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A longitudinal review of mobile HCI research methods

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ABSTRACT
This paper revisits a research methods survey from 2003 and contrasts it with a survey from 2010. The motivation is to gain insight about how mobile HCI research has evolved over the last decade in terms of approaches and focus. The paper classifies 144 publications from 2009 published in 10 prominent outlets by their research methods and purpose. Comparing this to the survey for 2000-02 show that mobile HCI research has changed methodologically. From being almost exclusively driven by engineering and applied research, current mobile HCI is primarily empirically driven, involves a high number of field studies, and focus on evaluating and understanding, as well as engineering. It has also become increasingly multi-methodological, combining and diversifying methods from different disciplines. At the same time, new opportunities and challenges have emerged.

Author Keywords
Research methods, research purpose, literature survey

ACM Classification Keywords
A.1. General Literature: introductory and survey.

General Terms
Design, Human Factors

INTRODUCTION
In 2003 we did a comprehensive literature survey of Mobile Human-Computer Interaction research. The purpose of the survey was to generate an empirically grounded characterization of state-of-the-art and current practices within this growing area of mobile computing. At that time, Mobile HCI and interaction design research was still very much in its infancy as an academic research area. Widely commercially successful devices had only been around for about a decade, and leading conferences had only a few years of history behind them. As a consequence only a small body of knowledge existed about this emerging research field, and no coherent sets of methods and techniques for research had yet been established.

The literature survey [3] contributed to bringing this issue on the agenda. It reviewed 102 mobile HCI publications from 2000-02. Inspired by a similar study in Information Systems [9]. Each paper was classified in terms of its research method and purpose (see table 1), extracted from [10] with supplementary input from [1][4][5][7][11].

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TRENDS AND ASSUMPTIONS
The literature survey revealed a strong bias towards applied research for engineering and laboratory experiments for evaluation, as shown in figure 13. Put simply, mobile interaction design research in the early 2000s was dominated by building new systems in a trial-and-error manner, and evaluating them in laboratory settings – if evaluating them at all. There was very little going on in terms of trying to understand the phenomenon of mobility itself in relation to interaction design and technology use, and to use such insight when designing and building actual interactive systems. Nor was much attention given to the role of real world context in relation to understanding, building or evaluating interactive mobile systems [3]. In essence this echoed a fundamental segregation between use- and technology-centeredness depending on whether the involved researchers were primarily interested in *people* or *systems*. On a more general level, it became apparent that methodology seemingly played a very small role. The approaches taken often remained unexplained, their suitability unchallenged, and their limitations and alternatives not discussed.

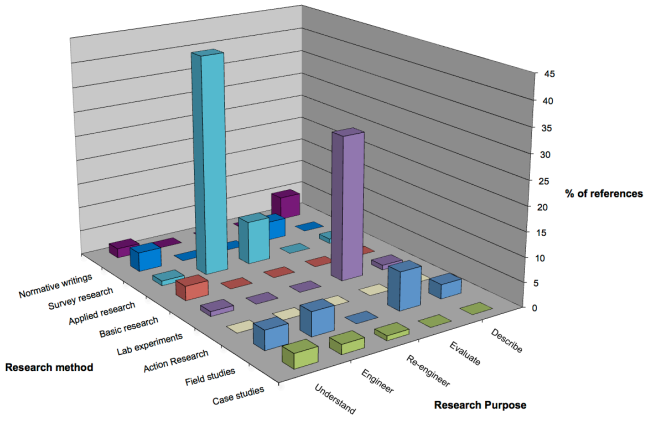

Figure 1. Distribution on methods and purpose in 2000-02 (%)

Based on our more detailed analysis of what types of research and purposes were missing, or largely underrepresented, we cautioned that the bias towards trial-and-error building of interactive systems, evaluations only in the lab, and the lack of research for understanding design and use in real world contexts, would limit the quality and

Method	**Case studies**	Intensive empirical investigations of contemporary phenomena within small size entities such as groups, organizations, individuals, systems or tools in real-life context with the researcher distinct from the phenomena being studied
	Field studies	Characterized by taking place in "the real world" covering a range of qualitative and quantitative approaches from ethnographic studies of phenomena in their social and cultural context to field experiments in which a number of independent variables are manipulated
	Action research	A method through which researchers not only add to the body of scientific knowledge but also apply that knowledge to the object of interest through intervention and participation in the activity being studied
	Lab experiments	Characterized by taking place in a controlled environment created for the purpose of research or in dedicated laboratories allowing a detailed focus on specific phenomena of interest with a large degree of experimental control
	Survey research	Informs research gathers large amounts of data through various techniques such as questionnaires and interviews from a known sample of selected respondents assumed to be independent of their environment
	Applied research	Builds on trial and error on the basis of reasoning through intuition, experience, deduction and induction. Typically the desired outcome of an applied research process is known while means of accomplishing it is not. This makes applied research very goal oriented.
	Basic research	Characterized by trial and error based development of new theories and the study of well-known problems to which neither solutions nor methods are known, relying on the competences of the researcher
	Normative writings	Cover the body of "non-research" writings about phenomena of interests such as concept development writings organizing ideas for stimulating future research, presentation of truth describing ideas that seem intuitively correct, and descriptions of applications.
Purpose	**Understanding**	The purpose of research focusing on finding the meaning of studied phenomena through, for example, frameworks or theories developed from collected data.
	Engineering	The purpose of research focused towards developing new systems or parts of systems, for example an interaction technique for a mobile device, or a mobile application or device.
	Re-engineering	The purpose of research focusing on improving existing systems by redeveloping them such as, for example, adapting a web browser to a small display.
	Evaluating	The purpose of research assessing or validating products, theories or methods, for example, the usability or user experience of a specific application, or a theory of interaction.
	Describing	The purpose of research focusing on defining desirable properties of products, for example, a mobile guide system, or mobile HCI method.

Table 1. Overview of research methods and purposes

scope of the body of knowledge about mobile human-computer interaction being accumulated, and thereby inhibit the advancement and impact of the research field in the future. In particular we found from our analysis that three underlying, and unfortunate, assumptions appeared to be characterizing mobile HCI research at the time:

- We already know what to build
- Context is not important
- Methodology matters very little

We already know what to build

The prevalent approach of applied research for engineering indicated an assumption at the time that we already knew what systems to build and what problems to solve, such as limited screen real estate, limited means for interaction, and limited network bandwidth. We just didn't know yet exactly how to build these systems and how to solve those problems, but the solutions existed out there and were just waiting to be uncovered. Only very little research addressed the more fundamental questions of what is useful and what is perceived problematic from a user-perspective, and evaluations focused on functionality rather than context-centred and user-centred issues. Given the young age of the research field we argued that this could hardly be true and that, on the contrary, young emerging research fields such as this particularly require research addressing such fundamental issues. Continuing to do research on the basis of the assumption that we already know the problem would, in it self, make it very difficult to set this assumption aside and identify the more fundamental challenges at hand.

Context is not important

The limited focus on real-world studies indicated an assumption that context was not really important for what we build, and that interactive mobile computer systems are by definition suitable solutions. Building and evaluating interactive systems on the basis of applied research and laboratory experiments also results in very concrete conclusions about very specific solutions. These conclusions can be difficult to generalize and therefore it can be difficult to elevate our learning from the systems we develop, and study in use, to an abstract level where knowledge can be transferred to other design cases, technologies, domains, users, purposes, etc. This limits our ability to move forward at a pace beyond incremental steps from one specific design to the next. Hence, in our opinion, the assumption, that building and evaluating systems by trial and error is better than grounding engineering, evaluation and theory in user-based studies, seriously weakened mobile HCI research at the time.

Methodology matters very little

The final observation, that only few studies were based on an explicit methodological foundation, indicated an assumption that methodology mattered very little in mobile HCI research. We presented this supposition as a particularly problematic one because it is a well-known fact that the choice of method clearly influence the results subsequently produced [5]. Applied research is, for example, viewed as a rather poorly performing method for problem solving because it requires researchers to investigate a very large space of possibilities.

REASONS

Having provided a snapshot of current practice within mobile HCI research and outlined a number of problematic consequences of this in [3], it was natural to continue by asking *why* research was currently being done this way?

In our opinion, a part of the answer is that bias towards applied research for engineering combined with laboratory experiments for evaluations is simply natural for a young and technologically driven area of research. Applied research and lab experiments are not as such easier than field studies, case studies, and action research, but they are a more straightforward way to start when exploring a new field of emerging technology. Before we can study and understand phenomena like use contexts, usability, and user experiences of new technology we simply need this technology to be available to us in some concrete and functioning form. However, if a field of *emerging technology* is to evolve into a field of *applied technology*, it is important not to get stuck in research methodologies where solutions are created and put to use by trial-and-error rather than grounded in real world context. Applied research methods alone do not create a field of where technology is applied well to real world problems. Another part of the answer, we believe, is that rather than mobile technologies being not ready for studies in natural settings, the body of mobile HCI research and researchers were probably not ready for natural settings research. In the early 2000s only very few studies had been published that used natural setting research methods within mobile HCI. Consequently only very few examples existed for others to be inspired by and to follow. Also, the whole debate about doing natural setting mobile research had not even really started yet. It was also still very unclear exactly how to make use of "new" methods like field studies, case studies, and action research in mobile HCI, and unclear exactly what value they could possibly bring to a specific project.

Finally, and somewhat related to the other two points, a part of the answer could also be attributed to the fact that in the early 2000s the *multi-disciplinarity* of mobile HCI was not yet strong. Like other areas of emerging technologies it was very much dominated by engineering and computer science. In terms of methodology this meant that methods and techniques from, for example, social science, the humanities, and the arts did not yet have a strong presence in the minds and traditions of the dominant mobile HCI researchers at the time, and not a lot of researchers from those disciplines were yet working with mobile HCI.

In summary, there were indeed very good reasons why the methodological landscape of mobile HCI research looked the way it did in 2003. The research up to that point had been fundamental in the creation and shaping of the field. It had created technological possibilities that allowed a paradigmatic shift away from the desktop and opened up for a wide range of new and interesting uses of computer technology within a wide range of interesting domains.

OPPORTUNITIES

Supplementing the descriptive analysis of state-of-the-art in mobile HCI research we also used the literature survey to identify opportunities for future research. The most obvious opportunities lay in responding directly to the assumptions outlined above: 1) conduct research that aimed at studying and understanding the problem space, 2) explore the importance and role of context, and 3) undertake methodological research, for example, development of new methods and techniques for studying, designing, and evaluating. Related to this, but on a more specific level, other opportunities lay in explicitly responding to the gaps in research methods and purposes identified.

In particular, the noticeable lack of *field studies* presented an enormous opportunity to use this method for exploring rich real-world use cases, contexts and user needs to gain deeper understanding of these. As a particular approach, we suggested that learning from other disciplines that have struggled with the study of similar "slippery" phenomena, such as ethnography, could provide important methodological insight. We also proposed that field studies within mobile HCI could be used to inform the engineering of new designs, and the re-engineering of existing ones, through identification of needs and opportunities for innovation. Finally, in response to the bias towards evaluating in laboratory settings, we promoted the opportunity for systematic investigation of field studies for this purpose, as mobility and context can be difficult to emulate in a laboratory. The clear lack of *survey* and *case study* research also presented interesting opportunities. In the field of Information Systems, for example these approaches are used widely. Survey research is often used to collect large amounts of data from, for example, a large segment of actual end-users of a system, enabling much wider reaching power of generalization. Case studies within mobile HCI could increase learning from existing systems within real-world contexts, for example mobile systems and infrastructure within organizations. Such case studies would enable close scrutiny of specific phenomena in specific contexts, which could then be used to enrich the collective knowledge in the discipline and to enable key issues to be described and understood. The issues generated could then be used to generate hypotheses to propagate further research. The very limited amount of *basic research* indicated an opportunity for the development of theoretical frameworks to promote description and understanding. Specifically, we promoted the opportunity for applying theories from other disciplines to the area of mobile HCI. Finally, the complete absence of *action research* pointed to both the lack of an established body of knowledge within the discipline and the unwillingness to implement mobile systems uncertain to succeed. This was perhaps not surprising, given the cost of technology and associated implementation overhead. Nonetheless, this was, again, an opportunity to develop new knowledge in the discipline through studies of practice and intervention.

7 YEARS LATER

In 2010, we felt that it was time to follow up on the survey, and see how the research field had developed in terms of approaches and focus. The second literature review took its offset in research papers on the topic of mobile HCI published in ten top outlets in 2009. These papers constitute all publications related to mobile human-computer interaction in 2009 in the top-level conference proceeding series and journals listed in table 2 below.

Outlet	Count
Mobile HCI Conference (MobHCI)	38
CHI Conference (CHI)	46
UIST Symposium (UIST)	6
Personal and Ubiquitous Computing (PUC)	27
Transactions on Computer-Human Interaction (TOCHI)	3
International Journal of Human-Computer Studies (IJHCS)	8
International Journal of Human-Computer Interaction (IJHCI)	7
Journal of Computer-Supported Cooperative Work (JCSCW)	2
Behaviour and Information Technology (BIT)	2
Interacting with Computers (IwC)	5
Total	**144**

Table 2. Selected outlets and paper counts

While other conferences and journals exist in which interesting research on mobile human-computer interaction is presented, we found that the listed conferences and journals provided a solid and adequately representative base for this study given the number of publications on the topic and the general level of the reviewing processes for these conferences and journals.

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Through a thorough manual reading of titles, abstracts, and sometimes introductions, of all papers published in the selected ten outlets that year, a total of 144 papers were identified as falling within the field of mobile HCI (table 2). A paper was selected for the study if it was in any way related to mobile devices and HCI. Thus a paper would be omitted if it focused only on mobile network protocol design or did not involve any aspect of mobility of users or systems. All papers were printed, numbered, read through and classified by identifying the purpose of the presented work and the research methods applied in achieving this. The classification was done in three steps. First the two authors of this paper classified each paper independently over a period of two weeks. To ensure consistency, the initial classification was then evaluated by looking through all papers a second time on a single day. Secondly, the classification of each paper was by the two authors in collaboration. Thirdly, we invited the first authors of all 144 papers to provide a self-assessment of their method and purpose. This was received for 55 of the papers, and was used to discuss the classification further where disparities were observed, resulting in some modifications. The self-assessment was highly consistent with the initial joint classification by the two authors. But the final classification contains 12 method disparities and 14 purpose disparities from the self-assessment, where we believed that our own classification was more correct and consistent with the classification of the other papers.

FINDINGS

The classification of research methods and purpose in 2009 is shown in table 3. Since several papers (44%) involved multiple methods and purposes, these appear more than once in the table. As in 2003, an example of this is papers presenting an engineered and evaluated system. As a consequence of this, some aggregate percentages in the findings section will amount to more than 100%.

The first observation that stands out from the 2009 literature survey is the sheer number of publications on the topic. In the first literature review we found 102 papers in the same outlets over a period of 3 years. By relative comparison this number had more than quadrupled by 2009 (424% increase). On the basis of this it is fair to say that mobile HCI is a highly active area of research and has grown substantially in the last 7 years. It is also interesting to notice that while the selected articles from 2009 included the full proceedings of the specialised annual Mobile HCI conference, there were actually more papers published on the topic at the annual ACM Conference on Human Factors in Computing Systems (CHI) that year. Out of the 246 full and short papers in the Proceedings of CHI 2009 almost a fifth (19%) concerned human-computer interaction with mobile systems or devices. This shows that mobile HCI is now a substantial part of mainstream HCI research.

Table 3 shows that in 2009, 49% of mobile HCI research falls within the lab experiment category (71 of 144 papers). The secondly most used method is field studies accounting for 35% of the research (50 out of 144 papers). The third most used method is applied research with 30% (43 of 144 papers). 21% of the papers report from survey research and 6% from case studies. 4% involved basic research and 2% normative writing. Only one entry was found for action research (<1%). Looking at research purpose, 68% of mobile research is done for the purpose of evaluating, of which 63% is done through lab experiments, 29% through field studies, and 7% through surveys. 40% of the reported research involves building systems, 72% of which is done through applied research. Research for understanding mobile HCI represents 31% of the papers, of which 43% is done through field studies and 32% through surveys. 7% of the classified papers describe aspects of mobile HCI, 60% of which is informed by surveys.

Thus within mobile HCI research in 2009 there is a clear tendency towards evaluating systems, and doing so in laboratory settings. Building systems is also a central activity, closely followed by research for understanding.

Method/ purpose	Case studies	Field studies	Action research	Lab experiment	Survey research	Applied research	Basic research	Normative writings
Understand	10, 54, 107, 136	8, 14, 28, 38, 46, 56, 61,63, 76, 79, 83, 87, 88, 92, 102, 110, 126, 129, 134	3	15, 42, 52, 77, 101	20, 26, 39, 43, 57, 61, 69, 70, 89, 90, 95, 100, 114, 117, 119, 122			131
Engineer	6	5, 40, 123		31, 62, 81, 94	39, 137, 141	1, 2, 7, 11, 13, 16, 17, 19, 21, 24, 27, 28, 36, 45, 46, 47, 58, 59, 65, 66, 74, 80, 82, 85, 96, 98, 104, 108, 111, 113, 114, 115, 116, 118, 120, 125, 128, 138, 140, 143, 144	29, 51, 109, 127, 130	
Re-engineer				35		37, 44	97	
Evaluate	84	9, 22, 39, 40, 43, 45, 58, 60, 75, 81, 86, 93, 96, 98, 104, 111, 112, 115, 123, 124, 128, 132, 138, 139, 141		4, 5, 6, 7, 11, 12, 13, 16, 17, 21, 22, 24, 25, 29, 30, 31, 32, 34, 35, 36, 37, 43, 44, 47, 48, 50, 51, 53, 55, 58, 62. 64, 65, 66, 71, 73, 74, 78, 80, 82, 89, 91, 99, 103, 104, 105, 106, 108, 109, 112, 116, 118, 119, 121, 125, 127, 130, 133, 137, 140, 142, 143, 144	1, 17, 18, 55, 75, 120, 135			
Describe	33, 93				23, 49, 50, 67, 68			41, 72

Table 3. Classification of mobile HCI research in 2009. Numbers refer to the list of reviewed papers.

Looking in more detail at the current distribution of papers on their research methods and purposes, a number of interesting observations can be made. Most interestingly, the literature survey shows that by 2009 the research area of mobile HCI is characterized by:

- Focus on evaluating, engineering and understanding
- Increased empirical research
- Multi-methodological research

Evaluating, engineering and understanding

The review shows that mobile HCI has become about evaluating, engineering and understanding mobile systems and their use (figure 2). From a user-experience perspective, this development towards multiple purposes is a positive advancement as it reflects better the different and well-acknowledged phases of the traditional user-centred design cycle than a purely engineering driven approach. However, looking more detailed at the specific research projects reported in the mobile HCI literature, those different phases are in fact still poorly integrated. Research with the purpose of *understanding* and research with the purpose of *engineering* are still very separate, and rarely appears together or as outcomes from the same project. Engineering systems is still predominantly done by trial-and-error based on potentially good ideas (73,6%), and studies aiming to understand mobile HCI phenomena reportedly seldom lead to new systems or designs (0,7%).

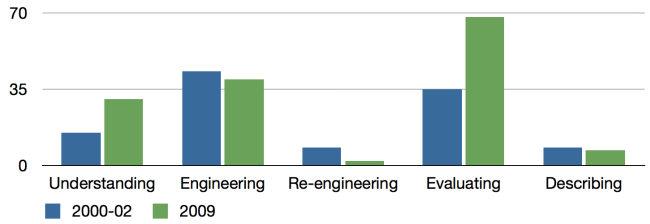

Figure 2. Research purposes in 2000-02 and 2009 (%)

Furthermore, while systems are today typically evaluated empirically (84%), these evaluations reportedly seldom lead to understanding beyond specific findings in relation to the concrete solutions being studied (1%). Hence, it seems that the broader scope of mobile HCI research in 2009 compared to 2000-02 is now reflecting the presence of *two* distinct approaches rather than one: a use- and a technology-centred one, depending on whether the involved researchers are primarily interested in *people* or *systems*. The first approach aims primarily at understanding mobile user experiences theoretically and conceptually, and the second aims primarily at building new mobile systems and evaluating them in use. Within both approaches *users* play an important role, but in first they are the *objects* of the research, while in the second they are research *subjects* in the study of technology. According to Rasmussen [8] such clear-cut distinction tends to cause the potentially fruitful dialectics between the two approaches to disappear. If one of the two approaches is considered 100% good and the

other 100% bad, from either side of the divide, then one is destined to subsume the other. Dialectic thinking, on the other hand, encourages us to develop a synthesis at a higher stage of the opposing interests, as also discussed by Dahlbom and Mathiassen [2]. This is not simply a matter of finding a balance between the two but about transcending beyond opposing views and shaping a new unity at another level [6]. Hence, in order to strengthen the "interaction" part of mobile human-computer interaction a closer integration of these two approaches, the use- and the technology-centred one, is needed.

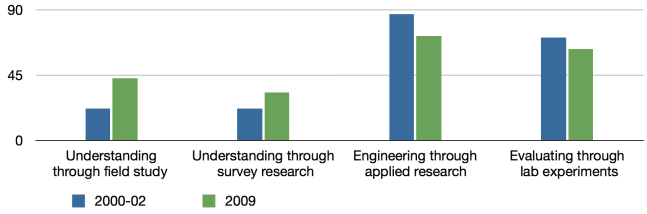

Figure 3. Research for understanding, engineering and evaluating by their dominating methods (%)

Another observation from looking at the three prevailing purposes is that they are each still dominated by the same particular methods as they were 7 years ago. This is illustrated in figure 3. Understanding is still done primarily through field and survey research (76% totally), engineering is done 3/4 through applied research (72%), and evaluations are done 2/3 through lab studies (63%). This means that while the overall focus of mobile HCI has shifted towards more research for understanding and evaluating, the research done *within* the different categories of research purposes is still to a large degree being carried out as before. Focus may have shifted, but methods used for particular purposes mostly have not.

The slight outlier here is research for the purpose of understanding. Not only is more research done overall with this purpose compared to 7 years ago, it is also done by more varying methods than research with any of the other purposes. Accordingly, figure 3 above depicts two groups of research for understanding informed by field studies and survey research, which accounts for 43% and 33% of the research for this purpose respectively. Looking more detailed at this research it is even evident that the category of *field studies* itself is beginning to diversify notably into varying *types* of field methods, such as field ethnographies and field experiments, and that there is even an evolving hybrid of field studies and survey research emerging in the form of "field surveys", such as cultural probes. This indicates that researchers concerned with *understanding* mobile HCI phenomena are successfully evolving their methodological repertoire to fit better with the contemporary research challenges facing them. This is not in the same way clearly evident for the other areas of focus.

Increased empirical research

The second general observation is that whereas applied technical research dominated the field 7 years ago, mobile HCI is today characterized by an increased amount of empirical research. As can be seen from figure 4, there has been a significant increase in the use of empirical methods. Because the total amount of research has increased this is true in both relative and absolute numbers. Most notably the relative amount of survey research has almost tripled, field studies have more than doubled, and lab experiments have almost doubled. On the contrary the relative amount of applied research has decreased by nearly 1/3.

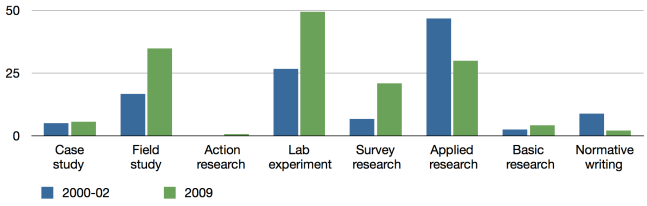

Figure 4. Mobile HCI research methods, 2000-02 & 2009 (%)

This means that mobile HCI is evolving as a research field towards a better balance between natural, artificial, and environment independent settings, and therefore also towards a better balance between the different use potentials of the specific research conducted. Research in natural, artificial, and environment independent settings have very different fundamental strengths and weaknesses, and balancing them well allows the field as a whole to draw on the relative strong points of particular types of research settings while compensating for their limitations.

Multi-methodological research

What can also be observed from the distribution of research methods in figure 4 is that no single method is now dominating mobile HCI but that it has become multi-methodological. Seven years ago mobile HCI was dominated by applied research but today there are just as many field studies, even more lab experiments, and also a substantial body of survey research. Hence the cumulative methodological repertoire of mobile HCI researchers seems to have broadened. Secondly, almost half of the reviewed papers (44%) reported on *explicit combinations* of multiple methods for multiple purposes. For example, it is now the rule rather than the exception to combine engineering with empirical evaluations (84%) where 7 years ago this was a much more rare occurrence (18%). This means that mobile HCI is evolving as a research field towards a more balanced distribution of research methods from across the broader range of disciplines involved. It does not, however, mean that these methodological foundations are *integrated* across disciplinary boundaries in an *inter*-disciplinary way [9], but the increasing explicit combination of methods is a good starting point for evolving in such direction. At the same time it is also important to notice that the amount of case studies, action research and basic research is, still, almost non existing. This shows that there is still a bias towards environment independent or artificial setting research, or in case of natural setting research, a bias towards basing it on snapshots of the real world rather than on longitudinal and in-depth studies of real world practice.

The tendency towards multi-methodological research indicates that mobile HCI researchers are discovering a need for diversifying their approaches and working more closely with other disciplines. As a part of this diversification, the specific category of *field studies* has notably changed. It now includes at least three notable sub categories of field ethnographies, field experiments, and field surveys, as described in table 3 below.

Field study	Description	%
Field ethnography	Qualitative and quantitative approaches to natural setting research where the researcher is present in the field from full-scale ethnographic studies of phenomena in their social and cultural context to smaller scale observational studies and contextual inquiry.	54%
Field experiment	Natural setting research where a number of independent variables are manipulated in the study of a particular phenomenon under controlled but realistic conditions. This includes, for example, usability tests and quasi experiments in real use contexts.	28%
Field survey	Natural setting research where survey techniques such as questionnaires, diaries, log files, interviews etc. are use for data collection rather than the researcher being present in the field. This includes, for example, cultural probe studies and the like.	18%

Table 3. Three notable emerging variations of field studies

Looking in detail at the papers in the field study column of table 2, field ethnographies and field surveys are both used roughly 50-50 for understanding and evaluating while field experiments are primarily used for evaluating (79%). Increasing methodological diversification can also be observed within studies for evaluation, although not as strongly. Whereas multiple methods appeared in only 5% of the evaluation studies 7 years ago, this is now the case of 9% of all evaluations. These multi-method evaluations typically span across different types of research settings. Unexpectedly, however, only 5% explicitly combines *field* and *lab* based methods, which is the same proportion as 7 years ago. This is surprising in the light of the long lasting debate on lab versus field evaluations within mobile HCI. It indicates that the view, which we share and promote, that lab and field evaluations both have justification, albeit for studying different things, and therefore should be combined and integrated, has not been widely established.

DISCUSSION

Based on the recent research review it appears that the three implicit assumptions dominating the area of mobile HCI a decade ago have changed, or are in the process of changing. Firstly, the multi-methodological character of recent research shows that methodology is now considered an important component of research and something that can be used actively as a means to shape research and guide its focus and contribution. Secondly, the increased amount of empirical and theoretical research into understanding phenomena surrounding and influencing mobile user experiences shows that the broader context is now indeed considered an important factor for mobile HCI. Finally, the increased amount of field studies research shows that, at least within some parts of the mobile HCI community it is clear that we do not already know what to build and what problems to solve. Unfortunately, however, as engineering is still predominantly informed by applied research, knowing what systems to build and what problems to solve still appears to be the assumption within the more technical camps of mobile HCI.

One of the things that is perhaps most disconcerting about current research practice in mobile HCI is the continuing lack of *case study* and *action research*. While there is a clear increase in natural setting research in the form of field ethnographies, field experiments and field surveys, there is still a gap in research that really embraces the full extend and complexity of the real world in which the mobile systems we design and develop are used. Field ethnographies, -experiments and -surveys are all good at grounding our knowledge in the real world, but they are often limited in terms of their scope, depth and duration, and typically don't involve an element of intervention during the progress of the study. Hence field the types of field studies currently dominating mobile HCI research often leave us with incomplete snapshots of use rather than the comprehensive accounts of it that case study and action research could facilitate providing.

Another disconcerting observation is the apparent segregation of mobile HCI research and researchers into two camps primarily interested in *people* or in *systems*. This segregation, of course, stems from the multi-disciplinarily of the research field, but maintaining such divide sadly also sustain an unfortunate implicit assumption that people and technology can, and perhaps even should, be studied separately. In turn, such assumption can be partially responsible for researchers in the people- and technology-oriented camps continuing to investigate the same types of questions and problems as before in a disconnected manner, rather than developing and investigating new shared ones in collaboration. In our view, not doing this impede the ability of mobile HCI research to continue informing the creation of better mobile devices, systems and services.

New opportunities and challenges

The distribution of research methods and purpose in the second research methods review offers a number of new opportunities and challenges within the area of mobile HCI. Most importantly, we believe that it is important that the current trajectory of doing *more* field work is extended with a move towards doing *better* field work. This does not just mean that we should improve the way we apply methods for field work, but also that we could be applying a different set of natural setting research methodologies when going into the field. Whereas field ethnographies, -experiments and -surveys offer a valuable opportunity for studying real-world phenomena and situating our design proposals in context, more *case studies* in mobile HCI could facilitate increased learning from both new and existing systems within real-world context through broader scope, increased depth and longer durations of our empirical studies, as exemplified in reviewed paper no. 6,

10, 33, 54, 84, 93, 107 and 136. As pointed out in [3] such case studies enable closer scrutiny of mobile system use and user experience, which would in turn increase the collective knowledge in the discipline and inform the generation of new hypotheses to guide further research. In extension of this, the maturity and proliferation of mobile technologies throughout society today means that some of the reasons for not doing action-research based empirical work discussed in [3] have disappeared, making this approach a currently underutilized opportunity for developing knowledge in the discipline through longitudinal deployment and evaluation in practice, as exemplified in reviewed paper no. 3.

The second opportunity and challenge facing current mobile HCI is, in our opinion, to transcend beyond the research questions and problems currently directing the focus of the people- and technology- oriented camps of mobile HCI respectively. Due to this continued divide we are at risk of missing the holistic nature of the mobile HCI challenges currently at hand, as mobile technologies have matured considerably and now pervade almost every aspect of our lives, work and leisure. What is needed then is a shift where new and shared problems are framed in a way that force new ways of thinking and operating [9]. This facilitates what Rogers et al. describe as *"reconceptualizing the domain of interest through using a modified unit of analysis"*. Hereby, the scope can be broadened while still allowing the use of existing concepts and theory. Candidates for such modified units of analysis for mobile HCI could be entities like "context" or "mobile device ecosystems".

Other opportunities include more basic research, and research that seeks to integrate, or at least combine, fieldwork better with engineering. In terms of evaluating, there are also still opportunities for exploring alternatives to field studies and lab experiments, such as case studies and action research for achieving better ecological validity. Finally, survey research could be explored even more for widening the scope and generalizability of evaluations.

CONCLUSIONS

This paper has provided a snapshot of mobile HCI research in 2009 based on a review and of 144 top-level publications classified by their methods and purpose. This is compared to a similar review from 2000-02. From this review and comparison we have identified a number of methodological trajectories within mobile HCI research showing that the research field is extending its focus and its repertoire of methods and techniques. Mobile HCI is no longer dominated by engineering systems using applied approaches, but has become a highly empirically driven area of research with a growing focus on understanding the phenomena of mobile HCI. However, there are still opportunities and challenges for mobile HCI research. Firstly, there is need and opportunity for doing better field research by applying more in-depth and longitudinal natural setting methodologies such as case studies and action research. Secondly, there is need and opportunity for distilling and defining a set of new research questions and problems, that transcends focus on either people or technology and are shared more broadly within the community. Other new opportunities lie in simply trying to populate the "less crowded" areas of table 3.

LIMITATIONS

The present study echo the limitations related to the methods and purpose categories potentially being criticised for being unclear and overlapping, and sometimes orthogonal. Hence it can sometimes be difficult to decide which category a paper belongs to, and the study relies on the researchers and authors' understanding of these.

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