How does the user interface design of mobile devices influence the social impact of mobile communication?

Paper by Stefan Marti, written for the main area of his Qualifying Exam at the MIT Media Lab

Version of February 18, 2002

1. Abstract

This paper describes how user interface design of mobile devices interacts with the social impact of mobile communication. Social impact is defined as the influence on relationships between social actors. In the light of mobile communication, one can distinguish among at least three relevant classes of relationships: human-machine relationships, interpersonal relationships between co-located persons, and machine mediated human-human relationships. The characteristics of each class are described, which lead to 13 statements about which social phenomena are important to this specific relationship, e.g., *Being aware of the social context of the other party before initiating a communication and during the act of communication might have a significant positive social impact on the interaction outcome.* Each statement is followed by a set of user interface design suggestions about how mobile communication user interfaces should be built in order to support the statement, or not to violate the social phenomena regarding a relationship described in the statement, or to make the social impact of mobile communication positive. Adding up across all three classes, 28 concrete user interface design suggestions are described that influence the social impact of mobile communication.

2. Preamble

I define the term *social impact* pragmatically as the *influence on relationships between social actors*. In the context of mobile communication, there are three relevant classes of relationships:

1. human-machine relationships
2. interpersonal relationships among co-located persons
3. machine mediated human-human relationships.

More specifically, the user interface design of a mobile device impacts these relationships by modifying social attributions, human behavior, and interaction outcome. In addition, all relationships are situated in a social setting. Social settings can be classified in a two-dimensional scenario space of group size (individual to society) vs. role (work, recreation, family, etc), and the social impact of a user interface varies depending on the specific social setting.

3. Introduction

It is well known that the design of a user interface has a significant effect on user learning time, performance speed, error rates and above all user satisfaction. However, the interface of a device used in presence of other people, or as a medium to other people, must obviously have also a social impact.

Designers of user interfaces have tried to take this impact into account: a well-known approach is putting the human in the center of attention, as opposed to the device or the task. This is referred to as the *human centered design approach*: "Human centered approach puts people first, technology second. It focuses upon human activities. It makes the technology invisible, embedded within activity specific information appliances." (Norman et al. 1986 [36]). Although this approach focuses on human activities, which I will show to be useful in classifying social context, its main focus is locally on the interaction between human and machine. It is not looking at possible "social side effects" of mediated human communication and telecommunication. Little work has been done in finding out the connections between user interface design of mobile communication devices and possible social impacts.

The social impact of mobile devices—devices that can be used while the user is on the move, which excludes laptops and PDAs that require two-handed manipulation (Pascoe et al., 2000, p. 419 [39], Dix et al., 2000, p. 298 [14], Hjelm, 2000 [22])—might be specifically interesting because the social context is much less restricted than for a static setting, like a desktop computer or a wired telephone (Ruuska et al., 2001) [43]. In a mobile context, the user switches easily from one social setting to another (work, private life), but also between different group sizes (individual, part of formal or informal group). This switching makes the user interface design of mobile communication devices more complex than with non-mobile devices.

In order to assess the social impact of user interfaces of mobile devices, I suggest looking at the social context where mobile communication can happen. In the following, I will outline three approaches to the problem of social context that might help to enlighten the otherwise hidden connections between user interfaces for mobile devices and social impact. In the chapters afterwards, I will draw upon these findings heavily.

4. Approaches to Social Context in the light of Mobile Communication

The main questions in this chapter are: *What is social context, what kinds of social contexts are there, and how can we classify social context?* All these questions are specifically asked in the light of mobile communication. I have found three approaches that are helpful to clarify these questions.

Rowson (2001) [42] spans an n-dimensional space and places an array of possible social context situations in it. This is a *pragmatic approach* that is feasible as long as n can be kept low and the range of social context situations is still large. Rowson suggests a two-dimensional space with the dimensions Role (work, home, recreation, etc.) and Relationship (group size). Although it is not known if these two dimensions came from a factor analysis of some kind, they seem to be a good compromise between precision and usefulness, and allow to locate a large amount of practical social context situations.

Dryer et al. (1999) [15] focus mainly on the diverse *social relationships* that are part of each social context, extending one of the dimensions of Rowson's schema. Dryer et al. suggest looking at four kinds of relationships that might be important to be distinguished: relationships among co-located persons, human-machine, machine mediated human-human, and the relationships with a community.

Oppermann et al. (1998) [37] focus on the different kinds of *human activities* that might determine social context. They classify social contexts via the human activities that happen within them.

In the next three sections, I will describe these approaches more in detail.

4.1. Scenario Space for Social Settings (Rowson 2000)

In order to formalize the space of all possible social settings, Rowson (2001) [42] suggests a two-dimensional *scenario space*: a matrix of *Relationship* (Community, Formal Team, Casual Team, Individual) vs. *Role* (School, Recreation, Family, Work, Spiritual) (Figure 1). A majority of all social activities and settings can be localized in this two-dimensional space. Although the target group is teens and preteens, it nevertheless shows a viable option how to classify social context relevant to mobile communication (which the author calls *Social Media* and *Frictionless Mobile Lifestyle)*.

This scenario space is useful as a first approximation for social context. However, it simplifies some parameters that might be worth looking at again. For example, the group a person might be part of is not only defined by size, but also by other parameters like *homogeneity*. More precisely, the arrangement of people around us can often be described as *layered circles*, or skins of an onion. Especially in the context of an ongoing communication, the people around an act of communication are first divided into those who are truly participating in it, and those who are not. Clark (1996, page 15) [10] labels these less and less involved layers as *addressee, side participant, bystander,* and *eavesdropper*. Each of these classes of participants has different rights and responsibilities. For example, a person talking to her best friend in a packed elevator and receiving a phone call faces a rather complex social context that is not to be classified easily by Rowson's scenario space. Nevertheless, it is useful as a heuristic to classify roughly social situations.

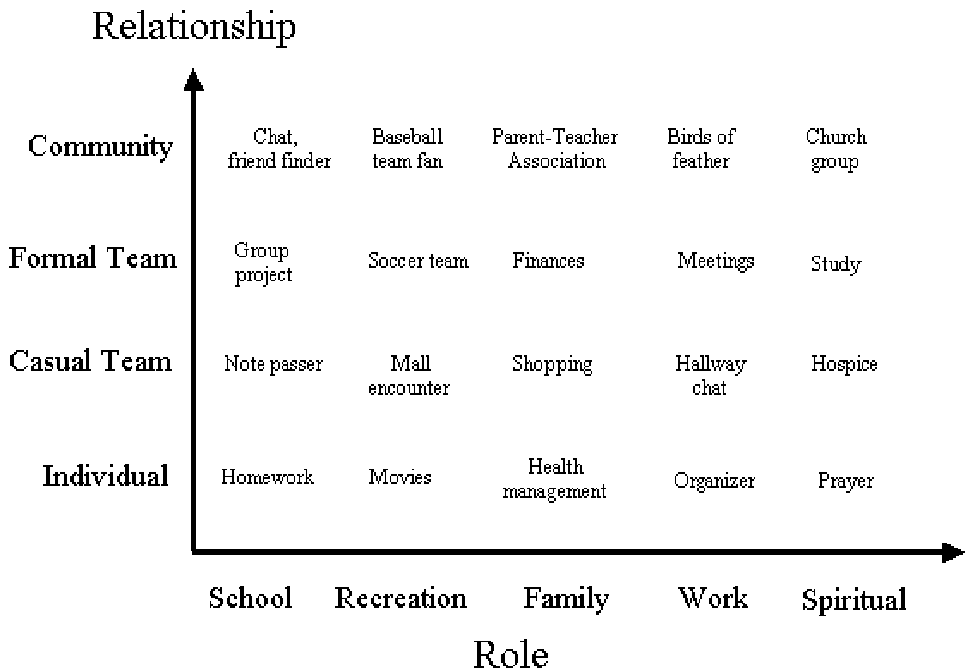

Figure 1: Scenario Space, with the two dimensions Relationship and Role (Rowson)

4.2. Social Computing for Mobile Computing Systems (Dryer et al., 1999)

The authors refer to devices that are designed to be used in the presence of other persons. These devices may promote or inhibit social relationships. There are four social relationships they consider:

- interpersonal relationship among co-located persons (social behavior directed toward a person)
- human-machine relationship (social behavior directed toward a machine)
- machine mediated human-human relationship
- relationship with a community

I will use a similar categorization of relationships in the following chapters to assess the interaction with user interface design parameters.

Dryer et al. refer to *Social Computing* as the interplay between a person's social behavior and her interactions with computing technologies. They draw on research from social interfaces (starting from the fact that humans can react socially to artifacts, and pervasive computing will lead to proliferation of artificial social actors), computer-supported cooperative work (CSCW), interpersonal psychology, and community research.

Their model of social impact has four components that relate in the following way to each other (Figure 2):

- **System design** (which includes UI design) influences both **human behavior** (what users actually do) and **social attributions** (how we explain for ourselves why others are behaving in a certain way, what we infer from that, etc.)
- **System design, human behavior, social attributions**, all together influence **interaction outcomes** (how we perceive the device, the communication, and the communication partner)

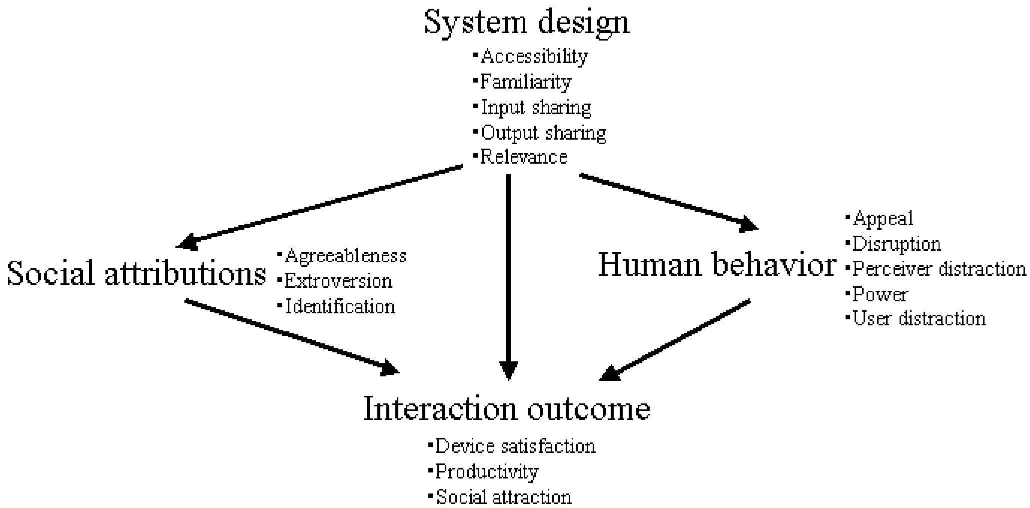

Figure 2: Model of social impact in mobile computing (Dryer et al., 1999) [15]

The authors conduct several extensive lab experiments to correlate these factors, comparing laptop, PDA, belt-worn wearable, and wearable with head-mounted display. The most important finding is that because these devices have not been designed to support social interactions, they can make users appear socially unattractive. Therefore, the authors suggest a 14-item "checklist for social computing," for devices that are designed to be used in the presence of other persons. These items describe factors that they expect to have an effect on interaction outcomes, such as device satisfaction, productivity, and social attraction:

1. **Accessibility.** Do nonusers believe that they could use the device easily, and do they understand easily how it works?
2. **Familiarity.** Is the form of the device one that is familiar and appropriate for the context of its use?
3. **Input sharing.** Does the device allow nonusers to input information easily and naturally?
4. **Output sharing.** Does the device allow nonusers to perceive easily and understand output?
5. **Relevance.** Does the device appear to nonusers to be useful to the user and to the nonuser?
6. **Appeal.** Is the device something that the user is comfortable being seen using, and do nonusers find the device, and use of the device, attractive?
7. **Disruption.** Does the device disrupt individuals' natural social behaviors, such as referring to shared information while interacting?
8. **Perceiver distraction**. Does using the device create noise or otherwise create a distraction for nonusers?
9. **Power.** To what extent does use of the device put one person more "in charge" than another person, and to what extent does using the device communicate a difference in status?
10. **User distraction.** Does the device place a high cognitive load on the user during use or otherwise create a distraction?
11. **Identification.** Does the device appear to include or exclude the user from certain communities, and do nonusers see themselves as persons who would use the device?
12. **Pervasiveness.** Is the device mobile or otherwise convenient to use in social settings?
13. **Communication.** Does the device make communication among persons easy, especially the sharing of important social information such as appointments and contact information?
14. **Social application.** Does the device support rich social interactions, such as through interest matching, meeting facilitation, or social networking?

I will revisit several items of this useful list in the following chapters, and draw upon them to generate user interface design suggestions.

4.3. Mobile information and communication technology which supports human activities (Oppermann et al., 1998)

Oppermann et al.'s (1998) [37] focus is on how mobile information technology can support human activities. Human activities extend in three dimensions:

- extension in time
- extension in space
- extension in social setting

Most of them are distributed in time and space, and perhaps in social setting (involve several people). Mobile information and communication systems have to support the user in her activities.

Nomadic activities are a subgroup of all human activities, using mobile information and communication technology. Nomadic media allow information access

- at any time (of the activity)
- any place
- with any partner involved

They have to adapt to the user's

- local environment (contextualization)
- interaction history (individualization)
- tasks and goals of the individual and his or her communication partners

Particularly useful for our purpose is the authors' approach to look at mobile communication in the light of *human activities*, especially nomadic activities. It is possible that such a classification might lead to an additional dimension of how social context can be defined.

I will reuse several of the classifications above in the following chapters to clarify user interface design suggestions, especially the need of nomadic media to adapt in the domains of contextualisation, individualization, and user task and user goal awareness.

5. Main question: How does the user interface design of mobile devices influence the social impact of mobile communication?

User interface design for mobile communication devices has not been a central research topic in the past. However, telecommunication is merging with information processing, intersecting with mobility and internet technology, and the resulting communication devices will be the largest consumer product segment in the world (Ruuska et al., 2001) [43]. The *convergence of information processing and communication* is a clear trend in mobile communication. One aspect of trying to create "good" user interfaces for this class of devices is to look at its *social impact*.

This paper is about the social impact of user interfaces of mobile devices. This question is related to areas like *social impact of user interfaces in general*, *social impact of mobile communication*, and *social impact of ubiquitous computing*, but our focus is not wide enough to cover these questions sufficiently. However, I will draw from research done in these areas.

How can we understand the social impact of the user interface design of mobile devices? As mentioned in the preamble, I define the term *social impact* as the *influence on relationships between social actors.* Drawing from Dryer et al. [15] (see earlier chapter), we can distinguish between at least *three different classes of social relationships* that could impact mobile communication:

- Class A: Social impact on relationship between person and machine/medium.
- Class B: Social impact on relationship between person and co-located people
- Class C: Social impact on relationship between person and two (or more) mediated people

Figure 3 illustrates these three classes in the context of mobile telecommunication. The perspective of interest is **Person 1** and her relationships to **Person 2**, to **co-located persons**, as well as to the **device** (used synonym for **machine**, or even **medium**).

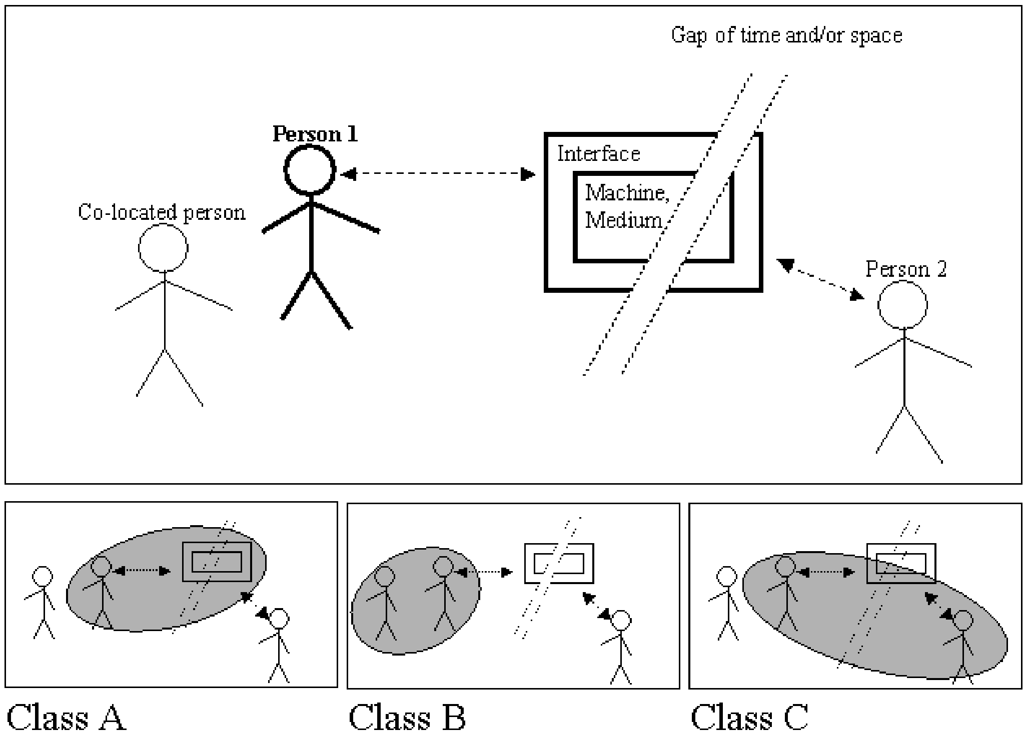

Figure 3: Three classes of social relationships that might have a social impact in mobile communication

In this basic setting, the co-located persons do not participate in the telecommunication activities of Person 1; I will soften this restriction later.

It is important to see that if Person 2 happens to be a non-biological entity such as an autonomous agent that sends requested information (which is a valid option), the distinction between relations of class A and C becomes irrelevant, since for Person 1 it doesn't matter if the agent lives in the local machine or is located somewhere remotely and connected through a medium.

Furthermore, let's start from the basic assumption that most acts of human communication, especially in the mobile domain, consist logically of two parts:

1. *Initiation*, including alert if communication initiated from the other party
2. *Act of communication*

This clear distinction between initiation (alert) and act of communication is not true all the time. There are at least three interesting borderline cases:

- *Not all initiations lead to actual acts of communication.* This means that the initiation does not necessarily lead to an act of communication. However, such "unsuccessful communication attempts" happen less and less because of two reasons: first, many telecommunication technologies are able to "degrade gracefully," which means that they can compensate for the absence of a party, e.g., the voicemail system picking up a phone call if the user is not available. Second, awareness applications (which I will describe later) reduce the amount of unsuccessful communication attempts remarkably because the caller has access to social and other context information *before* she initiates an act of communication.
- *Some communication modes "blur" the strict distinction between alerts and acts of communication.* For example, the alert can become part or the actual act of communication. The reason is that the two parts of

communication, alert and act of communication, are actually just two extremes on the opposite sides of a continuum: the alert usually carries minimal information, the message usually all of it. However, it is possible to populate the space in between the two extremes of the continuum as well. For example, caller ID information on a phone is part of the alert, but at the same time carries information which might be enough for the called person to decide if she wants to take the call or not. In the case of email alerts on the desktop, systems that allow the user to specify certain audio cues for a specific sender or a group of senders also add information to the alert itself. More sophisticated systems could allow for scalable alerts, ranging from simple cues, to cues including the sender, to cues that include sender and subject of the message, to cues that summarize a message, to the full message (Sawhney et al., 2000) [45].

- *Some communication modes have neither a clear beginning nor a clear end* (Abowd et al., 2000, p. 42) [1]. This is specifically true for *awareness communication* modes that I will discuss later in detail. But even widely used instant messaging systems that are based on the idea of buddy lists give a user a continuous overview over who is online and who is not. Therefore, it is difficult to define when an act of communication actually begins and ends, since the application is supposed to run continuously, more or less in the background of the user's attention. I will discuss more examples later (*Live Address Book* by Milewski et al., 2000 [30], *ConNexus and Awarenex* by Tang et al., 2001 [52], *Hubbub* by Isaacs et al., 2002 [24], *Somewire* by Singer et al., 1999 [49]).

In the following sections, I will describe the three classes A, B, and C in detail. These sections are structured as follows: first, I will describe the specific characteristics of the class, which will lead to **Statements about what specific social phenomena are important to this specific relationship**. Each statement will be followed by a (non-exhaustive) set of **suggestions for the design of the user interface.** These suggestions are marked with a diamond triangle.

There is a total of 13 statements and 28 user interface design suggestions.

Although the user interface can be looked at as the "dependent variable" in the following chapters, it is clear that the relationship between social impact and user interface is bi-directional: although certain social phenomena ask for certain kinds of interfaces, a given user interface design would also aggravate or alleviate desired social phenomena.

5.1. Social impact class A: Human — machine/medium

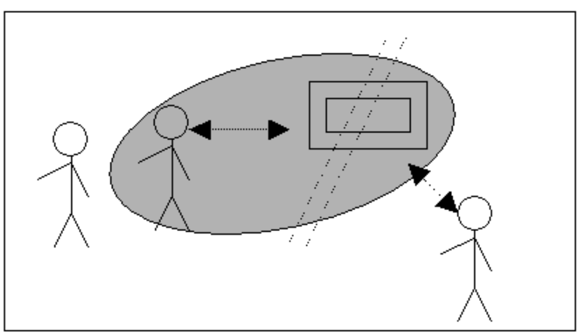

Figure 4: Class A relationship

This section is about the relationship of a user with a communication device, and how certain user interfaces influence this relationship drastically. This class includes interactions with non-biological agents of different levels of *autonomy* and *intelligence*, which means, ranging from interaction with predictable and simple machines to highly autonomous devices with complex behavioral patterns.

Ethnographic and anecdotal research has found that humans mimic human-human relationships in human-computer interaction (e.g., Nass et al. 1993) [33]. If computers provide certain social cues, humans will accept technology as an autonomous source, even if it shows no motivations and attitudes: computers will become *social actors*. Such humans do not have to be abnormal, and they do not have to intend to interact only with the creator of the technological source. The following cues seem to be enough to make the human apply social rules to computers (e.g., Steuer 1995) [50].

- *Language*. Interaction based on language vs. based on numbers or images.
- *Interactivity*. Reaction of technology is based on multiple prior inputs (context sensitivity)
- *Filling social role* (teacher, doctor, tutor). Role is actor with certain behaviors.
- *Human sounding speech.* Speech processing is different from other acoustical processing.

In addition, research has shown that user satisfaction with a human-computer interface is not determined by effectiveness and efficiency, but more by affective reactions (likes, dislikes, attitudinal responses) of users to the interface (e.g., Shneiderman 1998) [47]. This leads to our first statement:

Statement I: The more human-like the interaction, the better are the attitudinal responses of the user (and the more likely the user will show social behavior towards the machine).

This statement (and all the following ones) leads us to an array of *design suggestions*: suggestions about how a mobile communication user interface should be built in order to support the statement, or not to violate the social phenomena regarding a relationship described in the statement, or to make the social impact of mobile communication positive.

- Interfaces that support *common forms of human expression.* Abowd et al. (2000, p. 30) [1] call them *natural interfaces* and include speech, pen, and gesture input. Interestingly, Ruuska et al. (2001) [43] would exclude traditional QWERTY-keyboard inputting techniques.

- *Recognition based* user interfaces. Human-like interaction is obviously not based on menus and dialog boxes. Myers et al. (2000) [31] expect to see substantially more use of techniques such as gestures, handwriting, and speech input and output. They are called recognition based because “they require software to interpret the input stream from the user to identify the content.” (p. 18)

- *Multimodal interfaces* (natural human interaction is highly multi-modal) for cross-checks (Suhm et al., 1999 [51]; Oviatt et al., 2000 [38]), since recognition based interfaces are error prone.

- Interfaces that allow the user to *select the most appropriate modality* depending on the physical context (Ruuska et al., 2001) [43]). An extension of this design suggestion would be “Interfaces that allow the user *and the interface* to select the most appropriate modality.” This leads to the suggestion of mixed-initiative interfaces (see below).

- Architectures that allow for *mixed-initiative interfaces* (Walker et al., 1998) [53]. Although users might prefer system-initiative interfaces in the beginning, they might migrate to mixed-mode interaction with more experience (Walker et al.) [53]. A nice example for a working prototype is *LookOut* (Horvitz, 1999) [23]. This add-on to Outlook™ parses incoming email and tries to find out if the user wants to schedule an event, based on this email. More precisely, it computes the probability that the user wants to open the calendar or even schedule an appointment. It either waits (does nothing), asks the user if she needs the agent's service, or goes ahead and schedules an appointment for the user.
  The idea of mixed-initiative systems is well known in robotics, and related research is done in the areas of *human-robot symbiosis, mixed-initiative problem solving,* and *co-habited mixed realities* (e.g., Dautenhahn, 1998) [11].

- Interfaces that enable *human-level communication*: instead of controlling the machine, controlling the task domain (see Noncommand User Interfaces by Nielson, 1993) [35]. This has very wide implications on the social acceptability of artificial social actors (and our mobile communication devices might become social actors of some kind) (Nass et al., 1993) [33]. My hypothesis in this area is that the user wants to be in control of the machine, unless she “trusts” the machine. One of the reasons why one would trust a machine (or mobile device, for that matter) is if one can communicate with it on a human level.

- *Human sounding* interfaces. E.g., digitized speech is preferred over synthesized speech: the former has higher user satisfaction and more positive attitudinal responses (Gong and Lai, 2001) [19]. However, research shows also that synthetic speech can be more efficient than a mix of synthetic and digitized speech. The reason is that consistency in the interface might be more important than technological maximization. The quality and pleasantness of the human voice is important, but if it is combined with synthetic speech, it is less efficient.

Efficiency, however, is a less relevant variable for social impact than user satisfaction (e.g., Shneiderman 1998) [47]).

Statement II: The more socially intelligent the machine/medium is, the more comfortable its use, the more positive the social impact will be.

"Social intelligence" is a common research theme in work on *Socially Intelligent Agents* (SIA, Dautenhahn 2000: agents that show human style social intelligence) [12] and *Socially Intelligent Autonomous Robots* (SIARS, Breazeal 2001) [5]. SIA(R)s have human-like social intelligence to address the emotional and inter-personal dimensions of social interaction. Mechanisms that contribute to human social intelligence are, e.g., embodiment, empathy (scripts plus memory), autobiographic agency (dynamically reconstructing its individual history), narrative agency (telling stories about itself and others). The *Social Intelligence Hypothesis* claims that primate intelligence originally evolved to solve social problems, and only later was extended to problems outside the social domain, e.g., logic, mathematics, abstract thinking, (Dautenhahn, 2000) [12]. It is important to realize that social intelligence is a predecessor of common human intelligence. Therefore, socially intelligent agents do not have to have "human intelligence," which makes the problem probably easier.

This statement covers a wide range of user interface design challenges; here are just a few items:

- Interfaces with *reduced need for explicit human-computer interaction*, based on the machine's awareness of the social situation, the environment, and the goals of the user. Implicit human-computer interaction leads to disappearing user interfaces (Dey et al., 2001) [13]. Such a disappearance is a fundamental consequence *not* of technology, but of human psychology (Weiser, 1991) [54].

- Interfaces that are "*invisible*," meaning, not controlled directly by the user, but also by the machine. This is a consequence of the function of the machine: Its role will not be to obey orders literally, but to interpret user actions and do what it deems appropriate (Nielson, 1993) [35].
  However, Dey et al. (2001) [13] point out that when explicit user interfaces disappear, the notion of "a" user gets fuzzy, e.g., if several co-located people interact with (or become affected by) an artifact simultaneously, perhaps with conflicting goals. To what extent is a person "a" user of a system if all interaction with it is implicit, and the person is unaware of it?

5.2. Social impact class B: Human — surroundings (co-located humans)

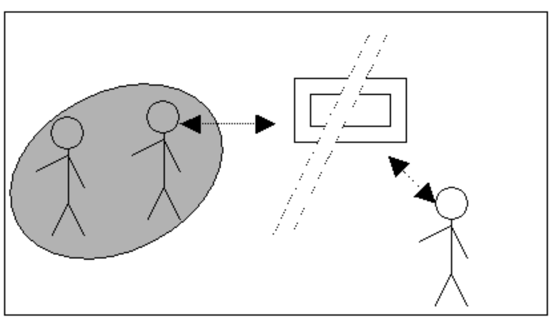

Figure 5: Class B relationship

This section is about how user interface design and the relationship between the user and her surroundings, mainly co-located persons, interact.

Statement III: The less telecommunication, the better for the interaction with co-located persons, and the more attention they will get.

This statement is based on the assumption that each act of telecommunication disrupts the communication of co-located persons (Dryer et al., 1999) [15] With mobile communication, however, interruptions are part of the design, and therefore expected (Abowd, p. 43) [1]. The interface design has to minimize the negative social impact of an interruption of ongoing activity involving co-located people.

- Interfaces that *filter in a context aware manner* and therefore *minimize the amount of telecommunication.* A user interface that could distinguish relevant from irrelevant communication attempts can of course help reduce the amount of unnecessary communication and alerts. Relevance is of course relative to the context the user is in. It is assumed here that the user interface is not just a dumb outer layer of the "intelligent" device, but integrated in the architecture.

However, it is obvious that restraining from all telecommunication is not a viable solution. This leads to our next statement:

Statement IV: Given that there will be interruptions, it is necessary to find a balance between useful interruptions (due to alerts and acts of telecommunication) and interactions with and attention for co-located persons.

This leads to the problem of alerting in public spaces: How do we attract one user's attention without disturbing and/or distracting co-located people? (Dey et al., 2001) [13]. One solution is the use of awareness communication modes that I will describe later in detail.

- Interfaces that allow communication in *parallel* to the ongoing co-located interactions, which in turn enable multiple activities concurrently (Abowd, p. 43) [1]. This is important since mobile communication leads to activities that are distributed in time and space, and even in social setting, involving several people (see also the earlier described framework of Oppermann et al., 1998) [37]. An obvious example for such a user interface is a speakerphone, which allows the user to communicate with remote partners, and at the same time not interrupt the interaction with co-located persons. In the mobile communication domain, *Nomadic Radio* (Sawhney et al., 2000) [45] explores the space of possibly parallel communication in the auditory area. The system, a wearable computing platform for managing voice and text based messaging in a nomadic environment, employs a shoulder worn device with directed speakers that make cues only audible for the user (without the use of socially distracting headphones). This allows for a natural mix of real ambient audio with the user specific local audio. To reduce the amount of interruptions, the system's notification is adaptive and context sensitive, depending on whether the user is engaged in a conversation, her recent responses to prior messages, and the importance of the message derived from content filtering with *Clues* (Marx et al., 1996) [28].

- Interfaces that support *multiple levels of "intrusiveness,"* enabling *background awareness applications* (Abowd, p. 43) [1]. An example for such an interface is *Audio Aura* (Mynatt et al., 1998) [32], a system that provides serendipitous information via background auditory cues. Because the system is intended for background interaction, the auditory cues tried to avoid the "alarm paradigm" so frequently found in computational environments. It uses the idea of sonic ecologies, embedding the cues into a running, low-level soundtrack so that the user is not startled by a sudden sound. Another example would be *Assol*, an adaptive song selection system that dynamically generates play lists from MP3 collections of users that are present in a public space. Each user can map certain songs to certain events (calendar events, reminders, weather events), so she can get personal alerts delivered to her through the music being played in the background. This allows for subtle ways of alerting an individual or group of users without interrupting other uninvolved users in a public space.

- Interfaces that present information at different levels of the *periphery of human attention* (Abowd, p. 46) [1]. There has been a lot of research in the domain of *ambient media* (e.g., Ishii et al., 1997 [25], Wisneski et al., 1998 [59]) and *ambient alerting* (e.g., Schmidt et al., 1999) [46], most of which could be transferred easily to the mobile communication device domain. E.g., ambient displays present information within a space through subtle changes in light, sound, and movement, which can be processed in the background of awareness. The authors anticipate a time when ambient media are "fully assimilated into future environments, appliances of all kinds may likely change. Air-conditioners may be computationally enabled to change the flow of air to convey information. Lamps bases may not only hold a light bulb in place, but will contain processors and motors so that the light can become a display medium." (Wisneski et al., 1998) [59] An example for such an alerting device is the wrist-worn *Reminder Bracelet*, a notification tool that alerts in the periphery of the user's attention of scheduled events in a subtle and non-intrusive way (Hansson et al., 2000) [20]

- *Minimal Attention User Interfaces* (Pascoe et al., 2000) [39]. The idea of a MAUI is to transfer mobile computing interaction tasks to interaction modes that take less of the user's attention away from their current activity. It is about shifting the human-computer interaction to unused channels or senses.
  However, attention, especially the phenomena of *limited divided attention* and *limited focus of attention* (Rhodes, 2000 [40], Wickens, 1992 [55]) are only indirectly relevant in our context: they are primarily psychological phenomena and influence social relationships only if co-located persons and the communication device are both seeking attention at the same time. The real issue is what effect the user's choice of focus of attention has on her social relationships. This is based on the assumption that the user interface gives the user the freedom to shift attention, and does not just override the user's conscious choice of focus.

Statement V: The less intrusive the alert and the act of communication, the more socially accepted it will be (Ruuska et al., 2001) [43].

- Interfaces that can adapt to the situation and allow for *mixed-mode communication.* An example for such an interface would be *Quiet Calls* by Nelson et al. (2001) [34], a technology that allows telephone users to respond to a call without talking aloud. Their prototype *QC-Hold* has three buttons for responding to a call, sending three types of pre-recorded audio messages directly into the phone.
  However, mixed-mode interactions are not very well explored yet. Transferring modes is difficult since the characteristics of communication modes differ greatly. It is easy to lose a great part of content during the transfer process. Therefore, the most important problem to solve is how to map communication modes adequately. E.g., Nelson et al. use a "Talk-As-Motion" metaphor for Quiet Calls, to me the most relevant finding in their paper. Communication is supported in three 'directions': move in to the call by engaging the caller verbally; move out of the call by disengaging; and in between these opposites, stay in place by listening to the caller. This design is implemented as a state transition process and overloading buttons with multiple meanings over the course of the call. The three buttons trigger three different kinds of messages: "engage," "disengage," and "listen." It enables the user to respond on a meta level, which is grainier than real speech, but still precise enough to control the mixed-mode conversation, letting the device decide about the wording of the sentences. This solution is preferable over the manual selection of a specific answer, e.g., via a long list of 'canned' replies that are difficult to manage and browse.

- *Ramping interfaces*, including scalable alerting (Rhodes 2000 [40], Sawhney et al. 2000 [45]). A way of making a user interface and its alerts less intrusive to an ongoing activity with co-locate persons is to avoid unnecessary alerts in the first place, but that is not always possible. The next best option would be to make the alerts at least almost undetectable first, possibly located in the user's periphery, and only scale them up later if the user does not respond (and a response is still needed and justifies the interruption of the user's ongoing activity involving co-located people).

Statement VI: The more public the preceding alert, the more socially accepted the following act of communication.

This statement is based on work done by Hansson et al. (2001) [21], where they discuss the design space of notification cues for mobile devices, and propose an exploration of the space that combines the two dimensions of *subtlety* and *publicity*. They suggest combining the properties of subtlety and publicity when designing notification cues in order to make them fit more smoothly into social settings. Public and subtle cues are visible to co-located persons, and can therefore avoid unexplained activity.

- Interfaces that support and encourage *public but subtle alerts*. An example of a crude subtle/public mobile communication alert would be a pager emitting a very short, low volume beep. If designed correctly, it might be unobtrusive enough not to disturb the social environment, but still audible enough to be public. Much more sophisticated, however, is *Reminder Bracelet*, a notification tool that is worn on the wrist and connected to a phone or PDA. It notifies the user in the periphery of her attention of scheduled events in a subtle and silent manner using light, color, and patterns (Hansson et al., 2000) [20]. It is deliberately designed so that not only the user can see the alert, but also co-located persons. One could ask why not just use the vibration alarm which is built into many phones already. Although such tactile displays are private, non-intrusive and silent, there are some major differences to the Reminder Bracelet. A vibrating device is not visible to co-located persons, and it is therefore hard for others to understand why, for instance, the user suddenly leaves from a meeting. "It provides the user with completely private information and therefore it has a low degree of publicity. An audible signal has a high degree of publicity, whereas a device such as the Reminder Bracelet falls somewhere in between these two extreme cases. Using notification cues with a higher degree of publicity

allows other people present to interpret the situation at hand, e.g., in terms of causality." (Hansson et al., 2000) [20]
However, I think there are limitations in the usefulness of subtle/public alerts in the mobile communication setting. Hansson et al. seem to come from the assumption that an alert that explains our behavior is a good alert: if we get an alert, we should be excused to interrupt our current activity (e.g., interaction) and do something else. That is not something new: In the most basic sense, if we interact with somebody, and suddenly an internal "alert" goes off ("something comes to my mind", "suddenly I remembered that..."), then we usually try to interrupt our current activity gracefully and politely, and switch to the new behavior. I am not sure if appropriate subtle but public alerts can take the burden off us, so that we don't have to say politely: "Would you excuse me for a second, something important has come up?" In short, transparency is not equal to acceptability. However, eventually social norms will decide if subtle and public alerts are sufficient to excuse the user; but even if such alerts are insufficient, they are more useful than subtle private alerts, and certainly more appropriate than any kind of intrusive alert.

Statement VII: The more obvious the act of communication, the more socially accepted it would be.

This statement is based on Fukumoto et al.'s (1999) [17] work regarding the "talking alone" phenomenon: The authors observe that today's earphone-microphone units are large enough to be visible, so the surrounding people can easily notice their presence. However, it is clear that almost invisible "ear plug" style devices—integrating telephone and PDA functionality—will be feasible sometime soon. Such devices can be easily overlooked by co-located people, and it will appear to these people as if the user is "talking to herself." The phenomenon of "talking alone" might look very strange, and is certainly socially not acceptable. Fukumoto et al. even hypothesize that the stigma attached to "talking alone" has hindered the spread of the wearable voice interface. Therefore, the important issues that must be addressed are the social aspects when designing and implementing wearable voice interfaces. However, the authors suggest that the "talking alone" phenomenon does not occur if the user *seems* to hold a tiny telephone handset, even if the grasped object is too small to be seen directly. Basically, this effect can be achieved by just mimicking the "grasping posture." Their prototype, *Whisper*, a wearable voice interface that is used by inserting a fingertip into the ear canal, would satisfy the socially necessary need not to conceal the act of communication.

- Interfaces that *support private communication without concealing the act of communication to the public*.
  I think that social norms influencing this issue might be subject to continuous changes. Society will probably "get used to" less obvious communication modes, and therefore penalize them less and less. For example, walking down the street talking on a cellular phone was regarded as very strange behavior in times such communication was novel. Today, however, it is absolutely acceptable, and the social norms have changed.

Statement VIII: A mobile device that can be used by a single user as well as by a group of any size will more likely get socially accepted by co-located persons.

In other words: A device which has a user interface that has the option to adapt to the group size of the social setting (from individual to community, see the above described two-dimensional social scenario space by Rowson 2001) [42], will be a better device.

This statement extends class B, including the option that the communicating party can consist of more than one person. It also means that the distinction between mere co-located persons and co-located co-communicating persons is not as clear-cut as we have assumed up to now. Furthermore, this statement is also relevant in the wider context of *mobility in collaboration*, to devices that are supposed to support mobility in collaborative activities (Luff et al., 1998) [27], which can be facilitated or hindered through the affordances of the user interface.

- Interfaces that can *adapt to a particular user group size*, from an individual to a group. This extends its usability, spanning more social context situations. Dix et al.'s (2000) [14] *taxonomy of different levels of mobility* describes this cooperative aspect of advanced mobile applications nicely. Their device taxonomy has three dimensions: 1. Level of mobility within the environment (fixed, mobile, autonomous), 2. The device's relation to other devices (free, embedded, pervasive), 3. Extent to which the device is bound to a particular individual or group (personal, group, public). This third dimension clearly demands the capability of a user interface to accommodate for communication parties of different sizes. The authors admit that these categories are not absolute, and that there are gray cases: for example, the category "group" includes devices that let several people work together at the same time, but also an active refrigerator (which allows messages to be left etc.) that "supports" only one person at a time, but is actually available to all members of a family.

An example for such an interface is my *TinyProjector*: it allows the owner of a small mobile communication device to share the interface with co-located people. The display size is highly scalable and can adapt to a group of a few (using a table as a projection surface), up to large groups of hundreds of people, using a wall of a building as a projection screen.
Interfaces that adapt to a particular group size have to address the problem of how to deal with shared public input and output, and who "owns" or controls the local "ether" in shared environments, a problem that Dey et al. (2001) [13] have addressed.

5.3. Social impact class C: Human — human (mediated)

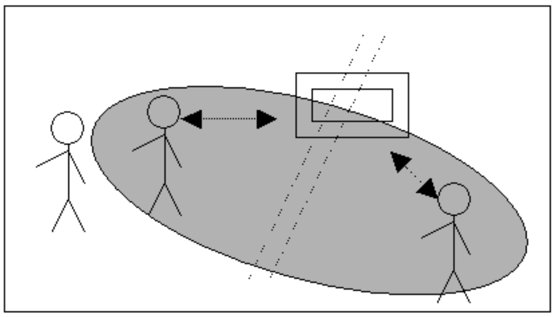

Figure 6: Class C relationship

This section is about how the user interface of a mobile device can impact the relationship between the communicating parties (Figure 6). In order to do so, we first we have to look at research that tries to determine how a telecommunication medium—which probably includes a user interface—can influence the message and the interpersonal evaluation.

Marshall McLuhan's quote "The Medium is the Message" implies that how a message is perceived is defined at least in part by the transmitting medium. From there, it would be a small step to hypothesize, "The Interface is the Message." In turn, if the medium is given, certain social side effects on the relationship between the communicating parties can occur. The same might be true for a given user interface of a mobile communication device: it might produce social side effects that impact the relationship between the parties.

There are two early theories that try to explain the effects of a medium on the message and on the evaluation of the communicating parties. The first says that media vary in the *efficiency of the interaction process*, having different amounts of channels, and being able to transmit different kinds of nonverbal cues. The second theory says that media differ through the possible amount of *nonverbal communication*.

Short et al. (1976) [48] combine both and suggest the heuristic of *Social Presence* to classify communication media and their social impact. Social Presence refers to a subjective quality of a medium, not to be defined objectively. It is a single dimension that represents a cognitive synthesis of several factors such as capacity to transmit information about facial expression, direction of looking, posture, tone of voice, and non-verbal cues as they are perceived by the individual to be present in the medium. These factors affect the level of presence that is the extent to which a medium is perceived as sociable, warm, sensitive, personal, or intimate when it is used to interact with other people. Social presence varies between different media, it affects the nature of the interaction and it interacts with the purpose of the interaction to influence the medium chosen by the individual who wishes to communicate (see also Sallnäs 1999) [44].

Related research is done by Williams (1975) [56], Chapanis, Ochsman, Parrish & Weeks (1972) [9], Williams (1977) [57]. They found that the communication medium has a significant influence on both the *evaluation of the act of communication*, and the *evaluation of the communication partner* (interpersonal evaluation, even interpersonal attraction), which means a high social impact. The nonverbally richer media—the ones with higher Social Presence—lead to better evaluations than the nonverbally poorer media: the transmitted nonverbal cues tend to increase the positivity of interpersonal evaluation. Mehrabian (1971) [29] suggests that nonverbally richer media are perceived as more *immediate*, which means that more immediate media lead to better evaluations and positive attitudes. This leads to our next statement:

Statement IX: The higher the *Social Presence* of the medium, or simply the more channels a medium can provide (= the more cues a medium can transmit), the more preferred the medium is, and the more positive the attitude of the user towards the message and towards the communication partner will be.

- ➢ User interfaces that support as many as possible channels, and that can transmit non-verbal cues.

However, I think that such a linear relation is simplistic and only true in a minority of all communication situations. At least these three parameters might modify the function:

- The *immediacy* of a communication medium. Immediacy, which is related to Short's concept of Social Presence, is the "directness and intensity of interaction between two entities" (Mehrabian 1971) [29], or, more concrete, the degree of perceived physical or psychological closeness between people. (An extensive survey paper about Social Presence theories including Immediacy is Biocca et al., 2001 [4])
- The amount of *intimacy* a communication *task requires* from the partners
- How well the partners *know each other*

Extending older theories (*Intimacy Equilibrium Model* by Argyle et al., and the above-mentioned *Immediacy Model* by Mehrabian (1971) [29], I suggest the following hypotheses:

- Both the communication partners and the communication itself are rated more positively (= are preferred) if the medium allows for higher immediacy, which can include the transmission of more nonverbal cues
- The above is only true if
  (a) the task does not require intimacy between the partners, e.g., if they don't have to disclose themselves extensively
  (b) the partners don't know each other well
- If the task requires the partners to disclose themselves extensively, and the partners don't know each other well, their preferences shift and might get reversed: they prefer media that are *lower* in immediacy. This might be explained with a drive to maintain the optimum intimacy equilibrium. Example: If a person's distant cousin dies, she would rather write the parents (low immediacy medium) than to stop by (high immediacy medium), because stopping by might be too embarrassing (since she doesn't know them at all).
- If the task requires the partners to behave in an intimate way *and* the partners know each other well, the preferences might shift back again, making higher immediacy media preferred. Example: If a person's father dies, she will choose the medium with the highest immediacy (which is face to face) to communicate with her mother.

From these hypotheses, we can extract another statement:

Statement X: The user's preference for a medium, and her attitude towards the message and towards the communication partner is not only influenced by the medium's *Social Presence* and *Immediacy,* but also how well the communication partners know each other, and if the communication task requires them to disclose themselves extensively.

- ➢ Interfaces that are *aware of the existing relationships of the communication parties* and adapt, suggesting communication modes that supports the right level of immediacy, social presence, etc. This might be done via an agent that is not only aware of all communication history, but also keeps track of the most important communication partners of the user and current interaction themes. This will require the assistance of an application like CYC (Lenat, 1995) [26] which can add commonsense knowledge to several kinds of log files, and might "fill in the blanks" with natural language understanding.

- ➢ Interfaces that are aware of the *task* the communication partners want to solve, either by inferring it from the communication history, or by looking at the communication context. These two items are interesting also from the perspective of human activities (see also the earlier described framework of Oppermann et al., 1998) [37]

Another relevant aspect that impacts the relationship between communication partners is if the user interface allows them to be *aware of each other's social context, during the act of communication, or even before.* As I have mentioned earlier in this chapter, the distinction between initiation and actual act of communication is not clear cut all the time. Applications like *GarblePhone* enable the user to be aware of the other party's crude social context—hints about the user's current "group size," about the role and type of her current environment—without establishing a direct connection. Therefore, I suggest the following statement:

Statement XI: Being aware of the *social context* of the other party *before* initiating a communication and *during* the act of communication might have a significant positive social impact on the interaction outcome.

- Interfaces that let the user *preview the social context of the communication partner*. This could include interfaces that give the user an idea where the communication partner is, or how open and/or available she is to communication attempts. Considerable amount of research has been done in this area, e.g., *Live Address Book* (Milewski et al., 2000) [30], *ConNexus and Awarenex* (Tang et al., 2001) [52], *Hubbub* (Isaacs et al., 2002) [24]. Many applications already give a limited amount of awareness, like commercial instant messaging buddy lists. Updating presence and availability information is probably best done by a combination of automatic detection and manual updating (Milewski et al., 2000) [30]

- Interfaces that allow the user to *be aware of the social context of the communication partner*. This refers to interfaces that enable the participants to understand each other's current social context *during* the act of communication. This is strongly related to the concept of Social Presence and Immediacy. A rather funny example for such an interface is the cellular phone that has built-in preset background noises, which can get activated by the user during a call, so that the caller could pretend to be on a train, at home, or anywhere she wishes to be. The possible social impact of this user interface feature is rather intuitive.

Awareness Communication

However, there is another case of awareness that requires special attention. At the beginning of this chapter, I implicitly assumed that the act of communication happens between person 1 and person 2. It is thinkable, however, that person 1 does not communicate with person 2 *directly*, but with something like an **outer layer** of person 2 (see Figure 7). Such an outer layer can be thought of as a personal agent that acts on behalf of person 2 (the user).

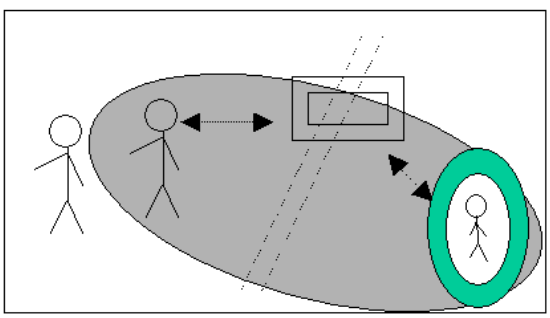

Figure 7: Special case class C, *Awareness Communication*: interaction happens only with the *outer layer* of person 2

This personal agent is familiar with the *social context* the user is currently in, including the group size, the person's role, and of course her location. This agent is also familiar with *contextual knowledge* like short and long-term goals of the user, which includes calendar events of the past and the future, To-Do lists, etc. Hopefully, the user does not have to instruct the agent manually about all this knowledge, but the agent should infer some of it based on common sense reasoning, as described as one of the applications of CYC (Lenat, 1995) [26]. Furthermore, this agent might be familiar with the *communication history* of the user. This would enable the agent to communicate on her behalf with people of interest. Or, in other words, the user could "radiate" certain pieces of information about her context, but they are visible of course only to a group of ratified users.

For example, such an agent could actively send out location information of the user to people that are eligible for this kind of information and might be interested in it. A scenario would include person 1 having scheduled a meeting with person 2. Person 1 would like to be updated of the most likely arrival time of person 2. Person 2 will not actively want to update person 1 continuously, but allows her agent to sent person 1 occasional updates, like "person 2 just left the subway station XY on her way to the scheduled meeting at MIT, and might arrive there at 16:04." *Electrical Elves*, multi-agent teams for scheduling and rescheduling events, are another example for such agents (Chalupsky, 2001) [6].

This leads to the following statement:

Statement XII: Receiving information directly from an "outer layer" of a person about her *wider context* might simplify the flow of awareness information between the communication partners, and might lead to a positive social impact on the relationship between the communication partners.

- Interfaces that are open for and actively request information from the *context layer of communication partners.* Such information is most likely to be displayed in the *periphery of human attention* (Abowd, p. 46) [1], which makes the user interface design challenges similar to the earlier mentioned *ambient media* (e.g., Ishii et al., 1997 [25], Wisneski et al., 1998 [59]) and *ambient alerting* (e.g., Schmidt et al., 1999) [46].
  An example for an appropriate user interface for communication with the context layer of a communication partner could be related to the earlier described wrist-worn *Reminder Bracelet* (Hansson et al., 2000) [20]. Taking the above-mentioned scenario of a meeting that will happen soon, person 1 would wear a wristband with an array of LEDs. The closer the time of arrival of person 2 is, the more diodes light up. Such an interface would display the information in an unobtrusive and still public way, so co-located people are indirectly aware of how soon the time of the meeting will arrive, a kind of information that can have significant social impact.
  Many similar kinds of ambient alerting mechanisms are thinkable. E.g., a small picture frame that changes color depending on information from the other person's agent. This interface idea is related to *LumiTouch* (Chang et al., 2001) [8], a pair of interactive picture frames that are cross connected so that when one user touches her picture frame, the other picture frame lights up. The authors call it a *semi-ambient display* that can transition seamlessly from periphery to foreground in addition to communicating emotional content.
  Another example would be a device that uses the haptic modality: *ComTouch* (Chang, 2001) [7], a system that allows a handheld device to register the force of pressure from each finger as the object is squeezed. At the receiving end, vibrations under each finger represent the transmitted force. *ComTouch* is an instance of a *Personal Ambient Display* (Wisneski, 1999) [58]: small, physical devices worn to display information to a person in a subtle, persistent, and private manner. Such personal ambient displays are small enough to be carried in a pocket (e.g., as key ring accessory), worn as a watch, or even as jewelry. Information is displayed through extended tactile modalities such as heating and cooling, movement and vibration, and change of shape. It has to be noted that this type of interface is often not public, which could lead to socially "unexplainable" behavior since co-located people are not aware of the alerts. Nevertheless, all these interfaces could be used to display information from the context layer of communication partners.
  Conceptually, such interfaces are actually related to interfaces of class A relationships, because the interaction happens between a person and a machine, e.g., a personal software agent. Therefore, some design suggestions of this class are relevant: Interfaces should allow the user to *select the most appropriate modality* depending on the physical context (Ruuska et al., 2001) [43]). Or the other way round: the user interface has to adapt to the user's current social context. This leads to the already described suggestion of *ramping interfaces* (Rhodes 2000 [40], Sawhney et al. 2000 [45]).
  Information about the current context could be coded according to the scenario space of Rowson (2000) [42] in two dimensions: first the current role context of the user (recreation, family, work, etc.), and then the current group size (individual, casual team, etc.)
  In general, as mentioned earlier, such contextual feedback about the user is probably best done by a combination of automatic detection and manual updating (Milewski et al., 2000) [30].
  The information flow in this kind of communication process has to be structured in some ways. *The Coordinator*™ (Flores et al., 1988) [16] could be an example for such a structure. This commercial software system provides structured messaging designed to give users a channel for communications specifically tailored to the generation, negotiation, and tracking of "commitments" for action. Messages are structured in accordance with Winograd and Flores' "conversation for action" model and the speech acts theory. Since its introduction, some elements of The Coordinator's implementation (including speech acts, political ramifications of structuring "commitments") have been objects for pointed debate (e.g., Bannon, 1995) [3].

5.4. Additional design considerations for user interfaces of mobile devices that will have social impact

As mentioned earlier, mobile communication is different from communication in a static setting because the social context is much less restricted (Ruuska et al., 2001) [43]. The different kinds of social context (Rowson 2001) [42] have a specific influence on mobile communication.

Statement XIII: Because mobile communication can happen *continuously* and virtually *everywhere* and *anytime*, its use can span many classes of social context, to which the user interface has to adapt.

- Interfaces with *small form factors*. This is a direct consequence of the everywhere-anytime paradigm of mobile communication. The smaller the device and its interface, the more likely they will get used. Ruuska et al. (2001) [43] mention as the first common theme for *Future Mobile Device User Interfaces* wearability: devices that will be attached to the body, most likely wrist or arm, which leads to the "wrist-top" and "arm-top" metaphor. This will raise issues of "fashionability" or "coolness" of mobile device design, which I will not address in this paper.

- Interfaces with *varying input and output capabilities* (such as wearable keyboards like *FingeRing*, Fukumoto et al., 1997) [18]. Such a diversity of inputs is also a consequence of Weiser's "embodied virtuality" vision (Weiser 1991) [54].

- *Distributed interfaces* that are not only part of the mobile device, but also of our environment. This includes a *modular approach* for user interfaces that dynamically connect to the available communication devices and channels (Ruuska et al., 2001) [43]). Weiser's (1991) [54] ubiquitous computing vision obviously includes such interfaces. In Dix et al.'s (2000) [14] *taxonomy of different levels of mobility*, the second dimension describes the device's relation to other devices: free, embedded, or pervasive, where with *pervasive* they mean that the functionality provided by the device is essentially spread throughout the environment. This most likely includes the user interface of the device.

- Interfaces that allow for *continuous interactions* (Abowd et al., p. 45) [1]. This is an important aspect of ubiquitous computing, and also relevant for the *always-on* metaphor of mobile computing. It refers to systems that continue to operate in the background without any knowledge of on-going activity. It is based on the assumption that not every interface should focus on conventional dialogue, an idea that I have described more in detail in the chapter about interactions with *outer layers* of users, and with awareness appliances.

6. Summary

This paper explored the interaction between user interface design for mobile devices and the social impact of mobile communication.

In the first part of the paper, inspired by work by Rowson (2001), Dryer et al. (1999), and Oppermann et al. (1998), I defined social impact as the *influence on relationships between social actors*. In the mobile communication setting, there are three relevant classes of relationships that could influence social impact: the relationship between the user and her mobile device (possibly as a social actor), the relationship between the user and other co-located people (her surroundings), and the relationship between the user and the people the user communicates with via her mobile device.

In the second part of the paper, I described some relevant characteristics of these three classes. Within each class of relationships, I listed a number of statements about social phenomena that can influence the social impact of mobile communication. Most of these statements are supported by theoretical and experimental work done in areas like social psychology, communication research, and social intelligence, and are related to questions like social impact of user interfaces, social impact of mobile communication, and social impact of ubiquitous computing.

As an example, in the second class of relationships (which looks at relationships between the mobile communication user and her surroundings), one of the statement read: *Given that there will be interruptions, it is necessary to find a balance between useful interruptions (due to alerts and acts of telecommunication) and interactions with and attention* *for co-located persons*. There is a total of 13 statements. Each statement lead to a number of design suggestions: suggestions about how a mobile communication user interface should be built in order to support that statement, or not to violate the social phenomena regarding a relationship described in the statement, or just simply to make the social impact of mobile communication positive. For example, one of the design suggestions for the above-mentioned statement described *interfaces that support multiple levels of intrusiveness, enabling background awareness applications.* Most of the design suggestions were explained with examples. In total, 28 user interface design suggestions were found. Equally interesting findings included a special case of mediated communication between a user and the "outer layer" of another person, which can be represented as a personal software agent. Such "Awareness Communication" requires special considerations for the user interface design of mobile communication devices.

7. References

[1] Abowd, G.D., and Mynatt, E.D. (2000). *Charting past, present, and future research in ubiquitous computing.* ACM Transactions on Computer-Human Interaction ToCHI, 7(1), March 2000, pp. 29-58. http://www.acm.org/pubs/articles/journals/tochi/2000-7-1/p29-abowd/p29-abowd.pdf

[2] Argyle, M. & Dean, J. (1965). *Eye-contact, distance, affiliation*. Sociometry, 28, 289-304. Abstract: http://nimbus.ocis.temple.edu/~mlombard/Presence/argyle65.html http://links.jstor.org/sici?sici=0038-0431%28196509%2928%3A3%3C289%3AEDAA%3E2.0.CO%3B2-Q

[3] Bannon, L. (1995). *Editorial, Commentaries and a response in the Suchman-Winograd debate.* Computer Supported Cooperative Work (CSCW), 3(1), Netherlands: Kluwer Academics, pp. 29-95.

[4] Biocca, F.,Burgoon, J., Harms, C., Stoner, M. (2001). *Criteria And Scope Conditions For A Theory And Measure Of Social Presence.* In proceedings of Presence 2001, 4th Annual International Workshop, May 21-23 2001, at Temple University, Philadelphia, PA. http://nimbus.ocis.temple.edu/~mlombard/P2001/Biocca1.pdf

[5] Breazeal, C. (1999). *Robot in Society: Friend or Appliance?* In Agents99 Workshop on Emotion-Based Agent Architectures, Seattle, WA, pp. 18-26. http://www.ai.mit.edu/projects/sociable/publications.html

[6] Chalupsky, H., Gil, Y., Knoblock, C. A., Lerman, K., Oh, J., Pynadath, D., Russ, T. A., and Tambe, M. (2001). *Electric Elves : Applying Agent Technology to Support Human Organizations.* International Conference of Innovative Application of Artificial Intelligence (IAAI'01) http://www.isi.edu/agents-united/papers/iaai2000.pdf

[7] Chang, A. (2001). *ComTouch: A Vibrotactile Emotional Communication Device.* Technical report, MIT Media Lab (unpublished paper). http://web.media.mit.edu/~anjchang/DS2001/comtouch.htm

[8] Chang, A., Resner, B., Koerner B., Wang, X and Ishii, H. (2001). *LumiTouch: An Emotional Communication Device.* In Extended Abstracts of Conference on Human Factors in Computing Systems (CHI '01), Seattle, Washington, USA, March 31 - April 5, 2001, ACM Press, pp.313-314. http://tangible.media.mit.edu/papers/LumiTouch_CHI01/LumiTouch_CHI01.pdf

[9] Chapanis, A., Ochsman, R.B., Parrish, R.N., and Weeks, G.D. (1972). *Studies in interactive communication: I. The effect of four communication modes on the behaviour of teams during cooperative problem-solving.* Human Factors, 14(6), 487-509.

[10] Clark, H. H. (1996). *Using language*. New York, NY: Cambridge University Press. Review: http://www.massey.ac.nz/~alock/virtual/clarke.htm

[11] Dautenhahn, K. (1998). *The Art of Designing Socially Intelligent Agents – Science, Fiction, and the Human in the Loop.* Special Issue Socially Intelligent Agents, Applied Artificial Intelligence Journal, Vol. 12, 7-8, pp. 573-617. http://orawww.cs.herts.ac.uk/~comqkd/papers.html

[12] Dautenhahn, K. (2000). *Socially Intelligent Agents and The Primate Social Brain - Towards a Science of Social Minds.* Proceedings of AAAI Fall Symposium Socially Intelligent Agents - The Human in the Loop, AAAI Press, Technical Report FS-00-04, pp. 35-51. http://orawww.cs.herts.ac.uk/~comqkd/papers.html

[13] Dey, A., Ljungstrand, P., and Schmidt, A. *Distributed and Disappearing User Interfaces in Ubiquitous Computing.* A workshop held at CHI 2001. In Extended Abstracts of Computer-Human Interaction (CHI) 2001, ACM Press, 2001, pp. 487-488. http://www.teco.edu/chi2001ws/disui.pdf

[14] Dix, A., Rodden, T., Davies, N., Trevor, J., Friday, A., and Palfreyman, K. (2000). *Exploiting space and location as a design framework for interactive mobile systems*. ACM Transactions on Computer-Human Interaction ToCHI, 7(3), Sept. 2000, pp. 285-321.
http://www.acm.org/pubs/articles/journals/tochi/2000-7-3/p285-dix/p285-dix.pdf
[15] Dryer, D.C., Eisbach, C., and Ark, W.S. (1999). *At what cost pervasive? A social computing view of mobile computing systems.* IBM Systems Journal, Volume 38, No 4.
http://www.research.ibm.com/journal/sj/384/dryer.pdf
[16] Flores, F., Graves, M., Hartfield, B., and Winograd, T. (1988). *Computer Systems and the Design of Organizational Interaction.* ACM Trans. Office Info. Systems, April 1988, pp. 153-172.
http://portal.acm.org/citation.cfm?id=45943&coll=ACM&dl=ACM&CFID=1282938&CFTOKEN=25128089
[17] Fukumoto, M. and Tonomura, Y. (1999). *Whisper: A Wristwatch Style Wearable Handset.* ACM CHI'99 Proceedings, pp. 112-119.
http://www.acm.org/pubs/articles/proceedings/chi/302979/p112-fukumoto/p112-fukumoto.pdf
[18] Fukumoto, M., and Tonomura, Y. (1997). *Body Coupled FingeRing: Wireless Wearable Keyboard*. ACM CHI'97 Proceedings, pp. 147-154.
http://www.atip.or.jp/Akihabara/links/johanwear/ntt/fkm.htm
[19] Gong, L., and Lai, J. (2001). *Shall We Mix Synthetic Speech and Human Speech? Impact on Users' Performance, Perception and Attitude*. ACM CHI 2001 Proceedings, pp. 158-165.
http://www.acm.org/pubs/articles/proceedings/chi/365024/p158-gong/p158-gong.pdf
[20] Hansson, R. and Ljungstrand, P. (2000). *The Reminder Bracelet: Subtle Notification Cues for Mobile Devices.* In: Extended Abstracts of CHI 2000 (Student Poster), ACM Press, pp. 323-325.
http://www.viktoria.se/~rebecca/artiklar/chi2000poster.pdf
[21] Hansson, R., Ljungstrand, P., and Redström, J. (2001). *Subtle and Public Notification Cues for Mobile Devices*. In: Proceedings of UbiComp 2001, Atlanta, Georgia, USA.
http://www.viktoria.se/~rebecca/artiklar/Notification_final.pdf
[22] Hjelm, J. (2000). *Designing Wireless Information Services*. New York, NY: John Wiley & Sons.
http://www.wireless-information.net/
[23] Horvitz, E. (1999). *Principles of Mixed-Initiative User Interfaces*. ACM CHI'99 Proceedings, pp. 159-166.
http://www.acm.org/pubs/citations/proceedings/chi/302979/p159-horvitz/
[24] Isaacs, E., Walendowski, A., and Ranganathan, D. (2002). *Hubbub: A sound-enhanced mobile instant messenger that supports awareness and opportunistic interactions*. To be published April, 2002 by ACM in the Proceedings of the Conference Computer-Human Interaction (CHI), Minneapolis, MN.
http://www.izix.com/pro/lightweight/hubbub.php
[25] Ishii, H., and Ullmer, B. (1997). *Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms*. In Proceedings of CHI'97, pp. 234-241.
http://tangible.media.mit.edu/papers/Tangible_Bits_CHI97/Tangible_Bits_CHI97.pdf
[26] Lenat, D.B. (1995). *Cyc: A Large-Scale Investment in Knowledge Infrastructure.* Communications of the ACM, 38(11):32-38.
http://www.acm.org/pubs/articles/journals/cacm/1995-38-11/p33-lenat/p33-lenat.pdf
[27] Luff, P., and Heath, C.(1998). *Mobility in collaboration*. ACM CSCW '98 Proceedings, pp. 305-314.
http://www.acm.org/pubs/articles/proceedings/cscw/289444/p305-luff/p305-luff.pdf
[28] Marx, M., and Schmandt, C. (1996). *CLUES: Dynamic Personalized Message Filtering*. Proceedings of CSCW '96, November 1996, pp. 113-121.
http://portal.acm.org/citation.cfm?doid=240080.240230
[29] Mehrabian, A. (1971). *Silent Messages*. Belmont, CA: Wadsworth.
[30] Milewski, A. and Smith, T. M. (2000). *Providing Presence Cues to Telephone Users.* Proceedings of CSCW 2000, Philadelphia, PA.
http://www.research.att.com/~tsmith/papers/milewski-smith.pdf
[31] Myers, B., Hudson, S.E., and Pausch, R. (2000). *Past, Present and Future of User Interface Software Tools*. ACM Transactions on Computer-Human Interaction ToCHI, 7(1), March 2000, pp. 3-28.
http://www.acm.org/pubs/articles/journals/tochi/2000-7-1/p3-myers/p3-myers.pdf
[32] Mynatt, E.D., Back, M., Want, R., Baer, M., and Ellis, J.B. (1998). *Designing Audio Aura.* ACM CHI'98 Proceedings, pp. 566-573.
http://www.acm.org/pubs/articles/proceedings/chi/274644/p566-mynatt/p566-mynatt.pdf
[33] Nass, C., Steuer, J., Tauber, E., and Reeder, H. (1993). *Anthropomorphism, Agency, & Ethopoeia: Computers as Social Actors.* Presented at INTERCHI '93; Conference of the ACM / SIGCHI and the IFIP; Amsterdam,

Netherlands, April 1993.
http://www.acm.org/pubs/citations/proceedings/chi/259964/p111-nass/

[34] Nelson, L., Bly, S., and Sokoler, T. (2001). *Quiet calls: talking silently on mobile phones*. ACM CHI 2001 Proceedings, 174-181.
http://www.acm.org/pubs/articles/proceedings/chi/365024/p174-bly/p174-bly.pdf

[35] Nielsen, J. (1993). *Noncommand user interfaces*. An updated version of a paper that appeared in the Revised version of Communications of the ACM 36(4), April 1993, pp. 83-99.
http://www.useit.com/papers/noncommand.html

[36] Norman, D. A. & Draper, S. W. (Eds.) (1986). *User centered system design: New perspectives on human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

[37] Oppermann, R. and Specht, M. (1998). *Adaptive support for a mobile museum guide.* Proceedings of Interactive Applications of Mobile Computing 98, Rostock, Germany.
http://www.rostock.igd.fhg.de/veranstaltungen/workshops/imc98/Proceedings/imc98-SessionMA3-2.pdf

[38] Oviatt, S. and Cohen, P. (2000). *Multimodal Interfaces That Process What Comes Naturally.* Communications of the ACM, Vol. 43(3), March 2000, pp. 45-53.
http://www.acm.org/pubs/articles/journals/cacm/2000-43-3/p45-oviatt/p45-oviatt.pdf

[39] Pascoe, J., Ryan, N., and Morse, D. (2000). *Using while moving: HCI issues in fieldwork environments*. ACM Transactions on Computer-Human Interaction ToCHI, 7(3), September 2000, pp. 417-437.
http://www.acm.org/pubs/articles/journals/tochi/2000-7-3/p417-pascoe/p417-pascoe.pdf

[40] Rhodes, B. (2000). *Just-In-Time Information Retrieval.* Ph.D. Dissertation, MIT Media Lab, May 2000.
http://www.media.mit.edu/~rhodes/Papers/rhodes-phd-JITIR.pdf

[41] Rice, R. E. (1992). *Task analyzability, use of new medium and effectiveness: A multi-site exploration of media richness.* Organization Science, 3(4), pp. 475-500.
Abstract: http://nimbus.ocis.temple.edu/~mlombard/Presence/rice92.html
http://links.jstor.org/sici?sici=1047-7039%28199211%293%3A4%3C475%3ATAUONM%3E2.0.CO%3B2-A

[42] Rowson, J. (2001). *The Social Media Project at Hewlett Packard Laboratories*. Talk at the Stanford Networking Seminar of November 1, 2001, Center for the Study of Language and Information (CSLI), Stanford University.
http://netseminar.stanford.edu/sessions/2001-11-01.html

[43] Ruuska-Kalliokulju, S., Schneider-Hufschmidt, M., Väänänen-Vainio-Mattila, K., Von Niman, B. (2001). *Shaping the Future of Mobile Devices*. Results of the Workshop on Future Mobile Device User Interfaces at CHI 2000. SIGCHI Bulletin January/February 2001.
http://www.acm.org/sigchi/bulletin/2001.1/mobile_cont.pdf

[44] Sallnäs, E. L. (1999). *Presence in multimodal interfaces.* Proceedings of the Second International Workshop on Presence, University of Essex, Colchester, UK.
http://www.nada.kth.se/~evalotta/Presence/IWVP.html

[45] Sawhney, N. and Schmandt, C. (2000). *Nomadic Radio: Speech & Audio Interaction for Contextual Messaging in Nomadic Environments.* ACM Transactions on Computer Human Interaction ToCHI, 7(3), Sept. 2000, pp. 353-383.
http://www.acm.org/pubs/articles/journals/tochi/2000-7-3/p353-sawhney/p353-sawhney.pdf

[46] Schmidt, A., Gellersen, H.-W., and Beigl, M. (1999). *Matching Information and Ambient Media.* In Proceedings of CoBuild'99. Second International Workshop on Cooperative Buildings, Pittsburgh. LNCS 1670. Springer: Heidelberg 1999.
http://www.comp.lancs.ac.uk/~albrecht/pubs/pdf/schmidt_cobuild99_ambient.pdf

[47] Shneiderman, B. (1998). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Third Edition, Reading, MA: Addison Wesley.

[48] Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications.* London: John Wiley.

[49] Singer, A., Hindus, D., Stifelman, L., White, S. (1999). *Tangible Progress: Less Is More In Somewire Audio Spaces.* In Proceedings of CHI '99, ACM, 1999, pp. 104-111.
http://portal.acm.org/citation.cfm?doid=302979.303007

[50] Steuer, J. (1995). *Self vs. Other; Agent vs. Character; Anthropomorphism vs. Ethopoeia*. In Vividness and Source of Evaluation as Determinants of Social Responses Toward Mediated Representations of Agency, doctoral dissertation, Stanford University, advised by Nass and Reeves.
http://www.cyborganic.com/People/jonathan/Academia/Dissertation/theory1.html

[51] Suhm, B., Myers, B., and Waibel, A. (1999). *Model-based and empirical evaluation of multi-modal interactive error correction.* ACM CHI'99 Proceedings, pp. 584-591.
http://www.acm.org/pubs/articles/proceedings/chi/302979/p584-suhm/p584-suhm.pdf

[52] Tang, J., Yankelovich, N., Begole, J., Van Kleek, M., Li, F., and Bhalodia, J. (2001). *ConNexus to Awarenex: Extending awareness to mobile users*. In Proceedings of ACM CHI 2001, Seattle, Washington, March 31 - April 5, 2001, pp. 221-228.
http://www.sun.com/research/netcomm/papers/CHI2001Proc.pdf
[53] Walker, M.A., Fromer, J., Di Fabbrizio, G., Mestel, C., and Hindle, D. (1998). *What can I say?: Evaluating a Spoken Language Interface to Email.* ACM CHI'98 Proceedings, pp. 289-290.
http://www.acm.org/pubs/articles/proceedings/chi/274644/p582-walker/p582-walker.pdf
[54] Weiser. M. (1991). *The computer for the 21st Century.* Scientific American, Volume 265, Number 3, September 1991, pp. 94-104.
http://nano.xerox.com/hypertext/weiser/SciAmDraft3.html
[55] Wickens, C.D. (1992). *Engineering Psychology and Human Performance*. New York, NY: Harper Collins.
http://vig.prenhall.com/catalog/academic/product/1,4096,0321047117,00.html
[56] Williams, E. (1975). *Medium or message: Communications medium as a determinant of interpersonal evaluation.* Sociometry, 38(1), pp. 119-130.
http://links.jstor.org/sici?sici=0038-0431%28197503%2938%3C119%3AMOMCMA%3E2.0.CO%3B2-P
[57] Williams, E. (1977). *Experimental comparisons of face-to-face and mediated communication: A review.* Psychological Bulletin, 84(5), pp. 963-976.
[58] Wisneski, C. A. (1999). *The Design of Personal Ambient Displays*. Master's Thesis, Massachusetts Institute of Technology.
[59] Wisneski, C., Ishii, H., Dahley, A., Gorbet, M., Brave, S., Ullmer, B. and Yarin, P. (1998). *Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information.* In Proceedings of CoBuild '98, International Workshop on Cooperative Buildings, Darmstadt, Germany, February 1998, Springer, pp. 22-32.
http://tangible.media.mit.edu/papers/Ambient_Disp_CoBuild98/Ambient_Disp_CoBuild98.pdf