trust.

ENJOYMENT

Enjoyment is related to the concept of flow (Csikzentmihalyi and Csikzentmihalyi, 1988), which is the feeling or sensation of enjoyable experiences and the process of optimal experience. Researchers have suggested that flow is a useful construct for understanding interactions with computers (Csikszentmihalyi, 1990; Ghani 1991; Ghani and Deshpande, 1993; Webster et al., 1993). Flow in human-computer interaction is related to the following characteristics: easy to use, fun to use, fast, personalizable, comprehensiveness, and highly visual and browsable.

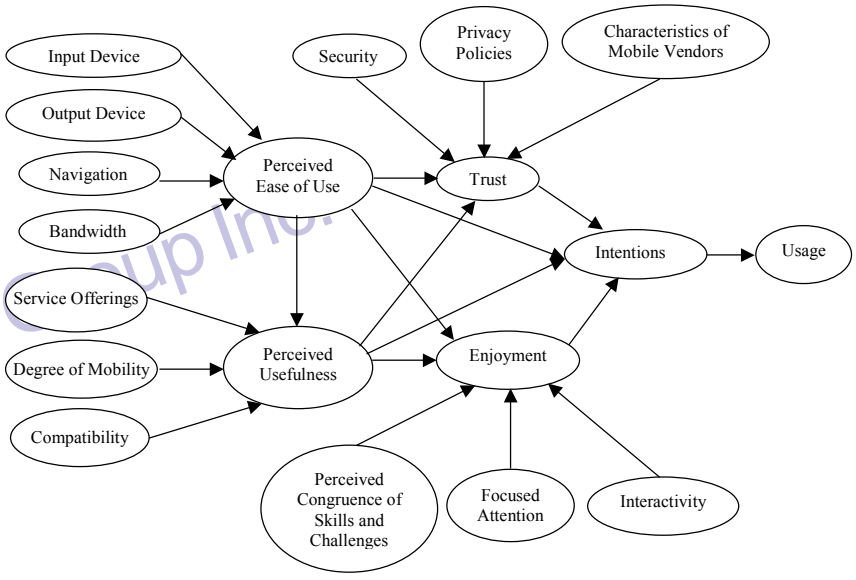
Challenges and skills are the universal preconditions of flow. For flow to occur, it is necessary to achieve a balance between the level of challenges faced in using a mobile device and the level of skills possessed by the user (Csikszentmihalyi and Csikszentmihalyi, 1988). If the user interface is not understandable to the user (i.e., high challenge with respect to the user's skills), then enjoyment or flow is not likely to take place.

Three determinants of flow that are relevant to mobile computing are: 1) Perceived congruence of skills and challenges, 2) Focused attention, and 3) Interactivity (Hoffman and Novak, 1996). The "perceived congruence of skills and challenges" condition is the prerequisite for flow to occur. Once the congruence between skills and challenges is achieved, flow is initiated. It is important to note that in order to sustain this flow state, congruence should always be present. During the flow state, the user experiences enjoyable feelings. If challenges are higher than skills (e.g., if a mobile device is difficult to use or its usage is difficult to understand), the user will exit the activity (i.e., adoption will not occur). Focused attention is also necessary to induce flow. Focused attention is defined as the "centering of attention on a limited stimulus field" (Csikszentmihalyi, 1977). According to Csikszentmihalyi and Csikszentmihalyi (1988), when one is in flow, one is so engrossed in the activity that "one simply does not have enough attention left to think about anything else". Next, interactivity is the availability of immediate feedback between entities. This exchange of information and feedback is in the form of a sensory dialogue. It is important for an activity to be interactive in order to induce or maintain flow. In terms of human computer interactions, interactivity can be thought of as an activity where the user requests some action to be performed and the computer responds promptly to that request by taking the appropriate action or displaying the results to the user. Therefore, response time directly affects interactivity.

DEVELOPMENT OF A TENTATIVE MODEL FOR ADOPTION OF MOBILE COMPUTING

We propose the following model shown in Figure 1.

Figure 1: Proposed model for adoption of mobile computing



The following factors are hypothesized to influence users' perceived ease of use:

1. Input device: the different types of input methods such as the use of a keyboard, a pen (and handwriting recognition), a soft keyboard, audio or touch screen input will affect the ease of use of a mobile device.
2. Output device: different screen size will affect the ease of use of a mobile device. The size of the screen of a smart phone, a PDA and a tablet style laptop will be very different in terms of how much information can be presented to users. The use of non-speech sound as output will also affect the ease of use of the device.
3. Navigation: navigation design will be the key element in helping users find the information they need in the shortest amount of time. It is a key element in determining the ease of use of the user interface of a mobile device.
4. Bandwidth: bandwidth directly affects system response time, which in turn, affects users' perceived ease of use.

The following factors are hypothesized to influence users' perceived usefulness:

1. Service offerings: without useful services from mobile service vendors, users won't be able to take advantage of the mobility of the device. Therefore, the quality and variety of services offered will affect users' perceived usefulness of mobile computing.
2. Degree of mobility: we hypothesize that the more mobile the user, the more valuable mobile computing is to the user.
3. Compatibility: mobile devices have to work well with users' existing computing devices such as their PCs if they need to synchronize data or transfer information back and forth.

In addition, based on the literature review, we propose that trust and enjoyment are two other key constructs that will affect users' intention to use mobile computing. More specifically, we hypothesize that the following factors will influence users' trust:

1. Security: a necessary and important factor of trust. The more security provided on the mobile devices, the higher the level of trust.
2. Privacy policies: privacy is an important component influencing user trust. The stricter the privacy policies, the greater the likelihood of gaining users' trust.
3. Characteristics of mobile vendors: familiarity, reputation and integrity of mobile vendors are three important characteristics that influence trust. The higher the familiarity, reputation and integrity of the vendor, the higher the level of trust exhibited by users.
4. Ease of use: we hypothesize that the user-friendliness and ease of use of a mobile device will influence users' perception of trust. The higher the perceived ease of use, the greater the level of trust.
5. Usefulness: we hypothesize that the perceived usefulness of a mobile device will influence users' perception of trust. The greater the perceived usefulness of the mobile device, the greater the level of trust.

The following factors are hypothesized to influence enjoyment:

1. Perceived congruence of skills and challenges: congruence between skills and challenges is necessary for flow or enjoyment to occur. If the mobile device is too difficult or challenging to use (relative to the user's skills level), then the user will not enjoy using the mobile device.
2. Focused attention: if the mobile device is fun to operate, then focused attention may result. Focused attention increases enjoyment in interacting with the mobile device.
3. Interactivity: availability of immediate feedback can induce and maintain flow or enjoyment. The responsive of the mobile device to users' requests can influence the level of enjoyment.
4. Ease of use: ease of use is hypothesized to influence enjoyment in using a mobile device.
5. Usefulness: usefulness of the mobile device is also hypothesized to affect the level of enjoyment.

PROPOSED STUDY

The model developed will first be verified and enhanced through interviews with users and non-users of mobile computing. Once the model is finalized, the survey methodology will be employed to test the model. Experimental studies will also be planned to gain a more in-depth understanding of issues in human-computer interface of mobile devices.

CONCLUSION

Mobile computing is a fairly new area of research. In this research, we identify both system design and user factors influencing individuals' usage of mobile computing. Human-computer interaction (HCI), which is also related to system design, in mobile computing is a very important area of research. Our long-term goals are not only to gain an increased understanding the adoption issues in mobile computing, but also to explain how specific HCI design issues affect the likelihood of adoption.

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