User−Perceived Requirements of Mobile Technology: Results from a Survey of Mobile Business Users

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Abstract

In this paper, we explore (a) the requirements of business users of mobile devices in relation with user tasks and user mobility, and (b) the relationship of the extent to which user−indicated technology requirements are met by user−perceived technology performance (fit), and overall user evaluation of the technology. Based on a survey of 216 business users of mobile technology, we found statistical evidence for a positive association of task difficulty with various functional and non−functional requirements, as well as for a positive association of fit and overall technology evaluation. In addition, our data suggests the relation between fit and overall evaluation to be asymmetric and non−linear, very similar to a typical convex consumption function. While user mobility did not play an immediate statistically significant role, we found indications of an indirect association: The non−functional characteristic of portability that described the availability of the technology in various mobile use situations turned out to be the most important factor to explain and predict technology requirements and overall evaluation in the current research study.

Published: 2007
URL: http://www.business.uiuc.edu/Working_Papers/papers/07−0116.pdf

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Abstract

In this paper, we explore (a) the requirements of business users of mobile devices in relation with user tasks and user mobility, and (b) the relationship of the extent to which user-indicated technology requirements are met by user-perceived technology performance (fit), and overall user evaluation of the technology. Based on a survey of 216 business users of mobile technology, we found statistical evidence for a positive association of task difficulty with various functional and non-functional requirements, as well as for a positive association of fit and overall technology evaluation. In addition, our data suggests the relation between fit and overall evaluation to be asymmetric and non-linear, very similar to a typical convex consumption function. While user mobility did not play an immediate statistically significant role, we found indications of an indirect association: The non-functional characteristic of portability that described the availability of the technology in various mobile use situations turned out to be the most important factor to explain and predict technology requirements and overall evaluation in the current research study.

Keywords: Task-technology fit, mobile technology requirements, user task, user mobility, user satisfaction

1. Introduction

Developments of mobile technology are characterized by ongoing technological progress and by growing diffusion, in particular in professional use settings (Computerworld 2003). In order to reap the expected benefits and to ensure investment effectiveness, it is important to develop a thorough understanding about the conditions for success of mobile technology, and the impacts on user performance (Mennecke and Strader 2003). Research and practice of software systems analysis and design have long categorized the needs that are associated with information technology as functional and non-functional requirements, whereby functional requirements relate to the different functions that a system needs to perform (what the system can do), and non-functional requirements relate to the characteristics that a system needs to have (how the system behaves) (Wiegers 2003, Yourdon 1989). Multiple perspectives apply, including the perspectives of an organization, individual user, and technology.

With the current research study, we investigate the functional and non-functional requirements of business users of mobile devices in relation with user tasks and user mobility; and the impact of the fit between user-perceived technology requirements and actual technology performance on the overall evaluation of the technology by the users. After discussing related research studies and theories in the following section, we describe our research model and data collection process, before we present the results of our data analysis, and offer concluding remarks.

2. Related Research

We position our approach with respect to two information systems theories: (1) the theory of task-technology fit (Goodhue and Thompson 1995, Zigurs and Buckland 1998), and (2) the technology acceptance model (Davis 1989, Davis *et al.* 1989). We apply a utilitarian approach (Van der Heijden 2004) and focus on the enablement of business tasks and support of professional users with mobile technology.

According to scholars of the theory task-technology fit, information systems will be more successful and have greater impact on user performance if there is a fit between task requirements and technology characteristics. Applications of the theory of task-technology fit to mobile information systems include Junglas and Watson's (2003) concept of ubiquitous commerce, and Lee *et al.'s* (2007) empirical study of mobile commerce in the insurance industry. For mobile electronic procurement systems, Gebauer and Shaw (2004) found a correspondence between the tasks that users performed and the functionalities of the mobile application that users valued. In addition, Gebauer and Shaw (2004) emphasized user-perceived technology performance as an important factor to explain and predict actual use and resulting benefits, in particular in the case of technological shortcomings.

The technology acceptance model has been developed to explain and predict the adoption of information systems by individual users. Among the main contributions of the theory are the findings that the intention to use technology—viewed as a precondition of actual use—is associated with user-perceived usefulness and ease of use of the technology. Applications of the technology acceptance model to mobile information systems include a research study by Fang *et al.* (2006) who concluded that user requirements varied with user tasks and who stated a need to include into the analysis factors such as perceived playfulness and perceived security. Beulen and Streng (2002) investigated the impact of mobile office applications in a business-related use setting over a period of time and found an increase in perceived usefulness and also in effectiveness, in particular for relationship managers.

Broadly related to the technology acceptance model and the theory of task-technology fit are research studies on usability that have investigated the conditions that make technology useful and easy to use. Mobile internet technology, for example, has been notorious for poor usability (Buchanan *et al.* 2001, Chan *et al.* 2002). The difficulty associated with the design of mobile systems that have high usability increases the need to develop a deep understanding of the functional and non-functional requirements of users (Perry *et al.* 2001). Based on a content analysis of online user reviews of mobile devices, Gebauer *et al.* (forthcoming) identified five types of requirements, namely functional requirements (e.g., voice communication, messaging communication, office applications), and non-functional requirements related to portability and ubiquitous use (e.g., form factors, ability to carry, adaptability, availability in various mobile use-situations); system operation (e.g., compatibility with other devices, speed, battery, and stability); usability and appearance (e.g., display, keyboard, and design); and network connectivity. The five types of requirements provide the basis for the current research model.

3. Research Model

Focusing on functional and non-functional requirements of mobile technology from the perspective of the individual user, we build on the findings of Gebauer *et al.* (forthcoming) who identified five types of requirements as relevant for the success of mobile information systems. The five types of requirements include functional requirements, and non-functional requirements that are related to portability, system operation, usability, and network access. We conducted an empirical survey of business-users of mobile technology in an effort to address the following four research questions: (1) What is the relationship between user tasks and user-perceived requirements of mobile technology (H1)?; (2) What is the impact of user mobility on the relationship between user tasks and user-perceived requirements of mobile technology (H2)?; (3) What is the relationship between user mobility and user-perceived requirements of mobile technology (H3)?; and (4) What is the relationship between the extent to which the mobile technology fulfills the requirements of mobile users (fit) and overall user evaluation of the technology (H4)? Figure 1 provides an overview of the research model.

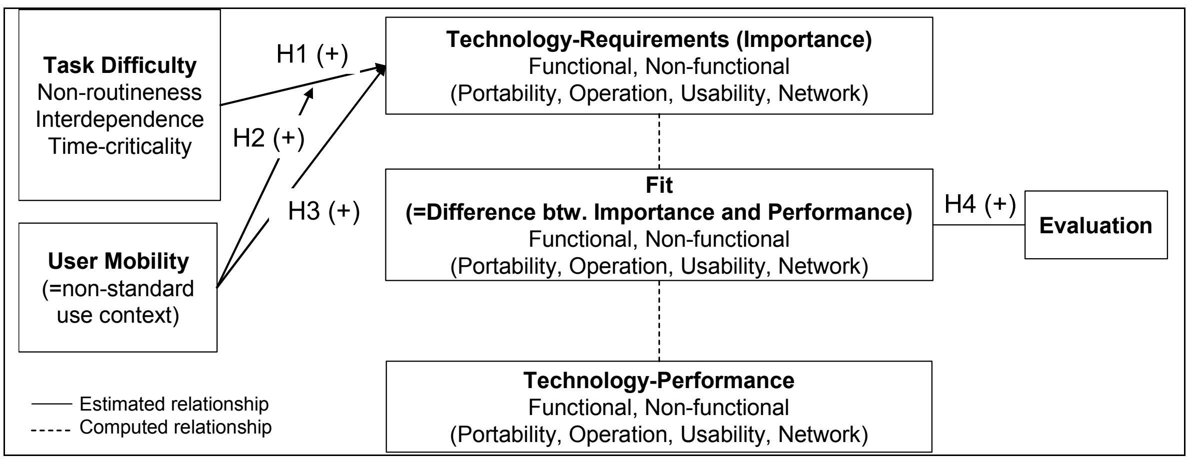


Figure 1. Research Model

The research model consists of two parts. Part one focuses on technology requirements (importance) in relation with task difficulty and with user mobility (H1-3). Part two focuses on the relationship between the fit of technology requirements and technology performance on the one hand, and overall evaluation of the device (satisfaction) on the other hand (H4). In the research model, all constructs are user-perceived, except for fit which is computed as the relative difference of user-perceived importance and user-perceived performance of the mobile technology. The two parts of the research model are now discussed in more detail.

3.1. Focus on Technology Requirements

Taking a utilitarian approach, we emphasize the usefulness of information technology as it has been identified by scholars of the technology acceptance model as an important factor to explain and predict technology adoption (Davis 1989, Davis *et al.* 1989). Related with research work of scholars of the theory of task-technology fit, usefulness may be viewed as a result of the extent to which the tasks of a business user are supported by the mobile technology (Dishaw and Strong 1999). In the current study we assume that the need for support with information technology generally increases with the difficulty of a given task. We consequently hypothesize:

H1: Task difficulty is associated positively with user-perceived technology requirements, including functional requirements (H1a); and non-functional requirements related to portability (H1b), system operation (H1c), usability (H1d), and network access (H1e).

Taking into consideration the individual use context, we include user mobility into the research model. We first view user mobility as a moderator of the relationship between task difficulty and technology requirements. The assumption is that highly mobile users might perform tasks differently than less mobile users, and that the differences will be reflected in the technology requirements. For example, compared to a less mobile user, a highly mobile user might perform tasks more often by delegation than directly resulting in a need to utilize mobile technology as a proxy to "stay in touch" and to monitor progress (Gebauer and Shaw 2004, Perry *et al.* 2001). As a result of such differences, we expect mobile users to rely more heavily on the various functional and non-functional features of mobile technology for the performance of tasks of a given level of difficulty. We hypothesize:

H2: User mobility moderates the relationship between task difficulty and user-perceived technology requirements, including functional requirements (H2a); and non-functional requirements related to portability (H2b), system operation (H2c), usability (H2d), and network access (H2e), such that the effect will be stronger for more mobile users.

The second research issue that is related to user mobility pertains to the direct association between the mobile use-context and the various user-perceived technology requirements. Users that are highly mobile may indicate different functional requirements and may indicate different non-functional features of an information system to be important than users that are less mobile (Gebauer and Ginsburg forthcoming). An obvious issue would be the ability to carry equipment. Technology to support a mobile user has to be light and small, a feature that is typically less important for a less mobile user. We hypothesize:

H3: User mobility is associated positively with user-perceived functional requirements (H3a); and with non-functional characteristics that are related to portability (H3b), system operation (H3c), usability (H3d), and network access (H3e).

3.2. Focus on Overall Technology Evaluation

In the second part of our research model, we focus on the relationship between technology requirements, technology performance, and overall technology evaluation. To determine fit between task and technology, different approaches have been applied by scholars of task-technology fit. Goodhue and Thompson (1998) used eight dimensions to assess fit directly, including data quality, data locatability, and authorization. A similar technique has been applied by scholars of the technology acceptance model who measure usefulness based on a number of questions, such as the extents to which technology enables a user to accomplish a task more quickly, and to improve a user's job performance (Davis *et al.* 1989). Other studies of task-technology fit have applied an indirect approach, equating fit with the difference between ideal (=expected) and actual technology characteristics. For example, Zigurs and Buckland (1998) developed a fit profile as a match between actual technology characteristics and the requirements of group tasks. Following Dishaw and Strong (1998) who suggested a computed approach to fit for case tools to support software maintenance tasks, we compute fit as the relative difference between user-perceived requirements and actual performance of the technology. We hypothesize:

H4: The fit between user-perceived technology requirements and actual technology performance is associated positively with user evaluation for functional characteristics (H4a); and with non-functional characteristics that are related to portability (H4b), system operation (H4c), usability (H4d), and network access (H4e).

In the current study, we further distinguish between fit in general ("pooled"); under-fit where requirement values are greater than performance values; and over-fit, where requirement values are smaller than performance values. In the following, we describe the empirical research study and discuss our findings.

4. Data Collection

We collected survey data during an 8-day period in the fall of 2006 in cooperation with CNET.com, a media company that operates an online media website targeting the users of high-technology devices. For sampling, a random intercept technique was used and the survey was presented to 2% of the site's unique visitors, as determined based on a cookie that was given to every visitor of the site. All participants were given the opportunity to participate in a random drawing of a cash prize of $1,000. According to the cooperation partner who administered the survey on our behalf, acceptance rates of the survey were average with about 6%, followed by a slightly lower than normal completion rate (40% versus 50-70%), which might be attributed to the comparatively extensive length of the survey. Of 811 completed surveys 337 qualified, as respondents indicated to be employed, over 18 years of age, and using a wireless device for work-related purposes. The survey instrument is available from the authors upon request.

4.1. Variable Measures

Web-server generated data provided information regarding the time a respondent took to complete the survey. Assuming that the survey needed at least 5 minutes (300 seconds) to be completed, we excluded 6 surveys for a remaining set of 331 responses. Demographic information that was included in the questionnaire related to gender, age, and residence country. We also asked about the use of mobile devices and included questions about the primary and secondary mobile devices that respondents used to perform their jobs, previous experience with mobile technology, frequency of technology updates, and the resources utilized during the purchasing process.

Related to the research model, we inquired about user tasks (task difficulty) and use environment (mobility): Task difficulty was operationalized with the three factors of non-routineness, interdependence, and time-criticality, and mobility was operationalized with questions about the extent to which a user performed work in a non-standard use environment. Technology requirements were assessed with a number of questions on the importance of functionality and non-functional features that were provided by a user's primary mobile device. Functionality relates directly to the activities that the system can perform and information that the system contains, and was operationalized as voice quality, written communication, internet access, office applications (e.g., word processing, presentations, spreadsheet software), camera, video and music player, games, ring tones and multi-functionality. Non-functional features relate to behavioral properties of a system, and were operationalized as portability (including the capability of the device to perform in an airport, while the user is driving car, using public transportation, during commute, work on location and meetings, outside of regular office hours, and form factors); system operations (including linkage with other devices, battery, speed, storage, durability, customization, and automation); usability (including input, display, ease of use, customer service, and internal sound); and network access (including network access and blue-tooth features). Besides questions about the importance of various functions and features, we also asked about user-perceived performance for each item of technology requirements, and used the relative difference between the two measures to determine fit. The last category related to the overall evaluation of the primary mobile device by the respondent.

4.2. Missing Data

Two sources of missing data caused concern in the dataset. The first source of missing data resulted from questions that respondents left blank. After performing a missing value analysis, we determined this type of missing data to be missing completely at random (MCAR) (Hair *et al.* 1998), deleted the 115 incomplete responses and retained 216 complete responses for further analysis. The second source of missing data was a result of respondents who indicated "Not Applicable" (N/A) on questions of how the mobile device performed with respect to functionalities, such as written communication, access to the internet, and photo imaging. 131 surveys contained a total of 815 data cells indicating N/A as a response to one or several performance-related questions. An analysis of the association between responses of N/A for performance and the user-perceived importance of the same functionality revealed a generally low level of user-perceived importance of the respective functionalities. As a result of this finding, we replaced N/A answers with "1" indicating performance as "Performs Poorly". The procedure resulted in a relatively good fit for the respective functionalities.

5. Data Analysis

We tested the conceptual model in two steps. First, we focused on the technology requirements of mobile users as they relate to task difficulty and user mobility (H1-3), using partial least squares (PLS) estimation for analysis. Second, we focused on the relationship between fit and overall evaluation (H4), using univariate regression for analysis.

5.1. Explaining Technology Requirements

In the first part of the model, the indicators underlying the latent variables of task difficulty, mobility, and five technology requirements of functionality, portability, system operation, usability, and network availability, were all modeled as reflective indicators. Reflective indicators are viewed as affected by the underlying latent variable, and as a result covariate with the latent variable. Task difficulty was modeled as a second-order latent variable comprised of the three first-order variables of task non-routineness, interdependence, and time-criticality. The remaining constructs of mobility and five technology requirements were modeled as first-order latent variables. All indicators ranged from 1 to 7.

Data analysis in PLS is typically done in two steps (Anderson and Gerbing 1988). In the first step, the quality of the variables and item measurements are assessed by testing the measurement model for convergent and discriminant validity (Gefen and Straub 2005). In the second step, the stated hypotheses are tested with a structural model that estimates path effects and significance levels of the suggested associations. Upon examining the measurement model, we found that he composite reliability estimates for each construct ranged from 0.74 to 0.90, exceeding the commonly used threshold value of 0.70 (Hair *et al.* 1998). The average variance extracted (AVE), ranged from 0.47 to 0.73, which is close to or above the recommended 0.50 level (Hair *et al.* 1998). To examine discriminant validity, the square root of AVE was compared with the correlation between the latent variables. The square root of the AVE exceeded the interconstruct correlation indicating adequate discriminate validity (Fornell and Larcker 1981). The detailed results of the measurement model have been omitted from the current paper because of space restrictions but are available from the authors upon request.

Upon examining the structural model (Table 1), we found task difficulty (TD) to be associated positively with functional requirements (RFUN) and with the non-functional requirements related to portability (RPOR), system operation (ROPE), and usability (RUSA). Consequently, all of H1a, H1b, H1c and H1d were supported. The effect of task difficulty on non-functional requirements related to network access (RNET), however, was not significant, and H1e was not supported. Neither direct, nor moderating effects of mobility (MOB) on technology requirements were significant, which means that none of the hypotheses of H2 and H3 were supported by our data. Nevertheless, we note that the non-functional requirement of portability and need for constant availability—conceptually related most closely with the aspect of user mobility—exhibited the closest statistical link with task difficulty, thus suggesting that mobility might perhaps play a more indirect role in determining technology requirements. R^2 turned out to be rather small, ranging from 0.03 (RFUN) to 0.10 (RPOR). The small R^2 values suggest that in our study task difficulty and mobility can only explain and predict a small part of user-perceived technology requirements, and that other factors are likely relevant.

Table 1. Task Difficulty, Mobility, and Technology Requirements (Results Based on PLS)

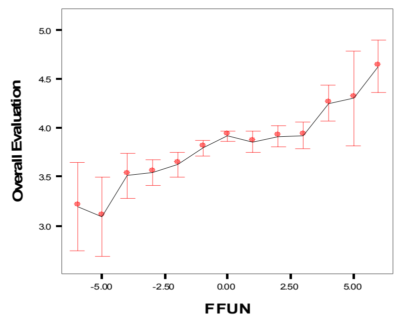
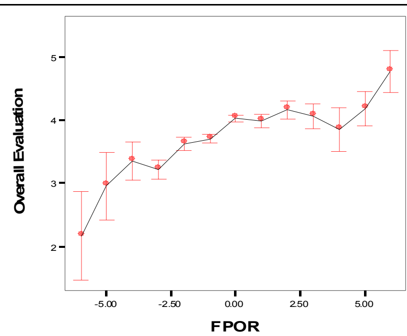
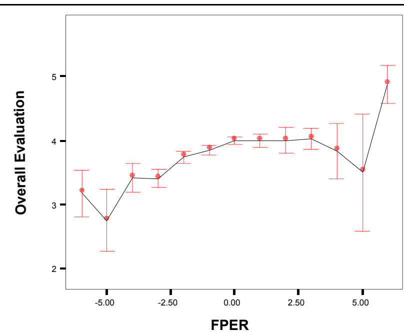
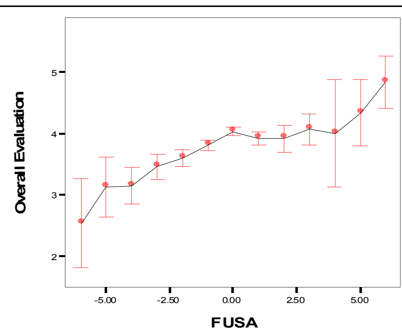
Path coefficients	**RFUN**	**RPOR**	**ROPE**	**RUSA**	**RNET**
TD	0.17**	0.24***	0.23***	0.20**	0.14
MOB	0.02	0.13	0.053	0.02	0.01
TD* MOB	-0.02	-0.13	-0.05	-0.05	-0.12
R^2	**0.03**	**0.10**	**0.06**	**0.05**	**0.04**

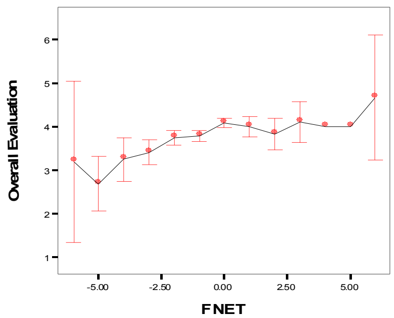
* p<0.05, ** p<0.01, *** P<0.001

5.2. Explaining Overall Technology Evaluation

In the second part of the model, we used univariate regression to analyze the relationship between fit—modeled as the relative difference between technology requirements and performance—and overall technology evaluation. In this part of the analysis, each of the individual indicators of fit was treated as an independent variable, and regressed against overall evaluation as the dependent variable for a given user. For each user, we pooled the original measurement items to form five new independent variables, whereby each variable corresponded with one of the five functional and non-functional technology characteristics. More specifically, we pooled nine items to measure the fit of functionality (FFUN), eight items for the fit of portability (FPOR), nine items for the fit of system operation (FOPE), five items for the fit of usability (FUSA), and two items for the fit of network access (FNET). We found significant positive coefficients between overall evaluation and all of the fit-variables, namely functionality and each of the four non-functional characteristics of portability, system operation, usability, and network access (Table 2, rows indicating "pooled fit"). H4 is, thus, fully supported for H4a through H4e.

Table 2. Fit and Overall Technology Evaluation (Results Based on Univariate Regression)

Graph	Variable	Fit	Coefficient	R^2
	**FFUN**	Pooled	0.090***	0.053
		Over-Fit	0.050**	0.008
		Under-fit	0.128***	0.056
	**FPOR**	Pooled	0.169***	0.139
		Over-Fit	0.044*	0.006
		Under-fit	0.242***	0.161
	**FOPE**	Pooled	0.128***	0.096
		Over-Fit	0.033	0.003
		Under-fit	0.174***	0.109
	**FUSA**	Pooled	0.141***	0.111
		Over-Fit	0.033	0.003
		Under-fit	0.207***	0.138

	**FNET**	Pooled	0.153***	0.125
		Over-Fit	0.016	0.001
		Under-fit	0.215***	0.149

* p<0.05, ** p<0.01, *** p<0.001

In addition, we note a consistent picture of greater variance of evaluation in situations of extreme under-fit (values of user-perceived requirements much lower than performance) and extreme over-fit (values of user-perceived requirements of a measurement item much larger than performance) and of smaller variance of evaluation in situations of good and perfect fit (values of user-perceived requirements of a measurement item equal performance). Our data suggest that users agree much more on the evaluation of technology that meets their expectations than on the evaluation of technology that either under-performs or over-performs.

We also performed separate univariate regressions of overall evaluation for situations of over-fit, and for situations of under-fit. Previous research studies of task-technology fit have typically assumed—often implicitly—a symmetric and linear relation between fit and a dependent variable, such as performance or system use. For our dataset, however, neither assumption appears to be valid, as indicated in Table 2 (rows indicating over-fit and under-fit): For all of the functional and non-functional characteristics of technology, the association between fit and overall evaluation is (a) non-symmetric, meaning that overall evaluation increases as under-fit is reduced, but does not decrease in a situation of over-fit—in other words, from the perspective of the user, under-fit is different from over-fit; and (b) the relationship between fit and overall evaluation is statistically stronger in an under-fit situation than in an over-fit situation. In fact, for all but two technology characteristics (FFUN, FPOR), the relationship between over-fit and overall evaluation becomes statistically insignificant. For all five constructs, the coefficients are higher for the regression of under-fit than for the regression of over-fit, as are the R^2-values to indicate explained variance. Our data suggest that in a situation of under-fit, overall user-evaluation increases steadily with technology improvements – yet only up to a situation of "perfect" fit. In a situation of over-fit, further improvements of the technology translate into either very limited or statistically insignificant additional increases of overall evaluation. In all, the relationship between fit and overall evaluation exhibits characteristics of the typical consumption function that is used by scholars of economics to explain consumer utility with decreasing marginal returns.

6. Discussion and Conclusions

The results of the current study provide insights about the requirements of business users of mobile technology, as well as about the applicability of established theories, such as the theory of task-technology fit and the technology acceptance model to mobile technology. Besides functionality, a number of non-functional requirements were found to be related significantly with the difficulty of user tasks, in line with the stated hypotheses (Table 3), and largely confirming the applicability of the theory of task-technology fit and the technology acceptance model to mobile technology.

Table 3. Summary of Hypothesis Testing

H1	Task difficulty is associated positively with user-perceived technology requirements, including functional requirements (H1a); and non-functional requirements related to portability (H1b), system operation (H1c), usability (H1d), and network access (H1e).	H1a, H1b, H1c, H1d Supported H1e Not Supported
H2	Mobility moderates the relationship between task difficulty and user-perceived importance of technology requirements, including functional requirements (H2a); and non-functional requirements related to portability (H2b), system operation (H2c), usability (H2d), and network access (H2e), such that the effect will be stronger for mobile users.	None Supported
H3	Mobility is associated positively with user-perceived functional requirements (H3a); and with non-functional characteristics that are related to portability (H3b), system operation (H3c), usability (H3d), and network access (H3e).	None Supported
H4	The fit between user-perceived technology requirements and actual technology performance is associated positively with user evaluation for functional characteristics (H4a); and with non-functional characteristics that are related to portability (H4b), system operation (H4c), usability (H4d), and network access (H4e).	All Supported (statistical significance stronger for under-fit than for over-fit)

Several results of the current study, however, indicate a need for additional research. We were surprised to find that the level of user mobility was not associated significantly with technology requirements, neither directly nor indirectly as a moderator of the relationship between task difficulty and the various requirements that users had stated. However, the general concept of mobility still appeared to play an important role, given the statistical significance of portability (RPOR). In the first part of the model, portability exhibited the strongest association with task difficulty (followed closely by non-functional requirements related to system operation), whereas in the second part of the model, the fit between requirements and actual performance of non-functional features related to portability exhibited the strongest link with overall evaluation (FPOR), not just for "pooled" fit, but also for the under-fit effect model, and was significant at the $p<0.05$ level for over-fit. This finding means that for portability, both over-fit and under-fit of importance and performance appear to be positively related with overall evaluation. In addition, we note that portability appeared to be the single most important construct in our model, and was associated with task difficulty and with the overall evaluation of mobile technology.

In line with the suggestions of task-technology fit, we found the functional characteristics of the technology to be associated significantly and positively with task difficulty (RFUN) and with overall evaluation (FFUN), even in the over-fit effect model. It appears that, in the eyes of the users, a broad range of functionalities has become an expectation of mobile technology. For non-functional features that are related to portability, system operation, usability, and network access, we found that the overall evaluation of the technology was associated in particular with situations where users indicated requirements to exceed technology performance (under-fit). For system operation, usability and network access, once technology performance meets user requirements (ideal fit), users appear to give little credit for further improvements of technology performance. Additional research will help to deepen the results of the current model, in particular to refine the concept of user mobility and the construct of fit that appears to be asymmetric and non-linear.

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