Handheld Computing from a Designer’s Perspective:
A 10-year Review - 2001-2010

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Abstract

This review has examined research on handheld computing from a design science perspective. The review was underpinned by the assumption that handheld computing has specific features compared to stationary computing that ought to be managed in order to harness the possibilities of handheld computing.

The purpose of this study was to identify areas of investigation in handheld computing from a design-orientated perspective. Publications were analysed by four dimensions: handheld computing, design oriented approach, accentuated factors of handheld computing and organisational settings – whether or not the users were a member of the mobile workforce.

The findings revealed that research on handheld computing is unevenly distributed and that research on the mobile workforce is under-represented. A reflection made is that more research on factors such as field use conditions, support issues, supporting technologies and time critical is needed in order to harness the possibilities of handheld computing.

1. Introduction

An undisputable fact today is that handheld information systems are evolving and the number of mobile workers, connected to their organisations via handheld computers and wireless technologies, are increasing. The origin of this development lies in the market growth of small handheld devices in the form of Personal Digital Assistants (PDAs) and smartphones with the capabilities of small computers; devices that are often able to connect to wireless networks for data communication. Simultaneously, wireless networks have developed with greater geographical coverage and increased transmission rates. This is the foundation for a technological shift coined the “mobile decade”, a term indicating the alleged importance and expectations of the phenomena [1, 2].

The statements that handheld computing as an installed technology base is large and rapidly growing can be underpinned by observations on the number of handheld devices in the world; they significantly exceed desktop computers and this difference is increasing [3]. In 2006 the number of desktop computers (i.e. stationary computers) was estimated at 850 million, compared to an estimated 2,700 million mobile devices. In 2008, there were 302 million PCs, 140 million smartphones and 1220 millions mobile phones shipped [4]. This, in conjunction with the prediction that mobile phones are expected to be replaced every 18 months with a newer and smarter mobile phone [5], demonstrates the fact that the technological base for handheld computing is considerable and will most likely affect the designers of information systems at large. What is notable is that these figures are pre-iPhone and pre-Android, and the share of smartphones have increased significantly since iPhone and Android entered the market.

A bright new future seems to beckon to the mobile workforce aspiring to the services offered by these devices and networks. However, there is evidence (studies), that systems developed for mobile users sometimes fail to harness the opportunities of handheld computing. These studies range from changes in organisational and social settings [6], changes in work practices [7-9], to problems related to the lack of user involvement [10] and how to support collaboration and mobility with mobile technologies [11].

One thing in common in these studies is that the developed systems did not take into account the properties of the mobile workforce, and the properties of handheld technologies. Zheng and Yuan [12] put forth a conceptual framework illustrating the differences between information systems for stationary office work and information systems for mobile work. They argue that the predominant focus in IS is stationary IS usage, and state the importance of understanding the nature of mobile work.

This raises questions about how handheld information systems should be developed to take into account aspects such as those mentioned. Can one answer be that handheld computing needs specific design considerations and that the knowledge base
aimed at the design and development of stationary computing is not always applicable to handheld information systems for a mobile workforce? As Fällman [13] puts it, “What we consider mobile information technology is related to and draws upon traditional ideas of desktop computing in a multitude of ways. These dependencies are not only beneficial and desirable but also carry with them restrictions and hidden assumptions that suppress mobility in different ways” [13, p. 65].

When thinking of desktop computing, in most cases the presumed environment is an office environment. The desktop as a meta-frame is present in a range of aspects: The computer resides on the desk, and is built for desk use (clerical use one could argue). The interface of the screen is a virtual replica or abstraction of the physical desktop. The screen tries to mimic the familiar workspace with metaphors such as the Recycling Bin, the email Icon in the form of a letter, the logical structure of the file system comparable with a binder, and so forth. This mind-set is a design paradigm within a system development that affects designers whether they are aware of it or not.

Drawing on Fällman’s [13] argument that the desktop metaphor as a mindset in some aspects is not suitable for the design of handheld information systems, there exists a need for design orientated research supporting designers in the design and development of handheld information systems. That is, prescriptive-normative research on the specific features of handheld computing for informing practitioners and scholars.

1.1. Objective

To facilitate research concerning the design of handheld information systems for mobile users it is vital to recognise the previous lesson learned by other scholars within our field of study. A recognition that can guide us in the design of both new systems and new areas of study because: “it facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed” [14p. XIII]. The aim is to follow the tradition within the field of information systems research by examining the relevant literature with the purpose of gaining a better understanding of the present situation in the field [15, 16].

In this paper, the applied perspective is design science and the audience is the designer of business applications, leaving computer scientists, game developers and similar out of the scope. That is, optimising hardware is of less concern compared to optimising business processes with information technology. A short discussion on design science is made in following sections.

The organisation of the paper is as follows: in the next section the theoretical departure is presented. This is followed by a description of the research approach and the framework applied for categorising publications. After that, the results are presented. The final section includes reflections on the knowledge gaps identified and suggestions on further research areas.

2. Theoretical foundation for the categorising framework

The overarching theme was handheld computing and from that, three dimensions establish the theoretical foundation of this review; design orientated research, accentuated factors of handheld computing illustrating important aspects in handheld information system development and the organisational setting implying differences in mandatory or voluntary use. These dimensions are presented in greater detail in the following sections.

2.1. Design science as a research approach on its own

Design as a scholarly endeavour has been on the agenda for almost a century, or longer if Aristotle [17] is included. However, in recent decades interest has increased and voices have been raised regarding the relationship between design science and natural or social science, and whether the major perspectives of natural or social science are useful when dealing with design as a scientific discipline [4, 18-20].

In the seminal, The Science of the Artificial, Simon [17] argues that there is a need for a specific science for design. The cornerstone in design science is that it is constructive compared to natural or social science which are analytical, rendering a “how to” or “how things ought to be” perspective on design research instead of “how things are” as in natural and social science [17, 21]. It is the conception of the realisation of new things; it deals with the planning, inventing and construction of artefacts. Its language is modelling and it has its own specific perception on “things to know, ways of knowing them and ways of finding out about them” [19] or as Archer puts it, “the art of planning, inventing, making and doing” [22]. The usefulness and applicability of design science have been vividly discussed in information system research (ISR), often in conjunction with the perception of ISR as an applied science [23-27].
However, the mutual concept is that the outcome of information system design sciences efforts must produce knowledge that is useful for practitioners as an applied science, and several frameworks illustrate how this knowledge could be expressed [23-27]. Here resides the interest in information system design: the usefulness for practitioners as the designers of information systems. An important difference is that most research may have practical implications, whilst design science should have practical implications. Therefore, from a designer’s perspective, design-oriented research with the ambition to offer normative solutions to the design situation is most relevant.

To categories into design oriented research approach, Gregor’s [23] taxonomy of IS theory were used. Although that Gregor presents five types of theory (I analysing, II explaining, III predicting, IV explaining and predicting, and V design and action), only publications corresponding to V design and action is presented in this review. Design and action is theory that “Says how to do something. It is about the principles of form and function, methods, and justificatory theoretical knowledge that are used in the development of IS” [23, p 628]

2.2. The mobile workforce as an important organisational setting

Departing from design science and the perception of a designer as someone who designs information systems for mobile users, the organisational settings of the user are of interest. This is because the aspects of the expected mandatory use of information systems inside an organisation, compared to voluntary computer use outside an organisation, say for example for computer gaming. The consequences of mandatory use of information systems are that the user has seldom any opportunity to select other information systems, or the opportunity to not use a specific computerised information system. Regardless whether the information system supports or hinders the user, the user must continue to use a particular system. These aspects influence the acceptance and adoption of systems more than when the usage is voluntary.

Meanwhile the technology base of handheld computing is expanding, as mentioned in the introduction, and the mobile workforce on a global perspective is also expanding.

Cozza states that the major change initiated by the increased possibilities of mobile information system use is for those who use PDAs, smartphones or comparable handheld devices in the field. Most likely, these large user groups previously had limited access to computers or computerised information systems. Computers may replace paper-based forms in these user groups, and field-workers equipped with handheld computers are considered to be those who have the most to gain with the increased opportunities of mobility [28]. If these predictions are accurate, information systems designers will increasingly face handheld information system development projects in the future.

2.3. Accentuated factors of mobile computing

This paper rests on the assumption that handheld computing has specific properties compared to stationary or desktop computing, that ought to be managed properly to harness the possibilities of handheld computing.

Within the categorising framework the set of accentuated factors of handheld computing put forward by Andersson and Henningsson is applied [29]. These accentuated factors are a set of factors covering aspects of importance from a designers’ perspective. An important feature of this set of factors is that professionals have evaluated it and considered it to be comprehensive and detailed.

In this setting, the term accentuated should be interpreted as a factor that already exists but that has gained greater importance or has changed its properties when the factors are managed from a handheld computing perspective, or that it is a new factor entering the system development domain when a handheld system is to be build. This leaves the overlapping factors between mobile and stationary computing out of scope. The term factor should be interpreted as a feature or circumstance contributing to or affecting design and developmental efforts (adapted from the New Oxford Dictionary, i.e. a circumstance, fact, or influence that contributes to a result or outcome). The small form factor or connectivity is an example of factors in mobile computing. Factors can be described by their properties as small screen or varying transmission rates. The accentuated factor framework is composed of the following 15 factors [29]:

Field-Use Condition: For the mobile workforce most work is obviously done in the field resulting in a use situation often labelled as field use conditions. This factor regards the physical surroundings as being quiet or noisy environments, with sunlight, darkness, heat or low temperature all influencing the field-use in their own way. A lack of a predefined workplace is also a part of this factor, mobile workers need to adapt to different and diversified workplaces.

Industry Dynamics: Illustrates the fast changing environment with competing vendors, manufacturers
and content providers and it is argued that this factor is more fierce and withstanding compared to within stationary computing. A high velocity environment exists in stationary computing, but the importance of this factor is greater in handheld computing. The lifecycle of an application is shortened for a handheld device due to the shorter expected lifetime of the device itself, with more frequent changes in operating system versions (with a low degree of backward compatibility) and faster changes in carriers, platforms, etc.

Information System Dependencies: With regards to the mobile workforce’s high reliance on their information system. If an implemented application is the only application the user may access, and this application is crucial for the user to conduct the work, the reliance on this application is high. If the application malfunctions, or the implemented workflow does not match the actual/real workflow, these problems will have extensive negative impact on the perceived usefulness and productivity.

Interaction Patterns: This factor illustrates that it is anticipated that the mobile user benefits from short interaction sequences, short time periods of use, aversion to long boot sequences and that active behaviour is patterned to manage this. The main reason is that the mobile workforce is often occupied with tasks other than working with their computer.

Location Awareness: Handheld devices are mobile and therefore able to appear in different places and they can by different means use the information of its physical location. This location awareness can be achieved by GPS, triangulation, accessing nodes or other techniques. However location and context may overlap in varying extent and where appropriate context are included into location awareness.

Multimodal Interfaces: Refers to new I/O possibilities such as motion control or LDR sensors. This factor is closely related to the small form factor, however, a separation of concern is argued. Multimodal interfaces are an extension rather than a reduction that the small form factor often is considered as.

Place Critical: Anywhere is almost a trademark of handheld computing which represents freedom of place, however in a work situation the interpretation of freedom of place can be questioned. The authors argue that for a mobile workforce and mandatory use the user is most likely not allowed to choose the place, on the contrary, the place may be specific. A “just on place” requirement is more applicable.

Platform Variation: The mobile industry is characterised by a large and heterogeneous set of actors and stakeholders. This creates a complex ecosystem with competing technologies and standards that in turn affect designers trying to design systems which are functional on different platforms. In respect to this set of actors, and in the case of handheld applications, the platform variation is large, meaning-large variations in operating systems among the handhelds and a large variation in hardware configurations.

Security Issues: In wireless communication, security issues are present due to the risk of interception. These may be different types of threat such as masking, listening, browsing, and distortion. Another security issue is the small form factor and its omnipresence. The handheld device’s small size means that it will be carried around to a greater extent than, for example, a laptop computer. This frequent exposure increases that the risk of it being stolen or lost (greater exposure in foreign environments) than for example a desktop computer. These two security issues are both illustrated by the Security Issues factor.

Small Form Factor – Hardware: Due to the miniaturisation of hardware, hardware capacity is limited compared to desktop computers. For example, the limited power supply is highly relevant for mobile devices, since in practice they require to be battery powered and independent of fixed power networks. The effects of which are reduced processing capability, limitations in storage, etc. Even if the capacity of handheld’s hardware increases there will most likely be a difference.

Small Form Factor – Interface: This factor concerns the small form factor with a small screen and limited keyboard. The keyboard may not be present or a keyboard offered which has a limited set of keys compared to an ordinary keyboard.

Support Issues: This factor illustrates issues related to providing support to geographically distributed users. The fact that a considerable part of the mobile workforce is working by themselves in the field render a lack of colleagues with which to interact in an informal fashion. The coffee room interaction may be missing, and furthermore the sheer physical distance can cause problems in offering support.

Supporting Technologies: Compared to the office worker, the mobile workforce’s accessibility to supporting technologies is often limited. Important documents may not be easily accessed and displayed through a handheld device. File management, servers, fax machines, written manuals, written ledgers or other support systems may not be available to the same extent as in an office environment.

Time Critical: One trademark of handheld computing is anytime, usually describing the fact that the user can access certain information, services or an application when the user wants, providing freedom in time. In contrast with the concept of freedom in time,
when members of the mobile workforce actually do need information it is often relatively time-critical information, such as the repair status on a machine or a purchasing status just before a client meeting making “just in time” a more accurate term to illustrate the mobile workforce and mandatory use relationship to freedom in time. For clarity of the possible restrictions on anytime, the label “Time Critical” is put forward instead of anytime.

Varying Connectivity: This factor illustrates the unpredictability of Quality of Service, both in transmission rate and connectivity. With wireless networks disconnection is a factor which needs to be managed. Temporary disturbances as sun flares, road tunnels, interference and skip zones affects transmission.

2.4. Summary of theoretical foundation

From a designer’s perspective, design research has significant relevance, offering well-studied solutions for design situations.

A user group that is expected to benefit greatly is the mobile workforce, making research on this user group relevant from a designer’s perspective due to the high probability that several handheld information systems for the mobile workforce are due to be developed. These two aspects combined with the overarching interest in handheld computing as having accentuated factors makes further studies in this field worthwhile.

3. Research Approach

3.1. Framework for the literature review

The publications in this review are classified into four dimensions; handheld computing, design as research approach, one of fifteen accentuated factors of handheld computing and one of three types of organisational settings (as will be shown).

However, some preceding work was carried out and the workflow was as follows:

A set of publications was collected from database searches using search criteria, and by excluding publications not related to handheld computing.

This was followed by an exclusion of publications which were not design orientated.

The next step was to exclude publications not fitting the 15 accentuated factors.

The remaining set of publications was classified into organisational settings, that is whether or not they belonged to the mobile workforce (see figure 1 for an overview on the workflow). A more detailed description is presented in section 3.2.

Figure 1. The workflow applied when categorising the different publications. First a collection of publications built on a database search based on the overarching theme, then a selection of publications with a design approach. The remaining publications were, if possible, classified into accentuated factors. Finally, categorisation of the remaining publications into organisational settings.

3.2. Selection of publications

In order to fulfil the objectives of investigating the current state of design-orientated research within handheld computing, a set of journals was selected. Using a combination of AIS Journal rankings, Hu et al. [30] list of major outlets in handheld computing and Ladd et al [31] list of major mobile computing outlets, a set of 31 journals between 2001 and 2010 with topics relevant to the study were selected (for the complete set of journals, see table 1). The main reason for only selecting journals was that journal publications are often considered as being of higher quality and rigor compared to conference papers. Another argument was that high quality and relevant conference papers make it into journals [32, 33].

Different search phrases were tested and the finally used search phrase (handheld OR mobile OR mobility) AND ((design OR designed OR designs OR developing OR development) AND NOT (algorithm)). The last search criterion (algorithm) was used in order to exclude publications with a computer science perspective. Databases offered by ACM, Palgrave Macmillan, Taylor Francis, Springer Verlag, IEEE, Informa, Ebsco, IGI and Elsevier were searched and a total of 634 publications were identified.

After identifying the publications, the abstracts were read to confirm that they were relevant to this study.

The search in the outlets European Journal of Information Systems, Information Systems Journal,
Journal of the Association for Information Systems and Journal of the ACM did not yield any publications.

The outlets ACM Interactions, ACM Transactions on Information Systems, Communications of the ACM, IBM System Journal, Information System Research, Journal of Information Technology, Journal of Information Technology Theory & Application and Journal of Strategic Information Systems had publications matching the search criteria, however they were not related to mobile or handheld computing at all and instead addressed, for example see Levina [34]

The remaining set of publications was analysed to identify design-orientated publications, as mentioned in section 2.1 only publications belonging to design and action was selected according to the design orientated approach.

Then the publications were categorised into the 15 accentuated factors of handheld computing described in section 2.3.

In an attempt to continuously calibrate the evaluation of the publications, a repeated look-back was made: When an outlet was finalised five publication of the previous categorised publications were reread and re-categorised in order to identify eventual drift in judgment.

In those case where a publication managed more than one factor, all factors were recorded.

A considerable drop-out or fall off regarding publications with a descriptive or analytical approach close to product information. Product information was, for example, the description of a new application without any prescription, business case or similar. In other words, publications describing a new application or a product and from that description constructing a business case were it would be useful (market push rather than market pull [35]).

Also a considerable drop-out occurred regarding publications with an overly technical approach, such as antennas, roaming or algorithms. The reason to exclude these publications was the information system designer perspective; research on topics manageable in a design situation was of interest. For example, how to manufacture an antenna is hardware engineering related and there is hardly anything that an IS-designer can do about it, however poor geographical coverage rendering varying connectivity may be within the designer’s manageable tasks.

There was also a drop-off on publications due to a low degree of importance to a designer. For example addressing such issues as new business models, educational matters, opportunities and challenges for information system research and so forth.

Finally, the remaining publications were filed into categories related to organisational settings, the mobile workforce represented by business-to-employee (B2E) and business-to-business (B2B), and users outside an organisation represented by business-to-customer (B2C) or consumer-to-consumer (C2C).

However, some aspects were not suitable to place in B2E/B2B or B2C/C2C. For example those concerning aspects such as cumbersome input due to the small form factor, which would most likely have the same effect on the user regardless of the organisational setting being technical or neutral, thus creating an extra category: Tech/Neutral.

Those publications remaining formed a set of 82 publications related to the development of mobile applications (see table 1).

<table>
<thead>
<tr>
<th>Outlet</th>
<th>Number of publications discovered by search phrase</th>
<th>Number of publications selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM Interactions</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>ACM Transactions on Computer-Human Interaction</td>
<td>17</td>
<td>10</td>
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<tr>
<td>ACM Transactions on Information Systems</td>
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<td>0</td>
</tr>
<tr>
<td>Communications of the ACM</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Communications of the AIS</td>
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</tr>
<tr>
<td>Computer</td>
<td>42</td>
<td>1</td>
</tr>
<tr>
<td>European Journal of Information Systems</td>
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<td>0</td>
</tr>
<tr>
<td>IBM Systems Journal</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>IEEE Pervasive Computing</td>
<td>51</td>
<td>2</td>
</tr>
<tr>
<td>IEEE Transactions on Mobile Computing</td>
<td>55</td>
<td>8</td>
</tr>
<tr>
<td>Information Systems</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Information Systems Frontiers</td>
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<td>4</td>
</tr>
<tr>
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</tr>
<tr>
<td>Information Systems Research</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>International Journal of Handheld Computing Research</td>
<td>7</td>
<td>1</td>
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<tr>
<td>International Journal of Human-Computer Interaction</td>
<td>23</td>
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<td>International Journal of Mobile Communication</td>
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<td>7</td>
</tr>
<tr>
<td>International Journal of Mobile Human</td>
<td>22</td>
<td>1</td>
</tr>
</tbody>
</table>
4. Findings.

As discussed previously, the study focused on four dimensions; handheld computing, design research, accentuated factors and organisational settings (see Figure 1).

4.1. Distribution among accentuated factors

According to the results, research on different accentuated factors was unevenly distributed. Most illuminated were factors that could be regarded as being explicit for handheld computing, the ability to be mobile and know the current location, as well as the small form factor.

Location awareness was treated in 22 publications comprising 26.8% of all publications, small form factor-interface was treated in 14 of the publications comprising 17.1% of the publications, small form factor-hardware were treated in 12 publications comprising 14.6%, and multimodal interfaces was treated in 11 publications comprising 13.4% of all publications. Less studied were aspects such as field use conditions, support issues, supporting technologies and time critical which all were treated in 0 publications comprising 0% of all publications (see table 2).

4.2. Distribution of organisational settings dimension

Regarding organisational settings, the category N/A (Technological/Neutral was the most represented and this is no surprise, the majority of factors managed are of a technological nature (for example, screen size would most likely affect customers or employees to the same extent) (see table 3). A speculation is that if softer aspects such as support issues or field use conditions were more elaborated on, then the numbers would probably look different. Research on B2B or B2E is least favoured with 13.4% coverage of the selected publications. However the findings support the fact that there is an opportunity for further research on mobile information systems for the mobile workforce, this is in conjunction with the prognosis that the mobile workforce is fast growing strengthens the proposal.

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<table>
<thead>
<tr>
<th>Accentuated factor</th>
<th>B2B</th>
<th>B2C</th>
<th>T/N</th>
<th>Total</th>
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</thead>
<tbody>
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<td>Field-Use Conditions</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Industry Dynamics</td>
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<td>0</td>
<td>1</td>
<td>1</td>
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<td>IS Dependency</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Interaction Patterns</td>
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<td>1</td>
<td>0</td>
<td>3</td>
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<td>Location Awareness</td>
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<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Multimodal Interfaces</td>
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<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Place Critical</td>
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<td>0</td>
<td>0</td>
<td>1</td>
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<td>4</td>
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<td>Security Issues</td>
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<td>4</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>SFF: Hardware</td>
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<td>1</td>
<td>10</td>
<td>12</td>
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<tr>
<td>SFF: Interface</td>
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<td>Time Critical</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Varying Connectivity</td>
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<td>3</td>
<td>5</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>21</strong></td>
<td><strong>50</strong></td>
<td><strong>82</strong></td>
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<table>
<thead>
<tr>
<th>Organisational setting</th>
<th>Number of publications</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2E/B2B</td>
<td>11</td>
<td>13.4%</td>
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<tr>
<td>B2C/C2C</td>
<td>21</td>
<td>25.6%</td>
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<td>N/A (technical or neutral)</td>
<td>50</td>
<td>61.0%</td>
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<td><strong>Total</strong></td>
<td><strong>82</strong></td>
<td><strong>100.0%</strong></td>
</tr>
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</table>
5. Summary of findings

This paper examines the literature on mobile computing in 31 outlets between 2001 and 2010. 634 publications were identified using search terms as handheld, mobile, mobility, design, and development in combination. These publications were categorised accordingly to the framework presented in section 2. 82 publications were finally filed into two dimensions (accentuated factors of handheld computing and organisational settings).

Although, this review does not allege to be exhaustive it does provide a reasonable insight into the state of research concerning developmental aspects of handheld computing. Other reviews have been carried out but there is a lack of reviews concerning developmental aspects.

On accentuated factors of mobile computing the results reveal an uneven distribution between factors.

Most studied are factors such as Location awareness (26.8%), small form factor/interface (17.1%), small form factor-hardware (14.6%), and multimodal interfaces (13.4%).

This is not surprising due to the uniqueness of these factors in relation to mobile computing and stationary computing.

Less studied were aspects such as field use conditions, support issues, supporting technologies and time critical which all were treated in 0 publications comprising 0% of all publications.

These findings identify the need for further studies on these factors, and this will be discussed in subsequent sections.

On the dimension organisational settings, the majority is technical/neutral, i.e. N/A, with a representation of 61.0%, followed by customers (B2C or C2C) of 25.6%. Research on the mobile workforce (i.e. B2E or B2B) is less favoured with 13.4%.

Although several voices argue that the most important environment is the mobile workforce (B2E and B2B) the topic is still underdeveloped [5, 28, 36]. This underdevelopment may serve as an explanation of the indicated problems of harnessing handheld computing, as mentioned in the introduction, within the organizational setting of the mobile workforce.

5.1 Limitations

Considerations on the limitations of the study can be made; there are possibilities that some themes (factors) are addressed in other outlets than the outlets chosen, however a selection must be made and in this study the selection is made by using journal-ranking lists and selecting high ranked outlets within the field of ISR. The selection of outlets in the form of journals may skew the findings because a major part of up-to-date research is presented in conferences and not journals. However, the argument to chose journals and exclude conferences, as mentioned in section 3.2, is that journal publications are often considered as being of higher quality and rigor compared to conference papers, and that high quality and relevant conference papers will often be published in journals.

Another limitation is that a detailed categorisation framework does make the selection process more difficult than more general or abstract categories.

Probably the most critical limitation is that only one person, the author, performs this review. To minimise drift in judgement when categorising the publications a control procedure as described in section 2.3 was conducted. The strategies applied were also discussed with colleagues to scrutinize the strategy. Finally, a prior review applying a similar framework and strategy has been published [37], and in this present paper the method, framework and strategy is improved and the set of publications is updated with more current publications, compared to the previous version.

5.2 Reflections

If a designer aims to harness the possibilities that handheld computing offers, the developer must strive to manage the important factors of handheld computing and handheld information systems. Evidence exists in previous research that the nature of handheld information system use and the development of handheld information systems are still novel, and that failure is common due to, for the designers’ perspective, unexpected circumstances.

This study displays areas that are well studied and areas in need of further research. Factors regarding the small form factor and mobility of the device are more thoroughly studied, probably because of the distinct uniqueness of handheld computing. However, factors that are worthwhile studying further are those closely related to the work situation. They are; field use conditions, support issues, supporting technologies and time critical. An important reflection is that one can argue that those factors are of lesser importance when the use is voluntary compared to mandatory, or forced, as often is the case of a mobile workforce.

Concerning voluntary use and field use conditions, in voluntary use the user can choose to either select another location with more suitable environmental conditions or to choose another application or device.

Viewing voluntary use and both support issues and supporting technologies, if the use is optional then the user can easily choose not to use the application, and as a consequence the need for proper support is lowered.
A similar argument is valid for voluntary use and time critical, in the case of the voluntary user the anytime aspect most likely rules out the just-in-time aspect, making time critical non important. If the user is free to choose when to conduct a transaction, aspects such as varying connections are less important because the user can just try at another time.

However, when the use is mandatory or forced, as is most often the case regarding the mobile workforce, the factors field use conditions, support issues, supporting technologies and time critical will have greater importance.

Regarding field use conditions, in mandatory use the user may suffer not being able to choose in which conditions to use the system. It may be service technicians working up in an antenna exposed to rain or cold etcetera needing the device to scan a barcode on some equipment. If the information system is not developed (hardware as well as software and other factors) the users may suffer improved performance due to problems related to field use conditions. Although ethnographically inspired studies can inform designers in the nature of mobile work, suggestions and strategies in design to manage the nature of mobile work is appreciated.

Regarding supporting technologies, if the handheld information system does not cover all information handling aspects, and the user must rely on additional resources, the geographical distance to those resources will inflict upon the usability on the system. Regarding this factor, there are opportunities to study alternative technological solutions and methods that the user may access during mobile work. For example, design patterns how to replace large blueprints or wiring diagrams?

Regarding support issues, if the support organisation is not designed for offering support in the field, or the application is not designed to reduce the need for support, the usability of the system will be negatively affected. Here exists a need for empirical studies on what kind of support the mobile and geographically distributed workforce needs, and also descriptions on methods and designs to offer proper support or to minimise the need for support are of value.

With respect to time critical, the user may need information on a specific time; imaging doing a service on a machine and some settings are needed to proceed with the service, information becomes critical and just-in-time is a more proper description of that case. Poor design not taking just-in-time into account will most likely negatively affect the usage of the system. Here there is a need for tested design principles on how to manage a range of aspects related to just-in-time. This is a difficult problem, and varying connectivity, security issues and small form factor-hardware issues coincide.

These differences in usage and technology are important, and in relation to the increasing number of users belonging to the mobile workforce as mentioned in the introduction, this topic is worthwhile studying further. From a developer’s perspective there is an evident need for further research on the design of handheld information systems for the mobile workforce. A need derived from the differences in nature between handheld computing and stationary computing, as coined by Fällman [13], Hu et al. [30] and Zheng and Yuan [12], and from the need for an extension of the design paradigms of desktop computing.

5.3 Conclusion

There is an evident need for further studies on the subject of the design of handheld information systems for the mobile workforce. The mobile workforce is expected to grow significantly in the near future, there are problems with handheld information systems in the form of failures and unsuccessful implementations due to a lack of understanding of the technology and users. Arguments have been put forth by scholars that knowledge of information system design originating from a desktop environment may be insufficient for designing handheld computing systems, and that handheld information systems are different from stationary/desktop information systems.

In examining what has been done from 2001 to 2010 in research on the development of handheld information systems, a knowledge gap is visible regarding design factors important to the mobile workforce. More studies on how to manage factors such as field use conditions, support issues, supporting technologies and time critical in the design phase are needed, and from a designer’s perspective design orientated research has the opportunity to extend the existing design paradigms to also embrace handheld technology and to embrace the aspects of mobile workforce’s needs from an information system.

6. References


[28] Cozza, R., "Pdas Overview ", Gartner Group Reports, 2005


