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User requirements of mobile technology: A summary of research results

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Abstract: As advanced mobile technology becomes more widespread, the impacts on professional environments and on the personal lives of individual users continue to increase. Devices, such as smart cell phones, personal digital assistants (PDAs), and laptop computers can free their owners of the need to remain close to a wired information system infrastructure that is provided in a stationary office environment, and provide the opportunity to perform tasks in a wide variety of use contexts. With changes in use context, however, come changes in requirements, such as the need to limit weight and size of a device. In order to achieve success in the form of adoption, use, and positive impacts on user performance, a thorough understanding is needed about the functional and non-functional technology requirements of mobile professionals. In this paper, we summarize the results of a series of research studies that we conducted to explore the technology requirements of mobile professionals. The research studies included a content analysis of online user reviews, two empirical surveys, and a series of user interviews. Our research findings indicate that (1) user-perceived technology maturity is a critical factor to explain and predict the use of mobile technology by mobile professionals; (2) mobile technology needs to be available in a broad variety of use-situations; (3) users require basic communication and productivity-related functionality, in particular to support non-routine and supervisory task profiles; and (4) mobile technology can have considerable impacts on the job performance and on the personal lives of its users. Our findings have implications for the design, management, and research of mobile information systems.

Keywords: Mobile workforce, user mobility, technology maturity, task-technology fit, user satisfaction

1. Introduction

In the current paper, we focus on technology that is employed to help improve the productivity of business users in need to perform general business tasks while being away from a stationary office environment (mobile professionals), most notably based on communication and information access functionalities. We summarize the results of four research studies that we conducted in an effort to address the following three research questions: What are the technology needs of mobile professionals?; What are the success factors of mobile technology in support of mobile professionals?; and To what extent can established information system theories be applied to innovative technology in support of mobile professionals?

Continuously increasing in technical sophistication as well as diffusion, mobile devices, such as smart cell phones, personal digital assistants (PDAs), and portable computers enable business users to perform work-related tasks without the need to stay close to a wired information system infrastructure. For companies as well as individuals to fully benefit from the – oftentimes considerable – investments in the new technology, researchers and managers need to develop a thorough understanding about the requirements and impacts that are associated with the technology and its use. Furthermore, in order to determine the applicability of the results of previous research and theories of information systems it is important to consider carefully the idiosyncrasies of the mobile technology, such as form factors and user mobility.

As one established theory that is concerned with the success of information technology, the theory of task-technology fit (TTF) suggests that a match between business tasks and technology is important to explain and predict use and performance impacts [18]. The applicability of TTF to mobile technology, however, is not necessarily straightforward. For example, usability studies [28] suggest that the use-context may have a non-trivial effect on the conditions of fit between task and technology: First, it can be observed that form factors, such as weight and size of a device, play a more prominent role in mobile than in non-mobile use contexts [9,30]. Second, functional requirements may shift as business tasks are often performed differently in mobile versus non-mobile use contexts [10,28,36]. Thirdly, appropriation may differ to the extent that mobile technology may be used differently and for different reasons than seemingly comparable non-mobile counterparts [24,33]. As a result of such observable changes of business tasks, technology requirements and use patterns, we need to assess the applicability of previously established information system theories to mobile technologies and mobile use contexts, and to carefully determine the needs for theory adjustments and extensions [19,23].

The studies that are presented in the current paper employ a mixture of quantitative and qualitative research methodologies that include two empirical surveys, a content analysis of user-reviews, and a series of interviews, and were conducted over a five-year period (2002–2007). Our iterative approach reflects the complexities of a multi-faceted field of study, whereby the results from the earlier studies served to inform the design of the later studies. In addition, the multi-part research program allowed for the triangulation of conceptual insights based on the application of established information system theories and of practical insights based on real-world data, thus supporting us in our effort to straddle academic rigor and practical relevance [25].

Epistemologically, we applied two distinct research approaches. We deduced insights about the conditions of use and impacts of mobile technology by applying elements from the technology adoption model (TAM) and TTF. With a focus on behavioral aspects of information systems, both theories seek to explain and predict system adoption and use. In addition, we applied an inductive, phenomenological approach, where we synthesized detailed user-indicated requirements in an effort to explain and predict user satisfaction. This second approach is largely in line with information system theories that focus on user beliefs and attitudes of technology as an object [7,34], and more specifically with frameworks that have been developed by scholars of requirements engineering and usability research.

In the following, we first position our research program by sketching out its theoretical background. We then summarize the objectives, methodologies, and results of the four, related research studies that we conducted between 2002 and 2007. We conclude the paper with a discussion of our findings and the implications for research and management.

2. Theoretical background

The success of information systems has long been discussed by scholars of two distinct research streams that have only recently been integrated and reconciled [34]. The two research streams assess information system success with (1) behavioral measures, such as technology acceptance and use; and based on (2) technology-oriented measures resulting in user satisfaction, respectively. Both have been applied to mobile technology.

2.1. Focus on behavior: Understanding technology use and performance impacts

In the technology acceptance literature, most notably TAM, the research objective is to explain and predict system success based on measures of user behavior, such as system adoption and use [6,31]. Among the most salient findings of TAM are the identification of user-perceived usefulness and ease of use as the main predictors of intention to use and actual use of an information system [5,6]. Applications of the technology acceptance model to technology innovations, such as the World Wide Web [22,26] and Internet-shopping [15,16] largely supported the suggested relevance of both usefulness and ease of use.

Despite many extensions that have been reviewed and discussed at length elsewhere (e.g. [31]), scholars of TAM usually offer little insights into the antecedents of user-perceived usability and ease of use, nor are they concerned with the wider reaching consequences of system use, for example from an organizational level [2]. TTF – in particular its notion of the "technology-to-performance chain" [17, 18] – complements TAM well [11]: TTF it is concerned with the extent to which technology meets task-related requirements (fit), a construct that is conceptually related with TAM's construct of user-perceived usefulness. In addition, TTF reaches beyond TAM's use-construct as a dependent variable, and emphasizes the importance of adequate task-support as a condition of positive impacts on the performance of individuals [18] and groups [37].

For mobile information systems, TTF has been shown to be generally relevant [10], but more specific questions regarding the applicability of TTF to mobile information systems remain unanswered. Given its primary focus on user behavior, TTF generally offers little practical guidance for the design of a technology or task to achieve an optimal level of fit. An exception is presented by Zigurs and colleagues who developed [37] and later tested [38] a specific theory that detailed the requirements of group support systems to fit group tasks of varying complexity.

2.2. Focus on technology: Understanding user satisfaction

A second stream of research that is concerned with information system success focuses on user beliefs and attitudes about the technology as an *object* [34]. Scholars are concerned with explaining and predicting user satisfaction, and, thus, focus on identifying and analyzing design attributes and characteristics of information technology that may be associated with system quality [7,34]. While typically less of a direct predictor of actual use [8] the satisfaction literature offers more practical design guidelines than the acceptance literature has typically been able to provide. In the current paper, we consider ideas from two related approaches, namely requirements engineering and usability studies.

Requirements engineering is an essential element of software design and development, whereby the careful specification of requirements is considered critical to ensure a high level of software and system quality [35]. Requirements engineers often distinguish between functional and non-functional requirements [32]. Functional requirements pertain to the particular behaviors of a software system that are inherent in the different functions that the system can perform. To the extent that functional requirements determine what the system can do they also determine the extent to which user tasks can be supported.

In contrast, non-functional requirements support the functions of a system in a more general sense, and relate to the operation of the system. Typical non-functional requirements, sometimes also referred to as "ilities", are reliability, scalability, usability, system performance, and costs. To the extent that non-functional requirements relate to the conditions of the use context they may impose constraints on the design and implementation of the system.

As the main focus of requirements engineering is on technology per se, the approach is well complemented by research and practice that focus on usability as an important aspect of human-computer interaction. Within the broader context of product development, usability is associated with the ease with which people can employ a tool or other human-made object in order to achieve a particular goal [27]. Usability studies typically include aspects related with the psychology and physiology of the user, and with the specific use context [29]. Among the goals of usability experts are the elegance and clarity with which the interaction between a user and a computer program is designed.

Despite the popularity of mobile technology, difficulties with achieving high levels of usability have long been reported, in particular for applications that extend basic voice communication to provide Internet access and more complex data processing functionality [10,24,33]. For example, Buchanan et al. [3] found mobile Internet technologies based on the Wireless Applications Protocol (WAP) standard to provide a poor user experience based on the fact that they were difficult to use, and lacked flexibility and robustness. The authors provided suggestions of how to improve effectiveness and usefulness on a small screen with a user-centered approach. In an effort to help overcome design constraints and to provide adequate support for various tasks related with mobile consumer electronic commerce, Chan et al. [4] developed guidelines for content presentation, search, and navigation systems. Insights about the specific needs of mobile business users have been provided by Perry et al. [28]. In an interpretive research study of mobile workers who traveled internationally from the U.K., the authors analyzed context and activities, and emphasized the use of various electronic and non-electronic information and communication tools and technologies. Functional requirements that were identified in the study included: support for planful opportunism to make sure that documents and information were available during a trip in the appropriate form when and where needed; effective use of "dead" time to avoid work overload when returning to the office; use of the mobile phone as a device "proxy" based on the flexibility that was provided with the phone and that allowed the mobile worker to call the home office to access information system resources and ask to act on their behalf: "While it may not be the perfect tool, the [mobile] phone allows the mobile worker to achieve important goals without investing a lot of effort in locating or carrying specialized information or communications appliances with them" (p. 340); and use of technology for remote awareness monitoring for both the traveler and the colleagues back at the stationary office.

The importance of the use context for mobile Internet applications was confirmed in a usability research study by Kim et al. [21] who emphasized that different use contexts present unique usability problems. Related are frameworks that conceptualize different forms of mobility, depending for example on the range within which a technology user typically moves, and the resulting requirements for collaborative technology [24]. Zheng and Yuan [36] discussed the requirements of information systems that support stationary versus mobile work with a conceptual framework that takes into consideration the worker, task, context and technology.

2.3. Relationships between theory approaches

Both, TAM and TTF underscore the general need for usefulness and ease of use in an effort to achieve adoption, use, and performance impacts. The research results provide a general background and justification for the importance to design, implement and use systems that fit user tasks and levels of proficiency. Typically focused on mature technologies, neither TAM nor TTF are very specific regarding the antecedents of usefulness or ease of use. Requirements engineering and usability studies provide a complementary research setting that focuses more explicitly on the design and development of innovative systems and technology.

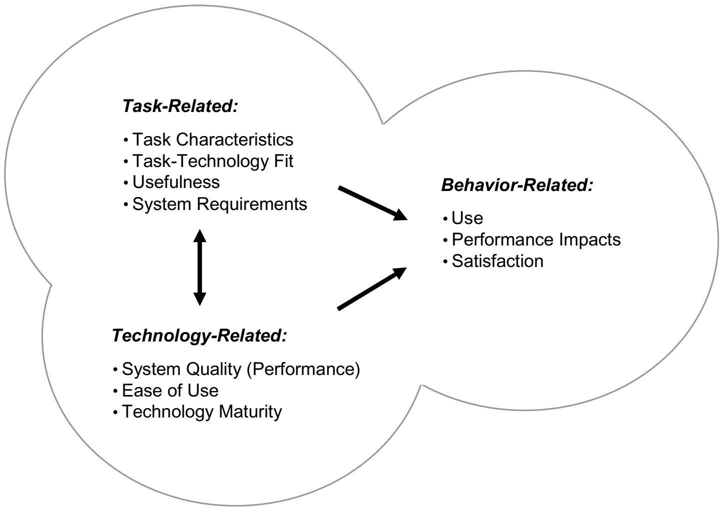

Fig. 1. Research constructs.

The research approaches that we just discussed also complement each other well because they collectively address three key elements related with information system success: task, technology, and user behavior (Fig. 1). Both TAM and TTF offer explanations for behavioral attitudes and beliefs that are related with system use and the resulting consequences on user performance. TTF, in particular in combination with conceptual elements from requirements engineering and usability, contributes insights about usefulness as one of the important antecedents of use. Usefulness and task-technology fit are conceptually related, inasmuch as in both cases the focus is on the potential of a technology to support a given task. TAM's second main antecedent of technology use – ease of use – is conceptually related with usability, as well as the assumed consequence of user satisfaction. Usability studies and requirements engineering – in particular regarding non-functional requirements – provide a framework to study user beliefs and attitudes about technology as an object. Figure 1 roughly positions the conceptual constructs with respect to the three themes of task, technology and behavioral consequences that are discussed in more detail when we present the four research studies in the next section.

3. Research studies

We conducted four research studies in an effort to improve our understanding about the requirements of business users of mobile technology, technology success factors, and impacts on user satisfaction and performance. In addition, we sought to assess the applicability of established information system theories. As mentioned earlier, we focused on mobile technology in support of general business tasks to be performed by business users who are away from a stationary office environment. We assessed systems with functionality to enable and support communication, information access, and productivity. Dependent variables in our studies included (1) user satisfaction, and (2) use and subsequent performance impacts. Explanatory variables included (1) the fit between the technology and the task profiles of its users, and (2) the extent to which the technology meets user expectations of functional and non-functional requirements. The four studies included (1) an empirical survey of mobile e-mail in a single company [11]; (2) a content analysis of online user reviews of various mobile technology devices [9, 14]; (3) an empirical survey of various mobile technology devices [12,13]; and (4) a series of interviews with business users of mobile technology. An overview of the objectives, data collection processes, and results of the four studies follows. For additional details that have been omitted in the current paper due to space restrictions, including information about constructs, questionnaires, and results of various validity tests, we kindly direct the reader to the referenced individual papers upon which the summaries are based.

3.1. Study #1: Empirical survey of mobile e-mail

In our first study, we surveyed the target users of mobile e-mail applications at a Fortune 100 provider of communication technology. The research objective was to contribute to the understanding of the success of mobile information systems as measured by use and performance impacts, and based on a behavioral research model that joined elements from TTF and TAM. To account for the idiosyncrasies of the mobile technology artifact, we included user mobility and technology maturity in the research model.

3.1.1. Data collection

The company operates in a number of global, dynamic, and highly competitive markets, and considers as much as thirty percent of its professional staff to be mobile. Survey data were collected at two separate times and included a total of 55 responses (30 users and 25 non-users of mobile e-mail). In 2002, we obtained data from 27 respondents that had expressed an interest to participate in mobile trial applications that were conducted in various parts of the company. We monitored the rollout of the trial applications that were in effect until early 2003. In 2005, we conducted a follow-up interview with a project director to assess the current state of mobile e-mail use in the company and to discuss the experiences with the trial applications in retrospect. For the second part of the survey, we collected a total of 28 responses from the same company at the end of 2006/beginning of 2007.

The 2002-3 trial applications were accessible via cellular phones and were based on WAP Docomo, and iDEN technologies. Login procedures required a combination of login name, password, pin, and/or a physical access card. In comparison, the 2006–2007 survey referred to the use of operational (= commercially available) mobile e-mail systems, whereby respondents indicated the use of a variety of state-of-the art smart cell phones and personal digital assistants. Figure 2 provides an overview of the research model that underlied study #1. In this study, task-technology fit was predetermined based on a presumed need for mobile e-mail to support business tasks that are characterized by medium levels of non-routineness (according to media-richness theory), and high levels of interdependence, time-criticality, and travel-related mobility.

3.1.2. Results

The data that were collected during study #1 were analyzed with structural equation modeling and the partial least square estimation method. The results of the separate analyses for the situations of pre-adoption (non-users) and post-adoption (users) are presented in Figs 3 and 4, respectively. More detailed information about the research model, hypothesis building, survey constructs, and the results of various validity tests is provided by Gebauer [11].

For both groups of users and non-users, the formative second order construct of task-technology fit was related significantly with three of the four suggested first order-constructs, indicating considerable statistical stability of the predetermined construct of fit. Only the path between mobility – measured as travel frequency and distance – and fit was not significant for either group (or for both groups combined).

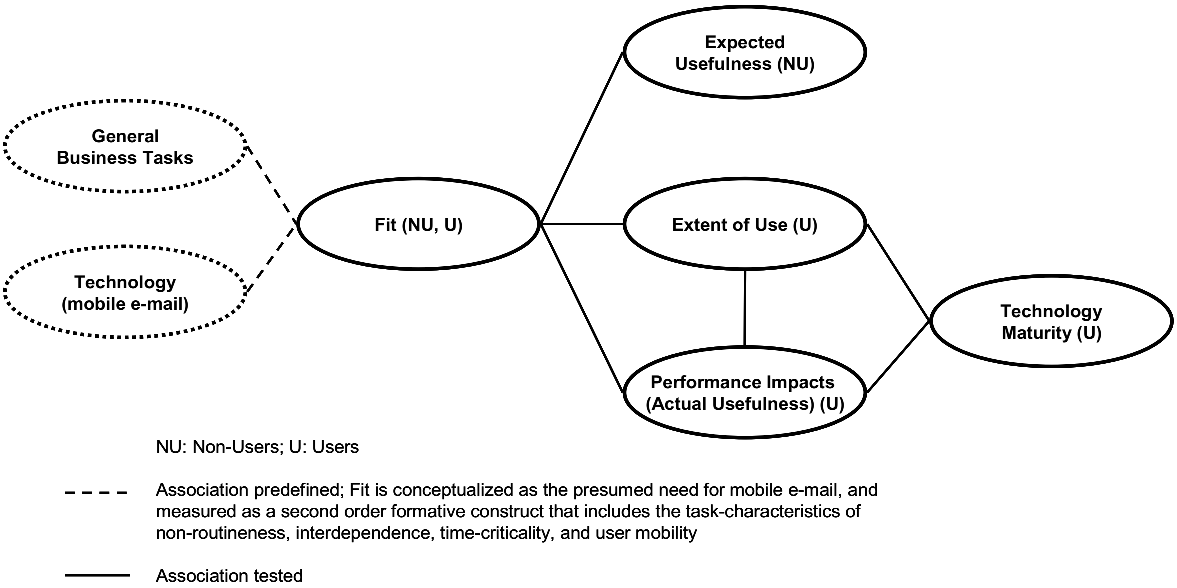

Fig. 2. Research model, combined for non-users (NU) and users (U) (study #1) [11].

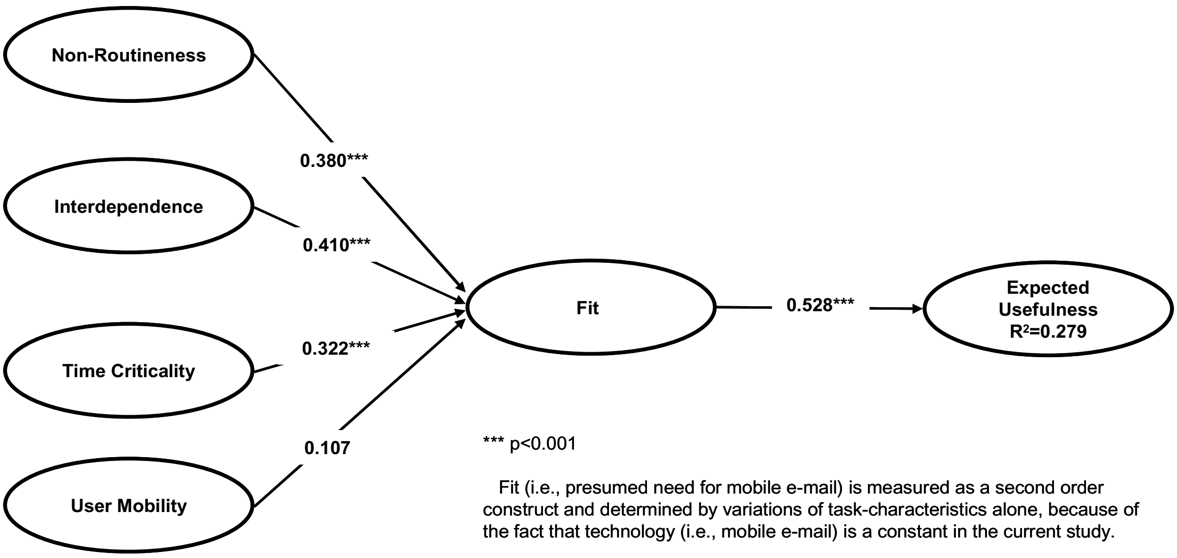

Fig. 3. Survey results (study #1): non-users (n = 25) [11].

For non-users, we found support for the hypothesized positive association between fit and user-indicated expected usefulness. For the user group, we found support for the hypothesized positive associations between extent of use and actual usefulness, between technology maturity and extent of use, and between technology maturity and actual usefulness. Not supported were two suggested associations, namely the associations between fit and extent of use, and between fit and actual usefulness.

Two of our findings are particularly remarkable. First, user-perceived technology maturity – measured based on service quality and stated need for improvement – had by far the strongest explanatory power

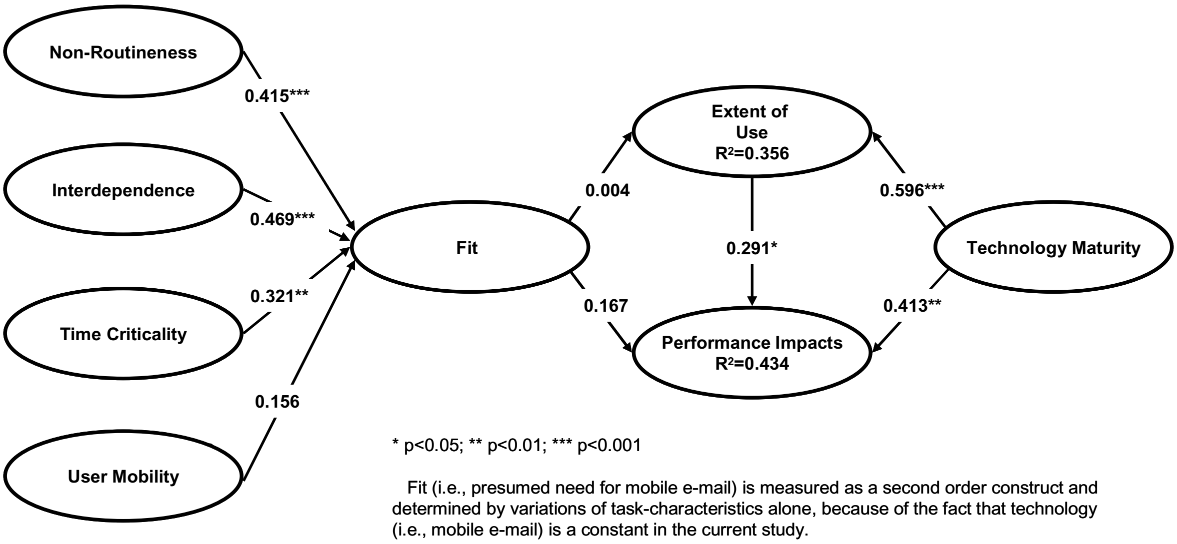

Fig. 4. Survey results (study #1): users (n = 30) [11].

in the model. While task-technology fit was related with expected usefulness for non-users, actual use and impacts of the technology on the performance of individual users were most strongly associated with user-perceptions of technology maturity. The quantitative results are further supported by numerous open and at times rather lengthy comments that we received from the survey participants, as well as by our own observations and by additional insights and documents that were provided to us by our corporate contacts. In all, the survey data indicate that only once (potential) users perceive the technology to be mature, will they be willing to try let alone use it, even in the case of a good presumed fit with individual task-profiles. Our results further suggest maturity to be a moving target, given that the issue of maturity (or rather the lack of it) was equally important at both points in time that we collected data (2002 and 2006) – even though participants explicitly acknowledged progress of the underlying technology. We conclude that technology maturity needs to be understood from the perspective of the user, and there appears to be a need to include user expectations into the analysis. [1]

Our second remarkable finding is related with the construct of mobility that was based on travel, including travel frequency and distance. In the current model, mobility contributed very little to explain fit – or any other variable. As a construct, and in line with earlier discussions [20,24,36], mobility turned out to be more complex than what we attempted to capture in study #1.

3.2. Study #2: Content analysis of online user reviews

In our second research study, we sought to obtain information from users on their belief sets regarding task-related requirements of mobile technology, and regarding the extent to which appropriate technology contributed to overall user evaluation (= satisfaction), use, and user performance ([9], see also [14]). In

[1] Unfortunately, because of limited statistical power as a result of the small sample size in study #1, we cannot derive meaningful conclusions regarding the suggested – yet insignificant – associations between fit, use, and performance impacts. While our interpretations of the survey data, user comments, and additional information that we analyzed all give us reason to believe that the expected relationships between fit and user behavior were overpowered by a user-perceived lack of technology maturity, statistical evidence alone is insufficient to draw such conclusions in the current study.

this study, we did not use a predefined survey, but applied a phenomenological, inductive approach that relied on the interpretation of online user reviews. Since the reviews were essentially unsolicited, we assumed that the comments would be particularly helpful in identifying requirements that are important to individual users. We intended to develop a realistic set of indicators with high practical relevance for design- and development-related decisions, and that would also help us assess the applicability of behavioral theories, such as TTF and TAM, to mobile technology.

3.2.1. Data collection

We gathered data from www.cnet.com, an online media website that allows its visitors to publish technology reviews. The site provided a large amount of relevant data that were readily available, as well as a homogeneous publishing environment. We analyzed reviews of four technology products, namely a smart cell phone, two personal digital assistant (PDA) devices, and an ultra-light laptop (Fig. 5). The devices were selected based on (1) the capability of the device to support business users, as stated in technology reviews that were published in the trade-press (online and offline) and as based on reported market share; and (2) popularity in the CNET online community, as indicated by the number of posted reviews, the number of site visitors who indicated the review to be useful, the number of comments on the reviews, and replies to comments. To ensure comparability of the technologies, we focused on devices that were introduced into the market during 2005, followed by reviews that were posted in 2005 to early 2006. For each of the four devices, we analyzed between 19 and 44 reviews in the order that the reviews were listed on the website, which by default was according to the number of visitors who indicated they found the respective review useful.

Three researchers collaborated to develop a database of coded user reviews, whereby we reiterated two steps over a period of several months: (1) development and refinement of a classification scheme that included the identification and description of comment categories; and (2) coding that included the classification and rating of the user reviews according to the classification scheme. Ratings ranged from very negative to very positive on a five-point scale. The content analysis resulted in a scheme of 49 categories as described in more detail in [14]. For the respective devices, the scheme included a number of functionalities, and four groups of non-functional features, namely portability, operation, usability, and network accessibility. We also recorded information about user satisfaction (= overall evaluation), and information about previous experience with the device and technology.

3.2.2. Results

When analyzing the content of online user reviews of mobile technology devices, we soon found that there was limited overlap between the user reviews and the suggested theory-based elements: Most of the essential theory components were hardly discussed in the reviews, including user-tasks, actual use, and impacts on task-performance. In contrast, many of the issues that were of concern to the reviewers were not part of the respective theories, such as detailed information about the technical performance of the devices. In other words, our content analysis yielded little information about behavioral aspects, such as the use and performance-related consequences of mobile technology, but provided us with a rich and detailed set of technology characteristics (technology as an object) that contributed to user satisfaction. In fact, the scheme that emerged resembled categorization schemes that have been developed by scholars of requirements engineering and usability.

We analyzed the data set with structural equation modeling, using partial least squares estimation to assess the impacts of the five factors and two control variables that were identified in the content analysis, on the overall evaluation of the mobile devices (Fig. 6). The results of the data analysis indicated that

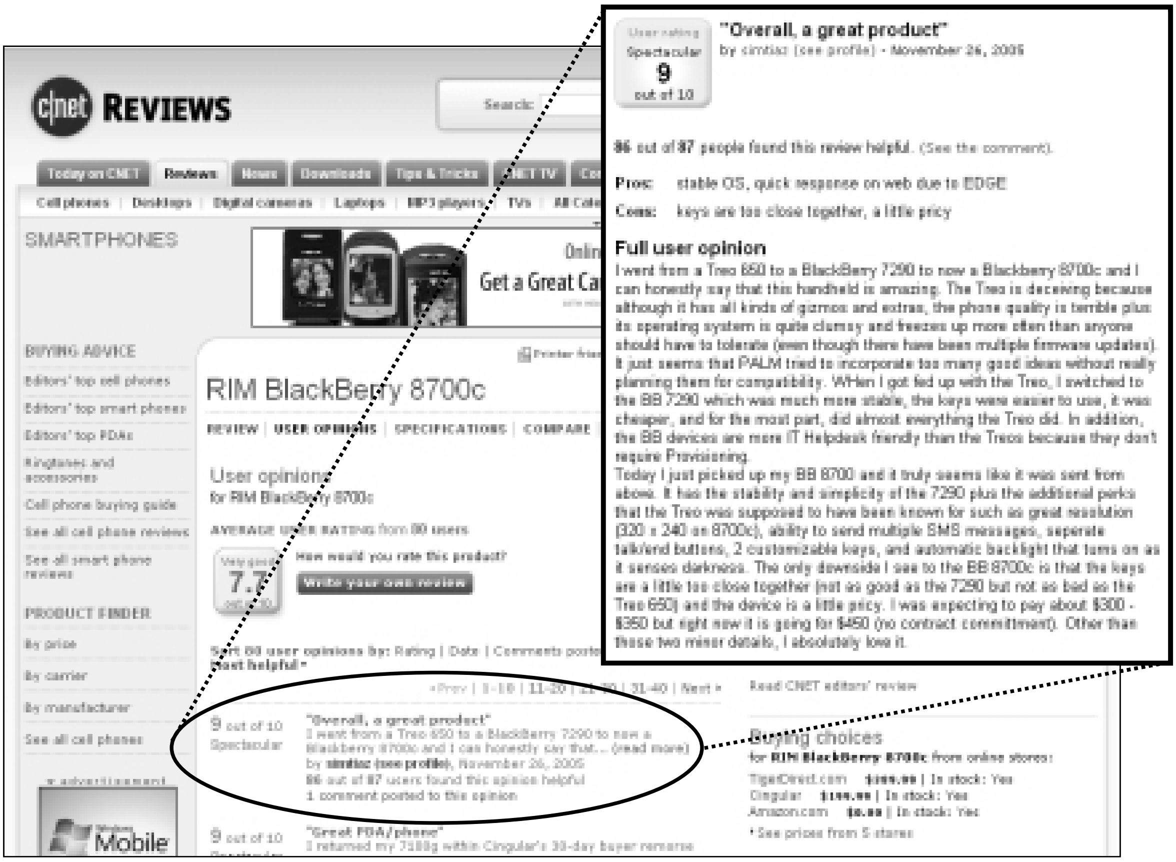

Fig. 5. Example review for study #2 (source: CNET.com).

as much as 66.2% of the variance of overall evaluation could be explained by the five factors (Fig. 6). For four of the factors, we found a significant positive relationship with overall evaluation, whereby functionality had the strongest influence on overall evaluation, followed by performance, usability, and portability. The relationship between network and overall evaluation, however, was not significant. Regarding the control variables, we found the results to vary significantly according to device, but not according to the indicated level of user experience. In particular the items associated with portability provided us with notable insights about the various use situations in which the reviewers expected the mobile devices to be available for service – an important extension of mobility construct that we applied in study #1.

3.3. Study #3: Empirical survey of mobile technology users

For study #3, we built on the insights derived in study #2 in an attempt to reconcile task-related aspects with technology characteristics, and the resulting impacts on user satisfaction [12,13]. The categorization scheme developed in study #2 provided the basis for a survey of mobile technology users that we administered in September 2006 (see Gebauer and Tang [13] for additional details about the survey, including survey questions). In this study, we were particularly interested in the associations between task profiles and the five user-indicated categories of functional and non-functional requirements

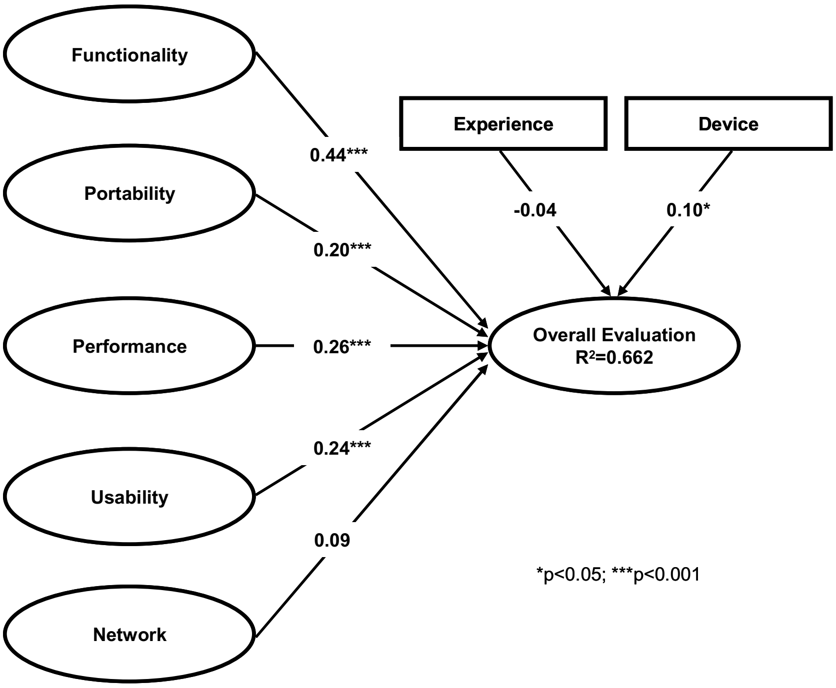

Fig. 6. Results of content analysis (study #2) (n = 144) [14].

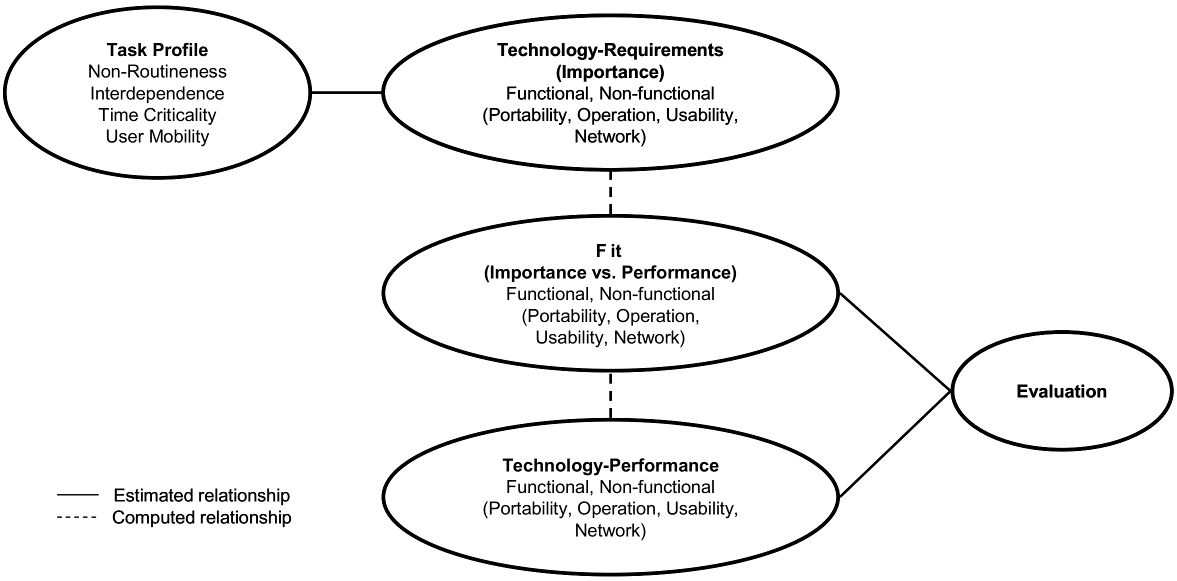

Fig. 7. Research model (study #3) [12].

that we had identified in study #2. In addition, we sought to explore the extent to which a match between user-indicated technology-requirements and user-indicated technology performance impacted user satisfaction (Fig. 7).

3.3.1. Data collection

The surveys were presented to a random sample of 2% of unique visitors at www.cnet.com. All participants were given the opportunity to participate in the drawing of a cash prize of $1,000. According to the cooperation partner who administered the survey, acceptance rates were average with about 6%, followed by a slightly lower than usual completion rate (40% vs. 50–70%), which might be attributable to the comparatively extensive length of the survey. We retained 216 qualified and complete responses from online visitors of the site who indicated to be employed, over 18 years of age, and who used a wireless device for work-related purposes. The survey data were analyzed with structural equation modeling and partial least squares estimation.

3.3.2. Results

We tested the conceptual model in two steps (see Gebauer and Tang [12] for additional details about the data analysis). First, we assessed the association between the task characteristics of non-routineness, interdependence, time-criticality, and user mobility on the one hand; and user-perceived requirements of mobile technology on the other hand. In line with the findings from study #2, user-perceived requirements were grouped into the factors of (1) functionality, including basic communication functionality, advanced data processing functionality, and leisure-related functionality (camera, video, music player); (2) portability and availability of the device in many different use-context situations; (3) operation-related features and versatility of the device; and (4) usability. Second, we assessed the extent to which a user's overall satisfaction with the devices was associated with (1) the user-perceived performance of the devices; and with (2) the extent to which user-indicated requirements differed from the user-perceived performance.

As a result of the first step in our analysis, we found that the overall the explanatory power of task characteristics for user-indicated technology requirements was limited, as indicated by the rather low R^2-values. In addition, only a small number of individual relationships were statistically significant (Fig. 8): Users who indicated their profiles to include highly interdependent tasks and users who indicated to be highly mobile also indicated the need for portable and widely available mobile technology. In addition, users who indicated their task profiles to be characterized by high non-routineness and time-criticality also indicated a strong need for highly operational and versatile technology. None of the other suggested associations was statistically significant at $p < 0.05$. In the current survey, technology functionality and usability were features that users indicated to be important *independent* of individual task profiles.

In the second step of our analysis, we found overall evaluation of the mobile technology to be explained to a large extent by a number of technology performance indicators that were most notably associated with the factors of usability, portability, and functionality, whereby the latter exhibited a negative path coefficient that was strong in particular for leisure related functionality (Fig. 9, left-hand side). In contrast to our findings in the first step of our analysis, the latent construct of operations and versatility was not linked significantly with overall evaluation of the technology. Our results become more poignant when we concentrate on the extent to which user-indicated requirements are met by the technology, and measured by the difference between actual perceived performance and stated requirements ("fit") with respect to the various functional and non-functional features (Fig. 9, right-hand side): In this case, both portability and usability have good explanatory power for overall evaluation, whereas functionality and operation have not. We also found indications of an interesting saturation effect: In situations where user-indicated requirements are lower than user-perceived performance ("under-fit"; expectations are not met) the difference between requirements and fit had significant explanatory power for overall evaluation, especially for usability-related measurement items. However, in situations where user-perceived actual performance of the technology was higher than the user-indicated requirements ("over-fit"; expectations are over-fulfilled), the link between the difference and overall evaluation was statistically insignificant.

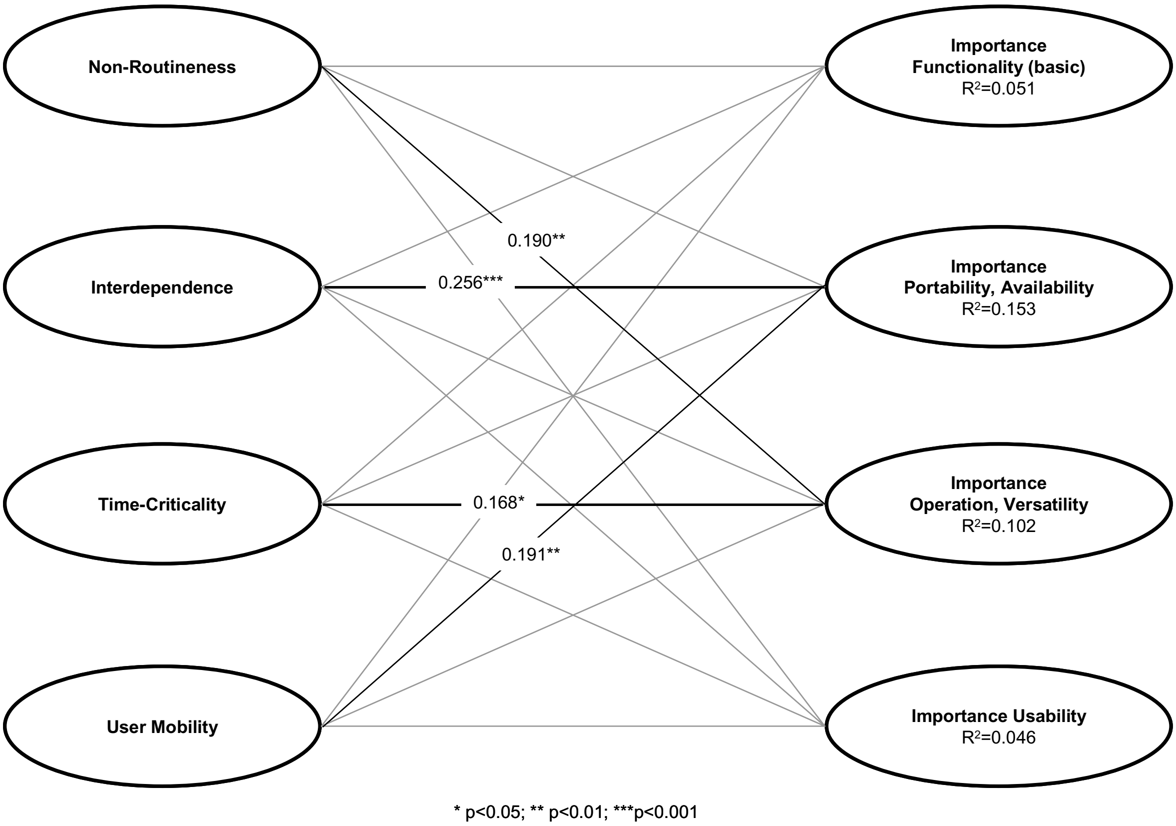

Fig. 8. Survey results (study #3): association between task profiles and user-indicated technology requirements (n = 216) [12].

3.4. Study #4: Interviews of mobile professionals

For our fourth research study, we conducted interviews with sixteen business users of mobile technology. In an effort to complement and extend our earlier studies, we hoped to obtain insights about both technology- and behavior-oriented aspects of mobile technology use. We also wanted to follow up on some of the open questions that we had identified earlier, most notably regarding the roles of user mobility and technology maturity, and the link between task profiles and technology requirements.

3.4.1. Data collection

The participants came from high-technology companies, and worked either in supervisory roles or in technical staff positions. The interviews were conducted during the summer of 2007 and included questions about the task and mobility profiles as well as the use-patterns of mobile technology, including smart phones, PDAs, and laptop computers. Again, we focused on various functions and features of the mobile devices that the participants indicated to be important as well as on the performance of the devices with respect to the functions and features. We also asked about differences in the way that tasks were performed depending on whether the user was mobile or not. Lastly, we asked the interviewees to indicate their level of satisfaction with the mobile devices they were using and the impacts of the technology on their individual performance.

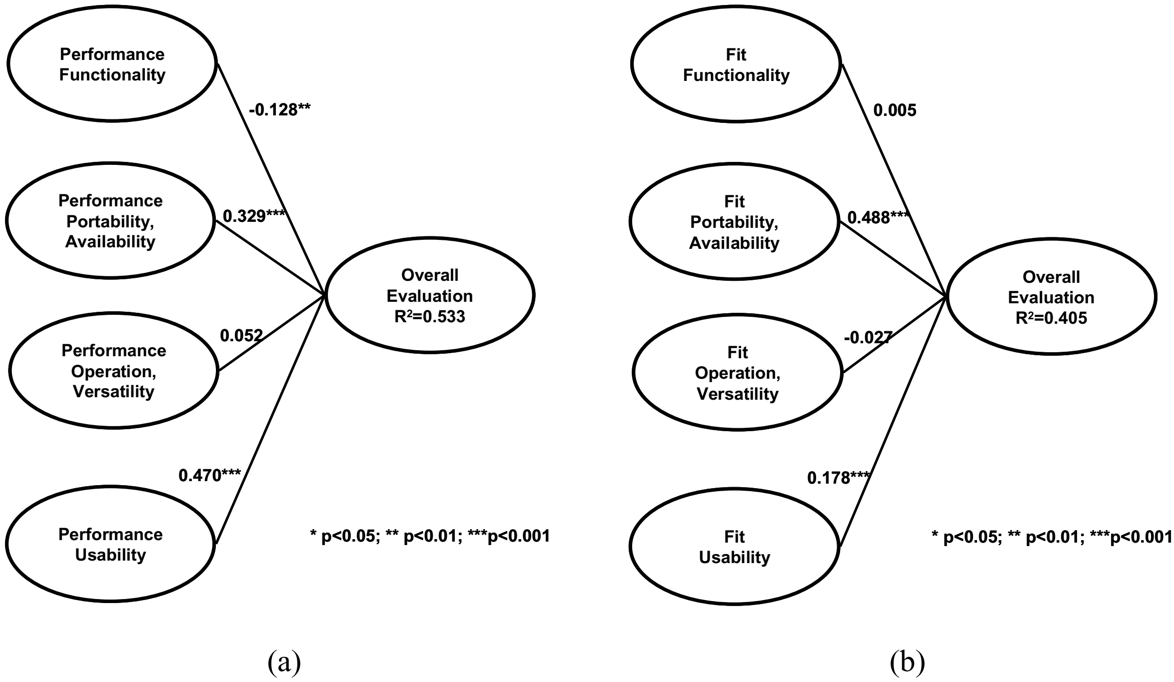

Fig. 9. Survey results (study #3) (n = 216): (a) Association between performance and user satisfaction (overall evaluation of the technology); (b) Association between the difference of indicated technology requirements and technology performance (= fit) and user satisfaction (overall evaluation of the technology) [12].

3.4.2. Results

Several findings emerged from our interviews that complement our earlier results. First, we gained additional insights about the concept of mobility. Several interviewees pointed out that mobility was not necessarily associated with specific geographical locations and long-distance movement, such as travel, but was more generally characterized by the possibility to "roam freely" during regular work hours, as well as during off-hours – all while continuously staying connected. For several interviewees, mobility included any situation where a user is away from his or her desk in a stationary office (and sometimes even situations when *at* the desk), such as meetings, commute, breaks, and when spending time at home after hours. The interviews were largely in support of earlier concepts of user mobility [24,36] and also confirmed the finding from our first study that a mobility construct that is based on travel alone is insufficient to provide insights about the technology needs of mobile professionals. Rather, mobility appears to be associated with the level of independence and flexibility that users gain with respect to any type of physical location and the possibility to change location frequently.

A consultant: "For me, mobility means the ability to work from anywhere and anytime. And when I work from home or remotely, I am not stuck to the house. The PDA gives me a lot of flexibility."

A software engineer: "At work, I have both a desktop and a laptop. I use the laptop at meetings and while changing office locations as I work at other company offices, and move around locations almost every other day. About one third of my time is spent at these meetings and different locations. I use my laptop to take notes, review documents and show people demos or data. Without the laptop it would be very difficult and inconvenient to do so."

Second, we found that users valued highly the convenience, flexibility, and timeliness that are provided by technology that is consistently available in many different use contexts. Interviewees indicated a reduction of stress just from being able to "check on things", to communicate swiftly, and to resolve issues on short notice.

A director of marketing: "One Friday night when I was out, I checked my email and found that one of the engineers had emailed me about some issues. Knowing about the message helped me to go back home, login and resolve the problems. Without the PDA I would not have known about it, so this way, I could respond and react faster."

Others, however, provided evidence for the suggested paradoxical nature of mobile technology (Arnold, 2003), as they indicated that being more accessible has contributed to an increase in workload, and at times has a negative effect on the balance of work and personal life.

Third, we found the need to keep connected to be especially strong for people with supervisory task profiles. PDAs appear to be the mobile device of choice for managers in particular.

A director of operations: "My job is very supervisory. As I am constantly delegating work when I am out of office I need to be constantly informed about the status. Without the PDA, I would have to use different devices like phones and pagers. But still I would not get email. Email is a huge deal in my job function, especially since even the pages are sent via email now."

In contrast, members of the technical staff appear to be much more willing to "let the office be", once their regularly scheduled work hours have ended, and to use laptops to support their work.

A senior software engineer: "I almost never work from home in terms of coding or my actual job. I work from home only when I have conference calls with a team in another time zone. At the most, I work from home about one to two hours a week, using a laptop."

Fourth, with respect to the functionality that mobile users value most, we found a predominant need for communication, including phone and e-mail, as well as a need for productivity tools that included scheduling functionality via a calendar, and contact management via an address book. The finding mirrors Perry et al.'s (2001) conclusion that users view the mobile phone as a versatile tool that can be used as a proxy in many different situations.

An engineering manager: "I am extremely forgetful and used to miss many meetings and tasks. It was chaos, because I was confused all the time. So, I bought the PDA specifically for this purpose. Now, I can schedule meetings and make notes more effectively. Even when I bump into somebody in the elevator and he wants to schedule a meeting, I can do that without any problem, as I have the PDA with me."

Lastly, the interviewees further confirmed the importance of portability, for example in terms of weight, size, and battery life; and usability (ease of use) that we also identified as important aspects of mobile technology in our earlier studies.

4. Conclusions

In the current paper, we have presented the results of four research studies that we conducted between 2002 and 2007 on the requirements of mobile technology in support of users who perform general business tasks. Our intention was to inform researchers and managers that are concerned with the development, implementation, and use of mobile information systems. Figure 10 provides an overview of the results as it positions the main constructs of the four studies in approximate relation with the three themes of tasks, technology and user behavior (compare with Fig. 1). In addition, we indicate with checkmarks ($\surd$) the extent to which supportive evidence for the suggested relationships was found in the various studies.

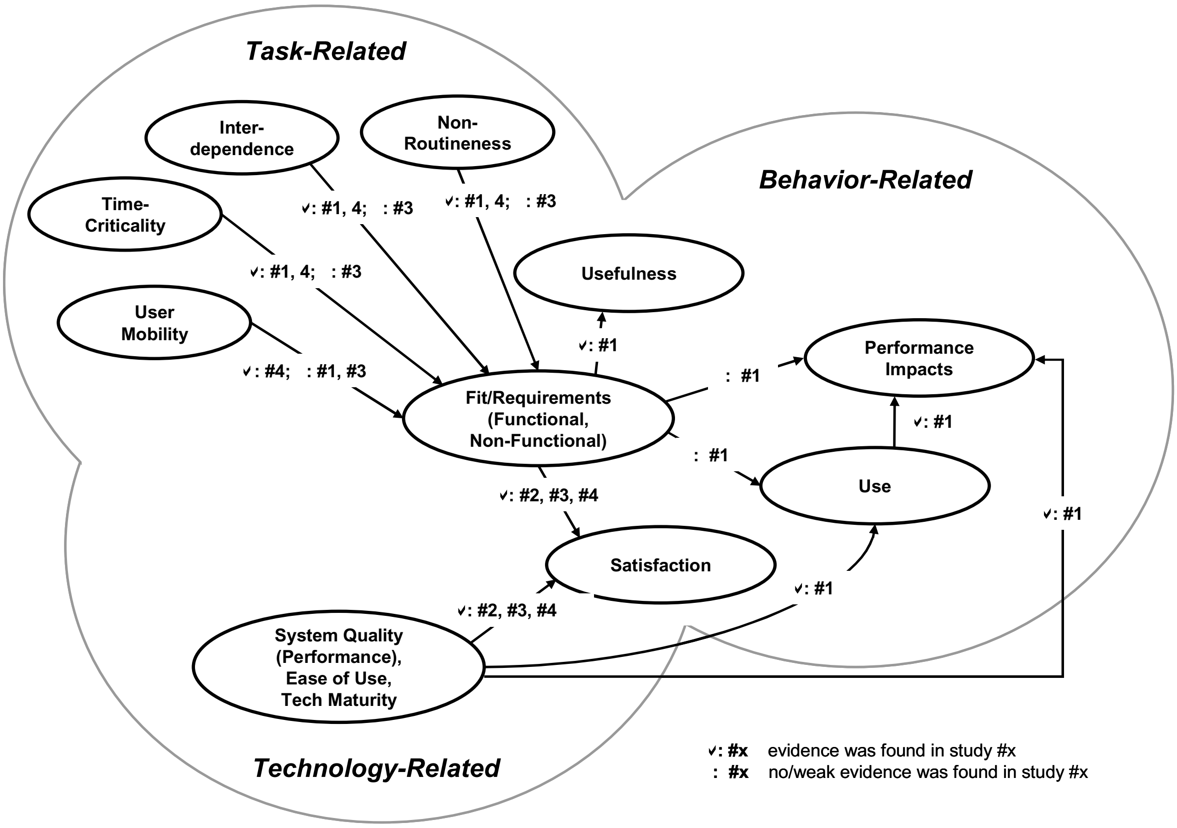

Fig. 10. Summary of results (studies #1–4).

Four findings stand out because of their statistical significance and their consistency over time. First, we found user-perceived technology maturity and system quality (technology performance) to be an important factor that can explain and predict not only the satisfaction of mobile professionals with the technology, but also its use and performance impacts. We conclude that technology providers, managers, and researchers need to take into very careful consideration the ease of use of the technology (usability), and more specifically the effort it takes a business user to set up and actually use the systems. Besides the perspective of the individual user *per se*, expectations also play a role, inasmuch as technology maturity can become a moving target that dynamically "adjusts" as the sophistication of the technology progresses.

Second, regarding the predominant technology requirements of the participants in our research studies, we found a strong need for the technology to be available in a broad variety of use-situations and contexts. The importance of portability of the devices in terms of size, weight, battery life, and availability of service independent of location was emphasized strongly and repeatedly.

Third, following the fulfillment of fundamental needs, such as ease of use and portability, straightforward communication and productivity-related functionality appear to be most valued, in particular in support of non-routine and supervisory task profiles. For many professionals, mobile technology has long become a proxy device that complements stationary office technology and that enables and possibly even deepens a high level of interdependence with team members and business partners.

Fourth, mobile technology can have considerable impacts on task procedures and job performance, but also on the personal lives of its users [1,33]. Convenience, timeliness, and flexibility are among the impacts of mobile technology that were mentioned most often by the participants in our research studies, and that lead to reported considerable increases in efficiency and effectiveness. We found an overall positive attitude of users regarding the technology-enabled blurring of the distinction between professional and personal lives. The majority of the users of mobile technology that participated in our research studies valued high the possibility to be kept "in the loop" while having the opportunity to be physically away from the office – during the work day as well as during off-hours – and be able to react flexibly and timely to important situations that may occur on short notice. Still, a smaller number of users (and non-users) voiced concerns about unwanted intrusion and added workload as a result of increasing accessibility.

Our results have implications for the behavioral and technology-oriented information system theories that provided the background for our studies. In applying TAM to mobile technology, we found that for technology that is characterized by ongoing developments, such as mobile technology, user perceptions of ease of use can have a stronger impact on adoption and use than what is typically assumed for technology that has progressed further. Similar to the situation for inexperienced users that has been examined by scholars of TAM, a situation of immature technology can bring into focus the need to carefully consider the ease of technology use, in addition to its usefulness.

Regarding TTF, we found the theory to be generally applicable to mobile technology insofar as a presumed need for mobile technology appeared to be associated significantly with user-expected usefulness of mobile email applications. We were surprised however, to find limited empirical support for the suggested links between task-technology fit and actual use and performance impacts. Our conclusions are two-fold: First, we found evidence for subtle changes in the way that tasks are performed in mobile versus non-mobile use environments. As some researchers have pointed out before us [28], mobile technology is often used as a proxy to complement more stationary technology. In a mobile use environment, the strongest needs appear to be for basic communication (phone, email) and productivity support (scheduling, contacts), rather than for more complex applications that would be appropriate to perform "back in the office" [24,33]. Second, we found a need to include into the analysis non-functional features, such as usability, portability and availability, in addition to functionality that has typically been the main focus of scholars of TTF.

We found categorization schemes and frameworks that have been developed by scholars of requirements engineering and usability to provide useful starting points for the exploration of the needs of a mobile workforce. In particular, the characterization of technology based on functional and non-functional features proved helpful to assess the suitability of mobile technology for use in many different contexts. In line with other scholars, such as Benbasat and Barki [2], and Wixom and Todd [34], we suggest the need for a thorough and explicit integration of elements from technology-oriented research disciplines, such as requirements engineering and usability, with elements from behavioral theories, such as TAM and TTF, when seeking to explain the use and impacts of *novel* applications, such as the ones based on mobile technology.

Important research opportunities remain in order to develop a deeper understanding about the needs of a mobile workforce and in order to more fully realize the benefits that are expected from the use of mobile technology. We see a need to assess in more detail the subtle changes that occur when users start to adapt their work-related tasks to mobile environments [36]. In addition to the need to understand changes in the way that mobile individuals perform their tasks, it will be important to assess changes that relate to the interactions between the mobile professional and other members of a work-team, including changes in the way that assignments are shared and allocated [24]. We also found a need to assess in more detail the aspect of user mobility and its various implications for technology requirements. Mobility appeared to be a complex and multi-dimensional construct that needs to be explored in greater depth before a mobile workforce can be supported most effectively with novel technology [20].

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