TOWARDS EMPIRICALLY VALIDATED UBIQUITOUS INFORMATION SYSTEMS: RESULTS FROM A PRETEST AND THREE EMPIRICAL STUDIES

Kowatsch, Tobias, Institute of Technology Management (ITEM-HSG), University of St.Gallen, Dufourstrasse 40a, CH-9000 St.Gallen, Switzerland, tobias.kowatsch@unisg.ch

Maass, Wolfgang, Chair in Business Administration esp. Information and Service Systems, Saarland University, 66123 Saarbrücken, Germany, wolfgang.maass@iss.uni-saarland.de

Abstract

Research on ubiquitous information systems (UIS) has recently gained attention in the IS community. But dedicated empirical instruments that are robust and capture individual characteristics of UIS are still missing. A rather new empirical construct derived from Task-Technology Fit theory was proposed and denoted as Situation-Service Fit (SSF) (Maass et al., 2012). This paper shows how SSF can be used within the Situational Design Method for IS, a design method tailored to UIS. For this purpose, the SSF instrument is first tested for face validity as well as discriminant and convergent validity. Then, SSF is evaluated as a predictor variable of behavioral intentions to use services that are embedded in UIS. Hereby, also discriminant validity of SSF with regard to perceived usefulness and perceived ease of use is assessed. For this purpose, data from a four-year EU project is used, which includes a pretest and three empirical user studies. Results show that SSF can be a significant predictor of service usage. However, validity issues still exist and thus, further research on the SSF instrument is recommended.

Keywords: Ubiquitous Information System, Design Method, Situation-Service Fit, Empirical Study, Instrument evaluation.

1 Introduction

One of the core research activities of the Information Systems (IS) community during the last forty years is the investigation into the "effective design, delivery, use and impact of information technology in organizations and society." (Avison and Fitzgerald, 1995, p. xi) Accordingly, the core objective of IS research is to increase the efficiency of business organizations (Hevner et al., 2004). In contrast to the more traditional IS in the organizational context and during the last two decades, however, information and communication services have become ubiquitous in our everyday life: "always-on" Internet-connected mobile phone for electronic commerce activities (Frolick and Lei-da-Chen, 2004; Mennecke and Strader, 2002), a radio-frequency enhanced lift ticket (O'Connor, 2008) or a Wi-Fi enabled refrigerator with a digital shopping list and calendar functionality[1]. These kinds of applications have been discussed under umbrella terms such as ambient intelligence (Keegan et al., 2008), experiential computing (Yoo, 2010), internet of things (Fleisch and Mattern, 2005; Floerkemeier et al., 2008), nomadic computing (Lyytinen and Yoo, 2002b), pervasive computing (Hansmann et al., 2012; Orwat et al., 2008), smart products (Thiesse and Köhler, 2008), ubiquitous computing (Cousins and Varshney, 2009; Lyytinen and Yoo, 2002a) or ubiquitous information systems (Vodanovich et al., 2010). All of these terms can be traced back to the seminal article entitled "The computer for the 21st Century" by Mark Weiser (Weiser, 1991). Since the current work is written predominantly for the IS community, the term ubiquitous information system (UIS) is adopted. In line with prior work, UIS is defined as a composite of people, processes, information and communication services embedded in hardware that is interconnected and interwoven into our lives (Vodanovich et al., 2010).

Computer scientists have successfully set up rather technical conferences on UIS such as the IEEE PerCom or ACM UbiComp. A few prominent topics at these conferences are devices and infrastructures, adaptive, autonomic and context-aware computing systems or the use of radio-frequency identification in pervasive systems. IS researchers, on the other hand, are rather interested in the socio-technical aspects of information systems. That is, they focus predominantly on the impact of technology on organizations or individuals. However, the IS community has rather slowly adopted research on UIS over the last two decades even though research opportunities exist to a great extent (Yoo, 2010). For example, only few articles and research commentaries can be found in top IS journals (e.g. Lyytinen and Yoo, 2002b; Vodanovich et al., 2010; Yoo, 2010).

Questions arise therefore whether UIS are distinct from traditional IS in organizations and, if so, whether they demand investigation with native research instruments. We will address both questions with the following four dimensions proposed by Vodanovich et al. (2010): (1) Context: work versus home, (2) Activity: professional versus personal, (3) User: digital immigrant versus digital native and (4) Technology: traditional versus ubiquitous. First, UIS are not restricted to traditional (business) organizations anymore but consider individuals or groups being at home, in the shopping mall, with friends at a party or on vacation. The context of UIS use is therefore extended from the traditional office environment to non-office and home environments. Second, activities supported by UIS include not only professional tasks such as managing customer requests, issuing invoices or writing business emails but also personal activities like meeting friends or personal shopping. Third, the user has changed over the last two decades. Digital natives, which are people that grew up with digital technology from the very first days of their lives, have adopted different behavioral patterns while using ubiquitous technologies than those digital immigrants that were born a generation before (Prensky, 2001). For example, using Facebook or Foursquare[2] on mobile devices at any time and in any place is perceived as natural for digital natives whereas at least digital immigrants without a strong technical background are required to change their traditional approach towards office computing or personal

[1] http://www.samsung.com/us/appliances/refrigerators/RF4289HARS/XAA
[2] https://foursquare.com/about/new

computing if they want to benefit from UIS. Finally, ubiquitous technologies are described as “hardware such as tabs, pads, boards, dust, skins, and clay that are interconnected and interwoven into the very fabric of our lives through ubiquitous networks.“ (Vodanovich et al., 2010, p. 713) By contrast, system consists of “people, processes, information, and communication systems and technologies.” (ibid.) UIS are therefore systems that embed ubiquitous technologies to support individuals or groups whereas computer systems such as desktop computers require users to actively approach and sit down at those kinds of traditional systems. UIS differ also in form, size and appearance from traditional systems such as desktop computers.

In summary, there is a fundamental need to better understand the design, deployment, use and impact of UIS. As a first step, this work focuses on the design of empirically validated UIS and is guided by the general research question: How can UIS be evaluated rigorously? This question will be answered with findings from an empirical instrument evaluation test and three evaluations of one particular UIS. The remainder of this work is structured as follows. Next, related work on a design methodology tailored to UIS as well as existing IS evaluation instruments are provided to frame the current work. Then, particular research questions are stated and it is outlined by which methodological approach they are addressed. Afterwards, the research questions are answered by discussing how UIS design artifacts of different levels of abstraction can be evaluated empirically. In particular, findings from a pretest and three empirical studies are reported and interpreted. Implications of these findings and limitations of the current work are then discussed from which an outlook on future research is derived.

2 Related Work

2.1 Situational Design Method for IS (SiDIS)

Designing UIS requires a common understanding of the involved stakeholders. For that purpose, models can be used which are abstractions of the real world (Maxim, 1999). They help to better understand what a particular UIS is all about, i.e. how it works, what information it requires and processes, which persons are supported by it and finally, which services are embedded into which sort of physical objects (e.g. tablet PC, furniture or other kinds of everyday objects). Depending on the level of abstraction, UIS can be modeled by narratives (i.e. textual descriptions), conceptual models, mock-ups or prototypes, all of which can be empirically evaluated at different kinds of stages of development.

In order to design UIS, the transitions from high-level abstractions (e.g. narratives) to more concrete forms of UIS representations (e.g. mock-ups or prototypes) should rely on justified design decisions. For this purpose, several methodologies currently exist, in particular from the engineering and computer science disciplines that guide the design process of information systems. Those methodologies usually include several steps such as problem definition, requirements engineering, formal system design, technical architecture, prototyping, implementation, testing, deployment and maintenance. Examples are the waterfall model or the rational unified process (Larman and Basili, 2003).

With regard to UIS, twelve design methodologies for IS according to relevant design principles were reviewed and, due to a lack of coverage of these principles, the Situational Design Method for IS (SiDIS) was proposed (Janzen et al., 2010; Maass and Janzen, 2011). SiDIS consists of four phases: (1) identification of the problem and needs, (2) design of the solution, (3) development of the solution and (4) evaluation of the solution. At its core, this methodology guides the design process from a highly level of abstraction of UIS representations to more concrete representations as described above. It also requires developers to build and continuously evaluate UIS representations. Thus, build and evaluate loops as proposed in design science research (Hevner et al., 2004; Peffers et al., 2007) are an integral part of each phase of SiDIS. That is, the primary objective of the design activities in each phase is the development of empirically justified artifacts. Examples are narratives, diagrammatic models, virtual or real mock-ups, prototypes or, UIS solutions that are ready to be deployed in the market. An overview of SiDIS is presented in Figure 1. In order to better understand the various design phases in which UIS can be evaluated, the current work refers to SiDIS to address its research questions.

Phase	Activity	Artifact		Evaluation
1. Identification of the Problem and Needs	Build & Evaluate	Problem descriptions		Workshops
2. Design of the Solution	Build & Evaluate	 Narrative	 Mock-up	Lab studies
3. Development of the Solution	Build & Evaluate	Propositional conceptual models, technical artifact		Engineering test methods
4. Evaluation of the Solution	Build & Evaluate	 Prototype / Solution		Lab studies Field studies

Figure 1. Overview of the Situational Design Method for IS (SiDIS)

2.2 IS Evaluation Instruments

The IS community traditionally performs empirical studies in the context of (business) organizations. One of the research questions is usually: What are the success factors of IT use? Two streams of research have primarily influenced these empirical studies. First, research on diffusion of innovations (Rogers, 2003) takes a social science perspective into account and argues that perceived characteristics of innovations, e.g. relative advantage, trialability, observability or compatibility, predict their adoption (Moore and Benbasat, 1991). Second, theory of reasoned action (Fishbein and Ajzen, 1975) and its successor, the theory of planned behavior (Ajzen, 1991), have been adopted by IS researchers from the field of social psychology. These theories describe attitudes, beliefs and perceived constraints that influence the behavior of individuals. In particular, the behavioral intention to use IT and actual (continuous) IT use are here the dependent variables in question.

Based upon these research streams, empirical models have been proposed and tested. Examples are the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), UTAUT2 (Venkatesh et al., 2012) or the (Updated) DeLone and McLean models of IS success (DeLone and McLean, 1992; DeLone and McLean, 2003). One of the more widely used empirical models is the Technology Acceptance Model (TAM) (Davis, 1989). It states that perceived usefulness and perceived ease of use predict IT use through behavioral usage intention as mediating factor. TAM was developed in the organizational context and thus, scale items include terms like *useful in my job* or *my effectiveness on the job*. That is, TAM is used to evaluate IS artifacts that support well-defined tasks.

By contrast, it is argued that UIS-specific constructs are required to capture dedicated situational characteristics that are often unpredictable and not well defined (Maass and Janzen, 2011; Maass et al., 2012). Accordingly, Maass et al. (2012) proposed the Situation-Service Fit (SSF) item for the evaluation of UIS, which is defined as "a perceived degree of match between a service and a situation." The following three dimensions complement the definition of this overall SSF item:

- *Behavior-Service Fit* is the degree to which an individual believes that a particular service is compatible with his or her own behavior.
- *Modality-Service Fit* is the degree to which a person believes that a service supports him or her in a feasible way of providing information (e.g. in the form of text, audio or video) and interacting with information (e.g. text, gestures or speech) according to a given situation.

- *Spatial-Service Fit* is the degree to which a person believes that the point of presentation or interaction with a particular service fits a particular situation.

3 Methodology

Up till now, existing work of the co-authors (Maass et al., 2012) has only reported descriptive statistics and one-sample t-tests of the SSF items and thus, it is still open how UIS can be evaluated rigorously. In particular, it is relevant to know (1) whether SSF shows construct validity, convergent validity and discriminant validity, (2) how SSF is used within the SiDIS design process and (3) to which degree SSF influences intentions to use UIS services. The rest of this section therefore aims at answering these questions as follows.

1. Testing construct validity, discriminant and convergent validity of the SSF instrument
   a. by a pretest in section 3.1 and
   b. by factor analyses with data from two empirical studies in sections 3.3 and 3.4.
2. Showing how SSF is applied in SiDIS by three empirical studies in sections 3.2, 3.3 and 3.4.
3. Using multiple regression analyses to test whether SSF influences the intention to use one particular UIS service with data from two empirical studies in sections 3.3 and 3.4.

3.1 Pretest: Item sorting

The objective of this pretest is to ensure construct validity, convergent validity and discriminant validity of the SSF construct. Consistent with prior work (Moore and Benbasat, 1991), an item sorting task was performed. For that purpose, four SSF items, four perceived usefulness items and four perceived ease of use items were used (cf. appendix). Two doctoral students, two research assistants and two master students from an IS department of a European University were asked to sort the twelve items into two to five categories. After they had finished this sorting round, they had to give their categories a concrete name, too. Overall, this pretest was done individually by each participant and took twenty minutes on average.

As a result of this item sorting task, participants have named the categories as follows: *raise of efficiency*, *usefulness*, *utility* and *effects on me* for the perceived usefulness items; *understandability*, *ease of use*, *handling* and *usability* for the perceived ease of use items; and finally, *adaptation*, *fit*, *service and situation*, *correct situation* and *contextualization* for the SSF items. Because the proposed names show face validity as they represent various dimensions of the theoretical constructs in question, it can be assumed that the new SSF items support construct validity.

A further indicator of construct validity can be obtained from the item placement ratios as shown in Table 1. These ratios were calculated from the sorting task and are used to demonstrate convergent validity with the underlying theoretical construct and discriminant validity with the other constructs. Results indicate that the overall hit ratio lies by over 95 percent. That is, most items have been placed into the theoretical correct category as shown by the diagonal values. Only one time, an SSF item was assigned to the perceived usefulness construct which shows excellent convergent and discriminant validity.

In order to test inter-rater reliability, the raw agreement was used as well as the more rigorous Cohen's Kappa (Cohen, 1960), which also considers the likelihood that subjects assign items into correct categories incidentally. Both measurements range between zero (no agreement) and one (full agreement). The average agreement scores for all 15 pairs resulted in viable .92 and a standard deviation of .08 for the raw agreement and remarkable .88 and a standard deviation of .13 for Cohen's Kappa.

In summary, results show good reliability such that construct validity, convergent validity and discriminant validity of the SSF construct are assumed.

	Actual					
Theoretical	PU	PEU	SSF	N/A	Total	% Hits
Perceived Usefulness (PU)	23	0	1	0	24	95.8
Perceived Ease of Use (PEU)	1	23	0	0	24	95.8
Situation-Service Fit (SSF)	0	1	23	0	24	95.8
				Total Item Placements	72	
				Hits (diagonal values)	69	

Table 1. Item placement ratios

3.2 Study 1: Evaluation of a UIS Narrative

The first empirical evaluation was conducted in the second phase of SiDIS, i.e. design of the solution. Accordingly, problem descriptions have been already identified in the first phase of SiDIS and were now transformed into narratives. Narratives are UIS representations in form of textual descriptions of everyday situations. An example would be the following narrative that describes the weather information service as part of our case study, too:

> *Anna gets site-specific weather information when she is brushing her teeth in the bathroom. Based on weather information and her calendar, free-time event suggestions are given, e.g. Today, 8 p.m. — Sneak Preview at CinemaOne. Do you want to order tickets? (Janzen et al., 2010)*

By rating twelve preliminary narratives, Study 1 had the objective to identify the most relevant of them for further development. This study was also the first that used an early version of an SSF item. The item wording was *the bathroom situation would fit very well into my private life*. Overall, 46 subjects from Germany (N=22, students and university staff from two computer science departments), Switzerland (N=13, doctoral students of an IS department) and Turkey (N=11, students from a computer science department) evaluated each narrative by indicating their consent with that item on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). The SSF item was used exclusively in this study rendering the situation as such and, implicitly, the individual behavior of the user as the only evaluation criteria.

However, subjects were not able to appropriately evaluate narratives with this item. That is, narratives, like the one presented above, might contain several services that subjects evaluate differently. In the worst case, the perceived degree of fit of service A would be very high whereas perceived fit of service B would be the opposite. As a result, subjects are indifferent rendering narratives neither positive nor negative. At the end, service A would have no chance to be considered for further development. Based on this observation, the following three guidelines are given for future evaluation of narratives:

- **Decompose narratives:** A narrative can be decomposed into a single-service narrative and evaluated with the SSF item. The drawback would be, however, to lose the stickiness of more complex situations we face in our everyday life.
- **Evaluate each service as such relative to the whole situation:** The SSF items of the pretest are appropriately designed such that narratives are not holistically evaluated. The drawback, however, is that each service embedded in a narrative would require an individual item. Thus, this approach results in an overall longer evaluation instrument that researchers have to cope with.[3]

[3] Nevertheless, this guideline was adopted for the mock-up-based evaluation in Study 2 and the prototype-based evaluation in Study 3 (cf. sections 3.3 and 3.4).

- **Systematically manipulate service configurations:** First, narratives should be created with different services configurations. Then, conjoint analysis can help to identify the most relevant service configuration by comparisons. For the comparison procedure, SSF statements can be used. The drawback here is that the planning phase of the evaluation is more complex.

As a general guideline at this stage of UIS designs, it is recommended that Situation-Service Fit and Situation-Behavior Fit of SSF are used. That is, because narratives do explicitly not provide any cues on technical details which subjects would require to appropriately rate services with the remaining two SSF dimensions Modality-Service Fit and Spatial-Service Fit.

In summary, SSF can be used to evaluate and identify relevant services that are embedded in everyday situations based upon a pool of preliminary narratives. However, researchers should consider the guidelines and drawbacks described above.

3.3 Study 2: Evaluation of a UIS Mock-up

The second empirical evaluation was also part of the second phase of SiDIS. But in contrast to Study 1, subjects had to evaluate only the top rated bathroom situations from Study 1. And compared to narratives, a mock-up including supplementary slides on a laptop represented the UIS now. The mock-up was a paper-based miniature of a bathroom with dolls whereas more detailed information about the services was provided by the slides (cf. Figure 1).

The objective of this sort of study is to add validity to the findings of Study 1 and to further reduce the amount of relevant bathroom situations in order to handle the rather expensive third phase of SiDIS, i.e. development of the solution. Various empirical constructs such as perceived usefulness (PU) or the intention to use a particular service were used for that purpose. Seven-point Likert scales from strongly disagree (1) to strongly agree (7) were used. This study was also the first that employed Behavior-Service Fit (BSF) and thus, compared to Study 1, narratives as such were not target of investigation anymore. Overall, 111 subjects were recruited from the same universities as for Study 1, i.e. they came from Germany (N=63, students and university staff from two computer science departments), Switzerland (N=36, doctoral students of an IS department) and Turkey (N=12, students from a computer science department).

Regarding the current work, data of the weather information service from Study 2 is now used to test convergent and discriminant validity of BSF. Because perceived ease of use was excluded from the study due to the non-functional mock-up-based representation of situations, only three PU items adapted from (Wixom and Todd, 2005) were used for this test. Consistent with prior work (Moore and Benbasat, 1991), confirmatory factor analysis with principal components extraction and varimax rotation was performed. With a value of .644, the Kaiser-Meyer-Olkin criterion indicates a mediocre measure of sampling adequacy (Hutcheson and Sofroniou, 1999). The first factor with an eigenvalue of 2.6, interpreted as PU, explains 65.3% of the variance whereas the second factor, interpreted as BSF, adds 22.9% of explained variance. However, with an eigenvalue of .917, the second factor lies slightly below the Kaiser criterion of one, a cut-off criterion which often overestimates the number of factors (Lance et al., 2006). Consistently, parallel analysis (Horn, 1965) confirms a one-factor solution.[4] In addition, the PU3 item loads clearly on the second factor as shown in Table 2. This is confirmed by reliability analysis, as Cronbach's Alpha (Nunnally, 1967) would increase from .82 to .91 if PU3 is dropped. It is assumed that there exists a problem with regard to the convergent validity of the PU scale and thus, PU3 is dropped from further analysis. After elimination, convergent and discriminant validity of the PU items and SBF items can be assumed by interpreting the values after the slash of Table 2 and taking an artificial two-factor solution for granted at this preliminary stage of research.

[4] https://people.ok.ubc.ca/brioconn/nfactors/rawpar.sps was used with SPSS 20.0.0.1 and raw data permutation.

With the two factor values from the second factor analysis, it was then evaluated to which degree BSF influences the behavioral intention to use the weather information service relative to PU. Multiple regression analysis was used for that purpose. Results indicate that with a score of .519 adjusted R Square is significant at the .001 level. Both variance inflation factors (VIFs) (Backhaus et al., 2006) are one indicating that multi-collinearity can be neglected. Furthermore, both factors have a significant relationship with the dependent variable at the .001 level. However, standardized beta coefficients show that the BSF factor is quite more relevant with .689 than the PU factor with a score of .235. All in all, it can be assumed in the context of this study and within the logic of TAM that the effect of SBF on behavioral intentions of service usage is by far more relevant than the effect of PU.

Item	Factor 1	Factor 2
PU1: Using [service] would enhance my effectiveness*	.92 / .94	.26 / .20
PU2: Using [service] would enhance my efficiency*	.93 / .94	.21 / .17
PU3: Using [service] would be useful for me*	.33 / —	.85 / —
BSF: Using [service] would fit very well to my behavior*	.14 / .19	.92 / .98

*Table 2. Rotated factor matrix before / after dropping PU3 (N=111). Note: * in the bathroom*

3.4 Study 3: Evaluation of a UIS Prototype

The third empirical evaluation was part of the fourth phase of SiDIS, i.e. evaluation of the solution. In this study, situations and services from Study 2 have remained the same due to the fact that particular services were top rated throughout all situations. But in contrast to Study 2, the situations were now evaluated based on a prototype that has been developed during the third phase of SiDIS (cf. Figure 2). That is, an interactive service-enhanced bathroom represented the UIS. The objective of this study was therefore to add external validity to the findings from Study 2 and to capture detailed requirements for a refined UIS version. This study was also the first in which all four SSF dimensions were used together with the TAM constructs. In detail, Modality-Service Fit (MSF) and Spatial-Service Fit (SPSF) were used in addition to Behavior-Service Fit (BSF) and Situation-Service Fit (SSF), because services were implemented physically and subjects were now able to rate these dimensions. Because the prototype of the interactive bathroom was only built up in Germany only, 27 students from a computer science department of a German University) evaluated the weather information service.

To be consistent with Study 2 while testing discriminant validity and convergent validity, confirmatory factor analysis was used with principal components extraction and varimax rotation with the PU items and the SSF, BSF, MSF and SPSF items as shown in Table 3. But now the analysis resulted in a three-factor solution based on the Kaiser criterion, i.e. with eigenvalues greater than one.[5] The Kaiser-Meyer-Olkin measure of sampling adequacy yielded a middling value of .729. The three factors explained 42% (interpreted as PU), 16% (interpreted as composite of MSF and SPSF) and 14% (interpreted as SSF) of the variance. Moreover, BSF loads clearly on the PU factor. It thus becomes apparent that the SSF, BSF, MSF and SPSF items do not show convergent validity and discriminant validity based on this data. Because only SSF, MSF and SPSF are distinct from PU, BSF was dropped for further analysis. The resulting factor loadings are shown in Table 3 after the slash.

Then the effects of PU and the remaining three SSF items on the behavioral intention to use the weather information service were tested with multiple regression analysis. For that purpose, PU items were aggregated because of their high internal consistency (Alpha = .84) whereas the SSF, MSF and SPSF items were taken separately into account because of the results of factor analysis and their low

[5] It must be noted that a comparison with the results from parallel analysis (cf. section 3.3 for further details) revealed a one-factor solution as in Study 2. Thus, the results must be interpreted carefully.

internal consistency (Alpha = .29). Adjusted R Square is significant at the .001 level and yields a relatively high value of .634. All VIFs lie between 1.0 and 1.1 indicating that multi-collinearity can be neglected. With .721 the standardized beta coefficient of PU is significant at the .001 level. Only the coefficient of the SSF item is also significant at the .05 level with a value of .305. This shows surprisingly and in contrast to the results of Study 2 that PU explains more variance on behavioral usage intentions than the SSF item.

Construct / Item	**Factor 1**	**Factor 2**	**Factor 3**
Perceived Usefulness (PU)			
PU1: Using [service] * would increase my effectiveness.	.79 / .79	-.25 / -.31	.16 / .21
PU2: Using [service] * would increase my efficiency.	.92. / 93	.13 / .08	-.14 /-.11
PU3: Using [service] * would increase my overall performance.	.72 / .77	.34 / .26	-.09 /-.11
PU4: I would find the [service] useful *.	.80 / .82	.17 / .13	.07 / .09
Situation-Service Fit			
SSF: [service] fits well to the situation I just played through.	.11 / .10	.06 / .06	.94 / .92
BSF: Using [service] * would fit well to my behavior.	.73 / —	-. 07 / —	.32 / —
MSF: The modality of content presentation fits well to [service].	.35 / .34	.65 / .68	-.21 / -.30
SPSF: The spatial placement of the contents fits well to [service].	-.15 /-.09	.84 / .81	.25 / .31

*Table 3. Rotated factor matrix before / after dropping BSF. Note: * in the bathroom*

4 Implications, Limitations and Future Research

Table 4 depicts the overall results with regard to the research questions stated in section 3. Results indicate that the application of SiDIS and the empirical data of the pretest and the three studies are generally helpful for answering the research questions. However, with regard to the results addressing the first and third question, current findings must be perceived as preliminary because they are not completely consistent with each other. Three reasons might be relevant for the interpretation of these inconsistencies and the discussion of corresponding implications.

First of all, individual subjects of the pretest and the three studies were not held constant. Thus, the participants differ in age, educational and cultural background. This is also one of the primary limitations of the current work. With this explanation, the inconsistencies with regard to the first research question (pretest versus Study 2 and Study 3) and the third research question (Study 2 versus Study 3) can be probably explained.

Second, validity issues might be further reasons for the inconsistencies of the results. Although the pretest has clearly indicated that SSF shows construct validity (being aware that participants of this pretest were rather semi-professionals in the IS field), convergent validity and discriminant validity when compared to perceived usefulness and perceived ease of use, the factor analyses of Study 2 and Study 3 have revealed that (1) eigenvalues of the extracted factors must be interpreted carefully, (2) BSF as one dimension of the SSF construct overlaps with perceived usefulness and (3) MSF loads on the same factor as SPSF. Whereas the former result indicates that BSF might be a relevant predictor of perceived usefulness (Benbasat and Barki, 2007), the latter result indicates the existence of a subgroup of the SSF construct, which could be termed as interaction-service fit because these items evaluate the modality, i.e. how to interact with UIS services, and the spatial placement, i.e. where to interact with UIS services.

And a third reason for the inconsistencies might be the different levels of abstractions of the UIS representations. That is, the narratives used in Study 1 are more abstract and focus rather on the quintessence of a UIS compared to Study 3, in which the participants could actually experience the UIS and interact with it. As a result, it is assumed that different conceptual models of the UIS were constructed in the mind of the subjects, which had, in turn, an influence on their evaluations. However, it would be interesting to assess the predicting value of relevant constructs of mock-ups compared to prototypes of UIS, which addresses in particular the third research question. Given a comparable sample of subjects and comparable correlations between the SSF construct and behavioral intentions to use UIS services for both mock-up-based and prototype-based evaluations, the design of UIS could be conducted under rather low-budget conditions and would therefore foster the design of UIS in general. That is, mock-ups and their evaluations would have a high predictive value or, in other words, would be cost-efficient and high approximations of the real UIS. Future research should therefore address this research topic in the context of UIS, also because it as it has been already done for more traditional information systems in the past (e.g. Davis and Venkatesh, 2004).

Research Question	**Data from**	**Pretest (N=6)**	**Study 1: Evaluation of narratives (N=46)**	**Study 2: Evaluation of a mock-up (N=111)**	**Study 3: Evaluation of a UIS prototype(N=27)**
1.	Is Situation-Service Fit (SSF) a valid construct?	✔ Item sorting	n/a	(✔) Factor analysis – but: overlapping with perceived usefulness	
2.	How can SSF be applied in the SiDIS design process?	n/a	✔ Identification and evaluation of relevant services and situations for the design of UIS		
3.	Is SSF a relevant construct for the adoption of UIS?	n/a	n/a	✔ Regression analysis	(✔) Regression analysis

Table 4. Research questions and results of the current work.
Note: ✔ =yes, (✔) =preliminary yes further / future research

In order to crosscheck the inconsistencies described above, the current analyses should be repeated with further UIS services. Empirical data of subjects that participated from different European countries should be also individually analyzed to account for any cultural bias. Special consideration must also be given to predicting factors of behavioral usage intentions. Based on the results of Study 2 and 3 it is assumed that subjects' evaluations and preferences may change with the target of investigation, be it a mock-up or a prototype. Thus, further empirical studies and analyses are required first. If the findings are then still inconsistent, a rigorous instrument development process should be performed for the four SSF dimensions. Prior work can guide this process (Davis, 1989; Moore and Benbasat, 1991). However, research on UIS probably requires an adaptation of the development methods for evaluation instruments. That is, the complexity of everyday situations and UIS services that support not only individuals but also groups should be considered as well.

All in all, findings from the Pretest as well as Study 1 and Study 2 are promising in the sense that UIS require dedicated instruments that might overrule traditional predictors of IS use such as those antecedents of TAM. In line with all the applications introduced at the beginning of this paper, it is therefore strongly recommended to investigate further into the individual characteristics of UIS.

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Appendix – Items of the Pretest

Perceived Usefulness (PU) Items were adapted from Davis (1989) and Wixom and Todd (2005).

- PU1: Using this service in the bathroom increases my effectiveness.
- PU2: Using this service in the bathroom increases my efficiency.
- PU3: Using this service in the bathroom increases my overall performance.
- PU4: I find this service useful in the bathroom.
-

Perceived ease of use (PEU) Items were adapted from Davis (1989) and Wixom and Todd (2005).

- PEU1: Using this service is easy for me.
- PEU2: My interaction with this service is clear and understandable.
- PEU3: Learning to use this service is easy for me.
- PEU4: It was easy for me to become skillful at using this service.
-

Situation-Service Fit (SSF) Items were adapted from Maass et al. (2012).

- Situation-Service Fit: This service fits well to the situation.
- Behavior-Service Fit: Using this service in the bathroom fits well to my behavior.
- Modality-Service Fit: I find that the modality of content presentation fits well to the service.
- Spatial-Service Fit: I find that the spatial placement of the contents fits well to this service.