Framing the Context of Use for Mobile HCI

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ABSTRACT

Author Keywords
Mobile, human computer interaction, context of use, usage context, mobile context of use

The need to better understand the role of context has emerged after the revolution of mobile computing as such devices are used in heterogeneous circumstances. However, it is still hard to say what context of use in mobile human-computer interaction actually means. This study summarises the past research in mobile contexts of use and aims not only to provide a deeper understanding of the characteristics associated with it, but also to indicate a path for future research. This article presents an extensive and systematic literature review of over 100 papers published in the five high-quality journals and one main conference in the field of HCI during the years 2000-2007. Our results show that context of use is still explored as a relatively static phenomenon in mobile HCI. Its most commonly mentioned characteristics are linked to social, physical, and technical components while transitions between the contexts were rarely listed. Based on our review we present a descriptive model of context of use for mobile HCI (CoU-HMCI) summarising five components, their subcomponents and descriptive properties. The model can help both practitioners and academics to identify broadly relevant contextual factors when designing, experimenting with, and evaluating, the mobile contexts of use.

INTRODUCTION

Mobile computing has emerged a specific research focus within human-computer interaction (HCI) and has gone beyond conventional desktop computing environments during the last ten years. In this change, interest in studying contexts of use has dramatically increased. Still, context of use is not the focus of interaction research, but it is something framing, surrounding and influencing the interaction between users and mobile computers. For designers, it is appealing to know the contextual
characteristics that can be taken into account in effectively supporting user’s actions. For user experience researchers, it is desirable to understand the features or properties of usage context influencing an experience. For modern mobile usability practitioners, conducting experiments on the field settings, it is important to understand and report the relevant contextual conditions as a necessary part of evaluation. However, when exploring and understanding what context of use is about, researchers and practitioners face a variety of definitions, frameworks and models (e.g. Bradley & Dunlop, 2005; Cheverts et al., 2000, 2001; Dey, 2001; Dourish, 2001).

There are multiple ways to approach and categorize context of use. Understanding context is one of the main aims of ethnographical research (Dourish, 2001, 2004; O’Hara et al., 2006, 2007), whereas research into context-awareness targets the modeling of features (Cheverts et al., 2000, 2001; Dey, 2001), and usability or user-experience researchers see context of use as a part of a holistic picture of experience (see e.g. Hassenzahl & Tractinsky, 2006; Roto, 2006). Recently Bradley and Dunlop (2005) presented a prominent multidisciplinary model of context by combining theories from the fields of linguistics, computer science and psychology. According to their model, context of use is characterised by task, physical, social and temporal components of context. Furthermore, similar categorisations have been presented not only in the mobile HCI (Roto 2006, Väänänen-Vainio-Mattila & Ruuska, 2000) and mobile work contexts (Wigelius & Väätäjä, 2009) but also in consumer studies (Belk, 1975). Besides these, technical, application or domain contexts have also been underlined as relevant factors for human-computer interaction (ISO 13407, 1999; Väänänen-Vainio-Mattila & Ruuska, 2000). While previous works provide a good base for viewing characteristics of usage context, their perspective is limited for mobile HCI.

Mobile usage contexts are heterogeneous and dynamic (e.g. Kaasinen, 2003; O’Hara et al. 2007; Tamminen et al., 2005; Väänänen-Vainio-Mattila & Ruuska, 2000). The usage sessions may contain transitions between contexts and within contexts (Tamminen et al., 2005): for example between personal and shared use; temporally, between waiting and hurrying; from walking to standing or sitting; or between multi- and unitasking (Cui et al., 2006; Kaasinen, 2003; O’Hara et al., 2007; Tamminen et al., 2005; Väänänen-Vainio-Mattila & Ruuska, 2000). To date, there have not been any wide scale attempts to understand special characteristics of these contexts in which the mobile interaction takes place. Rather, the previous reviews have either modelled general characteristics
without underlining mobile interaction (Bradley & Dunlop, 2005), or their focus has been upon the
research methods used in mobile HCI (Kjeldskov & Graham, 2003).

The goals of this paper are two-fold: firstly, we summarise the past research into mobile contexts of use
and determine to what extent its different characterizing components have been studied; secondly, in
order to understand what context of use in human-mobile computer interaction actually is perceived to
be, we develop a descriptive model which both underlines special characteristics of mobile HCI and
deepens the current knowledge of it. This paper presents an extensive and systematic literature review
based on the review methods presented by Schwarz et al. (2007). Our review examines over 100 papers
published in the five high-quality journals and one main conference in the field of HCI during the years
2000-2007. The results of our work will benefit both academics and practitioners in the mobile HCI
community in understanding the special characteristics of mobile contexts and assist in directing future
research in this area.

The paper is organized as follows: Section 2 gives an overview of context of use – what it is and what
kind of features are associated with it, this section forms the base for our review; Section 3 presents our
review research methods and materials; Section 4 summarizes the results in the form of a descriptive
model of context of use for mobile HCI (CoU-HMCI) including five components, their subcomponents
and descriptive properties; finally, Section 5 presents a discussion and conclusions regarding the study
and future research.

CONTEXT OF USE
Definitions and approaches
Originally, the concept ‘context’ referred to language meaning ‘con’ ‘text’, i.e., with text (see
Winograd, 2001). Webster’s Online Dictionary (n.d.) defines context as a “the set of facts or
circumstances that surround a situation or event; “the historical context”. In the field of HCI,
definitions of context give a broad overview to the major relevant factors. According to Dey (2001),
“Context is any information that can be used to characterise the situation of an entity. An entity is a
person, place, or object that is considered relevant to the interaction between a user and an
application, including the user and application themselves” (p. 5). According to ISO standard 13407
(1999), context of use is related to “user characteristics, task, as well as technical, physical, and social
environment”. The standard separates the user and system from other context components to reduce the
overload upon the term context (ibid). Later, the same categorization was applied by Roto (2006), who

developed an extensive model for user experience in mobile browsing with systematic definitions of the terms ‘user’, ‘system’ and ‘context related factors’ that offered a vocabulary for the field. According to Roto (2006), context represents the circumstances under which the activity (mobile browsing) takes place.

In the past, context has been understood in terms of objective, physical and external properties, following the ideas of natural sciences and systems theory (Ishii & Ullmer, 1997; Svanaes, 2001). Nevertheless, the notion of relevancy seems to be a general characteristic of context (Bradley & Dunlop, 2005). In relation to definitions of context, a context-aware system is defined as a system which uses context to provide relevant information and/or services to the user, where relevancy depends on the users’ task (Dey, 2001). Understanding these behavioural aspects of the context can improve design and make context-aware systems beneficial (Bellotti & Edwards, 2001; Bradley & Dunlop, 2005). A concept of “context dependency implies that when some aspect of context is used explicitly or intrinsically in a given situation, that aspect of context is required for that situation to occur” (Bradley & Dunlop, 2005, p.407).

In recent HCI context research, the situated action is emphasised when context is defined. The context of use is to see it as a relational, dynamic, occasional property, in which the action arises (e.g. Dourish, 2004, Hult et al., 2006, Tamminen et al., 2004). In this line of research, activity defines the context including a subject as user(s) doing the activity, object as a need/desire that motivates activity, and related operations for carrying out the activity (Nardi, 1997). It includes internal processes and goals as well as external resources such as artefacts, environment, people and settings (Nardi, 1997). According to Suchman’s (1987) situated actions, every course of action depends in essential ways upon its material and social circumstances. Context as a dynamic construct is characterised as taking into account a period of time, episodes of use, social interaction, internal goals, and local influences (Greenberg, 2001).

Context is not only a part of interaction, but is also an essential part of the subjectively experienced outcomes of these actions. Context is an essential part of user experience (e.g. Hassenzahl & Tractinsky, 2006; Roto, 2006). Context can be seen as “a process whereby a person consciously or unconsciously compares an external context with acquired personal experiences/knowledge (both of which may contain task, physical, social, and temporal dimensions) to form goals for undertaking concise actions, possibly with other people and/or objects” (Bradley & Dunlop, 2005, p. 424). Hassenzahl &
Tractinsky ’s (2006) classical definition of user experience (UX) echoes a previous definition of context, saying: “UX is about technology that fulfils more than just instrumental needs in a way that acknowledges its use as a subjective, situated, complex and dynamic encounter. UX is a consequence of a user’s internal state --, characteristics of designed system -- and the context – within which the interaction occurs” (p.95).

Taken together, the definitions and approaches presented here are diverse and numerous, with many different perspectives taken in attempting to understand this challenging phenomenon. Some of the definitions are very general and make it hard to explicitly describe, identify, quantify or operationalize the relevant dimensions (Bradley & Dunlop, 2005; Dey et al., 2001; Funk & Miller, 1997). We argue that we need a deeper overview to be able to understand which of the components and factors of context are vital in mobile contexts. Therefore, we take another approach from the recent context HCI research by basing our arguments and choices on the context definition in the ISO 13407 (1999) standard along with that of Roto (2006), i.e. focusing on context components that are external and separating these other context components from user and system. Some of these properties could be as objective as a natural phenomena, e.g. day of the week, whereas some of the properties are subjective, e.g., cultural behaviour (Oulasvirta et al., 2003). Finally, we use the term ‘context of use’ to clarify that the perspective taken is that of usage and user, rather than the application or system context.

**Categorisation of components of context of use**

To identify external context components from user, system and interactions between them, we firstly identify the context components acknowledged in the current HCI context research. We use the term ‘component’ to refer to any element of context to combine the previously used terms of factors, components, dimensions, aspects, state, and environment to under same umbrella. Table 1 gives an overview of the different components of context of use listed in the literature.

<table>
<thead>
<tr>
<th>Components of context of use</th>
<th>Field of studies (approach)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical, social, temporal, task</td>
<td>Consumer studies</td>
<td>Belk, 1974</td>
</tr>
<tr>
<td>Physical, social, temporal, task</td>
<td>HCI</td>
<td>Bradley &amp; Dunlop, 2005</td>
</tr>
<tr>
<td>Physical, social, temporal, task</td>
<td>Mobile HCI (UX)</td>
<td>Roto, 2006</td>
</tr>
<tr>
<td>Spatial, social, temporal, task, infrastructural</td>
<td>Mobile HCI (UX)</td>
<td>Wigelsius &amp; Viitiiäjä, 2009</td>
</tr>
<tr>
<td>Physical, social, technical</td>
<td>Mobile HCI (UX)</td>
<td>Väänänen-Vainio-Mattila &amp; Ruuska, 2000</td>
</tr>
<tr>
<td>Physical, ambient, social, cultural, legislative environment, technical environment</td>
<td>HCI</td>
<td>ISO 13407,1999</td>
</tr>
<tr>
<td>Location, computational and physical objects, persons</td>
<td>HCI (Context awareness)</td>
<td>Dey et al., 2001</td>
</tr>
</tbody>
</table>
Beyond young context research in HCI, in the domain of consumer studies the effects of context and particularly situations as a part of consumer decision making were acknowledged very early (see Belk, 1974). Therefore, based on the outcomes of consumer behaviour research, reflecting the dimensions of environmental, social and task-specific characteristics may be beneficial to HCI research. One of the most cited studies in consumer behaviour research is Belk’s (1974) categorisation of situational characteristics into physical context, social context, temporal context, task context and antecedent (~user) states.

Within HCI, there are slight differences in the categorising of components of context. Similar to Belk’s (1974) categorisation, physical, social, temporal and task components of context have been proposed as is, or with slight modifications, in several studies in HCI (Table 1). For example, Bradley & Dunlop (2005) defined a multidisciplinary model for context in which user-application interaction is surrounded by task, physical, temporal and social dimensions. Later, Roto (2006) proposed a similar categorisation derived specifically from mobile browsing context. In addition to these components, technical or infrastructural context is underlined in several other studies (ISO 13407, 1999; Schilit & Theimer, 1994; Väänänen-Vainio-Mattila & Ruuska, 2000). In the following, we will review the reported characteristics of these commonly appearing physical, temporal, social temporal, task and technical contexts one at a time.

- **Physical context of use** includes apparent features of a situation or physically sensed circumstances, including location (Belk, 1974; Roto, 2006). In more detail, according to Bradley and Dunlop (2005), physical context includes location, gradient and altitude, physical objects, orientation and weather and lighting conditions. Recently, a great part of context in the field of mobile computing has taken a location-dependent approach to physical context (Abowd & Mynatt, 2000; Dey et al., 2004). This specific domain of context research focuses upon location in a real physical environment, i.e., when developing context-aware applications, the information presented to a user is based on her/his geographical location. In addition, the physical context may also imply physical conditions such as lighting or infrastructure (Barnard et al., 2007) or background and environmental noise, and weather conditions (Smith et al., 2006).
• **Temporal context** of use can describe factors of past and future situations, from time of day to the week, month or season (Belk, 1976; Bradley & Dunlop, 2005). It also covers the time available for completing the task (Roto, 2006). In mobile interactions especially, the actions in the temporal dimension vary and can be classified as hurried, normal or waiting (Tamminen et al., 2004).

• **Task context** of use for mobile interaction describes in particular the multitasking and possible interruptions that are related to the execution of the task (Roto, 2006). On a broader scale, Bradley and Dunlop (2005) define it as ‘the functional relationship of the user with other people and objects and the benefits (e.g. resources available) or constraints (time pressure) this relationship places on the user’s achievement of his or her goal.’ In addition, studies of factors of task context can be identified which have divided them into current activities (Smith et al., 2006); work related tasks (see Agre, 2001); and according to the scope or criticality of a task, into primary and secondary tasks (Matthews et al., 2007); or as foreground and background interaction (Svanaes, 2001).

• **Social context** of use describes the other people present, their characteristics, their apparent roles, and interpersonal interactions (Belk, 1975). It can also describe other people’s influence on the user and the user’s social contribution goals (Roto, 2006), traditions (McCullough, 2001) privacy, informal interaction (Grudin, 2001), relationship with the surrounding people, and the behaviour of the surrounding people (Dunlop & Bradley, 2005).

• **Technical context of use** focuses on devices, available infrastructure, facts and system assumptions (Petrelli et al., 2001), sensors (Fogarty et al., 2004) and network services (Winogard, 2001). It can be related to hardware or software or other products (ISO 13407, 1999).

These components listed — physical, temporal, social, task and technical context — represent relatively static descriptions of context. However, to gain a deeper understanding of context, one must recognize the challenge between universal and domain specific conceptions (see Oulasvirta et al., 2003) and identify the multidisciplinary nature of the context dimensions. In mobile HCI, the studies of context of use repeatedly highlight its dynamic and heterogeneous nature even if it is not listed as a component of context of use in any studies (Cui et al., 2006; Kaasinen, 2003; O’Hara et al., 2007; Tamminen et al., 2005; Väänänen-Vainio-Mattila & Ruuska, 2000). For example, these studies state that socially, usage can vary between individual and group usage and, temporally, from fast hurrying to waiting.
In the task domain, appear environmental interruptions to the user’s main task (Ho & Intille, 2005). Resources in the technical context of use, such as network coverage or bandwidth, may vary within or between the usage session (Väänänen-Vainio-Mattila & Ruuska, 2000). Similarly, lighting or the position of the user — representing components of physical context — can differ (Väänänen-Vainio-Mattila & Ruuska, 2000), or devices may be used in different physical environments (Cui et al., 2006). There can be a primary and secondary context of use, each with different characteristics (Reponen et al., 2009). These transitions are domain specific characteristics that need to be taken into account as a component of mobile contexts of use.

- *Transitions* refers to changes within any contextual component as specific conceptions for contexts of mobile human computer interaction. In this article we use the term ‘transitions to refer to passage or shifts between or within heterogeneous contextual characteristics’.

In sum, different categorisations of components of context of use remained similar in the presented literature. They fall into five main categories: physical, temporal, social, task and technical context. However, from the viewpoint of mobile HCI, these characteristics do not underline the dynamics and heterogeneousness of mobile contexts. The goal of this paper is to review the past research of characteristics of mobile contexts of use and build a model to detail its special nature.

**RESEARCH METHOD**
The main aims of this review are to 1) integrate previous research, 2) create a deeper understanding of the components of context and 3) describe the path for future research into context in the field of mobile human computer interaction.

The research questions in this study are as follows:

1. Which components of context of use have been the focus of context research within the field of human mobile computer interaction?

2. What does context of use mean in mobile human-computer interaction?

The examination of the components of context underlines to what extent certain components have been studied in the past. It highlights possible research areas to be studied in more detail in future. The context of use is important in framing the relevant factors for human mobile computer interaction from a broad concept of context. Mobile context of use has special characteristics which are not well
highlighted in universal presentations of components of context. The model of context increases the understanding of factors that surround the mobile interaction and impact upon it.

The published research articles were examined in the following steps: the first three of them describe the identification of relevant articles (see Schwarz et al., 2007), being 1) selecting/searching articles for review 2) filtering relevant articles and 3) identifying content and structure. For deeper analysis of content a further three steps were taken, 4) grouping according of components of contexts 5) clustering and validating and finally 6) triangulating (see, Schwarz et al., 2007; Patton 2002).

1) Selecting the articles for review - Articles published between the years 2000-2007 were included in the review. We selected six central and high-quality publications with moderate to high impact in the field of human-computer interaction: five journals and one conference series. All articles are peer-reviewed and they have an established reputation as the major publications for HCI research for more than one decade. As mobile HCI is a subtopic of HCI we consider this pool of publications to be representative for studying mobile contexts in a selected time frame. The publications selected are presented in Table 2.

<table>
<thead>
<tr>
<th>Publications selected for review, 2000-2007</th>
<th>Number of articles included in the review</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM Transactions on Computer Human Interaction, TOCHI</td>
<td>6</td>
</tr>
<tr>
<td>Behavior &amp; Information Technology</td>
<td>8</td>
</tr>
<tr>
<td>International Journal of Human-Computer Studies</td>
<td>15</td>
</tr>
<tr>
<td>HUMAN COMPUTER INTERACTION</td>
<td>5</td>
</tr>
<tr>
<td>Personal and Ubiquitous Computing, PUC</td>
<td>24</td>
</tr>
<tr>
<td>SIGCHI conference on human factors in computing systems, CHI</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
</tr>
</tbody>
</table>

2) Filtering the articles for review - The articles were selected using three main criteria. 1) Context or mobile is mentioned in the title, abstract or as one of the keywords. This part was done aid of available search engines. 2) The contents of the paper described in the abstract or introduction revealed that paper was clearly related to mobile contexts or mobile computers were used in a study. This was done by reading through all published journal volumes one by one. For the CHI conference, due to the enormous amount of articles, only full-papers were reviewed and the first selection criteria used. We followed the definition of mobile device as being a handheld personal computer moving with a user in relation to their surroundings (Oksman et al., 2008), which can be for example a mobile phone, computer, personal digital assistant, navigators, MP3 players, portable radios, and wearable computers.
These criteria filtered out possible other systems of ubiquitous computing, like wide public screens and other portable computers such as laptops. These two selection methods were needed, because often the keywords - *mobile* or *context* - were either not very explicitly expressed or they were expressed as meaning something non-related. 3) The selected articles included in empirical user research to underline context of use. This selection criterion filtered out pure system development articles (context awareness), theoretical papers, essays, and introductory papers of journals. The total number of articles was 109 and the total number of articles per publication is presented in Table 2.

3) **Identifying content and structure** - All papers were collected electronically. The abstract and full text was read through to identify the focus components of context, including physical, temporal, task, social and technical context, and transitions between them. In the identification of components of contexts of use, we applied definitions of each of the components based on the related work presented in section 2 (strongly relying on work from Belk, 1974; Bradley & Dunlop, 2005; Roto, 2006; Tamminen et al., 2004; ISO 13407, 1999). The components identified, along with the appropriate pieces of text describing these components, were recorded to an external Excel file. The article was recorded to represent several components of context if it stated that several components had been investigated, like in the field studies.

4) **Grouping of components of contexts** - The common themes were grouped under different components of context. Within each component of context, the subcomponents were identified and categorising according to the recorded piece of text. In this process, we identified general structures that are common to all components representing the properties of context components. The total number of grouped descriptions of components of context was 477.

5) **Clustering analysis and validation** - Validation of analysis contained several iterations. We labelled the identified groups first. We then validated the groups by going through the data articles and collected descriptions sourced from articles. In this process, relabeling and reassigning took place with the aim of ensuring consistency across and within groups (Schwarz et al. 2007).

6) **Triangulation** - Triangulation of researchers, involving two researchers in each of the steps of analysis, was applied to improve the validity of the final analysis (Denzin, 1978, in Schwarz et al., 2007). The filtering of articles was done by two researchers for all publications. Identification of components of contexts was done by one researcher and reassigned by second researcher (for 30 randomly selected articles interrater reliability is excellent *Cohen’s Kappa* = .8 ). The grouping of
characteristics of components of context was in the initial phase done by two researchers independently and cross-checked and finally merged to represent the final categorization to show the agreement between researchers.

RESULTS
This section presents the results of the two main research questions. Firstly, the results of the most studied components of context in human mobile computer interaction are presented. Secondly, the extended model of components of context is described.

The most studied components of context
Six identified components of contexts in human mobile computer interaction and the related articles in the review are listed in Table 2. Among these components of context, social and physical contexts were most commonly mentioned in the studies. These were followed by descriptions of technical, temporal and task contexts of use. The least investigated component of context was transitions between contexts.

Table 3 Components of contexts of use in human mobile computer interaction, number and percent of related articles in the review and reviewed articles.

<table>
<thead>
<tr>
<th>Component of context of use</th>
<th>Percentage (max 100%) and number (max 109) of articles referring to components of all reviewed articles</th>
<th>Reviewed articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>66,1% (72)</td>
<td>1 2 3 4 5 8 9 10 11 12 14 15 16 17 19 21 22 23 24 27 29 30 31 32 33 34 35 36 37 38 39 41 43 44 45 46 47 49 50 53 54 55 56 60 62 63 69 70 71 72 76 79 80 81 82 83 85 86 87 90 91 92 95 96 98 99 101 102 103 104 105</td>
</tr>
<tr>
<td>Physical</td>
<td>61,5% (67)</td>
<td>1 4 5 6 7 8 9 10 12 13 14 18 20 21 22 23 24 25 26 29 32 33 35 36 37 38 43 44 49 50 52 53 54 55 56 57 58 59 60 62 63 66 67 68 72 73 75 76 78 79 80 81 82 83 84 85 87 89 90 91 94 96 100 101 103 107 108</td>
</tr>
<tr>
<td>Technical</td>
<td>36,7% (40)</td>
<td>1 2 9 10 11 22 23 24 28 31 32 33 37 39 43 46 49 51 52 56 59 60 61 62 65 71 74 78 82 86 87 88 91 93 94 98 99 104 106 109</td>
</tr>
<tr>
<td>Temporal</td>
<td>35,8% (39)</td>
<td>4 8 14 16 17 22 23 35 36 39 40 43 50 53 54 55 60 62 63 65 67 68 70 71 76 78 79 80 81 82 83 85 87 91 95 96 101 103</td>
</tr>
<tr>
<td>Task</td>
<td>31,2% (34)</td>
<td>4 6 7 20 23 28 29 36 39 42 48 50 52 53 54 55 56 63 64 66 70 72 77 78 80 82 83 87 89 91 96 97 103</td>
</tr>
<tr>
<td>Transitions</td>
<td>20,2% (22)</td>
<td>10 29 32 35 36 39 50 53 54 55 60 65 72 78 80 82 83 89 91 96 101 103</td>
</tr>
</tbody>
</table>

Context of Use in Human-Mobile Computer Interaction (CoU-HMCI)
An overview of a model of Context of Use in Human-Mobile Computer Interaction (CoU-HMCI) is presented in Figure 1. It describes the surroundings of the interaction between user and mobile system, including the major components (physical, social, task, temporal, technical and informational), related subcomponents and properties (level of magnitude, dynamism, pattern and typical combinations). Each of these is presented one by one in this section.
Figure 1. A model of Context of Use in Human-Mobile Computer Interaction (CoU-HMCI): Components of context (physical, temporal, task, social, and technical and information context), related subcomponents and properties of context (Level of magnitude, dynamism, pattern and typical combinations).

Physical context

Physical context describes the apparent features of situation in which the human-mobile computer interaction takes place, including spatial location, functional place and space, sensed environmental attributes, movements and mobility, and artefacts present.

1) Spatial location, functional place and space include aspects of location and material characteristics of location, functional space (e.g. zones as city areas, sport fields) and in distance participation. Location and material characteristics of location may be geographical location and distance and may contain a description of relevant landmarks (e.g. Arminen, 2006; Benford et al., 2005; Cheverst et al., 2000; Ludford et al., 2006; Nivala et al., 2007; Paulos & Goodman, 2004). The use of mobile maps has highlighted the development of a detailed description of location.

In the terms of functional place, mobile interaction has multiple places, e.g. at school, work or home, a cinema, or on transportation (e.g. Jung et al., 2005; O’Hara et al., 2007). In the higher abstraction level, location can be understood as zones for functional spaces for action. There are spaces for example for relaxation, for commercial exchanges such as shopping, leisure and work (e.g. Kaasinen, 2005; Paulos
& Goodman 2004). Spatial location also takes into account in distance or remote participation (Landgren & Nulden, 2007; Ludford et al., 2006; Salovaara et al., 2006). People can be interested in remote participation in an important event they cannot participate in by being physically present at (Salovaara et al., 2006), or the physical distance between the players sets the special requirements for mixed reality gaming (Flintham et al., 2003; Crabtree et al., 2004; Benford et al., 2006).

2) Sensed environmental attributes include light/lighting, sound, haptic and multimodal environment, temperature, weather conditions, and humidity (e.g. Paulos & Goodman 2004; Barnard et al. 2007; Nelson et al., 2001; Kim et al., 2004; Korpipää et al. 2003) To mention a few of these, Barnard et al. (2007) have studied the impact of the lighting level on task performance and workload on mobile devices under reading and selecting tasks, while Williams et al. (2005) have examined the relation between soundscape and physical location.

3) Movements and mobility describes the position and motion of the user’s body, the mobility of user, and the motion of the user's physical and functional environment. The position and motion of the user’s body can be anything from stopped and sitting to walking, fast running and climbing (e.g. Bentley & Metcalf, 2007; Intille et al., 2005; Seager & Fraser, 2007).

‘Mobility of user’ represents the higher abstraction level of movements rather than simply the motion of the user’s body itself. It contains three different mobility characteristics – wandering, travel between, and visiting in locations or functional spaces (Kristoffersen & Ljungberg, 1999). In wandering, the user wanders around with no specific destination. Travelling means that user spends some time travelling in a vehicle in order to get particular location, whereas visiting means that the user spends some time in different locations (e.g. Bentley & Metcalf, 2007; Jung et al., 2005; Pascoe et al., 2000).

Motion of the user's physical and functional environment indicates that the user’s environment is on the move. Such cases are, for example, travelling in any form of transportation (e.g. O’Hara et al., 2007; Pascoe et al., 2000)

4) Artefacts represent physical objects that surround a human-mobile computer interaction (e.g. Holtzblatt, 2005; Lamming et al., 2000).

Temporal contexts
Temporal context describes the user’s interaction with the mobile computer in relation to time in multiple ways such as duration, from time of day to years, the situation before and after use, actions in relation to time, and synchronism.

1) **Duration** illustrates the length of the interaction session or the certain event in which the interaction takes place (e.g. Bentley and Metcalf, 2007; Ludford et al., 2006; O’Hara et al., 2007; Perry et al., 2001). For example, preferred viewing lengths for mobile video may vary from 30s to 45 minutes, depending the duration of a given situation (e.g. waiting time, or travelling time) (O’Hara et al., 2007). The time taken to start up an application can also influence the ways it is used. Small units of time, like unpredictable pauses, are acceptable in mobile device usage, while longer predictable pauses are acceptable for laptop use (Perry et al., 2001). The time spent in a given location or on a trip, will also affect the usage pattern and the interaction (Arminen, 2006; Ludford et al., 2006; O’Hara et al., 2007).

2) **Time of day, week, and year** indicates the peaks of the user’s interaction in relation to time. There can be differences between anytime use, peaks as typical use time, one time use and use during the weekends and holidays (e.g. Halvey et al., 2006; Kaasinen, 2005; Salovaara et al., 2006). For example, Halvey et al. (2006) describe temporal peaks (time of week and time of day) for mobile internet use.

3) **Before – during – after** examines the actions before and after user’s interaction (e.g. Bitton et al., 2004; O’Hara et al., 2007; Salovaara et al., 2006). For instance, ‘before use’ may contain actions, like just before picture taking in the field work settings (Bitton et al., 2004) or preparations for opportunistic use in mobile work (O’Hara et al., 2007). ‘After use’ people might want to extend their experience of a certain event by saving digital souvenirs (Kaasinen, 2005; O’Hara et al., 2007).

4) **Actions relation to time** emphasises the relative temporal tensions of actions including hurrying, normal and waiting (e.g. Tamminen et al., 2004; Landgren & Nulden, 2007; O’Hara et al., 2007; Kern et al., 2007). It also includes rapid reactions to the environment e.g. from observing to action, such as when taking a camera shot or in the case of an emergency (Landgren & Nulden, 2007; Pascoe et al., 2000).

5) **Synchronism (synchronous-asynchronous)** describes the status of being simultaneous (Koskinen, 2000; O’Brien & Mueller, 2007). Talking on a mobile phone is a synchronous action whereas text messaging is an asynchronous action. Being updated e.g. with news or the results of a sporting event can aim to achieve synchronous one-way communication (Salovaara et al., 2006).
Task context

Task context describes the surrounding tasks in relation to user’s task of interacting with mobile computer containing the subcomponents of multitasking, interruptions and task domain. Task context is related to the demands of the entire situation upon one’s attention.

1) Multitasking describes multiple parallel tasks alongside the human mobile computer interaction and which compete for cognitive resources (overview in Oulasvirta et al., 2005; Lee et al., 2005; Salvucci, 2007; Intille et al., 2005; Tamminen et al., 2004.). The most important tasks, set by goals and needs, get the highest priority and the remaining resources are distributed to the other tasks, resulting in slowdowns, postponement, or actions being put on hold or terminated due to insufficient resources (Oulasvirta et al., 2005). For example, parallel tasks to the interaction with a mobile device may be walking, waiting, sidestepping, planning routes, avoiding collisions, estimating time-to-target, way finding, talking, driving, or simply maintaining one’s awareness of one’s surroundings (Oulasvirta et al., 2005; Salvucci, 2007; Lee et al., 2005; Pascoe et al., 2000). The majority of these tasks have been studied in parallel with mobile browsing (Oulasvirta et al., 2005), but there have also been studies conducted of driving while interacting with a mobile device (Salvucci, 2007; Lee et al., 2005). Primary or secondary tasks define the relation between the parallel tasks (e.g. Lee et al., 2005; Kaasinen, 2005; Salvucci, 2007). Using a mobile device while driving illustrates two parallel tasks, where driving is a primary task and using the device is a secondary task (Salvucci, 2007; Lee et al., 2005).

2) Interruptions - “An interruption is an event that breaks the user’s attention on the current task to focus on the interruption temporarily” (Speier et al., 1997, in Ho & Intille. 2005). In human mobile computer interaction, this non-continuity can be caused by such things as technical interruptions (like an unreliable network) (Crabtree et al., 2004), or interruption of the social or physical context (Kaasinen, 2005; Kern et al., 2007, Oulasvirta et al., 2007).

3) Task domain represents the macro level of task context by dividing the situation of an interaction into goal-oriented (work) and action-oriented (entertainment) classes (inspired by Hassenzahl, 2003). Work related applications, guides and navigation are examples of highly goal-oriented task domains in which the efficient task completion i.e. effectiveness and efficiency is important (e.g. Landgren & Nulden, 2007; Pascoe et al., 2000; Paay & Kjeldskov, 2005; Feng et al., 2006; Salvucci, 2007). In contrast, the action itself is the goal in the entertaining task domain, such as in mobile-gaming (e.g. Bell et al., 2006; Benford et al., 2006; Cheok et al., 2004), mobile video, television, or music
consumption (e.g. O’Hara et al., 2007; Salvucci et al., 2007), spectating at special events (Jacucci et al., 2007; Esbjörsson et al., 2006), or sharing content or experiences (e.g. Ahern et al., 2007; Bentley & Metcalf, 2007; Counts & Fellheimer, 2004).

**Social context**

*Social context describes the other persons present, their characteristics and roles, the interpersonal interactions and the surrounding culture that influence the user’s interaction with a mobile computer.*

1) **Persons present** in the situation are classified into self, group and organisation or public (e.g. Ames & Naaman, 2007; Jacucci et al., 2007; Landgren & Nulden, 2007; O’Hara et al., 2007). Other people may be either virtually or physically present. One of the most commonly mentioned aspects, one affected by the presence of other people, is the balance of private vs public (e.g. Nelson et al., 2001; Costanza, 2007; Tamminen et al., 2004; Eagle & Pentland, 2006). For example, on public transportation or in noisy or crowded situations people actively create private ‘spaces’ by listening to music (O’Hara et al., 2007; Tamminen et al., 2004). Other people’s characteristics and roles also have an influence upon the user.

2) **Interpersonal interaction** in the situation describes the interaction between the persons, their turn taking and co-actions. One-to-one, one-to-many, many-to-many, one-to-myself are for instance the possible communication structures between and within persons in mobile HCI (Crabtree et al., 2004; O’Brien & Mueller, 2007; Salovaara, 2007). Turn taking emphasizes the sequential structure of an individual’s active actions as they interpret, construct and act in a situation by using language and non-verbal cues (Sacks et al., 1974, in Oulasvirta, 2004;). Interpersonal interaction includes all collaborative actions on different levels. It can be co-acting or co-experiencing (e.g. Counts & Fellheimer, 2004; Perry et al., 2001; Jacucci et al., 2007), like co-viewing of video contents on the same device (O’Hara et al., 2007) or sharing the same situation by using photos (Salovaara et al., 2006). It can also be maintaining an awareness of other persons while doing remote mobile work (Perry et al., 2001), while at a certain important event (Salovaara et al., 2006) or while maintaining community (O’Hara et al., 2007).

3) **Culture** denotes the macro level of social context. It represents the values, norms and attitudes of a certain culture, like work and organisational culture (Eagle & Pentland, 2006; Jacucci et al., 2007; Holtzblatt, 2005; Palen et al., 2001). The differences can also appear in relation to time perception (monochronic or polychronic), tightness of social framework (individualism or collectivism), strength
in uncertainty avoidance and ways of interpreting the informational context surrounding the event (Hall, 1976, in Choi et al., 2005).

**Technical and information context**

*Technical context describes relation of other relevant systems and services including devices, applications and networks, their interoperability, informational artefacts or access, and mixed reality to the user’s interaction with the mobile computer.*

1) **Other systems and services include devices, applications and networks** which are related to the users’ system or service (e.g. Carter et al, 2007; Chalmers et al., 2004; Rogers & Muller, 2006; Saliba et al., 2007).

2) **Interoperability** between and across devices (e.g. mobile-PC), between applications (services) and between networks is part of the technical context. For example the interoperability between devices with equal (between phones) and unequal resources (phone-PC) has been studied in mobile HCI (e.g. Landgren & Nulden, 2007; Counts & Fellheimer, 2004; Crabtree et al., 2004; Perry et al., 2001; Flintham et al., 2003). In addition, access to the web from different platforms has been widely studied (Ahern et al., 2007; Ames & Naaman, 2007).

3) **Informational artefacts and access** relates to other artefacts that contain relevant information, devices which can reach the same or similar content or media in same place and remote document access (e.g. Lamming et al., 2000; Lin et al., 2004; O’Hara et al., 2007). For example, paper and pen might produce parallel information to mobile devices (Lin et al., 2004). Mobile television, PC and conventional television are examples of devices which can reach the same digital content and can therefore influence the pattern of interaction (O’Hara et al., 2007; Oksman et al., 2007).

4) **Mixed reality systems** combines technical and informational context with physical context. In mobile HCI, mixed reality applications are mainly focused on entertainment, such as gaming (Flintham et al., 2003; Crabtree et al., 2004; Benford et al., 2006).

**Properties of context**

Based on the components reviewed we found general properties for defining them in more detail and going beyond a current static modular description. The role of the properties is to help to perceive the central structures and regularity among the broad list of components and subcomponents of context and to underline dynamism between the modular descriptions of context. Properties condense the
differences in the examination levels within components of context. The properties presented here describe the name of the property and the extremes of its scale, with examples. The presentation is limited to only some of the examples; it is not meant to be an exhaustive or complete list of possible options. It is also limited to examining the properties of context component by component, although these properties may be applicable for examining multiple components at the same time.

1) **Level of magnitude (micro – macro):** There are different examination levels ranging from micro to macro levels in the components of contexts. For example, in the physical context, artefacts that are near to the user represent the micro scale whereas functional space is an example of the macro scale. Similarly, the position and motion of the user’s body are on the micro scale when compared to the mobility of the user. In task context, multitasking and interruptions define the micro level while a being a goal-or action-oriented task type illustrates the macro level. In social context, the micro level contains other persons and interaction, while culture represents the broad concept of macro dimension. The micro-level of technical and information context includes other devices, services and other systems and services including devices, applications, while the macro level is described in the terms of their interoperability.

2) **Level of dynamism (static – dynamic):** There are different examination levels of dynamism from static to dynamic levels in the components of contexts. To illustrate this property of contexts, let us consider the example of mobile browsing. In the static case, the user mainly browses during the evenings at home just before falling to sleep. The physical context (such as motion, location, artefacts, and lighting) stays similar between the usage sessions. Temporally, most probably the time relation to action, time of day, actions before and after, etc. remain the same as well as the social context, like other people present, or the technical and information context. In this case, the context of use can be understood as static - as in the past focus of HCI research of desktop computing in the work place.

To describe the dynamic properties of context, the same browsing may take place in many different circumstances. Transfers in physical and temporal context offer examples of dynamic properties of context. The user may be located in multiple different physical locations and also move during the use, for example entering or exiting a vehicle (Colbert & Livingstone, 2006; O'Hara et al., 2007; Oulasvirta, 2004; Jung et al., 2005; Perry et al., 2001), or be under different sensed environmental attributes including lighting and sound (Barnard et al., 2007; Chalmers et al., 2004; Brewster, 2002). A change in place can also trigger an interaction, as when people typically start a phone call whilst leaving a public
place (Nelson et al., 2001). The dynamism in temporal context can be illustrated by changes between resources to action, from hurrying to waiting (Tamminen et al., 2004; Pascoe et al., 2000), in different durations of use and time of day or week. For example, in mobile fieldwork, fast reactions to the changes in environment are needed in order to capture the movements of animals. In the user’s task, this can mean very quick changes from passive observation to rapid action (Pascoe et al., 2000).

In addition to physical and temporal context, dynamic properties are illustrated in the task, social, and technological and information contexts. Task context can dynamically change from a main task like browsing to an interruption (e.g. phone call) and then return to the browsing task, or may change between uni-multitasking, or different types of multitasking situations. Socially, the user may have transitions, for example between personal and co-viewing (O’Hara et al., 2007; Jacucci et al., 2007). In dynamic technical and information context the user may need to take notes by using a pen and paper, but then continue the task electronically on a mobile device (Lin et al., 2004). Similarly, the user may start browsing or viewing television by phone, but after a while would like to continue the same task on a laptop located in the same place (Mäki, 2005). Finally, dynamism between contexts is also illustrated by fluent transitions between virtual and real life contexts in mixed reality applications (Cheok et al., 2004; Flintham et al., 2003; Crabtree et al., 2004; Benford et al., 2006).

3) Pattern (rhythmic – random): The patterns may take place according to a regular rhythm or may occur randomly in the components of contexts. The random rhythm can be understood as a non-frequently appearing pattern, something that just happens once, or is otherwise exceptional from the common form of use. The usage of a certain application on a mobile device can frequently appear in same physical context, like home or work, or usage may occur only once at the same place, as in a location based service at a ski resort (Kaasinen, 2005) or special event (Jacucci et al., 2007; Esbjörsson et al., 2006). Temporally human-mobile computer interaction can appear according to a regular rhythm with a certain frequency, or may be random during the day, with the same duration, or there can be similarities in the patterns before and after use (Oulasvirta, 2004; Bentley & Metcalf, 2007; Grinter & Eldridge, 2003; Halvey et al., 2006; Jacucci et al., 2007). It can also temporally frequently happen when in a hurry and randomly in a waiting situation. In the task context, the usage might be frequently related to the goal-oriented domain - like use at work, or to an action-action oriented usage domain, or may typically appear in certain types of parallel tasks, like travelling. It can also describe the attentional
bursts of interaction, like in mobile devices on the move where shifts are approximately 4 seconds in mobile browsing task (Oulasvirta et al., 2005).

4) Typical combinations: It is possible to examine numerous combinations between two or more different contexts, although the combination of physical and temporal context is one of the most commonly examined. Special attractions like concerts and festivals, visits to the zoo or to a museum, represent a commonly mentioned combination between physical and temporal context which can influence human mobile computer interaction (Kaasinen, 2005; O’Hara et al., 2007; Bentley and Metcalf, 2007; Ludford et al., 2006; Jacucci et al., 2007; Esbjörsson et al., 2006). Similarly, many routines of life are combinations of physical and temporal context (Daytime – work, school; Night – home).

DISCUSSION AND CONCLUSIONS
This study aimed at clarifying the current important concepts of mobile context of use. We focused on summarizing past research in this topic in order to create a deeper understanding of its characteristics. We reviewed over 100 articles about context of use in the field of mobile human computer interaction conducted between the years 2000-2007. We based our review upon past models of components of context of use (such as those of Belk, 1974; Bradley & Dunlop, 2005; ISO 13407, 1999; Wigielius & Vääätäjä, 2009; Roto, 2006; Väänänen-Vainio-Mattila & Ruuska, 2000). The unique feature of this paper is the presentation of a model of contexts of use for human-mobile computer interaction (CoU-HMCI) containing five context components, their subcomponents and properties.

Our results showed that some aspects of context of use are more highly emphasised and that context of use is still mostly understood as a relatively static phenomenon in mobile HCI in the 2000’s. Two context components, social and physical contexts are well explored whereas temporal and task context and transitions are less explored. The importance of temporal context of use has been stated in several past studies (Greenberg, 2001; Jacucci et al., 2005; Tamminen et al., 2004) while its role in the current research in the field seems to be relatively small. Similarly, the task context especially focusing on multiple tasks and interruptions is not deeply explored although it essentially surrounds the user’s main task of interacting with mobile computer. Furthermore, understanding and exploring changes and transitions between contexts and within a single context are dismissed and are thus lacking from the current research into context and mobile HCI. Even though the dynamic nature of mobile computing is emphasized and repeatedly highlighted in the literature (e.g. Greenberg, 2001; Durlach, 2004;
Kaasinen, 2003) the current definitions of contexts are still using static modular descriptions of the phenomenon and do not go beyond ideas of context of use that were discussed in the time of desktop computing. To conclude, further work needs to target the dynamic aspects of context such as temporal and task dimensions and transitions when exploring the context of use.

Our work presented a descriptive model for context of use with five main components, their subcomponents and detailed properties by extending and substantially specifying the current views of context of use in mobile HCI. The main context components follow a similar abstraction level to that which has been presented in past literature about components of context including 1) physical, 2) temporal, 3) task, 4) social, and 5) technical and information context. In this level of description, information as a context component seems to be a tangible research issue in several context HCI studies (e.g. Bradley & Dunlop, 2005; Dey et al., 2001; Dourish, 2004) but when context is conceptualized and categorized, the significance of the information component disappears or is diffused. Furthermore, for each component we also identified subcomponents so as to clarify the content of these contextual components in more detail.

The major feature of our work is to define the set of properties for these components at the levels of 1) magnitude, 2) dynamism, 3) patterns and 4) typical combinations. Levels of magnitude is about finding the proper scale for exploring the context whereas levels of dynamism emphasises that context is not simply either a static or dynamic phenomena but also something between those two end points. When exploring context, understanding and finding patterns in a certain phenomena such as random interruptions or rhythm of temporal components (e.g. a day, an hour) helps us, for example, to evaluate the impacts of these properties more easily. Finally, the combinations refer to the fact that different components may be tightly related to each other (such as time and location specific events, like festivals) and therefore set special characteristics on interaction. The significance of the properties is in the aid of identification of the central structures, regularity and dynamism within and between components of context. In the ultimate level, they can help to 1) analyse and report the context of use in the user studies and 2) identify similarities, differences and comparability between the field studies and experiments in order to find general forms of contextual influences 3) to take into account broad set of central factors in design. In sum, the properties of context go beyond modular and static descriptions of context factors and take steps towards a dynamic, vital and heterogeneous description of mobile contexts of use.
There are four main challenges for future research in using and developing the presented model. Firstly, CoU-HMCI provides an overview of the characteristics of mobile context of use, but it cannot be assumed that role of different components and properties of context are equal. Rather, the importance of different characteristics depends greatly on the system at hand. Future work may explore this specific emphasis in detail. Secondly, we focused upon context of use and also paid close attention to the surroundings of the human-computer interaction. To gain a deeper understanding of contextual factors in relation to interaction and user experience, these factors need to be better related to the user’s actions with the system. This approach would then take steps towards understanding situated actions, and to see context as a relational, dynamic and occasional property in which action arises (e.g. Greenberg, 2001; Dourish, 2004).

The last two suggestions for future work targets on design. The components and properties of the model we present need to be further operationalised and related tools developed that can be applied in multidisciplinary mobile HCI research. There is a need for this in the area of user-centered design, such requirement elicitation, in the evaluation of systems and services in the expected contexts of use (e.g. Jumisko-Pyykkö & Hannuksela, 2008; Oulasvirta, 2009), as well as in the interpretation of field studies. The model presented can provide an extensive list for holistically covering the context of use in the early phase of design, such as with observations or contextual inquiry as a part of requirement elicitation (Holtzblatt, 2005), as well as in evaluations and field studies. For improving further design steps, we may develop or adapt the current user and user’s task modelling practices to consider the features of dynamic context of use. This may be modelling of principal transitions within context components parallel to user’s Hierarchical Task Analysis (HTA, Stanton, 2006), or applying ideas of other techniques (e.g. State Transitions (STD) or Sequence Diagrams). In a broader scale, future work needs to systematically assess the current design practices and identify overlapping and deficiencies of the components and properties of our model. Finally, to achieve a uniform understanding of context, we may also contribute to the further development of standards and above all, we may compare previous empirical findings in a manner that is more comprehensible. Our results are backward compatible with the existing ISO 13407 (1999) standard definition for context as well as previous published work (Bradley & Dunlop, 2005; Hassenzahl & Tractinsky, 2006; Roto, 2008), but also significantly deepen the definition with components, subcomponents and properties.
Limitations of this study
We used systematic method of review including certain filtering and selection strategies in the given time period to study the mobile context of use. Firstly, the limitations of this method are announced in the terms of incompleteness as it does not cover all relevant publication forums and articles in the same time frame. However, our study is based on a broad data set (including seven years review time, six core publications) which provides a good support for the presented results to describe central tendencies in the data. Secondly, we focused on mobile context of use from users’ perspective and therefore our filtering and selection process included in only empirical user studies with mobile devices. By excluding purely technical papers about context awareness we limited the depth of description of technical and informational context of our model. This part can be extended in the further work.

Conclusions
Our literature review of over high-quality 109 articles between the years 2000-2007 revealed two main conclusions. The context of use is still characterised as a relatively static phenomenon in mobile HCI and to shift towards examining the dynamic nature of mobile contexts of use, future research needs to pay more attention to temporal factors and transitions within and between contexts. Secondly, we have presented an extended model of context of use for mobile HCI, which summarises five key components, their subcomponents and descriptive properties, thus giving an overview of the characteristics of dynamic and heterogeneous mobile context of use. Further work needs 1) to explore these characteristics in relation to user experience in more detail to understand application specific characteristics, 2) to explore how to apply these in a modern user-centred development process, and 3) as a part of carrying out and reporting system evaluation studies in field settings.

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REVIEWED ARTICLES


