Situated Knowledge in Context-Aware Computing: A Sequential Multimethod Study of In-Car Navigation

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ABSTRACT

A central feature of ubiquitous computing applications is their capability to automatically react on context changes so as to support users in their mobility. Such context awareness relies on models of specific use contexts, embedded in ubiquitous computing environments. However, since most such models are based merely on location and identity parameters, context-aware applications seldom cater for users’ situated knowledge and experience of specific contexts. This is a general user problem in well-known, but yet dynamic, user environments. Drawing on a sequential multimethod study of in-car navigation, this paper explores the role of situated knowledge in designing and using context-aware applications. This focus is motivated by the current lack of empirical investigations of context-aware applications in actual use settings. In-car navigation systems are a type of context-aware application that includes a set of contextual parameters for supporting route guidance in a volatile context. The paper outlines a number of theoretical and practical implications for context-aware application design and use.

Keywords: Context-Aware Computing, Local Knowledge, Multimethod, Navigation, Situated Knowledge

INTRODUCTION

A central feature of ubiquitous computing applications is their capability to automatically react on context changes as to support users in their mobility (Dey et al., 2001; Henfridsson & Lindgren, 2005). Such context-awareness relies on models of specific use contexts, providing computational resources intended to facilitate user interaction in a given context. More advanced context-aware applications can also dynamically build models of their environment (Lyytinen & Yoo, 2002a). The typical objective of embedding such capabilities into computational artifacts is to support and enhance everyday use of IT over different settings.

Context-aware applications largely depend on their assumptions about user contexts. As highlighted by Dourish (2004), a common context view underlying context-aware applica-
tion design is the representational one, treating context as something fairly stable consisting of a set of informational properties. This context view has proved to be useful in unambiguous contexts. Many of the seminal explorations of context-aware computing such as the Active Badge (Want et al., 1992) embed such a view. However, treating context as a set of informational properties can be constraining in more complex social settings (Chalmers, 2004; Grudin, 2001; Williams & Dourish, 2006). As highlighted by Schmidt et al. (1999), there is more to context than user location and identity. It is therefore not surprising that entire journal issues has been devoted to provide insights about how to build context-aware computing applications and architectures that cater for the typical dynamism of user contexts (see Moran, 1994: Human-Computer Interaction, Moran and Dourish 2001: Human-Computer Interaction, Schmidt et al. 2004: Computer Supported Cooperative Work). Despite the vast debate about context (see e.g., Abowd & Mynatt, 2000; Dey et al., 2001; Greenberg, 2001; Schmidt et al., 1999; Suchman, 2007), however, it has proved difficult to implement comprehensive models of context in wide-spread applications.

An important but sparsely explored aspect of context-aware computing is the role of the user as a co-creator of context. As Dourish (2004, p.22) highlights, “context isn’t just ‘there’, but is actively produced, maintained and enacted in the course of the activity at hand.” This basically means that users’ local and situated knowledge is central to the perception, as well as definition, of a given context. Acquired through previous encounters with similar situations, users’ situated knowledge is therefore part of the use setting, shaping human-computer action (Suchman, 2007). While the relevance of user experience has been highlighted in conceptual articles (Chalmers & Galani, 2004; Dourish, 2004; Greenberg, 2001), there exist few empirical studies that deal with its role in everyday use of context-aware applications.

To address this omission in the literature, this paper outlines a sequential multimethod study (Mingers, 2001) of context-aware application use for better understanding the role of user context co-creation. The study was done in the context of car navigation systems for two reasons. First, car navigation systems are a widely diffused application of context-aware computing. This enables studies of authentic use across situations characterized by different levels of situated knowledge acquired through mundane activity such as commuting. Second, car navigation systems are often highlighted as a typical example of context-aware computing (Abowd & Mynatt, 2000), involving a whole set of context indicators such as position, road classification, traffic information, and driving speed. The paper addresses the following research question: How and why does users’ situated knowledge affect everyday usage of car navigation systems?

The remainder of the paper is structured as follows. Sections two and three outline the theoretical background and rationale for the study. This is followed by a description of the multimethod research methodology employed. Then, we present the findings of the survey and interview study conducted. Thereafter, the theoretical and practical implications of the study are outlined.

RELATED LITERATURE

Context-Aware Computing

Context-aware applications are a type of system that automatically reacts on environmental changes as to support user value (Abowd & Mynatt, 2000; Dey et al., 2001; Dourish, 2004). The key idea is to make information services used over a variety of spatio-temporal contexts more receptive to changing use settings. As Abowd and Mynatt (2000) highlight, such usefulness is typically accomplished by aligning implicit human activity with computing services. Dynamically building models of human activity, well-working context-aware applications can seamlessly and dynamically obtain information about the context in which they are used and adjust their behavior accord-
ingly (Henfridsson & Olsson, 2007; Lyytinen & Yoo, 2002a). Rather than relying on explicit acts of manipulation and communication, they draw on implicit human activity as to be unobtrusive to users’ task execution (Moran and Dourish 2001). In this regard, implicit activity should be understood as behavior that indirectly causes changes in the application’s state and response. As an illustration, the widely cited CyberGuide prototype (Abowd et al., 1997) promised to associate tourists’ location at exhibitions with relevant information about sights that they encounter during their visit (see also Watson et al. 2004). The implicit activity of moving between sights triggered the presentation of contextualized information to visitors.

In-car navigation systems are often highlighted as a widely diffused context-aware computing application in everyday life (Abowd & Mynatt, 2000). Using broadcasted real-time traffic information (e.g., accidents, road works, and slow traffic), geographical data (e.g., road class identities, and junction types), user input data (e.g., destination), as well as vehicle sensor data (e.g., vehicle location and orientation), a typical in-car navigation system provides route guidance adapted to environmental changes. Triggered by deviations from a user-selected route, an example of such adaptation is automatically initiated route calculations intended to guide the user back to the original route as soon as possible (often referred to as re-routing). Given repeated user deviations, navigation systems re-calculate new routes.

**Situated Knowledge**

As a central ubiquitous computing theme (Abowd & Mynatt, 2000; Andersson & Lindgren, 2005; Lyytinen & Yoo, 2002b), one of the tenets of context-aware computing is the immersion of computational artifacts into the fabric of everyday life (cf. Weiser, 1991). Users’ interaction with technology should be characterized by familiarity and calmness, making tasks-at-hand, rather than computer use, center-stage (Weiser & Brown, 1997). This ambition puts emphasis on the assumptions and views used for understanding context.

The typical view of context in application-centered context-aware computing research is representational, paying tribute to objective measures of human affairs (Dourish, 2004). Context is often conceived as something external to human activity, focusing considerable attention to finding ways of capturing information in the outside world with relevance for some pre-defined scope of activities. In this vein, many applications primarily use location and identity as the prime contextual parameters for detecting context changes (Schmidt et al., 1999). In this tradition, improving context-awareness tends to be about accumulating more parameters to the list of attributes that describe the world external to the user (see e.g., Abowd & Mynatt, 2000; Dey et al., 2001). As illustrated by Dourish (2004), this representational view treats context as a form of information; context is viewed as delineable, stable, as well as separable from human activity.

Addressing the problem of context in context-aware computing, a variety of situated perspectives has been outlined (see e.g., Chalmers & Galani, 2004; Dourish, 2004; Greenberg, 2001) as reactions to the representational view’s inattention to the dynamism of social settings. This body of literature focuses on the relation between human activity and objects. Typically grounded in phenomenology, situated perspectives concentrate on the role of human experience in using IT in various contexts. As highlighted in the literature (see e.g., Dourish, 2004; Kakihara & Sørensen, 2002; Suchman, 2007), social settings are typically fluid. Context is something that is produced in the course of human activity (Dourish, 2004). The user is essential as an interpreter of the events unfolding in the context. Context is thus created through the processes by which users assign subjective and inter-subjective meanings to their interaction with technology and the world. The meanings are based on the assumptions, expectations, and experience that people use for accomplishing action. Whether these meanings are correct or not in an objective sense are largely irrelevant,
as long as their consequences are intelligible and accountable for those who apply them (Belotti and Edwards 2001).

**CAR NAVIGATION**

Looking at the extant navigation literature, there exist some studies that indicate the relevance of human experience. However, the focus of these studies has primarily been directed at experiences associated with geographical familiarity (which we refer to as local knowledge). For instance, the navigation literature shows that drivers’ experience of the driving context affects the use patterns of navigation systems (Bonsall & Parry, 1990; Dale et al., 2003; May et al., 1992; Wallace & Streff, 1993). Drivers with much local knowledge are less likely to seek or follow guidance based on static information. This insight is confirmed by studies that have explored the behavior of human guides in navigational settings. These studies note that humans tend to adapt their guidance to the driving context by omitting steps that the automated systems include (Dale et al., 2003; Höök & Karlgren, 1991). Thus, geographical data provided by navigation systems is of less importance to drivers with much local knowledge. In addition, the literature suggests that drivers with much local knowledge prefer real-time information on which to base their own route choice decisions (May et al., 1992, Wallace & Streff, 1993). While the navigation literature has established that local knowledge is important in car navigation use, it has paid little attention to other aspects of situated knowledge such as computer literacy and driving experience.

The navigation literature indicates that use patterns and the need of support are related to local knowledge (Bonsall & Parry, 1990; Dale et al., 2003; May et al., 1992; Höök & Karlgren, 1991; Wallace & Streff, 1993). Such a perspective means that:

- Contextuality is highly **individual**, since every user has a unique set of experiences.
- Context is **hard to capture and describe**, since local knowledge is a lot more than location. A given intersection, part of an everyday route, can still cause significant problems to the driver when approaching it from a new direction.
- Context **cannot be defined in advance**, since the contextual components are defined dynamically.

However, today’s commercial navigation systems are designed to give the driver consecutive guidance instructions at every action point. This turn-by-turn paradigm tends to give poor support for such a view on context. Given the vehicle’s position and a configured destination, the system provides detailed guidance, action by action. As an alternative, the user can omit configuring destination, leaving the system as a scrolling map. This kind of usage mainly provides situation awareness and orientation. The systems are certainly context-aware, considering various context parameters such as position, road classification, traffic information, or driving speed. However, they do not contain any mechanism to include user’s assumptions, experiences, or expectations. Furthermore, they give poor support for the user to manually adapt usage to the individual needs of a given situation. Therefore, the turn-by-turn paradigm of today’s navigation systems brings a perspective where:

- Context consists of **environmental features** that can be captured, represented, and modeled.
- Context is **stable**, described by a fixed amount of such measurable features.
- Context is **generic**, equally valid for any user.

The two perspectives represent fundamentally different notions of context. Paraphrasing Dourish (2004), today’s systems are designed on
the basis of a *representational* view on context. With roots in the software engineering tradition, the main concern is with how context can be encoded and represented.

Given this literature review, we embarked on a study of the role of situated knowledge in the case of car navigation systems as an example of a type of wide-spread context-aware application. One key problem guided our investigation: how and why does situated knowledge affect the usage of car navigation systems? We approached this question using a sequential multimethod study (Mingers, 2001). The next section describes our research methodology.

**RESEARCH METHODOLOGY**

**Research Design**

The empirical study was conducted in collaboration with AutoInc, which is a manufacturing firm in the automotive industry that develops, produces, markets, and sells cars on the global market. As a result of the first author’s long term engagement in navigation R&D at AutoInc, we gained access to participants of the corporate product evaluation program. These participants use a specific car for both private and professional use over a period of one to five years. The main purpose of the program is to facilitate product quality feedback from everyday users.

A sequential multimethod approach (Mingers, 2001) was used for exploring situated knowledge in context-aware application use. First, we collected survey data (Dillman, 1999) as to document prevailing use patterns of in-car navigation systems. In particular, we were interested in collecting data on differences in degree and level of system usage between familiar and unfamiliar use contexts. We were also interested in the relation between situated knowledge and the use of context-aware features such as routing and traffic information. Second, as to understand the survey results further, we followed-up the survey with an in-depth inter-

view study (Myers & Newman, 2007) covering users’ interpretations of employing their situated knowledge in using navigation systems.

Following the principles of methodological triangulation (Lee, 1991), the use of the multimethod approach was an attempt to increase the validity of the study by combining quantitative and qualitative data sources. While the survey provided a general overview of use patterns, the interview study was used for enriching the understanding of the survey results (Mingers, 2001). By investigating the respondents’ subjective understanding of their system usage, we were able to both confirm and disconfirm the survey data. Furthermore, the mixed method facilitated our understanding as to why situated knowledge affects system usage. While the survey provided statistical confidence on existing user behavior, the interview study improved our understanding of the underlying rationale of this behavior.

**The Survey**

The target population of the survey was car drivers who frequently use car navigation systems. As suggested above, the selection of respondents was done among people included in AutoInc’s QUIC product evaluation program. All QUIC drivers who used a car equipped with AutoInc’s in-car navigation system were included in the sampling frame. At the time of the study, this group had 84 members, whom all received the survey. The response rate was 69% (58 out of 84).

The survey was designed to investigate situated knowledge and its relation to car navigation use. In this regard, a set of dependent variables was defined to cover background factors (such as age, computer skills, driving experience, educational level, habitation, family status) and system attitudes to different features (preferred source of guidance, routing, traffic information, traffic attention). System usage was measured with five different variables, relating the type of usage to familiarity with the traffic environment. Contingency tables
and chi square test of independence were used to analyze the data.

The typical survey respondent was male (77%) and married (75%), with one or more children living at home (70%). The age distribution was rather wide, with an average of 45 year. 62% had a university degree of more than two years. Further, the respondents were fairly comfortable using computers. 59% looked upon their own skills as considerable, while 31% considered themselves having moderate skills. Among the 58 respondents, 60% lived in the city of Gothenburg and 24% in the metropolitan area (defined as up to 50 km from the city). When rating primary car usage, private trips clearly dominated. The average annual mileage was almost 35,000 km, but some of the drivers exceeded 60,000 km/year.

The Interview Study

Semi-structured interviews were conducted with six respondents included in the survey. Two of these were woman. Reflecting the ambition to primarily access different interpretations of the research phenomenon (Walsham, 2006), however, they were not selected to reflect an entirely representational sample. In qualitative research, it is more important to be sensitive to possible differences in interpretations among users (Klein & Myers, 1999). Thus, we selected respondents with an ambition to cover differences in opinions within the sample used in the survey.

The semi-structured interviews were tape-recorded and transcribed. Lasting between 48 and 81 minutes, the interview transcripts amounted to more than 110 pages of data material. The interviews were guided by an interview guide (Patton, 1990) covering themes such as usage/behavior, usability/skills, user value and experience of functions. These themes were reflective of interesting issues highlighted in the survey results.

Study Limitations

Our sequential multimethod study involved a number of limitations. First, the QUIC drivers are selected to reflect the targeted end-user of a specific car. Since these drivers have not paid for the in-car navigation system, this might be a factor that influences both the usage level and the specific ways that the systems are used. Second, the sample size of the survey study was limited by the total number of participants in the QUIC program. While the QUIC participation enabled a high response rate (69%), a larger sample would have provided greater statistical confidence of the survey results.

THE SURVEY

This survey aims to create (1) a better understanding of how local knowledge, as a proposed element of context, relates to de facto navigation system usage. It also (2) explores the role of situated knowledge by capturing individual characteristics such as annual mileage, general computer literacy, and education.

In order to study these topics on the basis of a questionnaire, we have made a distinction between foreign and well-known driving environments. Foreign driving environments are defined as car trips where the destination and journey is more or less unknown to the driver (i.e., insignificant local knowledge). In contrast, well-known environments are defined as car trips where the destination and journey is familiar to the driver (i.e., significant local knowledge). When it comes to usage we have referred to the turn-by-turn operation, including routing, guidance, and traffic information notification, as active usage. When the system is used (switched on) without an active route, and consequently no destination, we consider the usage as passive. The term basic usage is used in terms of just having the system switched on.
Local Knowledge

To capture usage patterns in different contexts the survey addressed the level of usage in different driving environments. In a focal question, the respondents were asked to describe to what extent they have the system switched on (basic usage) in a familiar/foreign environment. As reflected in Figure 1 approximately 90% of the respondents reported basic usage “basically always” or “often” in foreign environments (in which local knowledge is poor). There seems to be a more or less total agreement among users that the system brings value in such a setting.

In contrast, the users expressed a different opinion when referring to familiar contexts. As depicted in Figure 1, there is a tendency not to use the system in such driving contexts. At the same time, approximately one third of the users reported that they “basically always” or “often” have the system switched on in well-known driving environments.

To better understand how local knowledge relates to usage, the respondents were asked to what extent the system was used actively versus passively in respective driving environment. The contingency table in Figure 2 relates basic usage to active usage in a foreign driving environment. As already illustrated in figure 1 an absolute majority of the respondents report a high level of basic usage in such a context.

Further, the contingency table shows that almost all of them reported that destination was configured. Obviously, turn-by-turn guidance brings significant value in foreign environments, since an absolute majority of the users reported a high level of usage and basically always in an active manner.

The diversity of use characterizing well-known driving environments (see Figure 1) is further explained by the contingency table in Figure 3. It relates basic usage to active usage in a well-known driving environment (in which local knowledge is high). One third of the users are frequently using the system also in a familiar context. In addition, the table shows that these respondents typically use the system passively. Although being familiar with the driving environment, they seem to appreciate the system without active route guidance.

Local knowledge apparently plays a decisive role in how today’s navigation systems are used.

They are frequently used (most respondents report a high level of usage) in foreign driving environments, and basically always in an active manner. When driving in well-known environments the systems are moderately used (one third of the respondents report a high level of usage), and then mainly in a passive manner. Passive usage in foreign environments seems to be less interesting to the users, at least as a frequent

**Figure 1. Basic system usage, in terms of having the system switched on, for different driving contexts**
mode of operation. Very few report this kind of usage “basically always” or “often”. The same applies to active usage in a well-known setting. The discussion is summarized in Figure 4.

Even though local knowledge is crucial to usage, it can be noted that users take different actions under similar conditions. Given a well-known driving environment, where the local knowledge is high, the respondents express contrasting behavior. While many of them immediately switch off the system, some make use of passive support. Some even care for configuring destinations, making use of active route guidance with automatic traffic information notification. These differences cannot be explained by local knowledge. Addressing this, we have studied other aspects of situated knowledge beyond geographical familiarity.
Users’ Situated Knowledge and System Usage

User experience associated with geographical familiarity, in this paper recognized as local knowledge, does not fully explain the rationale behind the observed user behavior. Therefore, we adopt a situated perspective that includes other pieces of relevant context including annual mileage, general computer literacy, and education. Contingency tables and chi square test of independence are used to investigate patterns of user differences in passive and active usage.

First, the survey shows that mileage is related to some interesting use aspects. Frequent drivers generally display more passive usage than the average user \( (p=0.024) \), see Figure 5. Frequent drivers also value voice guidance less than average \( (p=0.024) \), reasonably indicating a tendency to switch off the sound. Finally, they value traffic information more than average \( (p=0.024) \). Altogether, the three tests indicate that experienced drivers, with high annual mileage, regularly use the navigation system as a decision support tool. The system is a complement to their local knowledge – at hand, but not in charge.

Second, there exists a relationship between computer skills and usage \( (p=0.015) \). Chi square tests of independency suggest that skilled computer users operate the system actively in well-known environments more than the average user \( (p=0.015) \). In practice, they spend time on configuring the system although having local knowledge. Thus, users with high computer skills have a somewhat more active behavior than the average user.

Figure 4. Level of usage illustrated in the domain of application and local knowledge

<table>
<thead>
<tr>
<th>Context-aware application</th>
<th>Passive ( \longleftrightarrow ) Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Local knowledge</td>
<td>Frequent</td>
</tr>
<tr>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>

Figure 5. Contingency table relating mileage to passive system usage

<table>
<thead>
<tr>
<th>Level of passive system usage</th>
<th>Level of mileage (km)</th>
<th>( \chi^2 ): 7.45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basically always or often</td>
<td>(&lt;3500)</td>
<td>DF: 2</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>P: 0.024</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>(\geq3500)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Seldom or Basically never</td>
<td>(&lt;3500)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
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<td></td>
<td>25</td>
<td></td>
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<tr>
<td></td>
<td>(\geq3500)</td>
<td></td>
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<td></td>
<td>30</td>
<td></td>
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<tr>
<td></td>
<td>28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>58</td>
<td></td>
</tr>
</tbody>
</table>
Finally, we collected data on how users’ previous experience of navigation systems impacts usage. The respondents were asked to rate their perception of:

- The correspondence between traffic information provided by the system and its perceived real-world equivalence.
- The correspondence between system routing and personal preference, based on local knowledge.
- The level of reduced traffic attention when interacting with the system.

Real-time traffic information is often considered important to increase user value of in-car navigation. Surprisingly, the survey brings no evidence that the experienced quality of traffic information is reflected in actual use. There is indeed a tendency among high mileage drivers to value traffic services more than average (Figure 7), but we cannot see that traffic information promoters generally are the most persistent users. However, the survey suggests that negative experience of routing brings less active usage (where routing is used). Finally, it also suggests that users who experience reduced traffic attention when interacting with the system tends to avoid active usage in well-known environments. It is important to note that none of these variables show significant statistics, making them a poor basis for conclusions.

**Summary**

The survey indicates that:

- Local knowledge is highly correlated to usage. In foreign driving environments, a majority of users keep their systems switched on. At the same time, many users report a low level of usage in well-known environments.
- Local knowledge is an important explanation to the type of usage. In foreign driving environment, users consistently report active usage with route guidance.
support. In contrast, the system is used passively when driving in well-known environments.

- High mileage drivers, reasonably with significant driving experience, often use the system as a decision support tool, available when needed.
- Users with high computer skills show a more active behavior at systems interaction
- Experience from usage is likely to have impact back on usage.

In sum, the survey identifies local knowledge, experience, and skills as essential elements of situated knowledge in this domain. These findings come with supplementary questions and challenges, reasonable to address in a qualitative follow-up study. First, we need to take a wider perspective on usage. The active/passive model is suitable and relevant for the purpose of the survey, which primarily focused on local knowledge. Nevertheless, there are nuances in usage that can never be captured by such a method. The second challenge is to create a deeper understanding of the creation of situated knowledge. Why do local knowledge, experience and skills actually influence usage and how does this play out in practice?

**THE INTERVIEW STUDY**

The survey shows that local knowledge plays a significant role in car navigation system usage. It also indicates that a set of other factors, unrelated to the driving process, influence the way that navigation systems are used. This section reports the subsequent interview study, designed on the basis of the survey results.

Table 1 depicts the themes of car navigation use perceived by the respondents in our qualitative interview study. The table specifies the categories that emerged from the data analysis. We propose these categories to manifest typical aspects of car navigation usage in cars and provide a basis for understanding users as co-creators of context. The categories are: local knowledge, skills and experience, and social circumstances.

**Local Knowledge**

The survey shows that car navigation is used more actively in foreign traveling environments, where people’s local knowledge is insignificant. The interviews not only confirmed but also provided a rationale for this finding. When narrating situations where car navigation is perceived useful, several interviewees recalled foreign country traveling as an extreme example. In foreign countries, users’ local knowledge is insignificant in that the geographical surroundings, cultural conditions, and local traffic habits

<table>
<thead>
<tr>
<th>Level of active system usage in well-known environments</th>
<th>Computer Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expert or Considerable skills</td>
</tr>
<tr>
<td>Basically always or Often or Sometimes</td>
<td>17</td>
</tr>
<tr>
<td>Seldom or Basically never</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>-15.4%</td>
</tr>
</tbody>
</table>

\[\chi^2: 5.94\]

DF: 1

P: 0.015
are unfamiliar. One respondent reflected on his family’s active navigation usage in the US during a long term assignment:

When I lived there [in the US], we often used address search when, for example, going to a friend living at some little street in some little town. Almost always, we just entered the address. And we also used this “last ten” feature often. Let’s say we visited someone once a week, then it [the address] was covered by the “last ten”. […] You were not there often enough to learn [how to drive], you needed it all the time, over and over again. So, we used it a lot more than in Sweden.

Similarly, another respondent commented his active navigation use during vacation driving in Portugal:

I remember using it [actively] when arriving to bigger cities, like Porto. You didn’t even know what [address] to enter. You had a map, but it wasn’t updated. But the RTI was updated, so you could find a parking garage. There were many parking garages, but searching around the car [via the system] you found one, close and convenient. Yes, it was perfect! Leave the car and walk.

These user statements exemplify the most intuitive use case of car navigation (route guidance to unknown destinations), arguably what they were originally designed for. As suggested by the respondents, when local knowledge is more or less insignificant convenience and security are important motives for active navigation usage.

Moreover, our data suggests that in everyday car travelling (in which local knowledge is significant), the use patterns are far more diverse. In this regard, the interviews demonstrated a wide range of use patterns including those who simply turn off the system and others who routinely use the system. Several respondents described passive usage (i.e., without configuring a destination) as a way to orientate themselves in areas where the user has moderate local knowledge. This situation is illustrated by one of the respondents:

It’s when I’m partly up to date with a city without knowing the details […] I need support, both from the map and the compass, so that I’m not going in the complete wrong direction. Typically, I’m using it like this when I’m in Malmö, where I have my brother. I’ve studied in Lund [close to Malmö] and my wife is from Malmö. So, I’m fairly familiar with the town, but there are new streets… a lot is happening […] I have a fairly good idea where things are located, but… this is when the navigation system comes in very handy.

Another respondent told a similar story, referring to a situation without explicit destination. For about a year, he was looking around for a new place to live within his home town. Remembering these recurring expeditions he said:

Table 1. Car navigation use: Categories and case examples

<table>
<thead>
<tr>
<th>Categories</th>
<th>Case examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Knowledge</td>
<td>- Best route guidance</td>
</tr>
<tr>
<td></td>
<td>- Geographical awareness</td>
</tr>
<tr>
<td></td>
<td>- Back-up tool</td>
</tr>
<tr>
<td>Skills and Experience</td>
<td>- Unplanned travelling</td>
</tr>
<tr>
<td></td>
<td>- Feature rejection</td>
</tr>
<tr>
<td>Social Setting</td>
<td>- Co-traveler attention</td>
</tr>
<tr>
<td></td>
<td>- Passenger use</td>
</tr>
</tbody>
</table>

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So, you’re going there, checking out the area... what it looks like. This is when it’s great to be able to follow all the small streets and be able to say “OK, if I’m going in here, I’m coming out there” or “I’m not going in here because it’s a dead end”. I think that’s incredibly useful!

Offering a dynamic, scalable, and perfectly oriented map, such passive support is obviously valued as a tool for improving geographical awareness.

In addition, our data suggests real-time traffic information as another important motive for passive usage in well-known areas. One of the respondents explained that this is the single most important feature for him. I always have it switched on, or 90% of the time... at least. I keep an eye on it and, suddenly, there is an accident or a queue or something. This is how I use it most of the time actually. I can’t say I’m looking at it all the time... OK, in the beginning you sit there and say “what’s happening there?” or “I didn’t know it was a lake there”. Now I try to use it whenever I’m going in to Göteborg.

Indeed, the system adds value without configured destinations. In particular, the passive mode of operation seems to be appealing for well-known or moderately known environments. However, there were individual differences. One interviewee, who often used the system actively, stated that she would never switch on the system when driving to work. In fact, she considered the system annoying in this setting. She argued that passive system usage might be useful in countryside driving but rejects the idea of such support while driving in a city:

Urban driving... having it switched on – that’s a serious distraction! Annoying if I know where to go. It’s never switched on then!

This viewpoint depicts the main difference in opinion between users. Some consider the navigation system, more or less, as a backup tool that is normally inactive. Others look upon it as a piece of ubiquitous equipment, continuously delivering valuable support. People in the latter category, promoting usage over a wide range of traveling environments, seem to look upon the passive mode of operation as bridging an information gap. It makes them turn the system on, although destination and/or route are familiar in advance.

Finally, almost all respondents highlighted some undesired consequences of one of the context-aware function, namely automatic notification of traffic information. This system feature continuously monitors the active route, looking for incoming traffic messages. Any upcoming event, related to the route, will be notified to the user. The seemingly simple function sometimes renders unwanted consequences. One of the interviewed users explained:

This traffic information... here in Sweden I have to say that it’s kind of irritating when they pop up – these messages. With detours or alternative routes, or whatever it is asking. I know the [traffic] situation – it is always red in the tunnel and the area around! All these red arrows and road works and things – it doesn’t give me anything I didn’t know!

Another respondent expressed a similar opinion:

If I’m going from here to Stockholm, or from here to northern Sweden, then I’m interested in the road works. When I’m driving around in town I’m not. And there are no settings for this.

There seems to be total agreement among the users – traffic information is not necessarily of flash-me-in-the-face importance just because it relates to my route. On the contrary, many traffic messages are of low interest, since they are either already known or expected. Unaware to the system, users’ local knowledge is a highly relevant part of the context.
Skills and Experience

The survey suggested that users who are computer literate also demonstrate a more active behavior in using the navigation system. Given the high-level of in-car navigation experience among the respondents (each having, at least, two years everyday experience), the respondents could reflect upon the role of gradually growing experience. In this regard, the respondents recognized a correlation between skills and usage. As expected, they generally remember passing an initial threshold, before entering a mode of a more swift operation of the system.

However, they also recognize a more fundamental transition in use patterns; the more comfortable with the system, the more of an active user. Following increased skills and understanding, respondents developed a somewhat new perspective on both value and usage. Looking back on several years of experience with car navigation, one of the respondents stated:

I guess there has been a gradual shift. In the beginning it was right on the target, I mean “how do I travel to a destination”. Nowadays, after a couple of years with the system, it’s been more and more interesting with the general information. Searching for a restaurant, or looking for a specific place, or some kind of information along the route. It’s turning more into this than just looking for a destination.

In addition to changed use patterns, increased skills and experience seem to affect the attitude to travelling itself. Comfortable with the system, users tend to adopt a more relaxed attitude, starting a journey without gathering detailed knowledge about the destination in beforehand. One of the interviewees noted:

You’re getting kind of blunt once you’ve been used to the system, leaving without preparations. Like when you’re going to a shopping mall somewhere, knowing roughly where it is, but not exactly. Normally, you would probably check it up on a map at home, or in the phone book – then go. But now, you’re just leaving, trusting the system to find it.

Finally, respondents also voiced negative experiences of some context-aware features. One of them perceived the traffic information function as inaccurate:

I did use it for a while, but I felt it was so inaccurate - especially the road works. There were old road works, not updated. Or they didn’t exist when you arrived there.

Another respondent meant that the information probably is correct but still pointless to him since the system did not provide proper support:

I remember one occasion using this information. It wasn’t here in Sweden, but in Germany. One of these warnings was poping up on the highway, saying “now we have a problem”. I asked it to select an alternative route, but I felt this route was even worse. I mean, it took even longer time and it guided me through Cologne, or where ever it was, in to the city centre. The queues were not less problematic there!

The consequence of these negative experiences is major – users tend to abandon the entire idea of real time traffic information. A few negative experiences are enough to make them overlook the function as a whole.

Social Setting

The interview study also shows that the social setting intersects with usage. First, co-travelers call for attention, reducing the driver’s possibility to interact with the system. Navigation systems support visual guidance with a recorded or synthetic voice. Even though most users appreciate this support, several respondents highlighted voice guidance as annoying and interrupting when having a conversation with co-travelers. One of the interviewees argued
that it is too complex switching off the voice support:

*An improvement would be if you could switch off the volume and then turn it on again, to the same level. And not by “3, 2, 1”, deep down in the menu system. Yes, I would have preferred a traditional button, muting the volume.*

In his narration, a family father gave another reason for muting the volume:

*I guess I’m using the volume control pretty often since I have small kids. When they sleep I mute the volume, or adjust it properly. But, most of the time the volume is turned on.*

To be sure, the assumed user of an integrated navigation system is the driver. Everything, from steering wheel control to display position, confirms this assumption. However, the interviews showed that passengers are an important user group, possibly overlooked in the conventional design process.

Second, the passengers can operate the system themselves, allocating their full attention to the task and making them a fundamentally different user category. One of the respondents described his wife, mostly being a co-driver, as more skilled with the system than himself:

*I’m not an expert on this device. I’m sure there are many features that I’m not aware of. And many functions that I’m not using as intended, or in the smartest way. My wife is probably more skilled with it than I am. I guess it’s because she’s in the passenger seat, while I’m driving.*

In sum, there are a range of social circumstances that influence the use of context-aware applications. Typically, these circumstances are not part of the design rationale for car navigation systems.

**DISCUSSION**

In this paper, we set out to explore the user’s role as co-creator of context. We are doing so by studying how and why situated knowledge affects the use of car navigation systems. Using a sequential multimethod study (Mingers, 2001), we collected data on in-car navigation use as an example of widespread context-aware computing usage. Our investigation was triggered by a surprising lack of empirical studies of context-aware applications in real-world settings. Given the ongoing debate about the notion of context in the literature (see e.g., Dourish 2004, Schmidt et al., 1998) and the lack of empirical navigation studies in actual use settings, our ambition was to contribute with empirically grounded insights on the role of situated knowledge in using context-aware applications.

On a general level, our study provides considerable support for the user’s active role as a co-creator of context. Concurring with situated perspectives on context-aware computing (Chalmers & Galani, 2004; Dourish, 2004; Greenberg, 2001), we identify how situated knowledge is deeply intertwined with context-aware application use patterns. In this regard, there are at least three use implications of situated knowledge.

- **Frequency:** Frequency of use depends on situated knowledge. As suggested by the navigation literature (Bonsall & Parry, 1990; May et al., 1992; Lotan, 1997; Wallace & Streff, 1993), the most dominant aspect of situated knowledge in explaining frequency of use is geographical familiarity (local knowledge). In fact, our study documents a significant correlation between local knowledge and the frequency of use. The reasons to switch off the system vary, but many users consider the context triggered turn-by-turn instructions annoying when route or destination is known. Often they do not even reflect over alternative modes of operation.
• Diversity: Situated knowledge is an important explanation to individual differences in system usage. We refer to such a variety in use patterns of a given system as diversity. In the case of in-car navigation this phenomenon is salient once the dominant local knowledge is subordinate. Although driving in such a familiar setting, many drivers tend to find value in their navigation system beyond turn-by-turn instructions. They rely on their own capacity to make sense of the driving context, but look upon the system as a supplementary decision-support tool. In contrast to foreign driving, characterized by homogeneity in usage, they show a rich variety in operating the system. Some are, for example, completely focused on traffic information, while others value situation awareness and orientation provided by the system.

• Emergence: It is widely agreed that new use patterns emerge over time when technologies are appropriated by users in response to changing contexts (see e.g., Orlikowski, 1996). Our study shows that this holds in the case of context-aware applications as well. Triggered by accumulated situated knowledge, such new patterns do not necessarily match the original intents of the system but are developed and enacted by users over time. For instance, the interview study shows that database search, map scrolling, etc gradually become more important as a valued complement to the user’s situated knowledge. Moreover, the experienced user may change her way of preparing trips. Trusting the system as a decision support tool, trips to unknown destinations are initiated without any pre-planning.

The multi-method study documents a relation between users’ situated knowledge and their use patterns. In this regard, the study demonstrates the downside of the representational view of context (Dourish, 2004) in everyday usage of context-aware applications in dynamic settings. Because all environmental features cannot be modeled (the driving context is fluid and users’ preferences vary), today’s navigation systems cannot fully provide the intended support to users with a high degree of situated knowledge. While automatic sensing is clearly valuable in unknown contexts, this value is lower with high situated knowledge. Indeed, in the latter situations, the context awareness provided by the system is questioned. The system behavior is not intelligible to the user in view of her own understanding of the situation (cf. Bellotti & Edwards, 2001).

So, what can be learned from this study in terms of design? While the development of design principles and possible architectures that build on a situated perspective of context-aware computing is beyond the scope of this paper, our results render significant design implications that can serve as a basis for future research. First, a situated perspective on context suggests that the sensemaking process cannot be left to the application. As outlined by Bellotti and Edwards (2001, p. 193), “context-aware systems cannot be designed simply to act on our behalf”. This is generally confirmed in our study and is something that needs to be recognized in the car context too. As evidenced in our study, the experienced user tends to use the navigation system as a decision-support tool rather than a system for automatic route guidance. In designing navigation systems, it is therefore plausible to develop more and better functionality that informs the user about occurrences and context rather than concentrate on turn-by-turn use cases. Moreover, it is relevant to note that rich access to sensor data may tempt designers to include information without a proper grounding. Rather than adopting a representational view of context in which more context parameters are assumed to increase the sensitivity to context, however, designers are encouraged to be attentive to user creation of context in seeking a design that supports situated contextual understanding. Finally, our study suggests that users’ ongoing learning has to be increasingly considered in design. Today’s systems do not
cater for emerging use patterns, missing an opportunity to leverage customer satisfaction as user preferences change over time.

CONCLUSION

As an example of a wide-spread and mundane type of context-aware application, today’s navigation systems are characterized by a representational view of context. Following such a view, navigation systems tend to view context as stable, generic, and consisting of environmental features that can be captured, represented, and modeled. In this regard, navigation systems do not cater for the role of users as co-creators of context. Regardless of diversity between users and accumulation of experience over time, situated knowledge is not something that is accommodated in the design of navigation systems.

The sequential multimethod study documented in this paper provides a detailed understanding of context-aware application use and the implications of situated knowledge for the perception and operation of navigation systems. To this end, the study pinpoints a set of theoretical and practical implications that are derived from a study of actual use. Thus, the paper complements extant situated perspectives with empirical insights that highlight the consequences of inattention to the dynamism of user contexts.

There is little doubt that navigation systems are characterized by aspects that are specific to the driving context. While it is reasonable to assume that situated knowledge is a profound aspect of application use across settings, the results derived in this study cannot be directly transferred to other context-aware application domains. More research of situated knowledge and users as co-creators is therefore needed to further our knowledge about context-aware features intended to support the vision of ubiquitous computing to push the computer backstage.

REFERENCES


**ENDNOTE**

1 Road & Traffic Information.