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The SOCIAL Project

Approaching Spontaneous Communication in Distributed Work Groups

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Abstract. The aim of the project SOCIAL is to explore possibilities to facilitate spontaneous and informal communication in spatially distributed groups by exploiting ambient intelligence and smart environments. Spontaneous and informal communication has a strong impact on the productivity, social identity, and wellbeing of work groups. The spatial distance between peers plays a key role in successfully establishing and maintaining such communication. In co-located teams, spontaneous communication occurs daily: People occasionally meet on office floors, at the coffee corner, or have lunch together. Today, due to globalization we often encounter distributed work settings that impede spontaneous communication between co-workers, as teams are distributed over branch offices located in different cities and countries. We propose to approach this problem by (1) detecting situations with the potential for spontaneous informal communication, (2) representing and raising awareness for these situations appropriately, and (3) enabling users to engage seamlessly in spontaneous communication spanning spatially separated locations. In this paper we focus on the second aspect. A pilot study is described with results on combining various interaction modalities in order to raise awareness for communication. In addition, we describe a formal representation for ambient intelligence incorporating situational context and the system itself.

1 Introduction

Positive effects attributed to frequent spontaneous communication include seamless progress and coordination of work [1], a reduction in work-based conflicts [2], and more efficient collaborative learning [3]. In contrast, a lack of such communication is known to cause “difficulty in forming close collaborations, dealing flexibly with one another, and expanding the breadth of [...] relationships” [1], which can lead to further difficulties, such as a less successful transfer of complex knowledge between peers [4].

The spatial separation between peers plays a key role in successfully establishing and maintaining spontaneous communication. In co-located teams, spontaneous communication occurs daily: People occasionally meet on office floors, at the coffee corner, or have lunch together. However, today we often encounter distributed work settings that impede spontaneous communication between co-workers, as teams are distributed over branch offices located in different cities and countries.

Due to our need to stay connected with our peers, we use a multitude of methods to bridge such distances, including telephone, email, video-conferencing, and social networks. Nevertheless, the asynchronous (e.g., email, social networks) or synchronous (e.g., telephone, video-conference) nature of these methods fail to mimic the complexity of spontaneous interpersonal communication. When we are spatially separated, we cannot perceive implicit cues indicating the availability of our remote peers to communicate, such as the presence of a co-worker on the office floor. Furthermore, we typically cannot easily assess whether and when it is appropriate to engage in communication. For example, we would typically not call someone if we knew he/she is in a meeting or having lunch. As we usually have insufficient knowledge of the remote situation, we need to rely on other, possibly more formal and asynchronous channels for communication, such as email. In combination, these factors substantially reduce our opportunities to engage in spontaneous communication with remote peers.

We propose to approach this problem by exploiting capabilities of distributed smart environments and ambient intelligence focused on awareness and communication. The idea is to address three main tasks: (1) *detect situations* with the potential for spontaneous communication spanning multiple spatially distributed locations, (2) *present detected situations* appropriately to the users concerned, i.e., provide awareness without being obtrusive, and (3) *enable users* to engage seamlessly in spontaneous communication in a convenient way.

In this paper we introduce the project SOCIAL and motivate the approach. Especially, we present first insights of how to create respective awareness. That is, we describe an initial user study testing and evaluating social awareness signals. Furthermore, we present a formal representation for ambient intelligence allowing to describe the situational context and involved system.

2 Related Work

As the project SOCIAL addresses interdisciplinary research, we present related fields and projects. Comprising a brief overview of the sociological and psychological background (Section 2.1), as well as an introduction of implicit and explicit communication (Section 2.2). We conclude this section with a small survey of ambient intelligence and related projects, that focus on communication and awareness (Section 2.3).

2.1 Sociological and Psychological Background

Researchers in sociology and psychology have extensively studied the influence of spatial separation on the characteristics and behavior of work groups. Kraut et al. [5] stated that when the distance between work places increases to about 30 m or more, the amount of contact declines. Kiesler and Cummings [1] provide a survey of related work ranging from the middle of the 20th century to the beginning of the 21th century. They emphasize the relevance of (spatial) proximity for successful teamwork, which causes "emotional, cognitive, and behavioral changes that affect the work process for the better" [1]. Furthermore, they found that in distributed settings the frequency of daily contact as well as informal, i.e., spontaneous, communication decreased dramatically. They identified several negative effects resulting from this, including a drastic reduction of voluntary collaboration.

In addition, Kiesler and Cummings describe two effects of proximity in teams: First, co-location enables people to perceive the presence of peers, which lays the foundation for interaction among them. Second, it enables people to communicate with peers casually to exchange information. Today's work settings often prevent the geographical proximity of co-workers.To transfer the beneficial effects of proximity to a spatially distributed setting, we need to develop appropriate methods that detect and represent the presence of remote co-workers and provide methods to engage seamlessly in communication on demand in a dynamic spatial environment with multiple (interchanging) locations. In this context, we need to differentiate between two aspects of communication: implicit and explicit communication.

2.2 Implicit and Explicit Communication

Implicit communication can be understood in the notion of the first axiom of communication formulated by Watzlawick et al.: "one cannot *not* communicate" [6]. Even if we do not explicitly communicate, our behavior, e.g., body language, tone of voice, and facial expression, provide information that becomes communication when perceived by another person. Vinciarelli et al. [7] describes these aspects as *behavioral cues* emitted by humans. Furthermore, using social intelligence, we can interpret *social signals* from these cues, such as disagreement, fear, or joy. In the context of computing systems, Schmidt and Gellersen refer to these aspects as implicit input, "which is not primarily targeted towards interaction with computers, but is interpreted by computers as input" [8],*translated from German*.

In contrast to implicit communication, people are typically more aware of explicit means of communication, which we use on a daily basis to stay in contact with our peers. Explicit communication typically refers to specific information we communicate via speech or text, e.g., face-to-face talks, phone calls, or emails. The latter examples show the important role of explicit communication to stay connected to remote peers. Kiesler and Cummings [1] point out that explicit means of communication can indeed effectively support social communication between distributed peers.

With SOCIAL, we aim for interaction methods that permit seamless transition between implicit and explicit communication. This aspect, while playing a key role for effective social communication, is still an emerging field that has not been comprehensively studied. In this context, we point out the work of Streitz et al., who used a concept of three zones around an ambient interactive display for transition from implicit to explicit interaction [9]. In the notion of proxemic interaction, they infer a user's readiness for interaction based on his/her distance, i.e., users could only establish explicit interaction when in reaching distance of the display. Vogel and Balakrishnan revisited this approach, integrating the position and movement of the body into the recognition of interaction zones. They also suggested design principles and interaction techniques for different phases of implicit and explicit interaction of a human with a computer interface displaying information [10].

2.3 Ambient Intelligence and Related Projects

With the increasing miniaturization and integration of pervasive and ubiquitous devices in our everyday world, smart environments become a reality. In buildings technology is applied to provide supportive, ecofriendly, and security increasing functionality. Examples are motion detector activated lights or heating systems controlled by computers based on time and temperature sensors. Mark Weiser presented an early vision of the direction this research could take: "Ubiquitous computing has as its goal the nonintrusive availability of computers throughout the physical environment, virtually, if not effectively, invisible to the user." [11] Building on this vision and technological development the term *ambient intelligence* (AmI) appeared in Europe around the year 2000: "The concept of Ambient Intelligence (AmI) provides a vision of the Information Society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way." [12]

Thus, AmI also includes a variety of other disciplines, e.g., computer networks, sensor and actuator technology, artificial intelligence (AI), human-computer interaction (HCI), and computer supported cooperative work (CSCW), awareness systems, social sciences, or architectural science. Possible scenarios for the application are similarly diverse [13,14,15], e.g., smart homes and work places, patient or student monitoring and assistance, assistance for navigation and search tasks, or support of interaction and communication.

An early approach, around the 1980s, to provide interaction and communication possibilities to separated individuals by exploiting technologically equipped environments are so-called *Media Spaces*. A comprehensive survey of the projects, findings, and results is provided in [16].

A further important branch of related research deals with *awareness systems* [17]. This research addresses an individual's awareness of others, objects, or how to provide awareness for specific contexts. Thus, the goal is to gather or provide information updates about an individual's context, including events and situations. Gutwin and Greenberg defined workspace awareness as "the collection of up-to-the-moment knowledge a person uses to capture another's interaction with the workspace" [18].

In over 30 years of research, the fields of media spaces and awareness systems have provided a number of projects demonstrating the usefulness of mediated communication and awareness in public and private settings. Possibilities to increase productivity, to support wellbeing, and to decrease costs (e.g. [19,20,21]) have been addressed by investigating systems for synchronous and asynchronous communication as well as systems mediating awareness on a more abstract level.

An example of a project focusing on communication in the early 90s is RAVE (Ravencroft Audio Video Environment) [22,23] at EuroPARC. RAVE aimed at allowing interpersonal communication and awareness by connecting places in their laboratory building. The system consisted of audio-video nodes with a camera, monitor, microphone, and speakers placed in all rooms. These nodes were directly accessible, controllable, and modifiable by all users. RAVE was designed to support interactions. It works by providing means for informal encounter as well as formal cooperative tasks. These tools were mainly continuous longterm connections between two places and ad-hoc video-conference sessions. A further example is Telemurals [24] (2004), a system connecting two university dormitories through an abstracted audio-video stream. The project used cameras, microphones, and projectors installed in two seperate locations. The level of detail of the transmitted audio and video data was determined by the activity level at the respective sites. A low level of detail corresponded to low activity at the remote site. A less public and more personal project developed in 2010 is Family Window [20], which aimed at connecting and maintaining awareness between distant family members and close friends. It was designed to connect two locations through mobile communication units. The authors used two mobile displays providing a continuous audio-video connection and also supported small text or image messages.

An example focusing on awareness is the early Xerox PARC and EuroPARC project Portholes [25] (1992). To create interpersonal awareness, *Portholes* provided regularly updated images of remote sites. Another example is the ASTRA project [26] (2006) that aimed at providing awareness through asynchronous communication between family members. ASTRA was designed for a heterogeneous communication environment. This included the use of stationary and mobile computers and personal mobile devices, in order not to be dependent on specific locations.

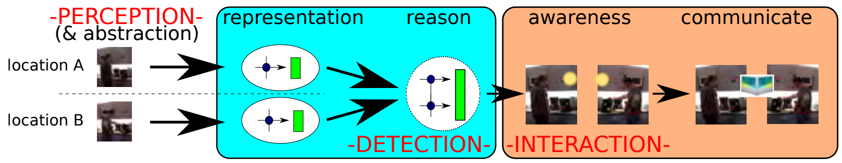

Fig. 1: Automated process to initiate spontaneous distributed communication

3 The Big Picture of SOCIAL

In this section, the general approach taken in the project SOCIAL is introduced by presenting and discussing a first scenario. Furthermore, we describe how we intend to facilitate spontaneous communication in spatially distributed environments using ambient intelligence.

The initial question was how a spontaneous encounter and evolving communication, i.e., a serendipitous meeting at a coffee dispenser, could be realized in spatially distributed environments. Additionally, the locations to be connected should be dynamically changeable, preventing the use of static connections. We decided to start with a scenario of a situation with potential for spontaneous communication in a co-located environment and transform it to a comparable spatially distributed version. The spatially distributed scenario not only requires a comparable situational context to the co-located scenario, but also methods for automated detection of the situation and for enabling a communication channel.

The *co-located coffee encounter scenario* features two individuals Alice and Bob located in the same office floor environment. Initially, Alice is in her office and fancies a coffee. She leaves her office to go to the coffee dispenser and have a cup. At the same time, Bob is already waiting for his cup of coffee to be prepared at the coffee dispenser. When Alice arrives, she greets Bob and the two start to talk to one another.

In order to transform this scenario into a comparable spatially distributed version, i.e., *distributed coffee encounter scenario*, it is assumed that Alice and Bob are located in two spatially separated office floor environments. Again, Alice is in her office and fancies a coffee. She leaves her office to go to the coffee dispenser and have a cup. At the same time in a branch office, Bob is waiting for his cup of coffee to be prepared at his local coffee dispenser. When Alice arrives at her local coffee dispenser, Bob is still waiting for his cup of coffee. An ambient intelligence installed at both locations perceives that Alice and Bob are both waiting at the coffee dispensers of the respective offices. The ambient intelligence initiates an unobtrusive transition from awareness to interpersonal communication. First, creating awareness of the fact that a colleague is also waiting at a coffee dispenser and then creating a direct communication channel for the two to talk with one another.

Based on this distributed scenario, we propose an automated three-step process to enable spatially distributed situations providing possibilities for spontaneous communication. This process is depicted in Figure 1 and features the following steps:

- *perception* of the current situational context of all environments, i.e., obtaining raw sensor data and providing semantically meaningful symbolic abstractions,
- *detection* of a suitable spatially distributed situation, and
- *interaction* is made possible in an appropriate and unobtrusive manner.

We restrict our research on the perception step to the use of-the-shelf products. Thus, we will use existing and available libraries, e.g., OpenCV[3] (computer vision), RAVL[4] (recognition and vision), Shark[5] (machine learning), and SIL [27] (laboratory environment). However, our focus within the SOCIAL project is on the detection and interaction steps.

4 Detection of Situations

The detection step addresses the identification of (spatially distributed) situations with potential for spontaneous communication, i.e., representation and reasoning about the situational context. This requires a formal language to describe specific situations of interest, available knowledge, e.g., abstracted perceptions of situation context, and the behavior of the system, e.g., reasoning and action rules. In addition, an appropriate method to process available knowledge to identify existing situations is required.

Regarding the formal representation language, we apply methods from the field of qualitative spatio-temporal representation and reasoning (QSTR), e.g., [28,29]. The applicability of these methods to the field of AmI is, for example, shown by Hois et al. [30]. QSTR deals with relations between spatio-temporal entities of a domain, i.e., representations that explicate spatial or temporal aspects relevant for a given task, while neglecting others. Furthermore, QSTR also provides a range of formalizations, i.e., calculi, for aspects like topology (e.g., RCC-8 [31]) or position (e.g. OPRA [32]). These calculi also include methods for reasoning, e.g., checking consistency of a given scenario or explicating implicit knowledge, e.g., [28].

Especially, we adapt a representation formalism provided in [33] for representing and reasoning with qualitative spatial information in combination with propositional modal-logic. The resulting formalism includes a collection of symbol sets representing the objects, functions regarding spatial features and activities of objects, spatio-temporal relations between objects, possible sensors perceptions and actuator actions, and how different states of the ambient intelligence connect regarding time and processed operations. Our formal representation is now introduced in a bottom-up way, starting with its ingredients and closing with an example.

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[3] `http://opencv.org/` (visited: 03/19/2015)
[4] `http://ravl.sourceforge.net/` (visited: 03/19/2015)
[5] `http://shark-project.sourceforge.net/` (visited: 03/19/2015)

– $\mathcal{O}$ is a set of symbols for physical and immaterial object
– $\mathcal{Q_S}$ is a set of symbols for qualitative spatial functions (qualitative spatial features of an object, e.g., region or orientation)
– $\mathcal{Q_A}$ is a set of symbols for activity functions (activities of an object)
– $\mathcal{A_S}$ is a set of symbols for sensor perceptions
– $\mathcal{A_I}$ is a set of symbols for actions (actuator changes by the AmI)
– $\mathcal{A_R}$ is a set of symbols for reasoning rules
– $\mathcal{A_A}$ is a set of symbols for action rules
– $\mathcal{R}$ is a set of symbols for qualitative relations
– $\mathcal{G}$ is a set of symbols for further propositions

The set of all possible propositions $\mathcal{P}$ (Eq. 1) is the combined set of objects, the activities specific objects are conducting, current sensor perceptions and actuator uses, and spatial relations[6] between objects.

$$\begin{aligned} \mathcal{P} = \mathcal{O} \cup \mathcal{G} \cup \{a(o)|a \in \mathcal{Q_A}, o \in \mathcal{O}\}\cup \\ \{p(o)|p \in \mathcal{A_S}, o \in \mathcal{O}\} \cup \{i(o)|i \in \mathcal{A_I}, o \in \mathcal{O}\} \\ \{r(x,y)|r \in \mathcal{R}, x, y \in \{s(o)|s \in \mathcal{Q_S}, o \in \mathcal{O}\}\} \end{aligned} \quad (1)$$

We consider a *state* as a (partial) snapshot of currently holding propositions recursively defined by:

– p is a state for every $p \in \mathcal{P}$
– if ϕ is a state, so is $\neg\phi$
– if ϕ, ψ are states, so is $\phi \otimes \psi$ with $\otimes \in \{\wedge, \vee\}$

A *situation description* also includes temporal relations between contained states. Thus, if ϕ is a state, then $M\phi$ with $M \in \{\circ[t_i, t_j], \diamond[t_i, t_j]\}$ is a situation description. The time points t_i and t_j define the existence and duration of an interval in which the related state holds. We assume linear time, i.e., it holds that $\forall t_i, t_j : t_0 \leq t_i \leq t_j < t_\infty$. The semantics of the modal operations M connect states sequentially to situation descriptions:

– $\circ[t_i, t_j]\phi$ (during): $\forall t_x : \phi$ holds at t_x with $i \leq x \leq j$ (i.e., $t_0 \leq t_i \leq t_x \leq t_j$)
– $\diamond[t_i, t_j]\phi$ (within): $\exists t_x : \phi$ holds at t_x with $i \leq x \leq j$ (i.e., $t_0 \leq t_i \leq t_x \leq t_j$)

Based on this formalism for situation descriptions, we formalize an AmI through its knowledge base. The knowledge base is understood as the internal representation of the world, as perceived by the system, i.e., a set of descriptions of perceived situations connected by specific internal actions of the system. Thus, if $\delta_1, \delta_2, \ldots \delta_n$ are situation descriptions, then $\delta_1 \oplus_1 \delta_2 \oplus_2 \cdots \oplus_{n-1} \delta_n$ with $\oplus_i \in \mathcal{A_S} \cup \mathcal{A_I} \cup \mathcal{A_R} \cup \mathcal{A_A} \cup \{\odot[t_i, t_j]\}$ is a knowledge base description, i.e., a description of the respective AmI and its situational context. The semantics of $\odot[t_i, t_j]$ explicate inertia between the two connected situation descriptions, i.e., all contained propositions that hold at t_i also hold at t_j (with $t_0 \leq t_i < t_j$).

[6] We define only the set of binary relations, due to understandability. However, this can be changed to any arity of relation without influence on the remaining specification.

For reasons of simplicity, we restrict the use of the modal operator M regarding situation descriptions that are part of a knowledge base to only allow $\circ[t_i, t_j]$ to prevent ambiguous interpretations of a given knowledge base.[7]

Regarding the rules given in the sets $\mathcal{A}_\mathcal{R}$ and $\mathcal{A}_\mathcal{A}$, each symbol represents an event-condition-action (ECA) rule (e.g., [34,35]) to trigger actions or infer additional knowledge based on a knowledge base provided. These are rules firing on a specified event if a specified condition holds to execute the specified action. For the defined representation, each rule consist of a trigger part T, which is a disjunction of conjunctions of situation descriptions, and an action part C, which is a conjunction of the form $\circ[t_{i_a}, t_{j_a}]P_a \wedge \cdots \wedge \circ[t_{i_b}, t_{j_b}]P_b \wedge c_1 \wedge \cdots \wedge c_n$ with $n \in \mathbb{N}, \forall P_z \in \mathcal{P}, \forall c_y \in \mathcal{A}_\mathcal{I}, \forall t_{i_x}, t_{j_x} : t_0 \leq t_{i_x} \leq t_{j_x}$. That is, the action part can either introduce new knowledge, e.g. $\circ[t_{i_a}, t_{j_a}]P_a$, or tell the system to use one of its actuators, e.g., c_1. An exemplary rule checking existence of the proposition P_1 at time 3 as well as P_2 within the temporal interval $[1, 3]$ and if fired issues P_3 to be holding at time 3 is $\circ[3, 3]P_1 \wedge \diamond[1, 3]P_2 \rightarrow \circ[3, 3]P_3$. The according generic rule to check at arbitrary time point t_x would be $\circ[t_x, t_x]P_1 \wedge \diamond[t_{x-2}, t_x]P_2 \rightarrow \circ[t_x, t_x]P_3$. To check the trigger of a rule regarding the knowledge base provided, methods from the field of logics can be applied, e.g., model-checking [36].

For example, the scenarios from Section 3 can be defined as follows:

- $\mathcal{O} = \{person_1, person_2, coffee_1, coffee_2, videophone\}$
- $\mathcal{Q}_\mathcal{S} = \{phys(X), func(X)\}$
- $\mathcal{Q}_\mathcal{A} = \{waits(X)\}$
- $\mathcal{R} = \{IN(X, Y), OUT(X, Y)\}$

With the spatial functions $phys(X)$ denoting the physical space of some object X, $func(X)$ denoting the functional space of some object X; the object activity function $waits(X)$ denoting that some object X is currently waiting on something; the (spatial) relations $IN(X, Y)$ denoting that some space X is within some space Y, and $OUT(X, Y)$ denoting that some space X is not within some space Y.

Then Equation 2 provides an exemplary formalization of the context in the co-located coffee encounter scenario directly before the communication starts. That is, Alice ($person_1$) and Bob ($person_2$) are waiting for their coffee at the coffee dispenser ($coffee_1$).

$$\begin{aligned}\circ[t_n, t_n]person_1 \wedge \circ[t_n, t_n]IN(phys(person_1), func(coffee_1)) \wedge \\ \circ[t_n, t_n]person_2 \wedge \circ[t_n, t_n]IN(phys(person_2), func(coffee_1)) \wedge \\ \circ[t_n, t_n]waits(person_1) \wedge \circ[t_n, t_n]waits(person_2)\end{aligned} \tag{2}$$

[7] In general, usage of $\diamond[t_i, t_j]$ is possible, but would lead to multiple interpretations of a single knowledge base.

The same context in the distributed coffee encounter scenario can for example by described by Equation 3.

$$\begin{aligned} \circ[t_n,t_n]person_1 \wedge \circ[t_n,t_n]IN(phys(person_1), func(coffee_1))\wedge \\ \circ[t_n,t_n]person_2 \wedge \circ[t_n,t_n]IN(phys(person_2), func(coffee_2))\wedge \\ \circ[t_n,t_n]OUT(phys(coffee_1), physf(coffee_2)) \wedge \circ[t_n,t_n]videophone\wedge \\ \circ[t_n,t_n]waiting(person_1) \wedge \circ[t_n,t_n]waiting(person_2)\wedge \\ \circ[t_n,t_n]IN(phys(videophone), func(coffee_1))\wedge \\ \circ[t_n,t_n]IN(phys(videophone), func(coffee_2))\wedge \\ \circ[t_n,t_n]IN(phys(person_1), func(videophone))\wedge \\ \circ[t_n,t_n]IN(phys(person_2), func(videophone)) \end{aligned} \tag{3}$$

By using one of these formalizations as trigger, we can define action rules to initiate the interaction step.[8]

5 A Pilot Study on Awareness

In SOCIAL, the interaction step follows the detection step (see Fig 1.). We subcategorize the interaction step into two phases: i) awareness and ii) communication. In this Section we describe a pilot study that focuses on awareness, and provide some initial results about which awareness signals are more appropriate to support informal communication at distant workplaces. The goal of our pilot study was to explore how participants would react to close and peripheral signals. Moreover, we made a distinction between simple visual and auditory signals in order to evaluate the general preference of the users. Last but not least, the transition from one state (awareness) to the other (communication) was tested in order to evaluate the whole interaction step. Müller et al. [37] presented six examples of ambient light information displays, which address humans' perception abilities to gain cues from the periphery instead of attracting the user's visual focus. Our system differentiates from [37], as it is an awareness system and not an information display system; however, both explore the "peripherality" of the system and perception through visual cues. Regarding sound, Kainulainen et al. [38] presented guidelines regarding six common auditory techniques: speech, auditory icons, earcons, music, soundscapes, and sonifications. To make the workplace a more social and enjoyable place, they developed an audio awareness application that depicts the activity and person of each person of the work group as sound, such as the singing of the bird. We used a whispering sound effect as an awareness signal, similar to an earcon.

5.1 Setup and Method of the Study

In order to evaluate how participants would rate the kind and perception of the triggered signals, we run a Wizard-of-Oz (WoZ) study at a lab at the University

[8] Currently only brute-force model-checking is applied, however, we intend to investigate the use of existing computational reasoners to address scalability.

of Oldenburg in April-May 2015. 17 subjects (11 female, 6 male) participated in the study (mean age 25). They were students of various disciplines (not computer science) and most of them computer-savvy; only one participant has never used a video communication software before. Each case study lasted about 45 minutes.

The participants were instructed to sit at a desk and watch a relaxing music video at low volume. Through this setting we tried to represent a situation at a working environment during a break, similar to the coffee lounge scenario described earlier. Then the investigator told them that there will be various signals in this environment and the participants should call the investigator through the communication software after they have been aware of a signal. The investigator, after receiving the call, would come into the lab and notify them that they are now going to test the next condition.

There were five settings with five different conditions tested:

1. Close light (lamp was next to the PC);
2. Distant light (lamp was on a chair on the participant's left side);
3. Sound (output of a wall-mounted speaker);
4. Combination of sound and light;
5. Absence of signals.

The investigator was at a surveillance room next to the lab where the study took place and triggered the light and sound remotely. The conditions were changed in random order, so that the training curve is not affected. The lamp used in the first, second, and fourth condition is a small lamp, ca. 30 cm high. It was illuminated white; no pulsing light or other light patterns. The investigator turned the lamp on and off with a time interval of 5 seconds. The light bulbs were from *Milight*, which offers an app for remote control. The aspect of colours and light patterns is currently out of the scope of the SOCIAL project. In the second condition, the lamp positioned left (ca. 90 degrees) from the user was placed at a chair which was of the same height as the chair where the participant was seated on. The sound (third and fourth condition) was a peripheral sound, triggered by an existing wall-mounted camera; it was a short "Psst...Psst" sound effect. The absence of the signals (fifth condition) was realized by the investigator calling the participants herself and not waiting for them to call the investigator, as in the other settings. With this condition we wanted to test how would the participants evaluate the transition from their activity to the communication, when they do not have the option to choose or give their consent if they want to communicate.

We selected two subjective evaluation measures: a think-aloud protocol during the experiment and a questionnaire at the end. For the design of the questionnaire, we adapted the following heuristics by Mankoff et al. [39] to our awareness and communication context: i) peripherality of display, ii) match between design of ambient display and environments (its design should not clash with its environment), iii) easy transition to more in-depth information, iv) visibility of state, and vi) aesthetic and pleasing design. The questionnaire consists of the following questions:

1. How easily perceptible was the signal?

2. How much did the signal distract you from your task?
3. How did you like the design/form of the signal?
4. How gradual was the transition from the task to communication?
5. Does the spatial position of the lamp influence its perception?
6. Which of the following signals do you prefer?
7. Evaluate the idea of using light, sound, and the combination of light and sound as awareness signals.

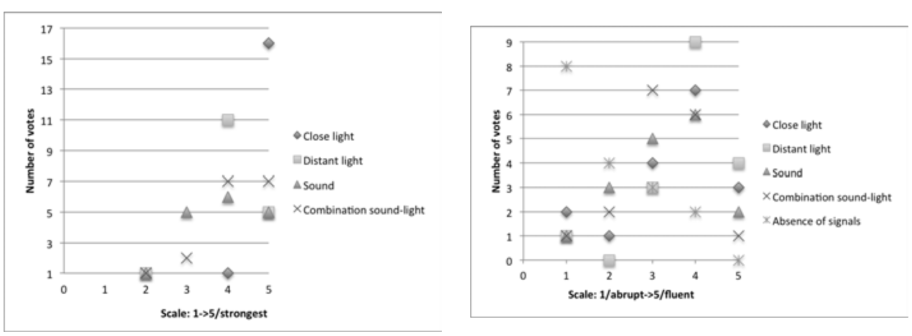
The pre-defined answers in the seventh question were on Likert scale from boring to interesting, familiar to unfamiliar, and unnecessary to necessary. At the end of the questionnaire, we also run a think-aloud protocol where the participants went through the study and described their thoughts.

5.2 Preliminary Results

Here we describe our three hypotheses along with the results of the questionnaire and the think-aloud protocol. The first hypothesis follows:

- *The spatial position of the signal's source influences its perception. A signal close to the user is more easily and faster receipted than a distant one.*

88,24% of the participants stated that the spatial position of the lamp influences its perception. Figure 2a presents the options along the Likert scale. The close light was evaluated as the most easily perceptible signal with 94,12% (scale 5-strongest perception) followed by the distant light with 64,71% (scale 4). That means that the close light raised by far the strongest awareness of most participants compared to the other options, supporting this hypothesis. One participant said that he receipted the light much faster than the sound, arguing that the sound has to be repeated to be more perceptible.



(a) Perception of signals

(b) Transition awareness-communication

Fig. 2: Perception and Transition

- *The signal source, which is close to the communication medium, is better accepted by the users than the distant one. Moreover, the combination of two or more awareness signals is better than a single signal.*

Indeed, most participants preferred the distant to the close light, as the former was proved to distract less than the close one or the other signals (41,18%-scale 2). A statement of the think-aloud protocol was: "the distant light provides a more discreet, background, and pleasant light, compared to the close light." Another participant noted that "it is easy to easy to blend the distant light out", showing that is is up to the user's convenience to enter into communication. The rest of the participants, though, found the distant light distracting, as they had to turn their head to the light source and then continue with the actual task, i.e. to watch the music video and call the investigator.

As far as the second part of the hypothesis is concerned, most participants (64,71%) preferred in general the situation-dependent option (i.e. light or sound) and not the combination of the signals (29,41%). One participant stated "one signal is actually sufficient, as the combination leads to stimulus satiation". While many participants selected "light" as well (the questionnaire allowed multiple answers), remarkable is that only 5,88% selected the sound. Most of the users described the selected sound effect as a "whisper" sound. Someone noted: "you can mistake the awareness sound with another sound or even imagine it, if you hear it often, specially if it is a short sound". They would rather prefer something like an alert tone, a bell sound, or typical mobile phone tones that most people are accustomed to. The fact that that the signal which is close to the communication medium was not as much accepted as we expected might be justified because the close light was very eye-catching and "penetrative" according to the think-aloud protocol. To sum up, the first part of this hypothesis was proved wrong while the second part is partly confirmed.

- Peripheral signals provide a more fluent transition to communication compared to signals close to our visual and/or auditory focus of attention.

Figure 2b presents the questionnaire's results regarding this hypothesis. The absence of signals was ranked as the most abrupt (47,6%-scale 1/most abrupt), whereas through the distant light as the most fluent (52,94%-scale 4). The fact that the distant light distracted less than the close light, as mentioned above, affected also the evaluation of the transition from the awareness to communication state. This shows that the awareness signals are necessary for a fluent transition to communication.

With regards to the heuristics provided by [39], we can deduce from the study's results that peripheral signals, in our case, the distant light, is less distracting and better accepted than the close light; however, the distant one is not as easily perceptible as the close light. As for the match between design and environment, and the aesthetic aspect, the design of the lamp was considered as pleasing, as was said to be a mundane typical lamp. The transition from awareness to communication was more fluent with the distant light, as it was regarded as a "background light". Last but not least, the visibility of state was clear, as the triggered signal per se (be it light or sound) was explicit enough and made the state of the awareness system noticeable.

6 Summary and Future Work

In this paper, we introduced the project SOCIAL investigating spontaneous communication in spatially distributed groups. After a brief survey of related research fields, scenarios illustrating our vision of spontaneous communication and the process to realize them in a distributed setting were described. We presented a formal representation language for ambient intelligence, considering the capabilities of a system and its situational context. Furthermore, we showed how this language can be used to describe and detect specific situations and enable a system to react. As a starting point for our work, we presented a pilot study investigating the rise of awareness for the possibility of communication through visual and auditory signals. The results indicate that peripheral signals are more pleasant, i.e., user-friendly, than signals close to the user. They also provide fluency to the transition state from awareness to communication. On the other hand, close signals are more perceptible.

However promising the presented work is, we are only at the beginning of enabling seamless spontaneous communication in spatially distributed environments. We are working on a prototype system to study different possibilities of the interaction step in the real world with real people. Furthermore, we are looking for further and more complex examples of co-located situations, e.g., including multiple or moving people, containing spontaneous communication and research possibilities to compute respective comparable distributed situation descriptions. Another interesting aspect would be to limit spontaneous communication between specific individuals or groups on purpose for specific times to reduce distractions. On the other hand, we are also studying different technologies and methods to unobtrusively raise awareness and different kinds of communication modalities for specific situations.

In general, it is necessary to look at scenarios spanning more than just two physical locations to understand the potential for strongly distributed work groups. We plan a user study, with another scenario closer to the SOCIAL project (in a coffee lounge), with more fine-grained signals (light patterns, auditory icons, like the sound of the coffee machine), so that we can evaluate better the signals' purpose and usability. The load theory of attention by Lavie et al.[40] will be considered in order to focus on perceptual load and explore effective selective and focused attention in relation to awareness. Also, different kinds of groups should be considered, e.g., family members, friends, or general communities.

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