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Perceived critical mass and the adoption of a communication technology

Craig Van Slyke[1], Virginia Ilie[2], Hao Lou[3] and Thomas Stafford[4]

[1]*Management Information Systems, College of Business Administration, University of Central Florida, Orlando, FL, U.S.A.;* [2]*Department of Accounting and Information Systems, School of Business, University of Kansas, Lawrence, KS, U.S.A.;* [3]*Management Information Systems, College of Business, Ohio University, Athens, OH, U.S.A.;* [4]*Fogelman College of Business and Economics, The University of Memphis, Memphis, TN, U.S.A.*

Correspondence: Craig Van Slyke, Management Information Systems, College of Business Administration, University of Central Florida, PO Box 161400, BA1-325F, Orlando, FL 32816-1400, U.S.A.
Tel: +1 407-823-4149;
Fax: +1 407-823-2389;
E-mail: cvanslyke@bus.ucf.edu

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Abstract
Computer-based communication technologies are increasingly important to personal and organizational communication. One important factor related to the adoption and diffusion of communication innovations is critical mass. Critical mass influences the adoption and diffusion of interactive communication innovations, both through network externalities and through sustainability of the innovation. Unfortunately, critical mass is difficult to measure and is typically only demonstrable after the critical mass point has been reached. Potential adopters' perceptions of critical mass also may be important to adoption decisions. In this paper, we extend this thinking using a synthesis of the Theory of Reasoned Action and Diffusion of Innovation theory by developing a research model. The model is empirically tested using survey data that are analyzed using partial least squares. The focal innovation is instant messaging. Results indicate that perceived critical mass influences use intentions directly and through perceptions of the characteristics of the innovation. The perceived innovation characteristics impact attitude toward use, which in turn impacts use intentions. The model predicts a sizable and significant portion of both attitudes and use intentions. Further, perceived critical mass is able to explain a significant portion of the variance in each perceived innovation characteristic. Implications for research and practice are discussed.
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Introduction

Understanding factors that influence individuals' intentions to use or reject information and communication technologies (ICT) is a topic of continuing interest. As new ICT continue to develop at a rapid pace, understanding these factors becomes increasingly important. In this paper, we combine the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975) with Diffusion of Innovation (DOI) theory (Rogers, 1995) to understand factors that influence intentions to use instant messaging (IM) systems. IM is a relatively new communication technology that has its genesis in recreational use. Interestingly, this technology migrated from households to organizations and is being increasingly used for organizational communication.

Many different factors have been studied that are thought to influence technology use intentions. One promising factor that has not been extensively studied is perceived critical mass. In the context of the diffusion of communication innovations, critical mass is the point at which the innovation is sufficiently diffused for its use to persist.

Communication innovations that fail to achieve critical mass eventually fall into disuse. The actual point at which critical mass is (or can be) achieved is difficult to determine and measure, but useful measures of *perceived* critical mass (which concerns adopter perceptions of the progress of diffusion processes) have been developed and hold great promise for the present application (Lou *et al*., 2000). In this study, we investigate the impact of perceived critical mass using a theoretically derived research model.

We begin by proposing a research model based on relevant theories. Various hypotheses are developed from the model and associated theories. Next, we describe the methodology by which we empirically investigate the hypotheses. Results of this investigation are provided, followed by a discussion of these results. Implications and limitations of the research follow.

Theoretical background

We use a synthesis of TRA and DOI theory to investigate factors influencing IM use intentions. TRA provides the basic theoretical framework to explain decisions about technology use, while DOI theory provides a relatively stable set of constructs and associated measures that have been widely demonstrated to impact fundamental attitudes and behavioral intentions that impact decisions about technology use. TRA posits that beliefs influence attitudes toward a behavior. These attitudes, in combination with subjective norms regarding the behavior, determine intentions to engage in the relevant behavior (Fishbein & Ajzen, 1975); in this case, the decision to use IM. DOI theory provides guidance on beliefs relevant to decisions about the use of new technology, for inclusion in our model. As part of model development, we include perceived critical mass as a factor that influences intentions both directly and though its influence on certain beliefs and subjective norms. Figure 1 shows the research model, which we will subsequently describe and test.

Although we specify and test a complete nomological network as a theoretical context for our hypothesized effects, we develop hypotheses only for those paths that include perceived critical mass, the construct of primary interest. The other paths are included to provide a more complete nomological network – a robust theoretical context in which to examine related concepts, and this permits more robust testing of the impacts of perceived critical mass. In this section, we discuss our research model and develop hypotheses for the impacts of perceived critical mass.

Theory of reasoned action

TRA (Fishbein & Ajzen, 1975) is a widely studied theoretical model designed to explain human behavior, and has seen specific application in the study of technology. According to TRA, a person's performance of a specified behavior is determined by his/her behavioral intention to engage in the activity. Behavioral intention is jointly determined by the person's attitude

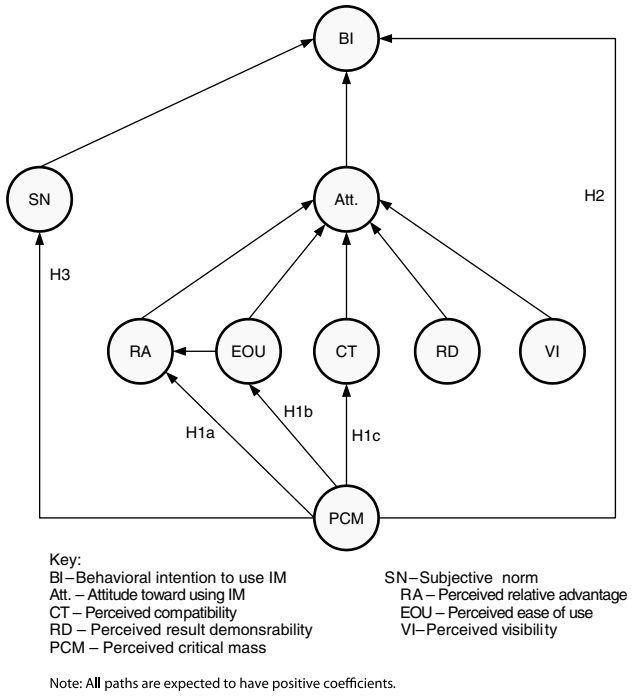

Figure 1 Research model.

and subjective norm concerning the behavior in question. Attitudes capture an individual's positive or negative feelings about performing the target behavior, and are determined by an individual's salient beliefs about the consequences of performing the behavior weighted by the individual's own evaluation of each consequence. Subjective norms capture an individual's assessment of the extent to which important referent individuals desire the performance or nonperformance of a specific behavior. TRA has received support across a variety of disciplines such as psychology, sociology, marketing and information systems (Agarwal & Karahanna, 2000). In information systems research, TRA is the theoretical foundation for one of the most widely used theories of technology-related individual behavior, the Technology Acceptance Model (TAM) (Davis, 1989; Davis *et al*., 1989), which has been empirically tested and supported in the context of acceptance of IT in a variety of IS contexts (Taylor & Todd, 1995; Karahanna & Straub, 1999).

TRA proposes that behavioral intention to engage in a behavior is the best predictor of the subsequent performance of that behavior. Because of this, behavioral intention is often used as the dependent variable in behavioral research, including that which is information systems-related (Davis, 1989; Karahanna *et al*., 1999; Agarwal & Karahanna, 2000; Chau & Hu, 2001; Gefen *et al*., 2003). Following this tradition, we use behavioral intention to use IM in the future as a dependent variable in our model.

TRA posits that intentions are determined by two basic factors, attitudes towards the behavior and subjective

norms related to performance of the behavior. Generally speaking, the more positive an individual's attitude is towards performance of a behavior, the higher that individual's intention to engage in that behavior. Likewise, the more normative pressure to perform a behavior an individual perceives, the more likely that individual is to intend to engage in the behavior. According to some information systems research, attitude is particularly important for continued usage, while subjective norm is relatively more important for initial adoption decisions (Karahanna *et al*., 1999). Other views of continued usage confirm that affective factors (such as attitude) influence continuance decisions (Bhattacherjee, 2001).

DOI theory

While the TRA posits that beliefs are important determinants of attitudes toward a behavior, the literature on DOI provides us with a number of beliefs that have been widely demonstrated to influence attitudes and behaviors concerning the adoption of innovations. Although the original conception of TRA requires identifying salient beliefs for each behavior to which the theory is applied, this is problematic both in terms of data collection overhead and as an inhibitor to the development of standard measurement scales (Agarwal & Prasad, 2000). In the context of innovation adoption, beliefs regarding the characteristics of an innovation offer a useful set of stable beliefs that can be applied using a TRA framework (Agarwal & Prasad, 2000). Others have also included beliefs from diffusion theory as determinants of IT-related attitudes (Karahanna *et al*., 1999).

Salient beliefs, termed perceived innovation characteristics (Rogers, 1995), concern potential adopters' beliefs regarding the characteristics of the innovation in question. These beliefs have been widely applied and have generally received empirical support, although exactly which beliefs have the greatest impact on intentions varies. Rogers (1995) proposed a number of perceived innovation characteristics as being important to innovation adoption. These include perceived relative advantage, compatibility, complexity and observability. Observability has been theoretically and empirically demonstrated to be comprised of two related beliefs, perceived result demonstrability and visibility (Moore & Benbasat, 1991).

Perceived relative advantage is 'the degree to which an innovation is perceived as being better than the idea it supersedes' (Rogers, 1995, p. 212). There are several dimensions to perceived relative advantage, including economic profitability, low initial cost, decreases in discomfort, social prestige and savings in time and effort. The last of these has been the most widely studied in the information systems literature. The idea of savings in time and effort corresponds closely with Davis' (1989) concept of perceived usefulness. In this research, we focus exclusively on this aspect of relative advantage since we believe that the usefulness dimension is likely to be more important to attitudes in our research context.

Perceived relative advantage has received empirical support as having significant influence on use intentions (Parthasarathy & Bhattacherjee, 1998; Plouffe *et al*., 2001; Van Slyke *et al*., 2004a). Relative advantage beliefs may also have a positive impact on attitudes, which can lead to usage intentions. Empirical research indicates that perceived relative advantage and the related concept of perceived usefulness significantly impact attitudes toward spreadsheet use (Al-Gahtani, 2001), computing resource center use (Taylor & Todd, 1995), programming languages (Agarwal & Prasad, 2000), a computer banking system (Brown *et al*., 2002) and an operating system (Karahanna *et al*., 1999), among others (Chau & Hu, 2001, 2002).

Perceived compatibility is defined as 'the degree to which an innovation is perceived to be consistent with the existing values, past experiences, and needs of the potential adopters' (Rogers, 1995). This construct has also been widely demonstrated to be an important determinant of ICT usage intentions. This influence holds across a variety of ICT innovations including e-commerce (Van Slyke *et al*., 2004a), groupware (Chin & Gopal, 1995; Van Slyke *et al*., 2002) and smart-card merchant systems (Plouffe *et al*., 2001). Theoretically, perceptions of compatibility should be positively related to attitudes (Agarwal & Prasad, 2000). TRA tells us that beliefs impact attitudes, which subsequently impact intentions. Because the impact of compatibility beliefs on intentions is well established (see above), it is likely that compatibility will also impact attitudes. There is limited research investigating the impact of compatibility on attitudes, and the results of this research are equivocal. Some research has found a strong, significant relationship (Agarwal & Prasad, 2000), while other research has not (Taylor & Todd, 1995).

Perceived complexity and its conceptual opposite, perceived ease of use, have been extensively studied by IT researchers. The bulk of this work uses Davis' TAM (Davis, 1989; Davis *et al*., 1989), which includes perceived ease of use as a key component. However, there is also a considerable body of literature that studies perceived complexity by using diffusion theory as a theoretical framework (Moore & Benbasat, 1991; Thong, 1999; Van Slyke *et al*., 2004a). For all beliefs in our model to have a positive relationship with attitudes, we use the term perceived ease of use, rather than complexity. This approach has been used in a number of studies that use diffusion theory (Karahanna *et al*., 1999; Agarwal & Prasad, 1998). Several studies find significant relationships between perceived ease of use (or complexity) and use intentions (Venkatesh & Morris, 2000; Plouffe *et al*., 2001; Van Slyke *et al*., 2004a). These studies indirectly support the notion that perceived ease of use impact attitudes due to the well-established relationship between attitudes and intentions. There is equivocal empirical evidence of the relationship between ease of use and attitudes, with some studies supporting this relationship (Davis *et al*., 1989; Al-Gahtani & King, 1999) and others

failing to support it (Taylor & Todd, 1995; Karahanna *et al*., 1999; Agarwal & Prasad, 2000; Brown *et al*., 2002; Chau & Hu, 2002).

As stated earlier, perceived observability has been empirically demonstrated to consist of two components, perceived result demonstrability and visibility. Perceived result demonstrability concerns the tangibility of the outcomes of using the innovation. In contrast, visibility pertains to how apparent the actual use of the innovation is (Moore & Benbasat, 1991). Few IT-based studies have investigated the impact of these constructs on attitudes. One exception is the work of Karahanna *et al*. (1999), who find that both result demonstrability and visibility impact attitudes of potential adopters of an operating system. Interestingly, however, these relationships did not hold for current users of the system.

Studies that exclude attitude provide empirical support for the impact of perceived result demonstrability and visibility on use intentions. For example, Van Slyke *et al*. (2002) found a significant impact on use intentions from perceived result demonstrability, but not from perceived visibility. Agarwal and Prasad (1997) demonstrated that perceived result demonstrability is a significant predictor of intentions to use the Web, while the impact of perceived visibility is not significant. In contrast, they found the opposite for actual use; perceived visibility was significant while perceived result demonstrability was not.

Before turning our attention to the discussion of critical mass, it may be worthwhile to position the constructs discussed above relative to an emerging view of user acceptance, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh *et al*., 2003). This theory posits that four factors have a direct influence on usage intentions. These are performance expectancy, effort expectancy, social influence, and facilitating conditions. Each of these is represented in our research model.

Table 1 provides definitions for the UTAUT constructs and also maps elements of our model to the corresponding UTAUT constructs. Note that each of the model constructs listed in our table are specifically mentioned by Venkatesh *et al*. (2003) as root constructs of the corresponding UTAUT construct. UTAUT does not include a number of constructs from our research model, including result demonstrability, visibility, attitude and perceived critical mass. Attitude is specifically excluded from UTAUT due to the expectation that it would be non-significant. Neither result demonstrability nor visibility was found to be significant predictors of use intentions in the empirically based development of UTAUT. Therefore, they were not included in UTAUT.

Despite the empirical findings in the UTAUT development study (Venkatesh *et al*., 2003, p. 282), as discussed above, there are a number of studies that empirically validate the importance of attitude, result demonstrability and visibility. Because of this, we believe that it is appropriate to include these constructs in our model.

As noted earlier, critical mass is thought to impact the adoption and diffusion of interactive communication technologies, such as IM. In the following section, we present hypotheses related to how the related concept of perceived critical mass impacts some of the technology adoption and acceptance beliefs discussed in this section. Specifically, we discuss how perceived critical mass positively impacts relative advantage, compatibility and ease of use beliefs.

Critical mass and perceived critical mass

Rogers (1995) defined critical mass as the point at which a certain minimum number of users have adopted an innovation so that the rate of adoption of the new communication technology suddenly takes off. Once the diffusion of a new interactive idea reaches critical mass, its further rate of adoption becomes self-sustaining. The concept of critical mass in the context of interactive media was developed by Markus (Rogers, 1995), and provides a complement to traditional diffusion theory. According to Markus (1994), critical mass theory revolves around two constructs: 'interactive media' (such as phone, e-mail and IM) that enable multidirectional communication flows and 'universal access.' Universal access reflects the belief that intended recipients are also using a communication medium routinely and that they can be reached routinely using the medium. In other words, a sender cannot successfully complete a communication via an interactive medium unless the other recipients also use that medium. In deciding which medium to choose, individuals must take into account whether the intended recipients are likely to receive and respond to a message (Markus, 1994). It is beneficial to have a medium through which anyone in the organization can be reached (universal access medium).

Table 1 Research model to UTAUT comparison

UTAUT construct	*Definition*	*Corresponding model constructs*
Performance expectancy	Belief regarding the degree to which the use of the system will result in improved performance	Relative advantage
Effort expectancy	Belief regarding the degree of ease associated with the system's use	Ease of use
Social influence	Belief regarding the degree to which important others believe s/he should use the system	Subjective norm
Facilitating conditions	Belief regarding the degree to which the infrastructure exists to support the system's use	Compatibility

Achieving universal access requires that nearly everyone in an organization or community agrees to use a medium on a regular basis. For example, the perceived value of IM as a communication medium for an individual in an organization depends on whether or not the other individuals are accessible via this IM. Thus, the use of interactive media involves more than one person behaving independently.

Critical mass theory points out that individuals' choices must be considered in the social context of their membership in communities, such as organizations (Markus, 1994). As more and more individuals in a system (organization) adopt an interactive communication innovation, the innovation is perceived as increasingly beneficial to both previous and potential adopters. This is related to the concept of network effects (Katz & Shapiro, 1986; Lou *et al*., 2000). Network effects refer to the positive external benefits that occur as a result of the technology use (Lou *et al*., 2000).

Once an interactive communication technology reaches critical mass, as in the case of a mass of radioactive material that goes critical (the phenomenon in nuclear physics from which critical mass derives its name), each additional user increases the number of potential network connections exponentially (Rice & Danowski, 1993). The importance of critical mass goes beyond network effects, however. Critical mass is also important to the sustainability of the innovation. Innovations that fail to reach critical mass are in danger of falling into disuse. This is a significant risk in the context of interactive communication media, where the value of adoption depends, in part, on the number of entities with whom the media may be used to communicate.

A good example to illustrate the critical mass concept is the telephone. To the first few adopters of the innovation, the telephone had limited value. However, as the telephone attracted more and more adopters, its value to each subsequent potential adopter increased, influencing adoption decisions (this is conceptually related to the concept of network externalities). At some point in the telephone's diffusion, the technology had attracted a sufficient number of users to reach critical mass. This led to an explosion in the telephone's use to the point where its use is almost ubiquitous in developed countries. Further, by reaching critical mass, the telephone demonstrated its sustainability. Potential adopters were less concerned about telephone use dying out, and thus were more likely to make the cognitive, time and financial investments required to adopt.

While the importance of critical mass is generally accepted in studies of the diffusion of communication innovations (Prescott & Conger, 1995), accurately determining the actual critical mass for a particular technology is difficult. Because of this, Lou *et al*. (2000) posit that potential adopters' perceptions of whether an innovation has attracted a critical mass of users influence subsequent adoption and use; this perception by potential adopters is called 'perceived critical mass' (Lou *et al*., 2000). Perceptions of critical mass can create the illusion among adopters and potential adopters that actual critical mass has been reached, which impacts the diffusion of the innovation. Thus, through interaction (within a social group), individuals develop their own perceptions about a particular innovation and they can also give others the impression they already use that innovation. The role of perceived critical mass has been demonstrated empirically in the context of diffusion of different innovations using different theoretical models. Lou *et al*. (2000) use TAM (Davis, 1989; Davis *et al*., 1989) to demonstrate that perceived critical mass influences intentions to use groupware both directly and through perceived ease of use and perceived usefulness, while Ilie *et al*. (2005) used the innovation adoption model to illustrate how different perceptions (including critical mass) differ by gender.

Given the above, we expect perceived critical mass to impact a number of important beliefs regarding IM. Thus, we state the following general hypothesis:

H1 *Perceptions of the critical mass of a communication innovation influence beliefs regarding the characteristics of that innovation.*

One important aspect of critical mass theory relates to the network effects; each additional user of a communication innovation adds value to adopting that innovation. Perceived critical mass reflects beliefs regarding the number of people who are using the innovation of interest. More users translates into more people the potential adopter can communicate with using the communication technology. This, through network effects, leads to more benefits to be gained from adopting. There is also empirical evidence of the impact of perceived critical mass on perceived usefulness (Lou *et al*., 2000). Because of this, we expect perceived critical mass to have a positive impact on beliefs regarding the relative advantage of using IM. Our expectations regarding the impact of perceived critical mass on perceived relative advantage are stated formally in Hypothesis 1a.

H1a *Perceptions of the critical mass of a communication innovation positively influence beliefs regarding the relative advantage of that innovation.*

While critical mass theory does not provide direct evidence of a link from PCM to perceived ease of use, the relationship between PCM and perceived ease of use has been shown empirically (Lou *et al*., 2000) and we expect PCM to have a positive impact on perceived ease of use. There are two reasons for our expectation. First, the perception that many others are using IM may serve as a signal that the technology is relatively easy to use. If many peers are using IM, the potential adopter may believe that using the technology is not so complex as to prevent adoption.

In addition, the beliefs that many others are using IM may provide some assurance that should the potential adopter require assistance in using IM, such help is available from a number of sources. Peers who have already adopted IM may be willing and able to share the benefit of their experience, which may ease any learning curve effects associated with IM use. Hypothesis 1b states our expectation regarding the impact of PCM on perceived ease of use.

H1b *Perceptions of the critical mass of a communication innovation positively influence beliefs regarding the ease of use of that innovation.*

Perceptions of critical mass are also likely to impact beliefs regarding the compatibility of using IM. That is, critical mass will influence adopters to consider the innovation to be more consistent with their existing values, experiences and needs, as per Rogers (1995). Because perceived compatibility positively impacts adoption, when others adopt an innovation it provides a signal to potential adopters that others find the innovation to be compatible. It is probable that individuals feel some sense of similarity with those in their communication networks. Others in their networks are likely to be in the same social or work groups as the potential adopter. The potential adopter may share experiences, values and needs with those in their communication networks. These individuals may work for the same organization, work on the same projects or share interests. This leads to some overlap in experiences, values and needs. Therefore, if many of those in a potential adopter's communication network find IM use compatible as indicated by their adoption, the potential adopter is also likely to believe that he/she will find IM use to be compatible. Further, it is possible that, because of perceived widespread use of IM, individuals may perceive that almost everyone with whom they wish to communicate is using IM. In essence, there may be a perception that using IM is a *de facto* standard. In such cases, the likely result is a perception that the use of IM is compatible with one's communication needs. This thinking leads us to Hypothesis H1c.

H1c *Perceptions of the critical mass of a communication innovation positively influence beliefs regarding the compatibility of that innovation.*

We expect PCM to be related to the remaining beliefs of perceived result demonstrability and visibility. However, we are unable to offer any conceptual or empirical evidence regarding the direction of influence between PCM and these beliefs. Because of this, we do not state any hypotheses for the relationship between PCM and these factors.

Critical mass perceptions may also influence use intentions directly, rather than through their influence on other beliefs. Rogers (1995) proposes that the likelihood of an individual adopting an innovation increases as the number of adopters in his/her personal network increases. Because perceptions of critical mass reflect beliefs regarding the number of others who are using an innovation, it is likely that as perceptions of critical mass increase, so will intentions to use the innovation. The impact of PCM on other beliefs may not fully account for its impact on behavioral intentions. When an individual believes that a communication technology has a critical mass of users it is possible the individual is willing to use the technology even if they have not formed a positive affective response to its use.

One potential reason for this is based on the likelihood that higher PCM implies more messages received via IM. In other words, an individual with high PCM beliefs is likely to receive more IM messages than one who has low PCM beliefs. Further, it is natural for an individual who receives a message via IM to reply using the same medium. So, an individual who perceives that many others use IM (high PCM) may believe that s/he will be likely to also use IM (high behavioral intention to use IM). This may occur regardless of the individual's attitude toward using IM.

Institutional theory (DiMaggio & Powell, 1983) posits that individuals in organizations choose a particular course of action due to mimetic or normative influences. Such choices are not necessarily 'rational' when viewed from an efficiency perspective, but rather may be driven by legitimacy concerns. Further, institutionalists believe that individuals and organizations may model their behaviors after those of other individuals and organizations. This 'bandwagon effect' (Abrahamson & Rosenkopf, 1993) drives diffusion through the number of prior adoptions, not by technical properties of an innovation. Thus, it may be that PCM influence on IM use intentions reflects a bandwagon effect. The mimetic effect on technology adoption has been demonstrated empirically (Teo *et al*., 2003).

It may also be that PCM is a facilitating condition (Venkatesh *et al*., 2003) of IM use. Without a large number of communication partners using IM (PCM), there may be few opportunities to use IM, even if the particular individual has positive attitudes towards IM use. Although PCM has not been widely studied, there is empirical evidence that PCM has a direct impact on use intentions as well as an indirect impact through beliefs (Lou *et al*., 2000). Given this conceptual and empirical evidence, we state the following hypothesis:

H2 *Perceptions of the critical mass of a communication innovation positively influence intentions to use that innovation.*

Subjective norms reflect an individual's belief regarding whether those other individuals who are important to him/her believe that he/she should engage in the behavior in question. In our context, this behavior is

the use of IM. The more people with whom the potential adopter communicates who use IM, the more likely it is that those persons important to the adopter will also use IM. The use of IM by these important others provides a clear signal that their approve of IM use. So, we posit that PCM will have a positive impact on subjective norm, as stated in Hypothesis 3.

H3 *Perceptions of the critical mass of a communication innovation positively influence perceived subjective norms of using that innovation.*

We engaged in an empirical study to investigate the efficacy of the hypotheses developed in this section. In the next section, we discuss the methodology and results associated with this empirical study.

Methodology and results

Overview

In order to test the hypotheses, a survey of beliefs, attitudes and intentions regarding IM was administered to individuals who were enrolled in classes in two large United States universities. The survey was comprised of measures derived from previously validated scales, along with a newly developed perceived critical mass scale. Generally, scale items were worded to reflect personal communication rather than course-related communication. The data were analyzed using partial least squares (PLS) via PLS-Graph 3. PLS is a statistical method that is increasingly used in information systems research. PLS has the advantages of allowing the analysis of non-normal data, and modest sample size requirements. In addition, PLS does not assume equal weight for each indicator of a latent variable. Further, PLS allows the simultaneous modeling of both structural and measurement models (Chin *et al*., 2003).

Although there are a number of valid research approaches, in this case a quantitative, survey methodology was chosen for a number of reasons. First, a quantitative approach allows researchers to minimize the subjectivity in the analysis of the data by employing statistical tests to examine the veracity of the research hypotheses (Kealey & Protheroe, 1996). Second, survey methods enable the clear and precise specification of independent and dependent variables. Third, quantitative methods allow high levels of reliability and repeatability, which facilitates replication of the research (Balsley, 1970). Finally, the survey approach is appropriate when extending existing models (Kositanurit *et al*., 2006).

In addition, using a survey is particularly appropriate for testing existing theories, such as the TRA. By using a survey, we can investigate the perceptions and intentions of a large number of subjects, which may not be practical with qualitative methods. The survey methodology has been applied to many studies of technology adoption (e.g. Straub, 1994; Karahanna *et al*., 1999; Thong, 1999; Plouffe *et al*., 2001; Venkatesh & Brown, 2001; Van Slyke *et al*., 2004a; Kositanurit *et al*., 2006), including those investigating the adoption of interactive communication technologies (Lou *et al*., 2000)

Sample

Surveys were administered to a convenience sample of 350 individuals enrolled in classes at two large United States universities, one of which is in the southeast and one of which is in the midwest. Two hundred and seventy usable surveys were collected for a response rate of 77%. Approximately 60% of the responses were from males. Almost all of the respondents indicated prior knowledge of IM (99%) and prior IM use (93%), recalling that our dependent variable is the intention to use IM in the *future*, rather than past usage. Virtually all (98.5%) of the respondents indicated that they had access to a computer that could be used to run IM. Respondents ranged in age from 19 to 51 years, with a mean age of 22.3 years.

Scale development and validation

With the exception of perceived critical mass, previously validated scales were used to measure all components of the research model. In the case of subjective norm, items from two sources were combined. In some cases, shortened forms of the scales were used in order to control the length of the survey. For all previously validated scales, items were slightly reworded to reflect the current research context. Scale items were measured on a seven-point Likert-type scale with the anchors 'strongly disagree' (1) to 'strongly agree' (7). Demographic and experiential data were captured using direct questioning. Scale items are provided in Appendix A. The final number of items, sources and descriptive statistics for all scales are provided in Table 2.

We developed a new measurement scale for perceived critical mass. We built on the two-item scale developed by Lou *et al*. (2000) with the goal of creating a scale that better captured the construct. After examining the literature on critical mass and perceived critical mass, a pool of candidate items was developed. Six of these were selected for inclusion in the scale. One of these items was dropped due to its negative impact on scale reliability. We also created a new scale for prior IM use, which we included as a control variable. Rather than simply using a dichotomous variable, we included two items, one referring to the frequency of use and one referring to the degree of impact on the respondent's life if IM were unavailable.

Even though the other scales were previously validated, because we altered the wording of scale items to reflect the research context it is necessary to assess the validity of the revised scales. During the process of establishing validity, several scale items were dropped. Relevant validity data are given in Table 3.

Internal consistency was assessed using composite reliability values reported in PLS-Graph. In all cases,

Table 2 Scale sources and descriptive statistics

Scale	*Items*	*Mean*	*Std. dev.*	*Scale source*
Behavioral intention	3	5.485	1.513	(Van Slyke *et al*., 2004a, b)
Attitude	3	4.454	0.773	(Taylor & Todd, 1995)
Subjective norm	3	3.158	1.423	(Taylor & Todd, 1995; Venkatesh & Davis, 2000)
Perceived critical mass	4	4.916	1.004	Newly developed
Perceived relative advantage	6	4.012	1.488	(Moore & Benbasat, 1991)
Perceived compatibility	4	4.519	1.580	(Moore & Benbasat, 1991)
Perceived ease of use	3	5.921	1.066	(Moore & Benbasat, 1991)
Perceived result demonstrability	3	4.837	0.841	(Moore & Benbasat, 1991)
Perceived visibility	3	4.481	0.596	(Moore & Benbasat, 1991)

Table 3 Scale validities

	ICR	*BI*	*PCM*	*Att*	*SN*	*RA*	*CT*	*CX*	*RD*	*VI*	*Prior*
BI	0.968	0.954									
PCM	0.948	0.751	0.856								
Att	0.918	0.882	0.753	0.888							
SN	0.892	0.435	0.550	0.455	0.856						
RA	0.948	0.595	0.626	0.587	0.604	0.835					
CT	0.943	0.579	0.601	0.574	0.503	0.754	0.898				
CX	0.878	0.545	0.432	0.511	0.142	0.306	0.380	0.839			
RD	0.874	0.571	0.492	0.551	0.233	0.373	0.480	0.626	0.835		
VI	0.850	0.541	0.595	0.532	0.275	0.299	0.370	0.480	0.487	0.809	
Prior	0.946	0.581	0.705	0.586	0.465	0.637	0.671	0.417	0.421	0.454	0.947

Notes: ICR = Internal consistency reliability.
The square root of the average variance explained is shown on the diagonal.
Remaining non-diagonal elements are inter-scale correlations.

reliability values exceed the recommended value of 0.70. All factor loadings exceed 0.707 and were highly significant ($P<0.001$), indicating convergent validity. Discriminant validity was demonstrated by comparing the square root of the average variance explained (AVE) to the inter-scale correlations. For each scale, the square root of AVE was larger than that of any other scale's correlation to other scales. However, several of the inter-scale correlations were high, indicating a potential lack of discriminant validity. We performed a further test of discriminant validity for those scale pairs that exhibit correlations greater than 0.70. To perform this test, we examined cross-loadings (shown in Appendix B). The cross-loadings revealed a potential discriminant validity problem with one attitude item (ATT2). Because of this, we did not include this item in the analysis of the structural model.

Having established that the psychometric properties of the scales were acceptable, we turned attention to examining a structural model with paths matching the hypothesized relationships. These results are presented in the next section.

Results

To assess the explanatory power of the model, we examined R^2 values for each predicted variable in the model. These results are given in Table 4. Results indicate that the model is able to explain a large portion of the variance in both behavioral intention and attitude. In addition, PCM is a reasonable predictor of beliefs and subjective norm. Overall, these results are encouraging.

Having established the predictive utility of the model, we examined path coefficients corresponding to the model's hypothesized relationships. These results are shown in Table 5. Results indicate general support for the model (using $P<0.05$ as a cutoff). All of our hypotheses were supported, with PCM having significant impacts on the beliefs of relative advantage (H1a), ease of use (H1b), compatibility (H1c) and subjective norm (H3). PCM also has a significant direct impact on behavioral intentions to use IM (H2).

The TRA components of attitude and subjective norm show mixed results, with attitude being highly significant, but subjective norm being non-significant. Several of the innovation characteristic beliefs were shown to have significant impacts on attitude. Perceived visibility and relative advantage had the greatest influence on attitude. Perceived ease of use and result demonstrability had smaller, but significant impacts on attitude. Perceived compatibility did not have a significant influence on attitude. Prior IM use did not have a significant impact on behavioral intentions. Overall, these results demonstrate the importance of perceived critical mass. In addition, the results indicate general support for the

Table 4 R^2 values

Variable	*Predictors*	*R^2 value*
Behavioral intention	Attitude, SN, PCM	0.796
Attitude	RA, CT, EOU, RD, VI	0.548
Subjective norm	PCM	0.286
RA	PCM, EOU	0.393
CT	PCM	0.361
EOU	PCM	0.187

Table 5 Hypothesis tests

	Coefficient	*t-value*	*Supported?*
Hypothesized path			
H1a: PCM→RA	0.607	11.267	Supported
H1b: PCM→EOU	0.432	7.684	Supported
H1c: PCM→CT	0.601	14.413	Supported
H2: PCM→BI	0.193	3.590	Supported
H3: PCM→SN	0.534	16.044	Supported
Non-hypothesized path			
Attitude→BI	0.730	14.770	Significant
SN→BI	−0.017	0.620	Not Significant
RA→Attitude	0.319	4.312	Significant
CT→Attitude	0.120	1.421	Not Significant
EOU→Attitude	0.145	2.273	Significant
RD→Attitude	0.168	2.498	Significant
VI→Attitude	0.235	4.051	Significant
EOU→RA	0.044	0.947	Not Significant
Prior IM Use→BI	0.026	0.695	Not Significant

importance of beliefs and attitudes in understanding behavioral intentions to us IM.

In order to further test the importance of PCM, we examined a model that added to our model direct effect paths from each of the innovation characteristics to behavioral intentions. If the influence of PCM on intentions holds even when the direct paths are added, we would be able to make a stronger case for the importance of PCM. This analysis indicated that the direct impact of PCM on intentions holds ($\beta = 0.180$, $P < 0.01$) as did the impact of attitudes on intentions ($\beta = 0.604$, $P < 0.01$). Interestingly, the only other factor to have a significant direct impact on intentions for this model was perceived ease of use ($\beta = 0.101$, $P < 0.001$). From this we can conclude that PCM has a significant direct impact on behavioral intentions, over and above the indirect effects through the innovation characteristics.

Discussion

Based on our analysis, the results support the research model: perceived critical mass does have an impact on behavioral intentions to use IM. In addition, the research model is able to account for a large portion of the variance in subjects' attitudes and behavioral intentions with respect to IM. The results also illustrate the importance of perceived critical mass in understanding behavioral intentions regarding IM use. PCM has both direct and indirect effects on behavioral intentions. While the direct effect of PCM on intentions is less than that of attitude, it is much stronger than the impact of subjective norm. Further, the impact of PCM on perceived relative advantage, compatibility and ease of use provides a path of indirect effect on behavioral intention.

In effect, our results show that PCM not only influences other important beliefs, it also carries an independent influence on intentions, and so may be critically important to the adoption and diffusion of interactive communication innovations. The impact of PCM on perceived relative advantage also lends credence to the idea that PCM is a reasonable alternative to actual critical mass. These results provide evidence for the efficacy of using an expanded view of TRA for examining interactive communication technologies.

Our results also hold implications for studies of IS continuance, by confirming earlier findings that attitudes are important to continuance intentions while subjective norms are not (Karahanna *et al*., 1999). Our results also confirm prior findings that relative advantage and result demonstrability are important beliefs in terms of their influence on continuance intentions (Agarwal & Prasad, 1997; Karahanna *et al*., 1999), though, contrary to these studies, we found that both visibility and ease of use have an influence on intentions (through their influence on attitudes). We suspect that our contrary findings may be an artifact of our focus on IM, which is quite unlike the focal technologies used in the above-referenced studies.

Our results also both partially confirm and partially refute UTAUT. Our study corroborates UTAUT in that we found performance expectancy (relative advantage) and effort expectancy to have significant (though indirect) impacts on use intentions. However, our results represent a major departure from UTAUT in that we found attitude to be a significant and strong predictor of behavioral intentions even when direct paths from innovation characteristics to intentions were included in our model. With the exception of ease of use, none of the innovation characteristics had significant direct effects, which provides considerable evidence of the efficacy of attitude as a mediating factor.

The findings of this paper hold a number of implications for managerial practice: first, it is important for those wishing to promote the diffusion of interactive communication innovations to pay attention to perceived critical mass. As our results indicate, perceived critical mass has both direct and indirect impacts on use intentions and we expect that increasing perceptions of critical mass will lead to significant increases in usage intentions. Second, our results demonstrate that visible activities of early adopters influence the adoption decisions of later adopters, so managers wishing to speed diffusion should seek to quickly build the impression of

critical mass by finding ways to make early adopters more visible to the majority.

Naturally, such managerial approaches to speeding diffusion require some means of overcoming the inherent lack of critical mass visible to the critical early adopters. One approach would be to influence other beliefs that impact attitudes and use among these early adopters. According to our research, perceived relative advantage may be a viable candidate because increasing perceptions of relative advantage should improve attitudes. If change agents can boost perceptions of relative advantage, they may be able to overcome low PCM among early adopters. Similarly, taking steps to increase perceived ease of use may also offset low PCM, which is easily accomplished through targeted training and support programs.

A third managerial approach to speeding diffusion involves building the impression of critical mass is to initially promote the innovation to groups that are likely to adopt en masse, leading to cascading perceptions of critical mass among the user population. Contrary to the simplistic representation of diffusion networks as simple groups of discrete individuals, diffusion networks are often 'networks of networks' with multiple sub-networks within the overall diffusion network of interest. As such, it seems reasonable to expect that an individual's perception of critical mass is heavily influenced by adoption within visible and relevant sub-network. If members of one sub-network adopt together, individual members of adjacent sub-networks should have high perceptions of critical mass. Adoption visibility between sub-networks will increase perceptions of critical mass for individuals in other sub-networks, which, in turn will improve PCM in other sub-networks, and so on. Thus, by inducing mass adoption by an initial and visible subgroup, change agents can bring about an overall impression that critical mass has been achieved.

Several opportunities exist for future research to build upon our findings. Work-related use of IM is increasing, so replicating our research in work-related contexts may be an interesting avenue of investigation. Diffusion subnetworks and early adopter characteristics are likely different in the world of work, as compared to consumer segments. Another potentially interesting area for future research concerns the nature of PCM. In our study, we focused PCM on people with whom one already communicates. It might be interesting to expand PCM to include the degree to which the communication technology can be used to reach new communication partners (who could not be communicated with unless one adopts the focal communication technology).

Contributions to theory and practice

This paper makes a number of contributions to the existing body of knowledge regarding theories and practices related to the adoption of interactive communication technologies. Contributions to theory center on the concept of perceived critical mass. This construct has not been widely investigated in the information systems literature. However, there is a growing body of evidence indicating that perceptions of whether a critical mass of users exists have considerable impact on communication technology adoption decisions. Our research adds to this body of knowledge. In addition, we use the context of IM, a communication technology that has grown rapidly in importance.

Our work demonstrates the utility of adding a context-specific construct to a well-established theory. The results of this research clearly indicate that adding perceived critical mass to the TRA extends the predictive and explanatory utility of the theory. Adding PCM to a synthesis of TRA and diffusion/adoption theories, we are able to explain a large portion in behavioral intentions to use IM. Perhaps more importantly, we are able to investigate the nature of the impact of PCM. This allows us to make a contribution to the existing knowledge of an emerging construct (PCM). We theoretically and empirically demonstrate that PCM impacts intentions both directly and indirectly through other beliefs and attitudes.

In addition, we position our work relative to UTAUT, a theory that seems to be growing in interest and importance. Although we did not directly use UTAUT as our theoretical foundation, we did shown how constructs from more established theories can be positioned relative to UTAUT.

Perhaps a greater contribution relative to UTAUT is that we call into question some conclusions of UTAUT. The empirical findings in the original UTAUT study (Venkatesh *et al*., 2003) found that some constructs in our model (result demonstrability, and visibility) were not significant predictors of intentions. In addition, attitude was specifically excluded from UTAUT on the expectation that it would be non-significant. However, our results clearly demonstrate that attitude, result demonstrability and visibility significantly impact intentions to use instant messaging. (Result demonstrability and visibility impact intentions indirectly through attitudes.) These findings lead us to conclude that perhaps it would be premature to consider these factors to be unimportant.

Our research also contributes to practice. In particular, this study provides guidance to change agents who wish to promote the use of interactive communication technologies. Based on our findings, we are able to offer a number of suggestions to these change agents (in the Discussion section). In the interest of brevity, we do not repeat those suggestions here.

A number of lessons emerged from the conduct and results of this research. First, we believe that information systems researchers should pay more attention to role of context in research. For example, some prior research has concluded that perceptions of result demonstrability and visibility do not impact use intentions. These findings may be quite valid in some contexts, especially where an organization promotes the use of a particular technology. However, instant messaging use often spreads informally and without organizational effort or sanction through

grassroots diffusion (Van Slyke *et al*., 2004b). In this case, the ability to easily communicate the existence (visibility) and outcomes of using a technology (result demonstrability) may be more important. Thus, we believe that it is critical for information systems researchers to carefully consider how context impacts the forces that influence technology adoption. Others have made similar calls (Chiasson & Davidson, 2005).

An additional lesson comes from the development of the PCM scale. Earlier studies of PCM, while groundbreaking in terms of developing the concept of PCM, used scales that did not capture the full flavor of the construct. Using the existing scale as a starting point, we were able to develop a scale that more fully captures the PCM construct. This demonstrates the importance of critically examining existing scales before deciding to adopt them simply because they have been previously published.

The final lesson is that researchers should not be overly hasty to adopt a new theory without a critical examination and testing of its propositions. While UTAUT offers an exciting, comprehensive view of technology acceptance and use, the research community should not simply accept this theory as being the final word. UTAUT can be strengthened through studies (such as this one) that test certain aspects of the theory. In information systems research, we seem to have a proclivity to test existing theories by adding constructs or testing them with new technologies. While such studies may be valuable, we should also perform studies that examine the veracity of *excluding* constructs from a theory. Such studies are necessary before 'writing off' factors as being unimportant. It is worth noting that these sorts of studies may be risky, but we feel that our theories can be strengthened by taking such risks.

Conclusions

Interactive communication technologies continue to be an area of considerable interest. Critical mass has long been thought to have a major impact on the adoption and diffusion of interactive communication innovations; however, critical mass is difficult to measure and typically can only be measured after the fact. Because of this, researchers have proposed the concept of perceived critical mass as an important driver of communication innovation adoption. In this paper, we theoretically and empirically demonstrate that individuals' perceptions of whether an innovation has reached critical mass have meaningful direct and indirect impacts on intentions to use IM. Together with attitude, perceived critical mass is able to explain almost 80% of the variance in use intentions. Beyond its direct impact, PCM has additional, indirect effects on intentions through beliefs that come together to form attitudes. Specifically, PCM impacts perceptions of the relative advantage, ease of use and compatibility of IM. Taken together, these results provide a compelling argument for including perceived critical mass in future studies of the adoption or acceptance of interactive communication technologies.

We suggest that future research expand on our results by testing the synthesized model using different innovations, and by investigating other beliefs that may be impacted by perceived critical mass. This future research may benefit from the expanded perceived critical mass scale, which was developed as part of this study.

This research also provides guidance for practitioners interested in promoting the use of IM or other, similar technologies. These change agents should consider taking steps to enhance the impression that the technology has reached a critical mass. Such actions may bring about improvements in other beliefs related to the technology. The impression that critical mass has been reached signals to the potential adopter the utility of the focal technology. Furthermore, the perception of critical mass also signals that the technology is sufficiently easy to use and is compatible with existing practices. According to our results, increasing perceptions of critical mass triggers a domino effect of positive impacts, culminating in improved attitudes and increased use intentions.

The development of new communication technologies marches onward. By expanding our knowledge of the adoption of interactive communication technologies, this study helps information researchers and practitioners better understand the forces that influence communication technology adoption decisions. This knowledge provides guidance for those wishing to promote the adoption of emerging communication technologies, and also provides a foundation for future systematic investigations of perceived critical mass and its role in communication technology adoption decisions.

About the author

Craig Van Slyke is an Associate Professor of Management Information Systems at the University of Central Florida. He teaches courses in database administration and electronic commerce at both the undergraduate and graduate levels. Prior to joining UCF, he taught at Ohio University. He holds a Ph.D. in Information Systems from the University of South Florida. Dr. Van Slyke also spent many years in the information technology industry in a number of capacities.

His current research interests focus on issues related to the adoption of information and communication technologies. He also does research in information technology personnel and virtual teams. Dr. Van Slyke has published in a number of journals including the *Communications of the ACM, Journal of the AIS, Decision Sciences, the Academy of Management Executive, Database for Advances in Information Systems, and Information Resource Management Journal* among other journals. In addition, he has presented papers at many academic and professional conferences.

Virginia Ilie is an Assistant Professor of Information Systems at the University of Kansas. She holds a Ph.D. in Information Systems and an MBA from the University of Central Florida in Orlando. Currently, her research revolves around issues surrounding individual resistance to information systems implementation, with a focus on healthcare organizations. Her other research areas of interest are information systems diffusion, decision support systems and outsourcing. Her work has appeared in journals such as *Database* and *Information Resource Management Journal*. She has published various conference proceedings at national and international meetings, two of which gained her best paper awards. Her teaching interests are database management systems and strategic management of information systems in organizations.

Hao Lou is a Professor of Management Information Systems in the College of Business at Ohio University. He received his Ph.D. in MIS from College of Business Administration (now Bauer College of Business), the University of Houston. His research interests include computer-mediated communication systems (CMCS), groupware implementation, e-learning and e-commerce in developing countries. His publications have appeared in *European Journal of Information Systems, Journal of Association for Information Systems, Journal of Organizational Computing and Electronic Commerce, Journal of Information Systems Resource Management, and Journal of End-User Computing*.

Tom Stafford is Suzanne Downs Associate Professor of Management Information Systems for the Fogelman College of Business and Economics at University of Memphis, and Editor of ACM Data Base for Advances in Information Systems. He holds doctorates in MIS from University of Texas – Arlington, and in Marketing from University of Georgia. Stafford's research spans issues of human computer interaction and technology adoption, and has appeared in journals such as *Decision Sciences*, *Communications of the ACM* and *IEEE Transactions on Engineering Management*.

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Appendix A

Measurement scale items

Behavioral intentions to use

I would use IM to communicate with others.
Using IM is something I would do.
I could see myself using IM.

Perceived critical mass

Many people I communicate with use IM.
The people I communicate with will continue to use IM in the future.
The people I communicate with using IM will continue to use IM in the future.
Of the people I communicate with regularly, many use IM.

Attitude

Using IM is a good idea.
Using IM would be unpleasant. (dropped)
I like the idea of using IM.

Subjective norm

My friends think I should use IM.
People who influence me think that I should use IM.
People who are important to me think that I should use IM.

Relative advantage

Using IM improves my performance when communicating with my friends.
Using IM increases my productivity when communicating with my friends.
Using IM enhances my effectiveness when communicating with my friends.
Using IM enables me to accomplish tasks more quickly
Overall, using IM improves communication with my friends
Overall, I find using IM to be advantageous when communicating with my friends

Compatibility

Using IM is compatible with all aspects of how I communicate with friends.
Using IM is completely compatible with my current situation.
I think that using IM fits well with the way I like to communicate.
Using IM fits into my communication style.

Ease of use

I believe that it is easy to get IM to do what I want to do.
Learning to operate IM is easy for me
Overall I believe that IM is easy for me to use

Result demonstrability

I would have no difficulty telling others about the results of using IM.
I believe I could communicate to others the consequences of using IM.
The results of using IM are apparent to me.

Visibility

I have seen many people using IM.
It is easy for me to observe others using IM.
I have not seen many others using IM.

Prior IM Use

How frequently do you use IM?
If you were unable to continue using this technology, how much impact would it have on your life?

Appendix B

Cross-loadings

	Attitude	*UseInt*	*RA*	*CT*	*CX*	*RD*	*VI*	*PCM*	*SN*
ATT1	0.943	0.857	0.546	0.569	0.521	0.552	0.527	0.734	0.435
ATT2	−0.778	−0.574	−0.262	−0.315	−0.346	−0.373	−0.402	−0.425	−0.094
ATT3	0.934	0.825	0.544	0.534	0.450	0.507	0.492	0.734	0.438
BI1	0.800	0.945	0.559	0.560	0.521	0.526	0.499	0.696	0.450
BI2	0.826	0.971	0.559	0.562	0.518	0.545	0.524	0.727	0.412
BI3	0.860	0.976	0.521	0.536	0.510	0.563	0.523	0.738	0.384
RA1	0.331	0.487	0.779	0.573	0.135	0.218	0.171	0.444	0.467
RA2	0.426	0.502	0.877	0.666	0.224	0.315	0.204	0.514	0.510
RA3	0.427	0.448	0.871	0.663	0.215	0.286	0.177	0.478	0.465
RA4	0.413	0.503	0.852	0.598	0.233	0.254	0.199	0.453	0.508
RA5	0.562	0.610	0.876	0.696	0.328	0.390	0.352	0.638	0.559
RA6	0.599	0.681	0.857	0.677	0.348	0.406	0.361	0.648	0.583
CT1	0.437	0.521	0.595	0.853	0.308	0.347	0.321	0.513	0.394
CT2	0.529	0.560	0.645	0.894	0.402	0.454	0.403	0.602	0.456
CT3	0.499	0.559	0.718	0.927	0.321	0.377	0.301	0.530	0.474
CT4	0.498	0.514	0.655	0.922	0.164	0.263	0.179	0.478	0.421
CX1	0.445	0.378	0.329	0.415	0.737	0.523	0.318	0.387	0.189
CX2	0.360	0.453	0.151	0.240	0.891	0.535	0.442	0.325	0.067
CX3	0.442	0.534	0.197	0.262	0.885	0.503	0.451	0.364	0.077
RD1	0.551	0.499	0.316	0.407	0.585	0.868	0.467	0.498	0.210
RD2	0.383	0.258	0.272	0.323	0.430	0.842	0.376	0.387	0.190
RD3	0.401	0.233	0.308	0.368	0.525	0.795	0.354	0.346	0.180
VI1	0.489	0.418	0.234	0.326	0.452	0.459	0.846	0.564	0.252
VI2	0.334	0.436	0.249	0.307	0.325	0.343	0.735	0.380	0.258
VI3	−0.460	−0.332	−0.189	−0.268	−0.377	−0.366	−0.840	−0.457	−0.161
PCM1	0.660	0.660	0.605	0.603	0.362	0.429	0.515	0.912	0.523
PCM2	0.715	0.661	0.549	0.428	0.352	0.261	0.471	0.901	0.483
PCM3	0.677	0.689	0.518	0.524	0.430	0.531	0.552	0.896	0.491
PCM4	0.632	0.622	0.563	0.558	0.363	0.405	0.574	0.905	0.522
SN1	0.483	0.501	0.572	0.494	0.221	0.270	0.333	0.606	0.869
SN2	0.173	0.241	0.453	0.354	0.013	0.116	0.103	0.343	0.841
SN3	0.227	0.339	0.501	0.392	0.032	0.154	0.175	0.389	0.860

We would like to thank an anonymous reviewer for her/his assistance in computing the values in this table.