Interpreting and Acting on Mobile Awareness Cues

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ABSTRACT

Mobile awareness systems provide user-controlled and automatic, sensor-derived *cues* of other users' situations and in that way attempt to facilitate group practices and provide opportunities for social interaction. We are interested in investigating how users interpret these cues as a situation, action, or intention of a remote person and then act on them in everyday social interactions. Three field trials utilizing A–B intervention research methodology were conducted with three types of teenager groups ($N = 15$, total days $= 243$). Each trial had a slightly different variation of ContextContacts–a smartphone-based multicue mobile awareness system. We report on several analyses on how the cues were accessed, viewed, monitored, inferred, and acted on.

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CONTENTS

A surprisingly large variety of inferences was enabled by the cues, transcending the expected "place," "availability," and "activity." The findings indicate that inferences are based mainly on 1 to 3 cues at a time and draw heavily on the user's preknowledge about the other person. Three kinds of interpersonal uses are argued. First, the inferences participate in the *coordination* of mobility and communication, typically between two users. Compensatory coordination is supported by inferences of the other's current state or situation (e.g., not being available due to attendance at a class) and anticipatory coordination by inferences of intentions and plans. The participants looked at the cues just before placing a call, and a positive effect on the success rate of communication attempts was observed in one user group. The cues also facilitate various ad hoc opportunities and informal encounters. Second, when a user-controlled text field was introduced as an additional cue, the use of the system evolved from coordination toward *discussion*, chatting, and expressions of emotions. The use of automatic cues evolved in parallel, emphasizing those cues that support availability and the presence inferences needed in the coordination of conversations. Third, the cues support *companionship* among group members: feelings of mediated connectedness, closeness, and communality. Several recurring issues in the design of mobile awareness systems are addressed in the light of the findings.

1. INTRODUCTION

Recently, many mobile awareness systems have been presented (Bardram & Hansen, 2003; Holmquist, Falk, & Wigström, 1999; Isaacs, Walendowski, & Ranganthan, 2002; Marmasse, Schmandt, & Spectre, 2004; Milewski & Smith, 2000; Oulasvirta, Raento, & Tiitta, 2005; Tang et al., 2001), each with different awareness cues and related interaction mechanisms. Typically, the claimed purposes for these have been to facilitate interpersonal practices and to provide new opportunities for social interaction when on the move.

Because mobility as a use context differs quite radically from desktop use, it is reasonable to expect that users' inferences of *mobile* awareness cues, particularly, and their supported activities are different as well, and perhaps unforeseeable to designers (Holmquist et al., 1999). First, mobility is characterized as an ill-structured activity where situational fluctuations and the dynamic changing of accessible resources are commonplace (Perry, O'Hara, Sellen, Brown, & Harper, 2001; Tamminen, Oulasvirta, Toiskallio, & Kankainen, 2004). Thus, the goals and resources present in processing the cues can differ from "nonmobile" applications such as instant messaging (IM). Second, the kind of continuous and peripheral awareness assumed in the office or in home environments is simply not possible. Mobile devices are kept in pockets and bags most of the time, and cues are out of immediate perception. Even when they are taken out of pockets, mobile users' attention is severely fragmented (Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005). However, no in-depth study of this issue has been previously presented.

The main goal of this article is to address the question of how mobile awareness cues are inferred and acted on. To this end, field trials were conducted and are analyzed from the perspective of social cognition research. Three argumentative components are distinguished: (a) the cue at the interface as an input to a social inference process, (b) the processing of the cue in the inducer's mind, and (c) the intended or real change in social behavior as an indicator of utilizing the inference in action. The results are synthesized as three roles of mobile awareness in everyday social interaction.

1.1. Approach: Social Inference of Awareness Cues

The unit of awareness information at the user interface, a *cue*, refers to a perceptually separable representational entity that can be used in the mental process of the social inference of a remote other. In this article, we use the term *inference* in a specific meaning to refer to all the mental activities and their products where cues are processed for the purpose of constructing or updating representations of remote people. Relevant research provides some ideas on the nature of this processing.

In everyday interactions, social inference takes often place in a piecemeal fashion (Fiske & Taylor, 1991; Garfinkel, 1967). People are surprisingly apt at utilizing even poor cues–represented in a time-limited channel and in a rigid format such as that of mobile awareness systems–to infer a wide range of psychological constructs, including mood states and dispositional characteristics such as personality, social relations, job performance, and so on (Ambady, Bernieri, & Richeson, 2000). The task at hand, social group affiliations, stereotypes, general knowledge of events and their scripts, "social intuition," and other types of preknowledge are drawn from in this process (Fiske & Taylor, 1991). Social inferences are *analytical* in the sense that an initial interpretation may be adjusted, changed, or even rejected. On the other hand, people are unwilling to expend a lot of mental effort to think about their interpretations and would rather rely on simple rules of thumb or heuristics to deal with complex information–effectively trading off accuracy and thoroughness for speed and minimal effort (Fiske & Taylor, 1991; Tversky & Kahneman, 1974). These shortcuts, although cost-efficient, can often lead to errors and biases.

Given the nature of everyday social inference, three questions arise for mobile awareness:

1. *The extent and meaningfulness of cues*. Because the accuracy of social inference is known to depend on the validity, meaningfulness, veridicality, and relevance of the evidence on which it is based, researchers need to examine whether the cues available in mobile awareness systems have the "power" to support any meaningful inferences. Moreover, if all cues

in a system support the *same* kinds of inferences, there is no need to present several cues at the interface.

2. *The role of preknowledge.* What kinds of preknowledge participate in the inferential process, to what depth do they allow elaborations of the literal meaning of the cue, and how is information from *multiple* cues taken into consideration?

3. *The reliability of cue-based inferences.* Will awareness cues enable making accurate judgments and forming a solid basis for social interactions? Related to this, we are interested in seeing if users actually problematize erroneous inferences and what the consequences of that may be.

To cover these issues, the phenomena can only be examined in the context of the social-cognitive activities and practices in which they are naturally participating. Both the individual and the use situation have to be analyzed to see how different inferences, even erroneous inferences, emerge.

1.2. Overview

This article provides an in-depth empirical inquiry of how awareness cues are interpreted and acted on particularly in mobile settings. Although the cues examined are those of ContextContacts, a particular multicue system, we believe them to be representative of the more general class of mobile awareness. We have deliberately chosen teenagers as our participants (see Grinter & Palen, 2002, for arguments) in three social settings: as family members, as a group running a small business together, and as schoolmates. To address the aforementioned three questions, several analyses of the use and inference of cues are presented. Both subjective and "objective" sources of data are utilized: interaction logs, message contents, interviews, and recorded communications.

The empirical sections follow a logical order, starting from an analysis of how the cues were accessed (Section 4) and continuing to analyses of how they were inferred (Section 5) and utilized in expression (Section 6) and in the coordination of communication (Section 7) and mobility (Section 8). Over the three field trials, a quite complex pattern of results emerges. Instead of just rephrasing and pooling results, we conclude the article by turning to the question of whether mobile awareness is "good technology," whether it can assume any meaningful role in the everyday lives of users. To synthesize the findings, we propose three "roles" of mobile awareness in everyday social interaction.

2. CONTEXTCONTACTS

ContextContacts is built on top of the ContextPhone platform running on Nokia Series 60 smart phones (Raento, Oulasvirta, Petit, & Toivonen, 2005).

It overrides the standard Contacts application of Series 60 smart phones but looks and behaves very similarly. It can be triggered from the application menu and from the stand-by screen by pressing the joystick, as in the standard version. The contacts can be scrolled through with the joystick and can be called by pressing a green phone button located below the phone display. Integrations into the communication application environment of the smart phone, including SMS and the recent calls list, have been implemented.[1]

Our approach to cue design has been to integrate cues into the *contact book* (see also Bardram & Hansen, 2003; Milewski & Smith, 2000), because call placement and answering are still by far the most commonly used functionalities of a phone. The contact book is also an indicator of a person's social networks and a source for finding opportunities for communication and interaction (Katz & Aakhus, 2002; Ling, 2002). See Figures 1A and 1C for the cues and an explanation.

Most cues are represented as *icons* to save space and to support visual search and the attentional pop-up necessary for spotting changes. In icon design, we relied on well-known usability principles: utilizing clear, communicative, concrete, and familiar metaphors. Therefore, the icons rely mostly on conventions in IM and Nokia's products. Among the cues, there is also textual information to express the location and duration of stay in that location. ContextContacts automatically fetches in the background a place name for a Global System for Mobile Communication (GSM) cell ID from teleoperators' (Elisa and TeliaSonera in Finland) positioning services. However, because ordering the positioning information is costly, the names for only those IDs where the user spends a significant amount of time—so-called *Bases,* as determined by a data-mining algorithm (Laasonen, Raento, & Toivonen, 2004)—are fetched. The algorithm also overcomes the frequent cell-switching problem in the GSM network. Thus, a familiar district name is represented in the district cue most of the time.

To support the understanding of the *veridicality* and *timeliness* of the cues, all cue information grays out gradually (in four intervals) if the user is disconnected. To support *self-awareness*, there is a view accessible from the Options menu showing how others see the user at the moment. The contacts using the ContextContacts service are grouped at the beginning of the contact list. This decision has been made with the aim of supporting understanding of the relative situations of others with as little interruptive scrolling as possible.

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1. The only omissions in comparison to the standard S60 contact book are (a) there is no way to switch between first-name and last-name-first ordering, (b) there is no built-in Help, (c) service numbers cannot be edited, and (d) there is no Groups functionality (enabling addressing an SMS to a group of predetermined contacts). In the field trials, we observed no problems arising due to these omissions.

Figure 1. **(A) Standard ContextContacts, (B) detailed view for a selected contact, and (C) a version with the free-text cue. Callouts for cues: (1) district (automatic label) or place (user-defined label), (2) duration of stay cue in hh:mm format, (3) phone manipulation (gray hand = no use for over 15 min, red hand = recent use), (4) alarm profile (audio/vibra and on/off), (5) number of people or friends in the vicinity (yellow/green person icons as determined by the presence of unknown/recognized Bluetooth phones), and (6) free-text cue.**
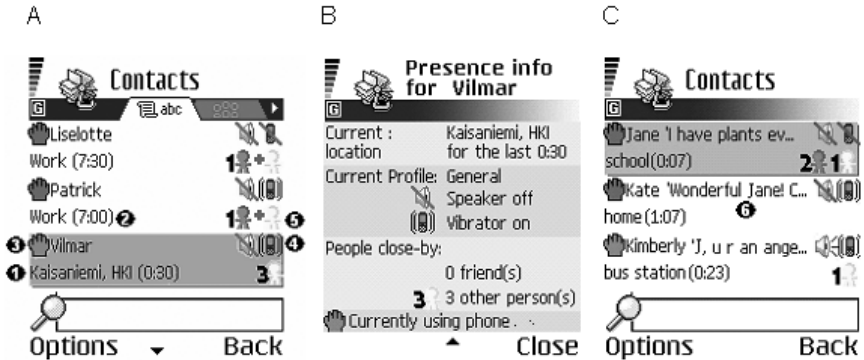
A detailed view of a contact is provided by pressing the joystick (Figure 1B). In the standard version of the contact book, no functionality was associated with this operation. In the detailed view, all cues are expanded to a table where the cue type is presented on the left and the corresponding explanation in text on the right. This helps the users to learn the meaning of the icons in the main view. Finally, the *reciprocality of self-disclosure* (Altman & Taylor, 1973; Prinz, 1999; Rubin, 1975) is supported only at a very rudimentary level: If the user decides to switch the application off, he or she receives no information on friends' situations either. Therefore, others cannot monitor a user without that user being able to monitor them back.

3. FIELD TRIAL METHODOLOGY

Three field trials were conducted with three different teenager groups and with slight variations in the ContextContacts's design. The groups are called the Family, the Entrepreneurs, and the Schoolmates. Common to the two first trials is the use of A–B and A–B–A research methodology adopted from intervention studies in clinical psychology and clinical medicine:

- In the A phase, a baseline for behavior is gathered by recording use during which the awareness *cues are not shown or activated.* All data collection is done normally, however, as in the B phase.

- In the B phase, the cues are installed and introduced to the participants. The length of the B phase should be about the same as of the A phase. All data collection is done as in Phase A.

In the A–B design, the aim is to collect a baseline of behavior in Phase A where the technology is *not* used. This baseline is used to put findings in Phase B (where the cues are in use) into a context to understand the effects of the cues. The logic of the *full* A–B–A design (used only in the first trial) is that the second A phase improves the strength of the argument to attribute the observed changes (in Phase B) to the technological intervention and only that. Given that the second A phase replicates the findings of the first A phase, we can with more certainty rule out the possibility that the changes were due to regression toward the mean or accidental events like holidays. The B-only design was considered sufficient for the third trial in which we were no longer interested in the *impact* of mobile awareness but in the relationship of user-generated and automatic cues, a question requiring a within-phase analysis.

3.1. Procedure

A general introduction included transferring information from the participants' old phones, an explanation of data gathering (including phone recording), instructions to use the phone "naturally," an explanation of the reimbursement of costs and of the subsequent anonymized analysis and publication of data, the completion of forms collecting background information, and the scheduling of interviews. At the beginning of Phase A, a version of ContextContacts without cues was installed into the participants' phones. An interview was held at the end of this phase. At the beginning of Phase B, the awareness cues were switched on. The participants were told that ContextContacts was to replace the phone's original phonebook. All cues were briefly explained, as well as the use of the related mechanisms (details and self-awareness). Interviews were held in the middle or at the end of the phase, as explained next. Within all three studies, we tried to make Phases A and B equally long (see Figure 2 for lengths).

3.2. Participant Groups

All the groups represent urban teenagers living in the Helsinki capital area. Figure 2 summarizes the characteristics of the three trials.

Group 1: The Family.   This group consisted of a mother and three children, ages 13, 15, and 17 (two girls, one boy), living in a single-family house.

Figure 2. **Trial design.**

Trial	N	Dates	Design	Version of ContextContacts
1. Family	4	5/2004–9/2004	A-B-A	No free-text cue, no Bluetooth-based cues
2. Entrepreneurs	5	12/2004 –3/2005	A-B	No free-text cue
3. Schoolmates	6	4/2005–5/2005	B	All (Figure 1C)

None of the participants used IM regularly. Three Nokia 7650 phones were given to the children; the mother used her own Nokia 6600. Each participant in this group had 115 entries in his or her phonebook, on average. All interviews were held at the family's home, save the last interview with the mother at the end of the trial. In contrast to the other trials, we interviewed this group not about the use of cues but about the system in general. They did not have the Bluetooth-based cues in Phase B.

Group 2: The Young Entrepreneurs.   Although this group (M age = 17.3; one female, four male) spent some time together outside the school (secondary school), their main motivation for being together was related to the running of their company (renting student labor). Two of the participants used IM regularly. Each participant in this group was paid a small incentive (100€) for their participation in the study. Nokia 6600 phones were used. A participant in this group had 132 entries in his or her phonebook on average. For this group, the Bluetooth-derived cues were added. All interviews were held on the school's premises.

Group 3: The Schoolmates.   This group consisted of six friends (M age = 16.2; five female, one male) from the same secondary school as Group 2. It had formed about 3 to 4 months before the trial, when the members started to hang out together frequently outside the school, both for leisure and schoolwork. Three of them used IM regularly. Each participant was paid a small incentive (100€) for participation. Nokia 6600 phones were used. A participant in this group had 76 entries in his or her phonebook, on average. For this group, the *free-text cue* was added (see Figure 1C). All interviews were held on the school's premises.

3.3. Interviews

In the first and second trial, there were two and three interview sessions divided between the phases, respectively. In the third trial, there was one in the middle and one at the end of the trial. In the introductory interviews, held af-

ter Phase A—and at the beginning of B in the Schoolmates trial—questions concerning communication behavior were asked: mainly on their use of mobile phone, alarm profiles, messaging channels, and so on. In addition, we informally interviewed them on their mobility-related practices: how they travel to school, whether they use their mobile phone while traveling, who do they typically call, and so forth.

The technology-focused interviews were held in the middle or at the end of the B phases. There were three parts in this interview. In the first part, a group interview was held, focusing on the use of the system as a group, which awareness cues were regarded as useful and for what, and what features they would like to add. In the Schoolmates trial, the use of the free-text cue was discussed. Second, individual interviews about the cues took place after the group interviews. A sample of 10 to 20 recorded phone calls made within the group were played, one by one, and the interviewee was asked to recount concrete episodes of what happened when that phone call took place. In the final part, we asked the participant to recount episodes separately for each cue in ContextContacts. Finally, at the end of the entire trial we collected opinions on the system and suggestions for improvement.

3.4. Automated Data Collection

ContextLogger (Raento et al., 2005) was used to collect the following information: (a) *context records*, meaning all time-stamped cue information; (b) *communication records*, including the contents and transaction logs of all SMS and voice communication (30-sec recordings of the beginnings of calls made within the group were indicated by a beep at the beginning of the call so that the participants could delay conversations that they did not want to be recorded); and (c) *interaction logs*, meaning all commands to and responses from the application.

ContextLogger represents relatively reliable and mature software for data collection in smart phones that has been widely applied to long-term social scientific and behavioral studies. It receives notifications of context changes from the sensors and customizable applications, writes these data in a local file, and periodically uploads the files to the researchers' server via the background file upload capability of the platform. It requires no user interaction and does not interfere with user interaction, although it does present small indicators on the phone idle screen as a reminder that data collection is in process. The collected text-format logs totaled 29 megabytes for the first trial, 177 megabytes for the second trial, and 141 megabytes for the third.

4. ACCESSING AND VIEWING CUES

To provide a context for the analyses presented in the following sections, this section reviews descriptive statistics on when, how often, and where ContextContacts and its cues were accessed and viewed.[2] These data come from the interaction logs and context records gathered in the three trials.[3]

4.1. Access of the Contact Book

Within the logs, there are two simple indicators to quantify access of ContextContacts: the number of activations of the application and the amount of time elapsed while it was in the foreground.[4] As presented in Figure 3, the Entrepreneurs trial provides strong evidence of increased interest in the system from Phase A to B. For this group, both the activation count and the cumulated usage time increased drastically (frequency almost quadruples, duration almost doubles). A dependent samples t test of the effect of phase (A vs. B) on cumulated usage time was statistically significant, $t(4) = -2.83$, $p < .05$, and nonsignificant for a number of activations, $t(4) = -2.54$, $p = .06$. In the Family trial, a noticeable increase appears between Phases A and B, which is not as strong an increase as for the Entrepreneurs, and this trend was not statistically significant, both $ts(3) < |2.00|$. The Schoolmates exhibited the strongest interest of all the groups in absolute numbers. This popularity is most likely related to the use of the free-text cue for group messaging (Section 6). Finally, an independent samples t test for Phase A versus B over all trials was significant for both DVs (the num-

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2. For reasons of simplicity, of enabling comparisons between Phases A and B across the Family and Entrepreneur trials, and of statistical power, we collapsed the two A phases of the Family trial in this and some of the subsequent analyses. Generally, data from the second A phase of the Family group did not contrast the first phase.

3. There were no significant technical problems in the three trials. In the Family group, the phone batteries drained quickly, and there were problems with a crashing application during the first weeks of the trial, but those were fixed after a few days. The positioning (district cue) was not functional when the group took a vacation abroad for a week during Phase B. In the Entrepreneurs trial, there were problems with positioning queries; because of a bug in the software, the phones asked for the phone's position needlessly at times, and this was fixed after the trial. The Schoolmates reported few instances of instability while receiving text messages. Besides these problems, the system performed as hoped.

4. Due to the battery-saving scheme, a screensaver will typically take over the foreground after only a couple of minutes of user inactivity, allowing a reasonable approximation: the foreground time of ContextContacts approximately equals its effective use time.

Figure 3. **Descriptive statistics on the use of ContextContacts in the three trials.**

	Participant Group		
Trial Phase	Family[a]	Entrepreneurs[b]	Schoolmates[c]
Period A	52 days	44 days	N/A
(without ContextContacts)			
Proportion of calls placed with	76%	40%	N/A
ContextContacts	(407/538)	(167/419)	
Daily amount of use per person	120 sec	254 sec	N/A
Daily activations	1.8	2.1	N/A
Use of the system in "base" locations (home, work, school, etc.) vs. between bases	94%/6%	91%/ 9%	N/A
Period B	49 days	56 days	43 days
(with ContextContacts)			
Proportion of calls placed with	81%	77%	87%
ContextContacts	(198/245)	(889/1,149)	(490/563)
Daily amount of use, per person in seconds	175 sec	589 sec	4,069 sec
Daily activations	2.6	7.9	58
Use of the system in "base" locations (home, work, school, etc.) vs. between bases	92%/8%	87%/13%	74%/26%
Daily Details View activations, per participant and per group member	0.2	0.3	10.2
No. participants exhibiting monitoring behavior	1 of 4	1 of 5	6 of 6
No. recorded monitoring behaviors	5	10	1,195

[a]$N = 4$. [b]$N = 5$. [c]$N = 6$.

ber of activations and the amount of time foregrounded), both $ts(22) < |2.13|$ and both $ps < .05$. To conclude, both groups exhibited an increase of access in Phase B, and this increase was particularly pronounced (and statistically significant) in the second group.

4.2. Viewing Others' Cues

From the logs, we can compare the cumulated time spent looking at the screen for cue-augmented versus nonaugmented contacts. In Phase B of the Family trial, the time that contacts were in the foreground favored augmented contacts (80% of the total time) over nonaugmented (the remaining 20%). For both the Entrepreneurs and the Schoolmates, this ratio is 90% to 10%. However, when the cues were *not* available (Phase A), these proportions were 77% to 23% in the Family group and 70% to 30% in the Entrepreneurs group. We next compared the daily amount of time spent looking at all group members' con-

tacts between Phases A and B. In both trials, there is a notable relative increase in the daily average: +145% and +300%, respectively. In the Schoolmates we noted the surprising average of 1.5 hr per day (exactly 5,317 sec) that users spent looking at others on their contact list. A two-way (A vs. B Phase x Augmented vs. Nonaugmented Contact) repeated measures analysis of variance on the duration measure for the two first trials yields a significant effect of phase, $F(1, 8) = 5.96$, $p < .05$, a nonsignificant effect of contact type, $F(1, 8) = 1.31$, and a significant interaction effect, $F(1, 8) = 35.87$, $p < .001$. Finally, we learned that looking at others through the details view was of no strong interest to the participants, save the Schoolmate group, who used this feature widely for group messaging purposes (Section 6). Overall, the data suggest that the introduction of cues induces a measurable increase in viewing of contacts.

4.3. Monitoring and Tracking Others

The participants fully realized the *monitoring capability* of the system: Most (9/15) indicated in posttrial interviews having monitored or tracked the other users. To understand how frequent this was, we analyzed the interaction logs for repetitive checks of the same contact in a short period.

Monitoring practices can be measured by the amount of time a user spends looking at group members through the contact list as well as counting the accesses to the details view. We observed that few users were strongly disinterested in the matter. For instance, in the Entrepreneurs group, one user spent only 1 hr (over the 56 days of Phase B) looking at his group members' contacts and made use of the details view only once. However, many others were interested. One participant spent as long as 120 sec per day looking at each of his cue-enhanced contacts and regularly accessed their details view. The data on the accesses of the details view show that even if the participants did not make an overall intensive use of the details view, they did, on several occasions, check the details of a fellow member *repetitively* at regular intervals. For example, on January 18, 2005, Akseli summoned the details view of another participant successively at 1:24 p.m., 2:42 p.m., 3:58 p.m., 4:42 p.m., 5:29 p.m., and 6:08 p.m., strongly suggesting tracking that contact. If we choose an (arbitrary) value of 30 min as the time threshold between two consecutive checks to operationalize monitoring, we observe that monitoring is indeed present throughout the three studies (see Figure 3) and particularly accentuated in the Schoolmates trial. In that group, the most common pattern consists of an average of six checks in a row; some extreme but rare cases add up to 60 successive checks.

4.4. Using "On the Move"

To understand how "mobile" the use of cues was, we utilized the concept of *base*, defined as a frequently visited set of contiguous cells in a GSM network

(Laasonen et al., 2004). The most typical bases in our data were locations that could be labeled as *home, workplace,* and *school.* Two situations can be distinguished with this method: being *at* a base and being *between* bases, and the latter is here used as the operationalization of being "on the move." This method is of course fairly dependent on the GSM network topology.[5] Moreover, stationary use in those places that are *not* frequently visited (and thus not counted as bases) is classified as mobile use here. Therefore, our argumentation here relies on comparisons between Phases A and B.

As reported in Figure 3, both the Entrepreneurs and Family trials exhibit an increase in the proportion of the mobile use of the system from Phase A to B. We analyzed the access of details view to quantify the use of cues in particular. In the Family trial, the data are unfortunately not sufficient due to the infrequent use of the details view. The Schoolmates accessed the details view 13,197 times during the trial, which translated into 61 accesses per day per user (pdpu) while stationary and 18 accesses pdpu while on the move. The bases *home* (67 accesses pdpu) and *school* (40 accesses pdpu) were the most popular places to use the service, even though being at school represented only a small fraction (13%) of the stationary time. All other locations account for 28% of the stationary time but only exhibit 20 accesses pdpu. Hence, in this trial, the details view was primarily accessed while stationary. On the contrary, the Entrepreneurs appeared to prefer accessing cues while on the move: 2.8 accesses to the details view pdpu when on the move, and 1.1 accesses pdpu while stationary. The fact that this group was not particularly mobile (87% of their time was spent at a base) makes this result more interesting. Their Phase B contains 578 base-to-base journeys (of at least 5 min), and almost every third trip included at least one access to the details view. Thus, in this group, Phase B witnessed an increased use of cues (details view) particularly when mobile. However, this increasing trend was only borderline significant in a dependent samples *t* test on the mobile/stationary use ratio, $t(4) = -2.41, p = .07$.

4.5. Controlling Self-Disclosure by Turning the Service On and Off

The participants had two ways to manage their information disclosure: turn the service on or off and turn the phone on or off. From the interviews, we learned two reasons for this: reducing GPRS expenses when abroad and

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5. Mobility *within* cells and bases is categorically excluded from our analysis. As opposed to a city environment where cell radius is typically a couple of hundred meters, a countryside environment involves radiuses of several kilometers.

denying disclosure of information to others. The former happened once in the Family group, and the latter was not very regular: Only 2 participants (of 15) made a noticeable use of the feature (15 times in 56 days), each time only for a period shorter than 1 hr. The Schoolmates group never turned the service off.

5. PERCEIVING THE OTHER THROUGH CUES

This section analyzes how the cues were *inferred* as situations of others (see Section 1.1).

5.1. Interpreting Cues as Situations and States of Others

Figure 4 presents inferences collected from the episodes that the participants recounted for each cue in the interviews. In labeling inferences, we tried to retain the participants' own level of description. For example, if a participant used a cue to infer that the other person is sleeping, we marked the inference as "sleeping" instead of "interruptability," although the two are closely related. There is remarkable variability in inferences in Figure 4, both when comparing the groups and the cues. Some inferences occurred for many cues and in all user groups: For example, "availability" occurred for almost half of the cues. However, some inferences were more closely associated with a particular cue. For instance, movement inferences (going to, arriving at, or having left a place) appeared exclusively with the duration-of-stay cue. The following broader categories of inferences were distinguished:

1. *Inferences related to space and place* (e.g., being at home, school, work). These were regularly at a more detailed level of granularity than what the district cue literally allows for (being in a GSM cell). *Movement* was inferred with the duration-of-stay cue, which implies both the time since arriving at the current place and that of leaving the last place. *Proximity* and *distance* (to self) were also inferred.
2. *Activity inferences* (e.g., sleeping, attendance at a class) were often inferred by using multiple cues. For example, 1 participant indicated that three conditions (it is morning; a phone has not been used for several hours; it is on silent mode) warrant the inference that the other is probably sleeping.
3. *Inferences related to potential or disposition.* Some inferences are best explained as potential for action. *Availability,* a person's likelihood of being able to have a mobile phone conversation, was often inferred using multiple cues such as being close to the phone and having used it lately. One participant said that having used the phone during the last 2 min

Figure 4. Inferences of the mobile awareness cues in two user groups. Self-reports from posttrial interviews.

Cue	User Group and System Version		
	Family[a] (Standard ContextContacts Without BT-Based Cues)	Entrepreneurs (Standard ContextContacts)	Schoolmates (Standard With Additional User-Defined Cue, "The Free-Text Cue")
District	Home, school, work	Home, school, particular room, particular restaurant, proximity/distance to self, attendance at a class, the next place, availability for communication, availability for face-to-face meetings	Home, school, floor in a building, particular room, being on the move, being together with friends, being in a public space, preferred communication channel, availability for communication, availability for face-to-face meetings
Duration of stay	—	Movement between places, sleeping, the next place	Time of arrival at current place, time of arrival at the next place, time since leaving the last place, duration of stay at the place, movement between places
Alarm profile	Availability for communication, interruptability	Attendance at a class, sleeping, availability for communication, interruptability	Availability for communication, preferred communication channel, interruptability
Phone manipulation (hand)	Current or recent use of the phone, availability for communication	Proximity to phone, current or recent use of the phone, availability for communication	Availability for communication and messaging, awareness of the other having received a sent message, current or recent use of the phone, inability to respond, sleeping, being awake, proximity to phone
No. of friends in BT range (the green guy icon)	N/A	Attendance at a meeting with other group members	Going to school together in a group, staying at another's house, being in the same place together (e.g., birthday party, restaurant)
No. of others in BT range (the yellow guy icon)	N/A	Transportation vehicle, number of people around, attendance at a class	Attendance at ice hockey game or other large-scale event, being in a public space

[a]This group was not asked to give accounts for each of the cues. The extracts here are from their answers to more general questions on the use and acceptance of the system.

meant availability for calls. However, after 6 hr of inactiveness with the phone, availability was much lower, he explained. *Interruptability*–here, the capacity to engage in a mobile phone call–was associated most closely with the hand and the alarm profile cues.[6] Naturally, activity inferences were often utilized in determining potential. The following quote exemplifies how the inference was constructed so that another communication channel should be used:

(1) Also when you have to call somebody during classes or send an SMS you can discover if he/she is attending a class. If it's on the beep mode, you can send an SMS, if you think that he/she is attending a class, and then the other can decide whether to answer, or then you call and if he/she answers that. . . . But if the sound alarm is on, you don't call during classes. (Entrepreneur)

4. *Inferences related to social situation.* The two Bluetooth-derived cues evidence inferences of the social situation. The Entrepreneurs elicited only four occasions where those cues were useful, whereas the Schoolmates used them frequently. One Schoolmate even regarded them as the most valuable cues, most likely because they have significance in inferring who is with whom, doing what, and where. In Figure 4, we find such inferences as going to school together, staying at another's house, and being in the same place together.
5. *Inferences referring to the past, present, and future.* Finally, the temporal range of the inferences was surprisingly wide, ranging from the past (e.g., another person has arrived at home), to the present (e.g., availability), and to the future (e.g., the next place; the probable next time for availability).

We return to the special case of the hand cue in the Schoolmates trial in Section 6.

5.2. Inferential Frames

The kinds of elaborate inferences just reported can only be enabled by the background knowledge available to the other at the moment of inference. What types of inferential frames were utilized to "go beyond" the literal meaning of the cues? The following frames could be distinguished:

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6. We learned from the interviews that "interruptability" is not the same as the *negation* of availability, *un*availability. For example, being unavailable because of not being able to hear the phone does trivially imply the interruptability of a person.

1. *Specific knowledge of another's current activity.* One participant, for example, said that if the phone is not on silent mode but she knows that the person is at school, then she knows when to call, because she knows when the breaks start and end. Situational knowledge, for example of ad hoc productions of space-time (e.g., previously agreeing to meet during the next break to go to a café) was also utilized.

2. *Time of day* was utilized often, sometimes even at a sophisticated level involving distinctions between just a few minutes (e.g., knowing when the other's bus home leaves).

3. *Known regularities of the movement patterns of* a person helped to augment, and at times overcome, the low grain of the district cue in the system. Related to this, behavioral patterns at the group level were utilized (e.g., two Schoolmates always hung out together after school at a certain place). A social situation can give rise to the need to utilize one's knowledge of movement patterns:

   (2) Jonne always goes home immediately after school; he doesn't loiter there in the hallways longer than five minutes. So when we often talked among friends and realized [...] that Jonne should be there, it was already too late, Jonne had gone already. (Entrepreneur)

4. *Patterns of alarm profile switching* were also utilized. Social knowledge (here, phones should be silent during classes) was utilized to give explanations for the observed alarm profiles of another person:

   (3) I change my profile almost every hour. But I have understood that the boys, Tero and the others, do not change theirs much. Then I have the impression that other people do change their profiles; for example, during classes they have it on silent mode. I keep my phone in my backpack. (Entrepreneur)

5. *Semantic knowledge of an area* was used to infer possible activities when another was seen in an unexpected or unusual location.

The availability of different inferential frames explains why the participants were able to use a cue for different inferences in different situations. Interestingly, at times when the situational and background knowledge was stronger than the information in the cues, the cues were rendered *un*informative:

   (4) If I was at school, then I almost never looked at the state [of others]. *If you know that they are in school, then it's unnecessary to look at it.* Maybe, at the most, you can see if they are in silent mode. (Schoolmate)

5.3. Processing of Multiple Cues

The multicue, icon-laden interface of ContextContacts forces the user to be very selective, because some of the available cues are always irrelevant, obsolete, or incomplete with regard to the inferential task at hand. We observed that *heuristic-like* mappings were often used to make quick inferences:

> (5) I've often had situations when I check, for example during a school day, if a friend is available or not. In practice, I check whether the phone is silent or not. *You cannot call a person with no [audio] alarm.* (Entrepreneur)

Without such rapid and effortless, yet effective, means for selecting cues for interpretation, users would easily become overwhelmed with "information overload." However, selection appeared to be natural to our participants; only 1 participant expressed difficulties ("symbols starting to flash in your eyes") at the beginning of Phase B. Our tentative explanation for the apparent fluency of selection is that interpretations were facilitated by the transfer of interpretation skills. The users had already used time of day as an implicit cue long before this trial, for example, in (daily) decisions of when to call a person. Transfer is a good candidate for explaining the fluent use of the hand cue as well because of its resemblance to the availability cues in IM. Similarly, locations are related at the beginning of phone calls, particularly in mobile coordination (Laurier, 2002), which may have provided a source of transfer for the district cue. From this perspective, the case of Bluetooth cues is particularly interesting, because whereas one group found almost no uses for it, the other developed an inferential skill for its use (see Figure 4).

However, as seen in the quotes previously presented, inference directly based on a single cue was not always achievable. Theories in social cognition suggest that the intake of a second cue is informed by the inference given to the firstly processed cue (Fiske & Taylor, 1991; Tversky & Kahneman, 1974). *Anchoring* means that the inference process is started with an implicitly suggested reference cue (the "anchor") and then adjustments are made to it to reach the inference. The following quote illustrates this:

> (6) The hand was mostly white, but it did give more hope when it was red. At that point when you call, I do not often look if it's red or not. The only thing is that when there's no audio or tactile alarm, there's no hope of reaching the other person if the hand is white. But if it is a red hand, you usually thought that he/she might notice your call. (Entrepreneur)

In addition to the hand cue, the district cue was a dominant anchor, whereas the Bluetooth-based cues were predominantly used only secondarily, in conjunction with the district cue:

(7) When I haven't been able to participate in some group work, I've been look-
ing [at the yellow guy] to see when they are leaving. Then the place thing [dis-
trict] has been used. And then how many people there are, and my friend Julia is
visible as a yellow guy. Nina is usually also there but there are no traces of her,
she's not visible as a yellow guy. (Schoolmate)

The participants did not make a single mention of *erroneous* inferences be-
ing a problem, even when asked what annoyed them or what should be
changed. Moreover, there were no instances of phone calls or SMSs prob-
lematizing another person's interpretation of the awareness cues. This is inter-
esting, because we also observed misunderstandings about the logic of the
cues. One participant, for example, thought that the hand cue fades from red
to gray in a matter of seconds, whereas the true interval is 15 min, and 2 others
had not correctly understood the logic of the yellow guy cue. Still, they did
not problematize the reliability of cues. The lack of such instances tentatively
suggests that errors in inferences are not a significant barrier for the use of mo-
bile awareness.

6. MIXING AUTOMATIC AND USER-CREATED CUES

Similar to some previous mobile awareness systems (e.g., WatchMe of
Marmasse et al., 2004), the version of ContextContacts used in the School-
mates trial mixed automatic and manual sources of awareness information
(see Figure 1C). This section investigates how the free-text cue was used.

6.1. Appropriating the Free-Text Cue for Expression and Chatting

Unanticipatedly, the group immediately picked up that the free-text cue
can be used for IM-like group messaging (see Isaacs et al., 2002). The field
was not designed for this: It has a maximum of 50 characters, and only 10 to
15 characters fit on the contact list, whereas the rest must be checked from the
details view. It was updated at most once a minute, and there was no notifica-
tion mechanism for changes. Nevertheless, 5,062 messages were sent during
the 42 days of the trial. The most active participant sent 1,180 messages, and
even the least active (and the only male) participant sent 452 messages.

Out of the whole data set, the last week of the trial was sampled ($N = 647$)
for analysis, which we believe represents the most mature and streamlined
use. A set of partially overlapping categories was derived from the messages.
The categories in Figure 5 were constructed bottom-up by one researcher
working iteratively with the raw data somewhat similarly to the Grounded
Theory method. The purpose of the categorization is neither to provide a

Figure 5. A categorization of 647 user-created cues in the Schoolmates trial.

Category	Characterization	Example	No. of Instances in the Data[a]
Availability	Explicitly stating being online or reachable for calls, *but* see next	N/A	0
Good mornings and good nights	Negotiating and announcing removal from the chat for the night	S14: Good night ((01:18)) S11: Good night... =) ((01:20, 3 msgs follow)) S13: Night <3 *zzz* ((01:S10, 2 msgs follow)) S11: Yes, good night ((01:S13, 5 msgs follow)) S13: Night! ((01:27)) S11: ok, I guess I should go to bed (01:36)	39
Mood and well-being	Descriptions of emotional state or physical well-being	S11: Tired... S14: Ah, why did I wake up before the alarm thinking it's gone off already S14: Awake, at school and ill.	99
Encouragement	Showing affection when somebody is complaining or feeling down	S14: Oh, lovely S13... have strength =) S12: Little S13. *Big hug* Bigger hug. Biggest.	14
Chat	Clear chains of related messages, questions and answers (in comparison to "broadcast" only), not related to coordination (Average length of a chain 16.5 messages, maximum 89)	S14: Rammstein is kinda alright. S14: Now it's starting to work. Rammstein and salsa. S13: Your taste in music is a real fruit salad. S13: Music - lovely (except for Eurovision) S14: They don't play music in the Eurovision contest. S13: :P S10: The contest sucks this year	357

Figure 5. (Continued)

Category	Characterization	Example	No. of Instances in the Data[a]
Self-expression	Describing the self, surface-level nonsensical text	S12: Scary. The crows tried to eat me outside. (after coming from a walk) S13: I'm glad I don't believe in God. I wouldn't have the energy to go to church right now. (on a Sun morning) S12: AHEM. I can speak Swedish. (after some of the discussion has been in Swedish)	22
Construction of nearby time and space	Setting up meetings, deciding on where to go, gathering resources	S11: PEOPLE! I'M COMING AFTER ALL. Wait for me. Where will you meet? S14: Come to the 1st floor foyer, those coming. S11: OK	57
Directed communication	Messages directed to specific individuals, rather than the whole group	S12: S11, do tell S12: S13, wait a moment S11: Don't you S12 have an exam now?	49
Activities	Describing current or near-future activity	S14: I'm going to be late as usual... S13: Going to have a shower S10: I'm going to an Eurovision party	41
System	Comments on the (non-)working of the presence system, including the phone	S10: Is this working? S14: This phone will die soon. Damn. S13: Yes, 'No saved voice tags'. Damn. S11: Last day of the system tomorrow.	12
Social situation	Explicit reference to other people around now or in the near future	S12: Somewhere with X. S12: A friend you haven't met for a while = Y? S13: Oh F*ck. I don't want to meet Z now.	14

[a] *n*= 647.

comprehensive enumeration or taxonomy nor to evaluate a specific theory or model but to illustrate the richness of use of the free-text cue.

The messages range from greetings to jokes to requests for information to sharing emotions. For example, the participants commented on a television program that everybody was watching in their respective homes, plans for tomorrow were shared before going to sleep, and so on. Many discussions were related to school, other students, studying, course choices, exams, and home assignments. Each night showed the protocol for establishing unavailability for messages when going to bed ("Good night") and availability when getting up ("Good morning"). Although we might be tempted to conclude from this that a "sleeping" indicator would be useful (e.g., deduced from the alarm clock on the phone), it would be a very narrow view, because availability was not *announced* but *negotiated*. It often took an hour and several messages ("I'm sleepy," "I'm going to bed," "I really have to go to bed now," "Good night!") to leave the conversation. The creation of a shared state is illustrated by the following quote:

> (8) I want to ensure that everybody else is awake as I am. That's what I'm using it for. And then, I want to know if others have done their homework. If others have daunting things, and I do as well, then I don't stress that much if nobody else has done their homework either. (Schoolmate)

Judgments of availability were mainly related to availability for free-text messages, not for phone calls, and in this respect this third study differs from the first two. The participants were keenly aware of the activity indicator (the "red hand"). They expressed that somebody's activity indicator had a direct bearing on their ability, responsiveness, probability, and willingness to participate in the conversation. They also told of producing fake activity (signaling) to show others that they were online.

6.2. Elaborating on and Referring to Automatic Cues

A sample of 3,750 out of the total 5,062 messages sent during the trial was analyzed in a similar fashion as in Section 6.1 for their relationship to the other (automatic) awareness cues. A small but important proportion, about 8% (292) of the sample, was linked, in a manner apparent to a nonmember of the group doing the analysis, to the automatic cues. The major part of these (and 7% of all) consisted of messages (258) that have something to do with the *location or movement* of somebody in the group. Typically, someone announced his or her current location or movement with no clearly defined goal ("I'm at home now," "At school," "On the bus"). They also hinted at physical meetings. For example, "I'm *now* at school," combined with preknowledge of typi-

cal places to gather or the day's schedule, allowed those at school to meet up with the person. The sender clearly assumed the automatically gathered information: The location was in most cases *more precise* than the automatic indication, although the users did also comment on their current automatically disclosed location or emphasize it. On the other hand, the effect of the Bluetooth-derived cues in the messages was small, although they were used creatively otherwise in the group (see Figure 4). In a few rare cases (22), the participants combined the location and buddy cues to infer who was with whom. They also often then *asked* who else was present: the knowledge of the presence of members of the group was presupposed, and this knowledge was shared between the asker and the answerer. Some free-text conversations *topicalized* someone's interesting situation. For example, friends might mock somebody for coming back too early from a party or for staying at school until late. Asking about somebody's location was not necessarily always goal oriented but seemed to function also as a subtle way of maintaining social relationships when the persons had not met for some time.

To summarize, the free-text cues clearly became the most evocative part of the system in this trial. Messages were used to augment the automatic cues in a way that gave details not otherwise available, the most crucial use being probably in reframing and contextualizing them. The participants could control the way others perceived them in a way that was not possible with automatic cues only.

7. COORDINATING COMMUNICATION

In general, the *absolute number* of phone calls made within-group increased after the introduction of cues (e.g., from Phase A to B from 35 to 104 in the Entrepreneurs group, although B was only 12 days longer). Also, over the three trials, the average number of calls per day in B phases (1.27) is larger than that of A phases (0.94). A tentative conclusion is that the cues may have invited more general interest in communicating with the group. In what follows, the cues' impact on communication is examined more closely.

7.1. Types of Communication Coordination

We observed four main types of support that the cues provided for the participants' efforts to coordinate communication. First, some incidents were reported where the cues were part of the participant being able to select a communication channel more sensitively, for example, when the other person was on silent mode. Second, avoiding placing calls that would be rejected were frequent:

(9) [Because of location] you don't get calls like "Hi, where are you?" if you know otherwise where you are. For instance, when you have to summon a meeting it is much easier when you know where the other person is. If we have five in the whole group [expected for the meeting] and then we see that there are four of us at school, then we can arrange the meeting. (Entrepreneur)

Third, some participants told us about looking at the cues after a failed communication attempt to make sense of and *rationalize* the failure. This also provided grounds for planning a future course of action. Fourth, and related to the first, was some reported increased responsiveness for the *timing* of reply:

(10) [At times] I waited until the status changed. I did not monitor that, let's put it that way, but I did check back after one hour or so. (Schoolmate)

7.2. Placing Calls From the Contact Book

The second question we examine is whether users, in placing calls, prefer a calling mode in the phone where the cues are observable and thus usable. Figure 3 illustrates the evolution, between Phases A and B, of the use of the contact book to place outgoing calls for each trial. Both the Family and Schoolmates group preferred to use the contact book straight from the beginning of the study. The Entrepreneurs, however, placed only 40% of their calls there, mainly because their contact list was empty when the study began, as opposed to the other groups whose SIM cards were imported on the very first day. The Entrepreneurs also exhibited a habit of using speed dialing and other shortcuts to place their calls from various applications. Phase B, however, shows their acceptance of the contact book as a call-placing resource, with 77% of their calls placed from there. More specifically, the proportion of calls to a fellow group member placed with the contact list increases from 28% in Phase A to 86% in Phase B, $\chi^2 = 43.72$, $p < .001$. To conclude, throughout the three studies, the contact list appeared to be the users' first choice when placing a call, and this tendency increased after the cues were introduced, particularly in the second trial.

7.3. Looking at Cues Just Before Placing a Call

Details View.   In general, the participants did not use the details view before and/or after placing a call as might have been supposed. Of the 391 calls placed in B phases, there were only 39 occurrences (10%) when a caller had looked at the details view of the person being called (the *callee*) 5 min before placing the call. Only the Schoolmates made real use of the details view in such a situation. They accessed the details before some 25% of their total 136

outgoing calls to another group member. Moreover, *after* a failed outgoing call, it was rather rare that a caller would check the details of a callee within 1 min: There are only 8 such occurrences (4%) out of the 151 unsuccessful outgoing calls throughout the three studies.

Contact List.   The 201 phone calls placed between two group members in the Entrepreneurs trial were categorized into two classes: whether or not the callee was represented with cues. For each call, we extracted from the logs a duration we name *pre-call delay* between the moment the callee's name appears on the phone screen and the time the call is actually initiated. As a result, we observed that there is a longer pre-call delay for those contacts for which the cues are available, suggesting that before calling the caller has been reading the cues and possibly inferring on the callee's situation before initiating the call. Calls placed in less than 1 sec when no cues were available constituted 50% of the 72 calls for the Family, 42% of the 118 calls for the Entrepreneurs, and 73% of the 45 calls for the Schoolmates. When cues *were* available, a clear shift appeared in the distribution of pre-call delays of all groups, indicating an increase of about 2 to 4 sec in the time it takes to place the call. The difference in pre-call delays between Phases A and B was statistically significant in a dependent samples t test, $t(8) = 3.11$, $p < .05$. To conclude, the users did actually look at the cues before placing a call for a brief time.

7.4. Impact of Cues on Communication Success Rates

It is generally known that the success rates (the proportion of communication attempts that are accepted and answered by the callee) of mobile phone calls are relatively low. The three trials reported here exhibit success rates of between 50% and 80%. In this subsection, we address the question of whether awareness cues had an effect on the success rates of incoming and outgoing phone calls.

In this analysis, the success rates of calls to *non*augmented contacts will provide a baseline for comparison. In the case of the Family trial, Figure 6A indicates a decrease in the success rates of communication attempts to group members of about 15 percentage units in Phase B. However, their Phase B included only 20 within-group phone calls. In the case of the Entrepreneurs trial, Figure 6B shows that, between Phases A and B, whereas the success rate of *out*going calls to nongroup members decreases from 72% (of 357 calls) to 61% (of 937 calls), the success rate of outgoing calls to group members increases from 50% (of 72 calls) to 62% (of 212 calls). A chi-square test comparing the success rate of outgoing calls to group members between Phases A and

Figure 6. Evolution of the success rate of outgoing and incoming calls for A and B phases: (A) Family trial, (B) Entrepreneurs trial. The Entrepreneurs trial exhibits a small (12%) increase in success rates when automatic cues were introduced in phase B.

A

B
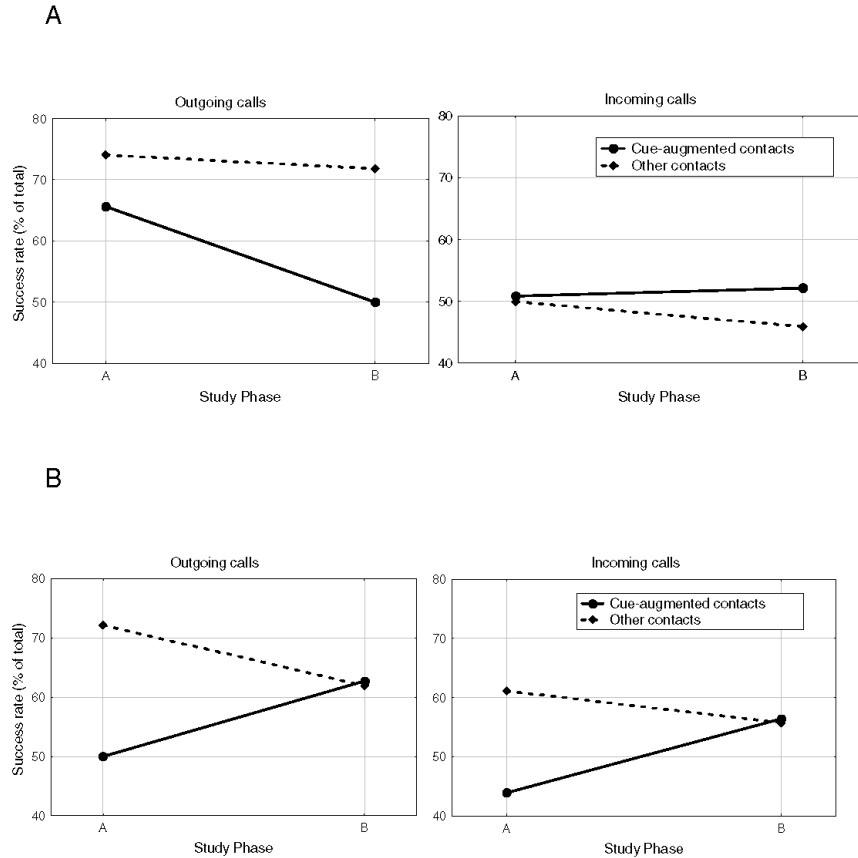
B was statistically significant, $\chi^2 = 4.51$, p 7 .05. (Parenthetically, the same figure indicates that the success rate of incoming calls to a group member noticeably increases from 44% to 56%, whereas the success rate of incoming calls to a nongroup member decreases from 62% to 56%.) The increase in the ratio of successful phone calls to group members in Phase B reflects well their own verbal accounts indicating that they were utilizing the cues to time their calls better (Section 7.1).

7.5. Impact of Cues on the Use of SMS

Inhibition in the use of other communication channels such as SMS, a frequently used channel among teens (Grinter & Palen, 2002; Ling, 2004), would hint that mobile awareness is a competitor to it, whereas observing a null effect would support the idea that it has its own "niche" in the ecology of communication applications. In the Family trial, this type of communication was quite limited (1.5 messages pdpu), and there were no noticeable differences between the two phases. The Entrepreneurs also generated very little SMS communication within the group; Phases A and B were quite similar with roughly one message exchanged pdpu. The Schoolmates averaged 2.6 SMS within the group pdpu. To conclude, no observable change in the use of SMS was associated with the introduction of cues.

8. COORDINATING MOBILITY

Real-time awareness has been argued and shown to have positive effects on the coordination of work (Dourish & Bly, 1992; Gutwin, Greenberg, & Roseman, 1996; Whittaker, Frohlich, & Daly-Jones, 1994). According to one definition, *coordination* is the act of managing "interdependencies between activities performed to achieve a goal" (Malone & Crowston, 1990, p. 362). In this section we look at the role of cues in coordinating mobility.

8.1. Types of Mobility Coordination

Two main roles of automatic cues can be recognized in the data. First, some participants said that they used the movement-related cues (see Figure 4) to monitor progress in agreed-on coordination. One participant recounted an episode where she noted from the duration-of-stay cue that others might be coming late to a meeting they had agreed on earlier. Second, 2 participants expressed that they looked at the cues when wanting to rationalize another's lateness. This use is similar to postreject rationalization in the coordination of communication (reported in Section 7.1).

But cues can also *initiate* social interactions instead of being *facilitators* in interactions that have been initiated by other means (e.g., Dourish & Bly, 1992; Grudin, 1994; Holmquist et al., 1999; Isaacs, Tang, & Morris, 1996; Kraut, Fish, Root, & Chalfonte, 1990). To investigate this, we analyzed the interviews to find incidents in which the participants recounted episodes in which cues inspired informal interactions and encounters. We found several cases where awareness cues were employed in initiating meetings opportunistically. The most prominent of such use was arranging face-to-face meetings with others who were found to be close by. These were dominantly based on proximity

and who's-with-who inferences. All other types were less frequent. It is important to note that seeing that the other person was present was not enough of an excuse to directly go to that person, but the meeting had to be *negotiated* or at least *announced*:

11) 01 Ada: Hi
    02 Oona: Hello, I can see that you're in school.
    03 Ada: The first [floor]
    04 Oona: Ok, bye! [End of phone call]

In this case the calling has two functions: first, to ask exactly where the other person is; second, to announce that one is coming. Moreover, one can observe that the inference and use of the cues is not problematized and does not need to be accounted for or explained. Another opportunistic type worth mentioning is what we call the *topicalization* of cue-based inferences; in other words, the exploitation of the cue as an *excuse* for calling or a physical meeting ("I saw you were there…"):

(12) I was doing math homework with Niina when I called Julia, I remember. I asked where she was because [I saw] she was on the Esplanadi [A common place to hangout with a park, cafés, and shops]. She was with Miriam. (Schoolmate)

In the subsequent phone-call recording we analyzed, the place was still queried to confirm the information related by the district cue, and it was asked who Julia was with. In the interviews, the participants also speculated about the cues, which afforded the possibility of *teasing* others, for example, by calling when the other person was attending a class but had forgotten to change the audio alarm profile.

8.2. Location Disclosure in Phone Calls

Empirical studies of mobile phone calls have pointed out the frequent disclosure of one's location at the beginning of a mobile phone call (Laurier, 2001; Weilenmann, 2003). Now, one can hypothesize that the availability of cues before placing the call renders some of this location disclosure unnecessary. To investigate this, we analyzed the contents of within-group phone calls.

Of the 330 recorded 30-sec phone call beginnings (a few calls could not be recorded due to technical problems), we first analyzed how often location was communicated to the other party. We distinguished between the caller and the callee in disclosing the location. (Obviously, this kind of analysis cannot capture the implicit and nonverbal ways of location disclosure.) Across the

groups, the cues had no practical effect on the amount of location disclosure. The Family group shows somewhat more location disclosure by callee (55%) in Phase B than in the two A phases (18% and 46%), whereas in the Entrepreneur group's pattern is the reverse (A = 40%, B = 26%). Overall, if we collapse all A and B phases in the trials, we learn that there were practically no differences between the phases (A = 37%, B = 35%). To sum up, the preavailability of district information seemed to change conversations only in a few instances, such as when instructing somebody on how to find a certain place.

A more sophisticated hypothesis is that groups using mobile awareness learn to expect more elaborate accounts of the other's situation. With this idea in mind, we sought to examine whether there would be a *granularity shift* from low- to high-granularity location disclosure–in other words, whether the parties would relate more accurate information than what is provided by the cues. To investigate this, we came up with a taxonomy where locations/places are ordered (roughly) according to physical size: room, entry point (in a building), floor, house (a building in which people live), building (any other manmade building), vehicle (e.g., car, bus, tram), street or road, field or park, city district, city or town, and country. The researcher who had interviewed the particular participants did the categorization. It turned out that, in the Family group's phone conversations, only 30% of all high-precision references (an area smaller than district) were made in Phase B. The fact that the shared locations of the Family group, such as the house, were smaller and spatially simpler might mean that locational pinpointing was not relevant in that group. On the contrary, in the Entrepreneur trial, of the 68 instances of high-precision location disclosure, 69% were made in the B phase when the cues were available, and only 31% in Phase A. A chi-square test comparing Phases A and B in high-precision location disclosure yielded a borderline significant result, $\chi^2 = 2.88$, $p = .09$. The group confirmed in the interviews that when they wanted to see somebody at school, they often looked at whether the other person was at school, called the person, and asked particularly in which room or on which floor to meet.

9. DISCUSSION: THE ROLES OF MOBILE AWARENESS IN EVERYDAY SOCIAL BEHAVIOR

In this article we presented an in-depth inquiry on the inference and social use of awareness cues in mobile settings. By employing A–B intervention methodology, we were able to establish baselines for systematic comparisons in assessing the impact and influence of the cues. Triangulation–the utilization of various sources of evidence–allowed us to place participants' verbal reports in the context of their actual interactions with the system. This helped us to appreciate, on one hand, how inferences were constructed through in-

teracting with the system and the cues. On the other hand, we learned how these inferences were utilized in social interaction with others.

Previous work in Computer-Supported Cooperative Work argues that there is no uniform awareness, but many types of awareness depending on the cues, the users, and the use situation (Gross, Stary, & Totter, 2005; Schmidt, 2002). In the light of the obtained results, this also seems to be the case for mobile awareness. Instead of uniformity, the findings evidence numerous possible inferences of a cue (Section 5.1), and those inferences were further deployed in numerous interpersonal pursuits (Sections 6–8). The use of the hand cue is illustrative; it was used in deciding when to call another person (coordination), as an indication of availability and responsiveness in messaging (expression), and in creating a feeling of synchrony between two dispersed users (companionship). On the other hand, an inference could be constructed by using different cues: "Sleeping," for instance, was inferred using district and free-text cues alone, district and duration cues together, and profile and hand cues together. However, the analysis of inference frames (Section 5.2) shows that a cue is but *one* resource in the social inference–other resources such as situational and background knowledge and goals are relevant as well.

To conclude the article, we synthesize the complicated pattern of results under three classes of uses. Previous field studies looking specifically at mobile awareness have concentrated on either of its two dominant roles–coordination and expression (see, e.g., Holmquist et al., 1999; Isaacs et al., 2002)–but have provided no synthesis of the whole spectrum of use. Our observations echo findings from recent studies on the use of IM, mobile phones, and SMS (e.g., Grinter & Palen, 2002; Katz & Aakhus, 2002; Ling, 2004; Nardi, Whittaker, & Bradner, 2000), which have shown how those technologies can also support maintaining perpetual contact and the feeling of connectedness. The ultimate goal of our synthesis is to explain *why* the users of our mobile awareness system were motivated to prefer the contact book for communications (Section 7.2), why they devoted so much time to looking at each other through the cues (Sections 4.1–4.2), why they persisted in disclosing information to others (Section 4.5), why they were in general more interested in interacting with each other over the phone even when cues were available (Figure 3), why all this was particularly pronounced when mobile (Section 4.4), and ultimately why they found ContextContacts to be likable (50%, 75%, and 100% of the three groups, in respective order, indicated liking the system when asked about this in the final interview). The general line of argumentation attempts to tie cues and their inferences to their interpersonal and social functions.

9.1. Awareness Cues as a Tool for Coordination

The first and main role for mobile awareness we discuss depicts it as a tool for coordination–a tool in the sense that it is a personal instrument embedded

in a mobile phone and kept available for specific utilitarian purposes, the work of coordination of interpersonal activities. Here, we want to emphasize a user's mindset when processing the cues: They are approached with a particular goal or purpose in mind in terms of *pursued influence*. It is known that active perceivers, immersed in the interactions that they seek to interpret, who can affect the objects of their perception, have different motivations and information-processing goals than passive perceivers who cannot affect the objects of their perceptions (Jones & Nisbett, 1971). Active perceivers in general "concentrate primarily on the relation between their influencing behaviors and the responsive behaviors of their target and ignore other important sources of information relevant to social inference" (Gilbert, Pelham, & Jones, 1987, p. 861). This echoes our findings on anchoring (Section 5.3). Two types of coordination surfaced:

1. *Mobility-related coordination*, mainly of productions of near space-time (like meetings), involved inferences of place, proximity, movement, and activity. Here, automatic cues were of decisive importance, because they could be relied on as being updated and timely. Through automatic cues, several of our participants also initiated face-to-face meetings when others were seen to be close by–and knew when not to do so. Cues were not only used in a compensatory manner (e.g., to explain why a person is late after an event has unfolded) but used to generate *anticipations* of future events–of what the other will do in a given situation–and they were taken into account when planning one's own actions (e.g., Gutwin et al., 1996; Knoblich & Jordan, 2003). We also saw that participants monitored the progress of others in agreed-upon group coordination (Section 8.1). It is interesting that the availability of cues did *not* release them from telling others their location in phone calls (Section 8.2). There are substantial grounds to believe that even with more time and better cues, the location disclosure practice would not have changed. Conversation-analytic studies of mobile phone calls (Katz & Aakhus, 2002; Laurier, 2001) have pointed out that the disclosure of location serves two functions in interpersonal interactions: First, it provides a basis for mutual communication and the planning of activity, and second, disclosure of location facilitates the building of interpersonal understanding and trust. Mobile awareness is unlikely to make these conversational functions obsolete. However, at least in the Entrepreneurs group the cues helped to *pinpoint* their location to a smaller area (e.g., "I'm in the computer room"; Section 8.2) without explaining the overall context (e.g., "I'm in school"). The generalizability and implications of this finding remain to be explored in detail.

2. *Communication-related coordination*, particularly of phone calls, mostly relied on the "hand," location, and alarm profile cues; the key inferences were availability for communication, interruptability, and responsiveness to asynchronous messages. Some of this coordination was of the compensatory type–for example, looking at cues to understand why a recent call attempt was rejected or not answered (Section 7.1). However, a significant part was anticipatory. We learned that cues were systematically looked at just *before* placing a call (Sections 7.2–7.3), and one group indeed had a small improvement (~12%) on success rates in communication (Section 7.4.). The participants, for example, said that they used them to postpone calling when the person is attending a class (Section 7.1). To summarize, we learned that cues can reliably support important aspects of coordination of communication (see also Wiberg & Whittaker, 2005).

Our study indicates two general approaches to improve mobile awareness cues in their support for coordination. First, coordination requires that cues are both *reliable* and *informative*. Whereas ContextContacts's cues were reasonably reliable (at least timely), their informativeness could obviously be improved. Our study suggests approaching informativeness from the perspective of inferential frames. For example, we have built a device environment cue (e.g., "being on my *own* laptop" or "being next to the workgroup's printer") for information workers, who can employ their preknowledge of typical device environments in the office to infer the other person's engagement in a certain task or activity. We believe that too abstract cues, such as "the person is interruptable," might not allow for the use of familiar inferential frames and thus severely limit the variety of possible inferences. On the other hand, too concrete cues (e.g., "the person is in the computer room") may focus the interpreter's attention on minute details of actions and risk sensitivity to the overall activity they constitute. In addition, concreteness may of course pose a privacy problem. Second, one of the related problems of ContextContacts is that intersubjectivity and negotiation were not supported, although both are important in coordination in general. Only in the Schoolmates trial, where the free-text cue was available, did we see group-level coordination carried out because of the better direct support for negotiation processes. To support this aspect, one option is to go beyond the current individual-centric visualization of cues per contact row to designs that help users to perceive differences and similarities between contacts. Furthermore, to improve the cues in respect to accountability, we are developing a mechanism called "lookup logs" to show a user that his or her cues have been seen/monitored (see Figure 2 in Oulasvirta, Raento, & Tiitta, 2005).

From the perspective of this role, mobile awareness systems are the most useful for intimacy groups (families, groups of close friends, fraternities, etc.) and for task-oriented groups (coworkers, juries, etc.), which assume preexisting and evolving knowledge of other members' behavioral patterns. This in turn is a critical part of the ability to develop inferential frames to make sense of cues. These group types also share goals and outcomes, which implies that they have a genuine interest in each others' moment-by-moment undertakings. One of the key challenges for these groups is posed by power structures, which implies a disparity between who does the work and who gets the benefit (Grudin, 1994). The children in the Family group indeed showed a lack of motivation to use the system, whereas the mother was more positive about it. By contrast, the two *non*hierarchical groups enjoyed using the system and did not turn it off almost at all (Section 4.5).

9.2. Awareness Cues as a Medium for Expression

The second role for mobile awareness exists in its use as a medium for expression, a *medium* to the extent that it is used as a channel for actively expressing ideas and emotions and for communicating. This type of use was accentuated in the Schoolmates group, who appropriated the free-text cue for chatting, discussions, opinion formations, and so on (Section 6), a good part of which was emotional instead of rational (Figure 5; see Isaacs et al., 2002). As extreme examples, the cues were used to reproduce poetry and to play a game ("The ship is loaded with the letter …"). In contrast to the role of coordination, which involved mainly person-to-person communication, this role implies an audience at the group level.

We believe that two features of ContextContacts contributed to the phenomenon that could also be characterized as its "emergence of a place" (Erickson et al., 1999) or as a "*locale*"–"a digital place that offers a group the site and means for maintaining awareness of another and for rapidly moving into interaction" (see McEwan & Greenberg, 2005, p. 21). First, the *grouping* of the cue-augmented contacts at the beginning of the contact book allowed for quick access to the situations and messages of the group. Second, as said, the automatic cues, particularly the hand cue, allowed for presence, availability, and responsiveness inferences, which have been observed to be important in IM and other online messaging systems (Nardi et al., 2000). Users of awareness systems prefer to know who else is present in a shared space, and they use this awareness to guide their actions (Erickson et al., 1999). Thus, this medium puts user-created cues, or maybe user-created *content*, on center stage, while relegating automatic cues to a secondary, supportive role. The hand cue was in effect appropriated for understanding and negotiating (for a study of this phenomenon in the desktop domain, see Wiberg & Whittaker, 2005)

when to send a message so that others will see it, to infer *conversational availability* (Nardi et al., 2000), to check to see who is "online," to estimate the rapidity of response to one's own turn, to infer if others have received a message after it was sent, and to signal one's own availability to others. However, the effect of the automatic cues to the content of messaging remained smaller than expected, although some reframing, referencing, and topicalization was observed (Section 6.2).

Seeing cues as expressions *produced* for others, rather than impressions *consumed* of others, might be fruitful also for designers, because efforts can be directed to features that support this use. Three general approaches can be suggested. First, the expressiveness of the medium itself can be extended, for example, by allowing sharing of richer multimedia content or by creating cues that can be appropriated for expression. For example, calendar markings shared as cues can become expressive mediums. Second, notification and other turn-taking mechanisms can be provided to support coordination of discussion. Third, the strategy of representing multiple *automatic* cues, instead of a few, increases the probability that for a given expression there is cue-based information that can help sense-making by contextualizing and grounding interpretation (Section 6.2).

9.3. Awareness Cues as a Proxy for Companionship

The third, and currently the weakest, role is the role of cues as a proxy for companionship–a *proxy* in the way they can act and be used in the place of a distant person, having that someone somehow "with you." The need for companionship and relatedness is among the fundamental human needs (Deci & Ryan, 2000). In this pursuit, the *content* of the inferences is secondary to the *outcome* of their processing: the feelings and experiences of closeness and companionship.

A relevant theoretical notion here is *social presence,* "the moment-to-moment awareness of co-presence of a mediated body and the sense of accessibility of the other being's psychological, emotional, and intentional states" (Biocca & Harms, 2002, p. 10). Markopoulos, IJsselsteijn, Huijnen, and de Ruyter (2005) showed that media-rich awareness cues (real-time video of the other group) can enhance the feeling of social presence among dispersed users sharing a task. Two kinds of evidence in our data support the idea that mobile awareness cues, although much poorer than real-time video, can also serve as a proxy for companionship. First, we found that many participants voluntarily expressed mediated companionship (they were not explicitly asked about this). Two users in the Entrepreneurs group and four in the Schoolmates group expressed feelings of presence, closeness, affection, communality, or connectedness as being mediated by the

cues. The cues were used to stay in touch, to be reassured about the well-being of others (e.g., if others got home safely), and to connect through expressions of moods and feelings ("I don't want to do math!"), like in the following quote:

> (13) I am like oh god, if I don't go [to sleep], then I want to know that others are not either. A feeling of *communality* in there. It is nice to know that I am not the only one staying awake. (Schoolmate)

Second, there are instances of the users tracking others and looking at the cues in ContextContacts for long periods (Section 4). This resembles "awareness moments" behaviors in IM (Nardi et al., 2000). Moreover, there were a few reports evidencing that individuals put extraneous effort into keeping the phone close to themselves just to maintain a connection to others. The benefit of the cues being in a mobile device is related to their being accessible most of the time, supporting user-initiated access "anytime, anywhere" (but not peripheral awareness). Repeatedly looking at cues increases the priming of the related social representation and thus the probability that it pops into mind and is actually acted on (Bargh & Ferguson, 2000). This constitutes a kind of "social awareness," which may have been reflected in the increased calling within the groups in B phases (Figure 3).

It is worth noting that the automatic cues also contribute to the mediated companionship: They are used as weak "signals" of another's situation and presence. We believe, although there is not much direct evidence in our data to back this up, that in this kind of use the cues are approached in a more *exploratory* way than when using them for coordination or expression. The aim is not so much in deciding on a few alternative inferences (e.g., available or not) but in constructing a more holistic representation of the other so that he or she can be felt as "present." As we reported (Section 8.1), such inferences may secondarily inspire informal encounters and interactions. The role of free-text cues particularly in this role lies in the fact that they provide a more *controlled* means of expression and are thus a better resource for reciprocally deepening companionship (Altman & Taylor, 1973). To improve on the companionship aspect, automatic and user-controlled cues for mood communication and emotional expression could be considered (for an example, see Hansson & Skog, 2001).

NOTES

projects is to examine how sensor-derived information can be meaningfully represented and put into use in everyday social interaction.

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