A Qualitative Review of Empirical Mobile Usability Studies

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ABSTRACT
The turn of this century marked an increased focus on mobile usability studies for research in the field of Human Computer Interaction. Such studies offer practitioners the needed insight to deliver usable mobile products and services adopted by consumers at increasing rates contributing to a $20 billion industry. Scholars also benefit by identifying new questions that need to be addressed, thereby enriching our understanding of this dynamic domain within HCI. A challenge for both of these groups exists in that many scholars define and operationalize usability differently.

This paper presents a roadmap for future usability research that consists of two parts. First, a framework is adapted for the taxonomy of empirical mobile usability studies. Second, results of the qualitative review of 45 empirical mobile usability studies include: i) the contextual factors studied; ii) the core and peripheral usability dimensions measured; and iii) key findings. Expected contributions of the completed research are also outlined.

Keywords
Mobile, usability, efficiency, effectiveness, satisfaction, mobile device, wireless, context, meta-analysis.

INTRODUCTION
Mobile devices are becoming increasingly popular, having already reached over one billion mobile subscribers. A recent forecast by the UMTS forum (2005) estimates that the global number of subscribers will be between 1.7 to 2.6 billion for mobile voice and 600 to 800 million for mobile data. As consumers’ technology fears and adoption costs are reduced, mobile devices are approaching “mainstream” status around the developed world. Mobile devices propose increasing value to consumers found in “anytime, anywhere, and customized” connectivity, communication, and data services.

Although progress has been made in terms of technological innovations, there are obvious limitations and challenges for mobile device interfaces due to the characteristics of mobile devices (i.e., the size of small screens, low resolutions of the displays, non-traditional input methods, and navigational difficulties) (Nah Siau and Sheng 2005). Therefore, usability is a more important issue for mobile technology than for other areas, since many mobile applications remain difficult to use, lack flexibility and robustness.

Research Motivation & Objectives
Usability has been the focus of discussion (Venkatesh Ramesh and Massey 2003) and described by varying definitions (Nielsen 1993; Shackel 1991) in both academia and industry for a long time. Many of these definitions propose that the central theme of usability is to denote the ease with which people can employ a particular technology artifact in order to achieve a particular goal. The turn of this century marked an increased focus on mobile usability studies for research in the field of Human Computer Interaction. Although a considerable volume of research on general usability exists, due to the novelty of mobile technology relatively few studies have been conducted on mobile usability. Even worse, only 41 percent of mobile usability papers are empirical in nature (Kjeldskov and Graham 2003). Moreover, there is no meta-analytical view on the usability dimensions considered in such mobile studies. Thus, this research aims to fill this gap and in doing so will also provide a roadmap for future mobile usability studies that will be of value to this relatively young research area. Specifically,

this study addresses the following research question: *What are the key formation and evaluation dimensions of usability in mobile technology usability studies?*

To this end, this paper describes the qualitative review performed of 45 empirical mobile usability studies. First, the selection of the taxonomy used for the coding in this review is discussed. Then, the procedure followed for this qualitative review is described. Based on the literature review, a qualitative review framework for empirical mobile usability studies is presented next. The results emerging from this review regarding such studies are then presented, which include: i) the contextual factors studied; ii) the core dimensions defined and measured; iii) the peripheral dimensions explored; and iv) key findings. Finally, the paper discusses the expected contributions of the completed research.

**Overview of Usability**

Usability studies have their roots as early as the 1970’s in the work of “software psychology”. Over time, the focus of this body of research has shifted and most recently centred on the relevance of context of use for usability. The concept of context of use as it relates to usability emerged out of the work of several scholars (Bevan and Macleod 1994; Shami Leshed and Klein 2005; Thomas and Macredie 2002), who attempted to identify additional variables that may impact usability. Varied situational contexts will result in emerging usability factors, making traditional approaches to usability evaluation inappropriate. The significance of this area emerges from its importance in yielding a reasonable analysis during a usability study (Maguire 2001; Thimbleby Cairns and Jones 2001). Furthermore, during the evolution of HCI described earlier, the conceptualization of usability has varied extensively. The broad set of definitions and measurement models of usability complicate the generalizability of past studies at the level of the latent usability variable. Therefore, a usability study may be of limited value if it were not to be based on a standard definition and operationalization of usability. The next section looks at the key formative factors of usability explored in contextual usability studies.

**Framework for Contextual Usability**

The work of several scholars (Bevan et al. 1994; Shami et al. 2005; Thomas et al. 2002) that attempted to identify additional variables that may impact usability and subsequently adoption, led to the conceptual emergence of context of use (herein referred to as context) as it relates to usability, also referred to as contextual usability. Several frameworks encapsulating context have been proposed (Han Yun Kwahk and Hong 2001; Lee and Benbasat 2003; Sarker and Wells 2003; Tarasewich 2003; Yuan and Zheng 2005). While there may be other usability frameworks that attempt to capture the essence of context, the models cited here provide a representative set of work in this area. From these we adapted the framework proposed by Han et al. (2001), because it offers considerable detail for each dimension they identified. In their work they propose four contextual dimensions (i.e. user, activity, environment, product) as the principle components of any human-computer interaction, a perspective that has long been accepted (Shackel 1991). Two minor modifications are made here in terms of nomenclature. First, “Technology” replaces “Product”, as this term helps conceive the system that a user may interact with as a greater set of components, instead of simply the device or application itself. One example of this is found in the case of mobile usability where the inclusion of the wireless network is likely in addition to the mobile device (i.e. the product) when studying usability of a mobile product or service. Second, “Task” replaces “Activity”, as the former term appears more commonly in usability literature when describing the nature of users’ interaction with the technology.

These four variables (i.e. user, task, environment, technology) will be used for the presentation of the review of previous empirical research that relates to the usability assessment of mobile applications and/or mobile devices. The benefit of using these variables for the literature review is found in both the structure it provides for the discussion to follow, as well as to help highlight any areas that are lacking investigation.

**QUALITATIVE REVIEW**

**Procedure**

This qualitative review began with the search for empirical mobile usability studies literature. To this end, we used multiple databases to minimize the chance of omitting relevant studies. We continued with cross-referencing the references of the retrieved studies. Hand searching of appropriate journals in this research included journals ranked among the top 10 in terms of perceived quality, as well as journals deemed relevant to the field of usability by the authors. Specific criteria were set for
the selection of articles sought in this literature review: i) a mobile technology was studied; ii) the study was empirical in nature; iii) the time frame for included studies was from 2000 onward. A conscious decision was made to not limit the reviewed literature to peer-reviewed journal articles, as it would significantly reduce the reviewed articles, given the relative infancy of the mobile usability field. The above procedure resulted in the identification of 45 empirical mobile usability studies.

Qualitative Review Framework of Empirical Mobile Usability Studies

On the basis of the discussion on contextual usability, along with the findings from the literature review of usability measurement, we present a framework that offers a qualitative review of empirical mobile usability studies. The framework is depicted in Figure 1 and contains three elements. First, the outer circle shows the contextual factors described earlier as impacting usability. Second, the inner circle shows the usability dimensions found to have been measured in the reviewed empirical mobile usability literature. Third, the box on the right shows a list of consequences being impacted by usability and studied in the reviewed literature.

![Figure 1. The Qualitative Review Framework of Empirical Mobile Usability Studies](image)

While the use of an adapted perspective for context assisted in the classification of this qualitative review, it should be revisited. A next step for this research will be to define those factors based on the contextual dimensions studied in the reviewed literature. It would be of interest to compare that revised set of contextual factors found in empirical mobile usability studies with those of the general usability studies. Next, we turn our attention to the measured usability dimensions of the reviewed literature.

Usability Measurement Dimensions

The literature review of empirical research on mobile usability performed appears in Appendix A consisting of two sets of data. First, the cited research is described in terms of the context defined in the study and second, the dimensions measured and the relationships validated. The focus of this study is on the usability dimensions measured in these empirical mobile usability studies. Table 1 presents a summary of these measured dimensions, which include: Effectiveness, Errors, Efficiency, Satisfaction, Attitude, Flexibility, Learnability, Memorability, Operability, Accessibility, and Acceptability.
Table 1. Frequency of usability measures used in the reviewed empirical mobile usability studies

<table>
<thead>
<tr>
<th>ORIGINAL LIST OF MEASURES</th>
<th>COLLAPSED LIST OF MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASURES</td>
<td>COUNT</td>
</tr>
<tr>
<td>ERRORS</td>
<td>23</td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>15</td>
</tr>
<tr>
<td>EFFECTIVENESS</td>
<td>5</td>
</tr>
<tr>
<td>ATTITUDE</td>
<td>5</td>
</tr>
<tr>
<td>LEARNABILITY</td>
<td>5</td>
</tr>
<tr>
<td>SATISFACTION</td>
<td>4</td>
</tr>
<tr>
<td>ACCESSIBILITY</td>
<td>3</td>
</tr>
<tr>
<td>OPERABILITY</td>
<td>2</td>
</tr>
<tr>
<td>MEMORABILITY</td>
<td>1</td>
</tr>
<tr>
<td>ACCEPTABILITY</td>
<td>1</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>1</td>
</tr>
</tbody>
</table>

From Table 1 it appears that the constructs of errors, efficiency, effectiveness, satisfaction, attitude, and learnability are most commonly measured in empirical mobile usability studies. All of these measures were defined in the work of Han et al. (2001) on the classification of performance and image/impression dimensions with slight variations. The measure of errors was defined by Nielsen (1993) as the “number of errors, ability to recover from errors, and existence of serious errors.” Han et al. (2001) address errors through two measures: i) error prevention (i.e. “ability to prevent the user from making mistakes and errors”), and ii) effectiveness (i.e. “accuracy and completeness with which specified users achieved specified goals”). With respect to the reviewed literature, mobile usability studies measured the error rate, as opposed the error prevention, associated with the system. Hence, the errors measure found in this literature review may be collapsed with effectiveness (effectiveness offering a broader definition and operationalization). Similarly, attitude is defined as the “level of user satisfaction with the system” (Shackel 1984). Han et al. (2001) define satisfaction as “the degree to which a product is giving contentment or making the user satisfied.” Hence, attitude (as defined in these usability studies) may be collapsed in the single measure of satisfaction. Upon review of the measures’ relative appearance in the reviewed literature the core constructs for the measurement of usability appear to be:

- Efficiency: Degree to which the product is enabling the tasks to be performed in a quick, effective and economical manner or is hindering performance
- Effectiveness: Accuracy and completeness with which specified users achieved specified goals in particular environment
- Satisfaction: The degree to which a product is giving contentment or making the user satisfied

These three dimensions also reflect the ISO 9241 standard making a strong case for its use in related future studies. The use of this standard would allow for consistency with other studies in the measurement of efficiency, effectiveness, and satisfaction (Brereton 2005). Either all or at least one of the three constructs have been used in the work of most researchers cited in the literature review. The remaining measures identified in Table 1 reflect the peripheral dimensions measured in empirical mobile usability studies, while key findings are included in the Appendix.

Beyond the benefit of a standard view of usability, an important opportunity for future research arises from the data in Table 1. Accessibility appears to be one of the most underserved research areas. This observation may come as a surprise, given the growing popularity of accessibility research in less conventional (e.g. non-IS, non-peer-reviewed) publication outlets, and the increasing levels of legislative support and community interest. Further exploration of this construct, including its role with the remaining usability dimensions, is warranted.
CONCLUSIONS

This research-in-progress presents the basis of a continuing research, which aims to enhance our understanding of mobile usability considerations and measurement. Expected contributions of this study include the following:

- To our knowledge, this breakthrough meta-analytical research is the first to offer a holistic view of usability dimensions found in empirical mobile usability studies.
- The results of a future gap analysis between general usability and mobile usability studies will offer academics guidance for future research directions.
- The identification of a common measurement metric will support a future quantitative analysis (meta-analysis) of mobile usability studies. In turn, this could offer a unified view of empirical mobile usability studies.
- This study provides insights for practitioners regarding the aspects of the technology that may be considered during a usability evaluation of their mobile products and/or services.

REFERENCES


# APPENDIX A: Formations and Dimensions of Usability

<table>
<thead>
<tr>
<th>Usability Studies</th>
<th>Formation of Usability</th>
<th>System/Technology/Product</th>
<th>Research methodology* (Sample Size)</th>
<th>Key Usability Dimensions/Constructs**</th>
<th>Other Variables</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Ma 2005)</td>
<td>Culture (Turkey and USA)</td>
<td>Mobile phone</td>
<td>Survey (273)</td>
<td>Price, accessibility, efficiency, personal innovativeness, perceived usefulness, perceived ease of use, intention to use</td>
<td>For USA sample: PU → Adoption; PEOU → usefulness; efficiency → ease of use, personal innovativeness → PEOU. For the Turkish sample: All above and PEOU → adoption; price → adoption, personal innovativeness → usefulness, personal innovativeness → efficiency.</td>
<td></td>
</tr>
<tr>
<td>(Fasani 2004)</td>
<td>Culture (Italy and USA)</td>
<td>Mobile phone, PDA, i-pocket PC</td>
<td>Field (Interview 58; Focus groups (24 groups), phone questionnaires (100))</td>
<td>Motivability, availability, functions, accessibility, ROU, bandwidth, cost, hardware and software functionalities, privacy, Motivation, degree of service innovation, interest for service, preference, ranking of service</td>
<td>Usefulness was the most important factor in adoption, followed by ease of use, price, and speed of use. PU → Adoption; PEOU → Adoption. Price → Adoption. Speed → Adoption.</td>
<td></td>
</tr>
<tr>
<td>(Chen 2002)</td>
<td>Novice</td>
<td>Checking &amp; booking a flight, searching and buying a book, etc.</td>
<td>Lab (Devices data)</td>
<td>Information overload, depth of site structure, search, connection feedback and latency</td>
<td>Strong relationship between e-commerce and m-commerce.</td>
<td></td>
</tr>
<tr>
<td>(Kakizawa 2005)</td>
<td>NA</td>
<td>Closed 10 tests</td>
<td>Mobile phone</td>
<td>Device data (40 users)</td>
<td>Errors, Learnability, Operability</td>
<td>Problems observed</td>
</tr>
<tr>
<td>(Rodden 2001)</td>
<td>Experienced</td>
<td>12 closed tasks (web browsing, web search)</td>
<td>PDA</td>
<td>Experiment, questionnaires (24)</td>
<td>Efficiency (time)</td>
<td>N/A</td>
</tr>
<tr>
<td>(Waterson 2002)</td>
<td>NA</td>
<td>Closed</td>
<td>PDA</td>
<td>Observation, Devices data, questionnaire (10)</td>
<td>Errors</td>
<td>N/A</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Expertise</td>
<td>Methodology</td>
<td>Device Type</td>
<td>Lab Type</td>
<td>Variables</td>
<td>Study Details</td>
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<tr>
<td>Lindtjoff 2001</td>
<td>Expert interviews</td>
<td>Adding a person to the address book, scheduling lessons, creating a card</td>
<td>PDA</td>
<td>Lab</td>
<td>Questionnaire, Device data (12)</td>
<td>Efficiency, Errors, Learnability, Misprediction, Satisfaction</td>
</tr>
<tr>
<td>Magata 2003</td>
<td>Experienced</td>
<td>Responded to the phone call, instant message or IM notification</td>
<td>PDA, desktop</td>
<td>Lab</td>
<td>Questionnaire, interview, Device data (6)</td>
<td>Efficiency, errors</td>
</tr>
<tr>
<td>Knudson et al. 2003</td>
<td>N/A</td>
<td>Closed</td>
<td>PDA, E91 mobile phones</td>
<td>Lab/field</td>
<td>Experiment, device data, Questionnaire, observation (6)</td>
<td>Errors, Efficiency</td>
</tr>
<tr>
<td>Wigger 2003</td>
<td>N/A</td>
<td>Entered short phrases of text</td>
<td>Mobile phones</td>
<td>Lab</td>
<td>Experiment, device data (10)</td>
<td>Text entry interface</td>
</tr>
<tr>
<td>Kim, Kim, Lee, Chae, and Choi 2002</td>
<td>Experienced</td>
<td>Open (put written diary into the web diary)</td>
<td>Mobile internet phone</td>
<td>Field</td>
<td>Device data (5)</td>
<td>Languages, accuracy</td>
</tr>
<tr>
<td>Batta 2000</td>
<td>Usage experience</td>
<td>Closed (enter five sentences using each input method)</td>
<td>Mobile phone</td>
<td>Lab</td>
<td>Experiment, device data, observation (5)</td>
<td>Efficiency, errors, Learnability</td>
</tr>
<tr>
<td>Chittaro 2002</td>
<td>No previous experience</td>
<td>Closed (search and selection)</td>
<td>Mobile phone</td>
<td>Lab</td>
<td>Experiment, device data (40)</td>
<td>Efficiency, Operability</td>
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<tr>
<td>Breuzin 2002</td>
<td>No previous experience</td>
<td>Closed (navigate to find the answers of questions)</td>
<td>Mobile phone</td>
<td>Lab</td>
<td>Experiment, device data (30)</td>
<td>Efficiency, steps, browser</td>
</tr>
<tr>
<td>Updebeck 2001</td>
<td>Computer experience, level of concentration</td>
<td>Closed (accomplish single-page info, need take using different methods)</td>
<td>Palm Pilot and mobile phone</td>
<td>Lab</td>
<td>Experiment (15)</td>
<td>Efficiency, Performance (Use and System)</td>
</tr>
<tr>
<td>Ando 2004</td>
<td>Physician</td>
<td>Open</td>
<td>Tablet PDA</td>
<td>Lab/field</td>
<td>Focus group, survey (9)</td>
<td>Errors, Weight, wireless infrastructure, technical support, security, reliability</td>
</tr>
<tr>
<td>Shariat et al. 2000</td>
<td>Medical and dental students, and residents</td>
<td>Clinical examination</td>
<td>PDA</td>
<td>N/A</td>
<td>Device data, questionnaires (45)</td>
<td>Effectiveness, efficiency, satisfaction</td>
</tr>
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</table>

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<table>
<thead>
<tr>
<th>Study</th>
<th>Participant Information</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
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<tbody>
<tr>
<td>Kim et al. (2002)</td>
<td>Experience in using Mobile Internet, Ages 15-40, Average 33.1, Female: 57.8%</td>
<td>Web diaries, Street/field study, Noisy and Quiet, Visual cues, Public and alone</td>
<td>Study (27), Collecting and analyzing data, Comparing electronic and paper content, Errors, Goal (Utilitarian, Hedonic Use), Use in movement, state, Emotion, Hands, Availability, Auditory Distraction, Lack of appropriate content over internet, user</td>
</tr>
<tr>
<td>Palen and Salzman (2002)</td>
<td>Novice: 12 female, 7 male, Age: 16-75</td>
<td>Phone calls, Explore the functionalities of the phone, Wireless Telephones (N/A), Field study, Everyday Life</td>
<td>Study (19), Observation, Interviews</td>
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<tr>
<td>Fang (2003)</td>
<td>Adults Alumni Students, Ages 20-50</td>
<td>Evaluate characteristics of the devices, Mobile commerce task</td>
<td>Study (101), Questionnaires</td>
</tr>
<tr>
<td>James (2001)</td>
<td>Novice and Experts</td>
<td>Text typing (multi-touch and T9), Mobile phone</td>
<td>Study (20), Observation, Errors</td>
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<tr>
<td>Juelke (2004)</td>
<td>Undergraduate Students (Engineering and Psychology)</td>
<td>Establish Bluetooth, Create calendar, Locate a document, Create a contact entry, Bluetooth devices, mobile phones</td>
<td>Study (48), Surveys, Observation, Monitoring and recording</td>
</tr>
<tr>
<td>Kasoum (2003)</td>
<td>Ages: 14-65, Very different experiences</td>
<td>Follow instructions using a GPS system, Different GPS devices (PDA, mobile phones)</td>
<td>Field and laboratory study, Collecting data (device)</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Methodology</td>
<td>Mobile Device</td>
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<td>2002</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>2001</td>
<td>MacKenzie</td>
<td>Text Typing</td>
<td>Lab study</td>
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<td>2002</td>
<td>Duda &amp; Hess</td>
<td>WAP services</td>
<td>WAP phones</td>
</tr>
<tr>
<td>2002</td>
<td>Schäfer &amp; Hess</td>
<td>Shopping</td>
<td>PDA</td>
</tr>
<tr>
<td>2000</td>
<td>Brevator</td>
<td>University students</td>
<td>Palm V</td>
</tr>
<tr>
<td>2000</td>
<td>Brevator &amp; Musgrave</td>
<td>Palm III</td>
<td>Lab Experiment (12)</td>
</tr>
<tr>
<td>2000</td>
<td>Christie</td>
<td>Experts, student</td>
<td>N/A</td>
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<tr>
<td>Study</td>
<td>Participants</td>
<td>Context</td>
<td>Methodology</td>
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<tr>
<td>Coursaris &amp; Kim</td>
<td>Age, experience with stylus and PDAs, and with IM and SMS writing</td>
<td>Locate an individual and send a message, view event details and attend locations, etc.</td>
<td>PDA phones combination, field</td>
</tr>
<tr>
<td>Chittaro 2001</td>
<td>Novice of WAP phones</td>
<td>Search and selection</td>
<td>WAP phones, lab</td>
</tr>
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<td>Damste 2001</td>
<td>Students in an elementary school</td>
<td>Transfer of data, use album, drawing</td>
<td>Palm, lab</td>
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<tr>
<td>Goldstein 2001</td>
<td>Novice</td>
<td>Adding a visit card &amp; makes an appointment</td>
<td>PDAs or Smartphones, lab</td>
</tr>
<tr>
<td>Popp 2002</td>
<td>All male</td>
<td>Store a list</td>
<td>Palm, lab</td>
</tr>
<tr>
<td>Ross and March 2002</td>
<td>People with severe visual impairment</td>
<td>Cross from intersections</td>
<td>Wearable device, field</td>
</tr>
<tr>
<td>Ling 2001</td>
<td>Culture - Youth, Parents</td>
<td>Use of Text messages</td>
<td>N/A, N/A</td>
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<td>Pan 2001</td>
<td>Novices (16-72)</td>
<td>Talk about their experience</td>
<td>Mobile phones, lab study</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Methodology</td>
<td>Data Collection</td>
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<tr>
<td>(Lioupe and Huvrin 2001)</td>
<td>French users</td>
<td>Lab study</td>
<td>- Questionnaire and face-to-face interview (20)</td>
</tr>
<tr>
<td>(Guo and Huang 2004)</td>
<td>27 graduate students, Mostly Novices with PDA</td>
<td>Lab study</td>
<td>- Questionnaire and face-to-face interview (100)</td>
</tr>
<tr>
<td>(Miner 2000)</td>
<td>2 women, 3 men, 30-50 years old</td>
<td>Lab study</td>
<td>- Visual training (simulate a visually intensive real-world task such as driving)</td>
</tr>
<tr>
<td>(Stevens 2001)</td>
<td>5 males, 4 females</td>
<td>Field study</td>
<td>Mobile phone, PDA, Walk /disc man, camera</td>
</tr>
<tr>
<td>(Jenai 2002)</td>
<td>Volunteers (University students, experts)</td>
<td>Lab study</td>
<td>- 5 scenarios - 3 tourist type task for each scenario</td>
</tr>
<tr>
<td>(Lakshminarayanan and Salehian 2002)</td>
<td>Students, Teachers, Engineers</td>
<td>Lab study</td>
<td>Search tasks</td>
</tr>
</tbody>
</table>

Note: *Research methodology: How (Observation, Interview, Focus group, Survey, Device data), and Where (Lab study, Field study) *

** Key Usability Dimensions: Effectiveness, Efficiency, Satisfaction, Learnability, Flexibility, Attitude, Operability, Errors, Memorability, Accessibility, and Acceptability

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