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Gerfried Mikusch
Matrikelnummer 0425952

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Betreuung
Betreuerin: Univ. Prof. Geraldine Fitzpatrick, PhD
Mitwirkung: Univ. Ass. Dr. Florian Güldenpfennig

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Supporting Social Awareness Across Distributed Work Groups with Interactive Tangible Devices

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Advisor: Univ. Prof. Geraldine Fitzpatrick, PhD
Co-Advisor: Univ. Ass. Dr. Florian Güldenpfennig

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(Signature of Author) (Signature of Advisor)

Erklärung zur Verfassung der Arbeit

Gerfried Mikusch
Kurt-Tichy-Gasse 3/1/27, 1100 Wien

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Abstract

The term 'awareness' in work environments describes knowledge people gain about their colleagues state primarily through passively observing other peoples activities. Through this people stay constantly informed about the presence of others, their current availability, gatherings in common rooms, the emotional state of co-workers as well as about the rhythm and social life within a work group. Awareness is obtained almost effortless in environments were people are collaborating in spatial proximity, but for workers or work groups that are distributed across buildings, cities or even continents such connectedness is much harder to maintain because of missing proximity. Therefore in distributed work environments awareness information can be provided through the support of technology, which is the key objective in this Master's thesis.

For supporting awareness across three distributed work groups of the Institute for Design and Assessment of Technology at TU Wien a system was designed and developed. This system comprises three identical *awareness cube* devices, which are tailored to the expectations of the users and the particular use context of these work groups. The three devices focus on the support of informal and social awareness, since these forms of awareness appear to be the most relevant for the group members to be supported.

The development process of the technology is based on the principles of participatory design where users are integrally participating during the design and implementation of the system. An initial design workshop was conducted to understand user expectations and the particular use context of the system. During the design, development and test phases of the system, ethnographic interviews and surveys were conducted to achieve user participation throughout the entire process. The design process finally resulted in three *awareness cube* technology probes deployed to the common rooms of the work groups, because these public areas appeared to be most suitable for supporting informal exchanges across the distance. The technology probes sense the amount of activity and liveliness in their surroundings through a built-in microphone, transmit the data to their counterparts where this awareness information is presented visually through LEDs on the cubes' sidewalls. The visual presentation of remote activity allows following distant peoples' actions peripherally and therefore the *awareness cubes* were perceived as embedded ambient displays. Additionally the devices support active interaction possibilities through a tangible button interface on the top of the cubes, where users can express overall group moods and actual group activities such as "having coffee/lunch".

A four-week test phase revealed alternative, playful ways of button use through creating colourful patterns with the embedded LEDs or playing TIC-TAC-TOE games. Users reported enjoying following the representations of the remote work groups on the sidewalls and used the activity display not only to stay informed but also as an indicator for possible direct interaction. Here the transition from passively following the activity of others to actively interacting with them was achieved by raising the users curiosity. The system led to conversations about it within and across the work groups, where people talked about the observed activity. Thus the *awareness cube* system managed to facilitate awareness and a feeling of connectedness through its implementation as an ambient display and the possibility for direct interaction through the buttons was a key characteristic for maintaining the connectedness.

Kurzfassung

Der Begriff „awareness“ (deutsch: Bewusstsein) in Arbeitsumgebungen beschreibt Wissen, welches Mitarbeiter durch konstante passive Aufmerksamkeit gegenüber der Aktivitäten ihrer Kollegen erhalten. Dadurch sind Mitarbeiter informiert darüber, welche ihrer Kollegen aktuell anwesend sind, ob diese verfügbar sind, wer sich momentan miteinander unterhalten, aber auch über den emotionalen Zustand der Kollegen sowie über den Rhythmus und das soziale Leben innerhalb einer Arbeitsgruppe. Sind Mitarbeiter einer Organisation jedoch räumlich getrennt und arbeiten in unterschiedlichen Gebäuden oder Städten, ist eine derartige Verbundenheit schwer aufrecht zu erhalten da die unterstützende Nähe fehlt. In solchen Arbeitsumgebungen kann „awareness“ durch den Einsatz von Technik erreicht und gefördert werden.
Im Zuge dieser Arbeit wurde ein System für die drei räumlich getrennten Arbeitsgruppen des Instituts für Gestaltungs- und Wirkungsforschung der TU Wien entworfen und implementiert. Dieses System umfasst drei identische Geräte, welche speziell auf die Bedürfnisse der Nutzer und den Einsatzkontext in diesen Arbeitsgruppen zugeschnitten wurden. Der Entwicklungsprozess folgte den Prinzipien von partizipativem Design bei dem die aktive Teilnahme der Nutzer am gesamten Prozess ein integraler Bestandteil ist. Um einen detaillierten Einblick in die Erwartungen der Nutzer und des Nutzungskontexts zu erhalten wurde zu Beginn des Projekts ein gemeinsamer Design. Weiters wurde mit Hilfe ethnographischer Interviews und Umfragen während des gesamten Prozesses die Nähe zu den Nutzern hergestellt und ihre Teilnahme an der Entwicklung gefördert. Der Entwicklungsprozess resultierte schließlich in den drei *awareness cubes*, die in den Pausenräumen der Arbeitsgruppen zum Einsatz kamen, da diese Umgebung als überaus passend erschien um den informellen Austausch zwischen den Gruppen zu unterstützen. Die Würfel erfassen den Grad an Aktivität in ihrer näheren Umgebung durch ein eingebautes Mikrofon und übertragen diese Lautstärkeinformation zu den Würfeln in den jeweiligen anderen Gruppen wo sie visuell über LEDs an den Seitenwänden aller Würfel angezeigt wird. Die visuelle Darstellung erlaubt es den Mitarbeitern das Geschehen passiv zu verfolgen, wodurch die Geräte als eingebettete Umgebungsdisplays wahrgenommen werden. Zusätzlich unterstützen die *awareness cubes* auch direkte Interaktion zwischen den Gruppen durch eine taktile Benutzeroberfläche in Form von Tasten an der Oberseite der Würfel, durch welche aktuelle Gruppenstimmungen oder Aktivitäten ausgedrückt werden können. Eine vierwöchige Testphase offenbarte alternative, spielerische Nutzungsweißen der Tasten indem Mitarbeiter mit Hilfe der enthaltenen LEDs bunte Muster generierten oder TIC-TAC-TOE spielten. Nutzer berichteten, dass die Repräsentation der Kollegen über die LEDs an den Seitenwänden als angenehm empfunden wurde und neben der kontinuierlichen Darstellung der Aktivität auch als Hinweisgeber für Möglichkeiten direkter Interaktion verwendet wurde. Der Übergang von passiver zu aktiver Nutzung wird hier durch die Neugierde der Nutzer unterstützt. Das System führte zu Konversationen innerhalb von Arbeitsgruppen aber auch zwischen den Gruppen, in welcchen über am Würfel beobachtete Aktivitäten gesprochen wurde. Die *awareness cubes* ermöglichten durch die Präsentation der Aktivitäten ein Bewusstsein über die Präsenz entfernter Kollegen zu schaffen und die zusätzliche Möglichkeit zur direkten Interaktion ist eine Schlüsseleigenschaft zur Aufrechterhaltung dieses Zusammengehörigkeitsgefühls.

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Although a Master's thesis like the one at hand is certainly elaborated individually and independently, there are a some supportive people to name who provided relevant contributions help for getting this thesis finished.

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In particular, I want to thank my supervisor Geraldine Fitzpatrick who was always available whenever things were challenging or somehow unclear and thus specific questions arose and help was needed. Furthermore, she actively supported me through giving advice, providing relevant literature and pointing out recent developments in the research field. Thanks also to Florian Güldenpfennig who accompanied the technical development in this work, gave advice for the choice of components, helped setting up the system and, most importantly, was responsible for the 3D printed parts of the *awareness cubes*. Without his personal engagement the appearance of the devices would not be as nice as it is now.
I also want to thank my colleague Noemi Steitz who worked on the same project before. Her results are a relevant contribution to the commonly conducted design workshop. The planning of this workshop was my first action within this project and Noemi's experiences helped for planning the first steps in my thesis and getting introduced to the community.

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1 Introduction

Almost everyone who collaborates with other people in a work group is used to the noises colleagues make, the smell of freshly brewed coffee coming from the office's kitchen and overhears conversations of colleagues in the hallway. Following the others' activities passively is natural for collaborators and supports various aspects of relationships with a work group. Through passively collecting information about who is around and which people are talking to each other, workers know if their colleagues are currently available, what they are actually up to and how the emotional state of colleagues and the rhythm of the entire group is at the very moment. The peripheral observation of other peoples' conduct and the environmental knowledge achieved by this enables people to actively engage and interact with co-workers more easily. These characteristics of joint work are referred to as "awareness" of other people in a common environment. Bødker and Christiansen (2006, p. 6) describe these subtle activities as traces and breadcrumbs appearing in the background without calling for focal attention but still being perceivable. According to Bødker and Christiansen "awareness takes two actors and a medium, as well as a place to sprinkle the breadcrumbs so they are likely to be found" (2006, p. 6). In the case of co-located workers or workgroups there are many possible places to sprinkle these breadcrumbs, like corridors, kitchens, common rooms or other meeting points, but what if workers or work groups are separated for whatever reason? Then the awareness cues are missing and people cannot generate such knowledge about colleagues when they are working spatially separated in other buildings, cities or even continents. Dourish and Bly's (1992) experiences in awareness research "… suggest that awareness across distance has meaning, that it can lead positively toward communications and interactions, and … that it can contribute to a shared sense of community" (Dourish & Bly, 1992, p. 546). Since in modern working environments workgroups are often distributed, the support of awareness across these groups needs to be provided by technology. Computer-Supported Cooperative Work (CSCW) and Human Computer Interaction (HCI) are the most relevant research fields for investigating the support of awareness through technology. These fields provide valuable contributions and insights into common work practices, interaction among collaborators (CSCW) and the role technology and especially computers play for facilitating interaction between human beings (HCI) (cf. Gross, 2013). These research fields are broad and encompass various perspectives on collaborative work, its support through technology and the design of interactions between human beings and computers or machines. The variety reaches from task-oriented approaches that facilitate the effective accomplishment of particular work tasks over attempts for formally integrating distributed workplaces up to facilitating informal factors of work such as social relationships between co-workers and the rhythm of work groups. The latter perspective on

CSCW and HCI is the subject of this Master's thesis because the support of awareness is closely related to informal social exchanges between people.

Investigating the possibilities of technology for supporting awareness across distance and thereby enhancing social bindings across distributed workgroups on the group level, which means that the relationship on the group basis is the focus and not relationships among individuals, is the main objective of this Master's thesis. Further possible changes in the behaviour of collaborators that are related to the implementation of a particular awareness supporting system are also the subject of this investigation. Following these considerations, two sets of research questions emerged regarding awareness support and a possible behavioural change of users, and these are studied through the scientific approach presented in this thesis.

How does technology with elementary functionalities and interaction possibilities support and maintain awareness between distributed work groups in informal, non-work related settings?

What benefits (or disadvantages) for informal exchanges between distributed work groups can be related to the implementation of such artefacts?

How do noticeable changes in the conduct of the group members occur that reportedly were provoked by the implemented awareness system?

How does the implementation of the awareness system affect the daily routines of the group members in their local common room?

Which follow-up actions are reportedly triggered through the preceding use of the artefacts?

How does the system influence the perception of and relation to the distant groups?

As research field for the investigations within this work, the Institute of Design & Assessment of Technology at the TU Wien appeared to offer a promising environment for a case study since it comprises three distributed work groups. Within each group there is frequent exchange and communication among the colleagues, but there is less contact at the group level besides official meetings and occasional conversations on a personal level. There is a certain requirement for the groups to enhance and support informal exchange for all members at the group level. For developing an artefact that supported social awareness on the group level this work followed the principles of participatory design. Here, the future use not only informed the design of the technology, users, too, played an integral, participating part in developing the technology. The project comprised three major phases: An initial context evaluation where user expectations towards a system were explored; a concept development and implementing phase where technology probes were designed and realized and a concluding evaluation phase where the technology probes were deployed in the work group facilities and used over a period of four weeks.

Before giving an overview on the contents of this thesis' chapters I want to briefly inform about my personal motivation for the work on this project. This motivation is closely bound to my understanding of technology as a user, on the one hand, and as a student of the media informatics Master's program, on the other. In my opinion, the major contribution of technology to the lives of human beings is to provide support and assistance for daily routines. Obvi-

ously, this is done in various ways through complete automation of certain work processes, by designing computer programs and hardware pieces to enable people to achieve tasks faster and more easily, and it also comprises getting people closer together by facilitating communication and interaction processes. Regarding the objective of this project, where social relationships between work groups are the most relevant factor, this means that a piece of technology has to be designed that is embedded into the daily routines of users and the social life at their workplaces. Designing such system requires the designer – me in this case – to take one step back, inviting the users to join the process and focus on their actual expectations and the use context. For my previously outlined understanding of technology it is very motivating to get the chance of being part of the design of technology that serves the purpose of facilitating social bindings. On a scientific level, motivation factors are based on the process itself. Elaborating solutions, analysing collected data is a challenge and often a long and sometimes exhausting process, but seeing the bigger picture becoming clearer until conclusions can be drawn definitely pays back.

This thesis comprises eight chapters starting with this introductory chapter followed by Chapter 2 comprising the theoretical elaboration of valuable contributions in awareness research. The theoretical chapter is about awareness research in CSCW and HCI and starts with an illustration of the benefits of proximity for maintaining awareness of local colleagues followed by a variety of notions of the awareness term such as informal awareness, social awareness, artefact awareness or workplace awareness. The chapter continues with a presentation of relevant scientific approaches and studies in recent history. Two early ethnographically informed studies of awareness in co-located settings are introduced that mark the starting point of awareness research in the late 1980s. Subsequently, a collection of relevant systems supporting awareness across distance on personal desktops and workstations is introduced followed by the presentation of more metaphorical representations of remote people. To link awareness research with recent developments in information technology relevant concepts are presented in the concluding part of the theoretical chapter. Ubiquitous computing, ambient displays and tangible interfaces are discussed in particular because these concepts play a relevant role for the development of the artefacts in this thesis.

Chapter 3 illustrates the scientific methodology and approach taken in this Master's thesis. As outlined above the research took place in three work groups at the Institute of Design & Assessment of Technology at the TU Wien and detailed characteristics of the research field are given in the first section of Chapter 3. The second part of this chapter comprises an illustration of the principles of participatory design, which built the basis for the approach taken in this thesis. For collecting valuable data a selection of mixed scientific methods were implemented, which are introduced in the third subsection of Chapter 3. The mixed methods include a participatory design workshop, ethnographic interviews and surveys. Furthermore, the characteristics of technology probes are introduced and the differences to prototypes illustrated. Thematic analysis for qualitative data is presented and the chapter concludes with an illustration of the actual approach taken, how the research methods were applied in particular, as well as a brief discussion on my role as researcher, reliability and validity of data.

The fourth chapter of this thesis takes the work from the theoretical level to a more practical one by presenting the evaluation of system and use context. Chapter 4 starts by introducing key elements of earlier work in this project conducted by my colleague Noemi Steitz. The conducted participatory design workshop marked the concluding point in her Master's thesis and the starting point of the present thesis. The second section of this chapter presents the results of the workshop, which originated from three different workshop techniques: Storytelling, phrasing questions and generating ideas. The collected data of the workshop, such as audio recordings, photographs and artefacts created by participants, were thematically analysed and the findings from this analysis presented in the final section of Chapter 4. Basically, the findings suggest the design of a technology that is simple, flexible, comprises playful elements, allows users to exchange informal types of content and does not require any effort in use or maintenance.

After having clarified users expectations in the design workshop Chapter 5 reports the resulting *awareness cube* system concept and development. The planning and artefact design of three identical cubic devices for supporting awareness across the distributed work groups is illustrated in the first section of this chapter. The *awareness cubes* are principally designed to serve two purposes. The cubes with a size of about 15 centimetres sense loudness information in their surroundings, transmit this information to their counterparts at the other groups and display the information visually via LEDs on their sidewalls. Thus the cubes act as ambient displays in the periphery of the users' perceptions informing about activities in remote common rooms where the devices are placed. Another purpose is to enable possibilities for direct interaction between users. Thus nine tangible buttons, each housing one LED, were mounted on top of the cubes for expressing current group moods and activities. The concept was presented to the users and after required adaptations to resolve privacy concerns the actual development of the devices began. The second section of chapter five introduces the components used and their assembly, and the third section illustrates the construction process of the devices. Finally, the development of client and server software is the topic of the final two sections of Chapter 5.

Since the *awareness cubes* were deployed to the three work groups after construction and development was finished, Chapter 6 comprises the results of the test phase and system evaluation. First, descriptive quantitative log data from the use of the buttons is presented that shows how the direct interaction developed throughout the entire test phase. Second, the results of ethnographic interviews and paper-based surveys conducted during the test phase are presented. These results illustrate the actual use of the *awareness cubes* and for example reveal alternative, playful ways of use the participants developed in addition to the intended ones. Similarly to the workshop data these results were also analysed thematically and eight basic themes emerged from three iterations of coding. These themes reveal valuable insights on how the design of the devices met the expectations of the users, on the one hand, and the systems ability to support awareness across distance, on the other. The most relevant themes describe the experienced representation of remote groups, possible nudges towards changes in the groups' relationship, users' engagement with the system, as well as aspects of communication, content and interaction.

Chapter 7 provides a discussion of findings from this thesis and addresses several relevant aspects of these findings regarding the scope of this investigation. In the first part of this chapter findings are related to theoretical aspects regarding collaboration, for example, how the system facilitated the establishment of a common ground. The second part comprises a reflection on methods applied in this thesis and illustrates benefits and minor problems occurring during the process. This part is followed by a discussion on results from different stages of the project and, for example, shows how 'effort' turned to 'engagement' between the workshop and the end of the test phase. These reflections on results are followed by the resolution of the research questions illustrated above. How the system supported awareness across distance and conversational activities triggered by the *awareness cubes* are topics of this part. The chapter closes with a discussion of possible contributions of this work to awareness research in general.

Chapter 8, the final chapter of this thesis, comprises conclusions and future work. A brief illustration of the most relevant findings of this thesis are given regarding the *awareness cubes* as a highly tailored system for these particular work groups, as well as more general findings derived from the specific system such as the need for customization and the tension between revealing the identify of users and curiosity of not knowing one's interaction partner. The very last part of the thesis comprises suggestions for future enhancements of the *awareness cube* system, as well as more general possibilities for future scientific endeavours.

The present introductory chapter provided a brief overview of the entire project, comprises an introduction of the term "awareness", the research questions of this thesis, as well a characterization of the research field and my personal motivation. A brief overview of each chapter was given to provide a first taste of what follows in this thesis, and the well-disposed reader will find further details in the appendix at the very end of this work.

2 Awareness Research in CSCW & HCI

The term *awareness* encompasses the knowledge someone gains about happenings in his or her surroundings. These happenings comprise many different sources of information like the weather outside a window, activities of other people and the status of oneself within the environment. Such information facilitates people maintaining awareness of other people, e.g. collaborators, friends, family members, so as to develop an understanding of their presence, availability, social relationships and emotional status. This knowledge finally enables people to interact accordingly with others within a given environment. Gross (2013) remarks that there is no common definition or usage of the term "awareness" and subsequently determines awareness as follows:

> "… awareness is a user's internal knowing and understanding of a situation including other users and the environment that is gained through subtle practices of capturing and interpreting information; and this awareness information partly exists in the environment, and is partly provided by awareness technology." (Gross, 2013, p. 432)

Awareness research has its roots in the field of Computer-Supported Cooperative Work (CSCW), a research field that "… aims to achieve a deep understanding of work and other types of social interaction in groups and communities" (Gross, 2013, p. 425). The CSCW field combines the examination of work and interaction among co-workers with the ongoing development in information technology to identify the potential of emerging technologies for supporting collaboration (cf. Schmidt & Bannon, 2013). Awareness research evolved within the CSCW field because, in addition to task-related support, successful collaboration also needs facilitation of social aspects, which may be more subtle and peripheral but provide co-workers with relevant context information (cf. Rittenbruch & McEwan, 2009). Regarding HCI approaches on awareness support, tailored computer-mediated interaction techniques, through the implementation of automated sensing and presentation by technology, potentially reduce the effort it takes collaborators to sense environmental information (cf. Gross, 2013).

The following sections of this chapter illustrate the terms "awareness" and "awareness research" on various levels. Initially, several supporting factors achieved by simple physical proximity outline characteristics of awareness information that already exists in the environment. Such information is easily retrievable by users and therefore maintaining awareness is almost effortless. The second part of this chapter introduces various types of awareness that support different aspects of collaboration such as efficiency-oriented task support or community-

oriented support of social relationships. To give insights on how awareness can be supported in practice some relevant scientific studies are discussed, ranging from co-located approaches via desktop-based systems to more abstract representations of collaboration embedded in the environment. Since distributed collaborators have to make use of technology to obtain awareness across distance the last part of this chapter presents related concepts in information technology. Ubiquitous computing, tangible user interfaces and ambient media displays appear to be promising strategies for informing the design of awareness systems in general as well as the development of a technology probe elaborated within the scope of this thesis in particular.

2.1 The benefit of proximity

To be able to understand why the support of awareness is an important practice for improving the connectedness of distributed workers, an overview on various supporting factors of physical proximity between co-located workers provides a theoretical illustration of the problem statement of this thesis. People who are working together in an environment that provides close proximity experience multiple awareness- supporting effects that emerge merely through the co-location of workers and work groups. If such an environment cannot be provided – for whatever reasons – computer-mediated awareness support systems represent helpful tools for re-establishing proximity, at least to some extent.

Chance encounters initiate communication

Wherever people work in close contact with each other, communication among co-workers gives rise to manifold possibilities of encounters. People meet frequently in the hallways or common rooms of their workplaces and therefore the effort entailed in initiating conversations through such chance encounters is very slight; it just happens because of the physical proximity of the co-workers (cf. Kraut, Fussell, Brennan & Siege, 2002). This leads to a higher frequency of communication among co-workers and "each communication episode provides the potential for people to learn something new about their partners, make decisions, monitor the state of the work, take correction action, and perform other joint activities" (Kraut et al., 2002, p. 141). Learning more about collaborators, getting to know them better, getting a feeling for their work rhythms are examples of awareness about the shared work context of co-workers, which is mainly provided by physical proximity. But such a shared context among colleagues does not only provide opportunities for meeting, it also supports the development of a shared identity (cf. Hinds & Mortensen, 2005) of the members of a work group through such spontaneous, informal encounters. A strong shared identity within a work group reduces conflicts between group members and the stance towards in-group colleagues is likely to be cooperative rather than competitive (Hinds & Mortensen, 2005, p. 292).

In an earlier study Kraut, Egido and Galegher (1988) examined the influence of proximity on relationships among co-workers in a scientific environment, which is similar to the setting investigated in this thesis. They argue that finding a partner for collaboration, planning common projects, executing research tasks and preparing reports are all processes that require extensive

social interaction. As already mentioned above such interactions between researchers initially arise in a rather informal setting, for example during lunch or coffee breaks. Opportunities for unconstrained interactions promote shared knowledge about the work of others, their personalities and the likelihood of future collaboration. The results of the study show that collaboration among researchers is more likely to emerge when their offices are close to each other and physical proximity supports occasional encounters for starting conversations (Kraut et al., 1988).

Another study conducted by Sarbaugh-Thompson & Feldman (1998) even revealed that the increased use of e-mail communication in an organisation led to a decrease in face-to-face communication. The authors conclude that occasional meetings where people greet each other and hence open a conversation by just saying "Hi" have been suppressed by the intensive use of electronic communication. Consequently, participants perceived a decreased connectedness among the co-workers within a work group (Sarbaugh-Thompson & Feldman, 1998). These findings show that the implementation of computer-mediated communication systems, besides the many positive effects they are supposed to engender, also my have negative consequences for the social relationships within an organisation, such as in cases where chance encounters are suppressed.

A common ground facilitates the communication process

Once a conversation between two (or more) co-located communication partners is established, all the partners are able to make use of the entire common environment as a reference point within the conversation. This means that if someone, for example, is pointing in a specific direction to clarify an utterance, the others can see the object the person is pointing to and can therefore understand this clarification. But not only nonverbal aspects of a conversation like gestures and facial expressions are easier to interpret when people are co-located. The interpretation of verbal expressions like "we have to fix this" also is facilitated by co-presence in the same environmental context. These examples illustrate the beneficial effects of proximity that result from making use of a common ground within a conversation (Kraut et al., 2002, p. 148). Communication partners build their interaction upon a common ground they assume to share, which evolves from the fact that they are members of the same group and therefore share past experiences like prior collaborations, seminars or group celebrations. The common ground comprises not only past experiences and social relationships among co-workers, it also covers special knowledge about work practices like task-related vocabulary or commonly used tools. Physical proximity provides for the development and use of a broader common ground for collaborators (Kraut et al., 2002).

During an ongoing face-to-face conversation, speakers permanently receive multi-sensory feedback from their listeners, which enables the speaker to react to that feedback and readjust some utterances or rectify misunderstandings. The physical proximity of a face-to-face conversation enables the participants to give rich feedback via various channels through their behaviour. Especially turn-taking is facilitated by physical proximity of the communication partners, because handing over or requesting the speaker role is often expressed by a look or a gesture (Kraut et al., 2002).

In their case study on physical proximity in a scientific work environment Kraut et al. (1988) illustrate that the quality of communication (two-way interaction on multi-sensory channels) is an important factor for successive collaboration as well as the low costs of communication processes when collaborators are situated near each other. They conclude that "… proximity supports a convivial personal and working relationship by building a consensus of views and interests and maintaining shared knowledge about the project and about the local culture in which it is embedded" (Kraut et al., 1988, p. 9). These characteristics of personal and working relationships are integral parts of the common ground people establish through co-located collaboration.

Awareness about the local environment obtains social relationships

"… when teammates are collocated, they can passively monitor activities going on around them and pick up relevant information without explicit communication." (Kraut et al., 2002, p. 154) Physical proximity not only supports opportunities for starting conversations by chance encounters and the mutual development of a common ground, it furthermore supports awareness of the context by providing easy access to information about the habits of colleagues, their availability, as well as possible problems with which they have to deal. Kraut et al. (2002) distinguish between task and team awareness.

To gain task awareness collaborators regularly monitor their partners' work progress in order to be able to identify dependencies in their own work or align the completion of a subtask to the partners' progress. By establishing task awareness all collaborators know about the current state of the task although it may be split into several parts that are elaborated by different people.

Team awareness, on the other hand refers to more social characteristics of a team. Through co-located collaboration, the workers have a feeling about the rhythm within the team, the motivation of their teammates, their roles and responsibilities. They can identify more easily if their collaborators need advice for a task, are available for interaction or need silence to be able to work in a concentrated manner (cf. Kraut et al., 2002).

Beneficial effects of proximity illustrate aspects crucial for support across distance

In summary, the opportunities for easily having contact with co-workers, to be able to make use of a common ground within conversations and to gain awareness about the environment are characteristics that are highly supported by the physical proximity of co-workers. These factors also facilitate socially mediated group attractiveness of its members and therefore lead to increased group cohesion (Gebert & von Rosenstiel, 1992, p. 123).

Physical proximity is an important supporting factor for group cohesion and awareness, but work constellations may arise in which the implementation of a supporting technology may either enable co-located workers to grasp information on their surroundings more effectively, or technology is implemented as a substitute for the lacking physical proximity. The first case addresses environments where collaborators are co-located but need to be highly focused on their task and still need to obtain knowledge about their surroundings, such as, for example, air traffic controllers. Here the already given physical proximity can be accompanied by the implementation of a supporting technology to provide additional channels for perceiving information. In the latter case, collaborators are spatially distributed and there is no physical

proximity. In such a constellation communication technology is often the only possibility for supporting group cohesion and awareness. Referring to awareness support through technology Kraut et al. (2002) state the following:

> "The major design challenge is that the information needed to maintain awareness of team, task and environment may overwhelm team members and prevent them from actually doing work. … What is needed are automatic ways of detecting relevant changes to the collaborative state and then presenting these changes to interested parties without overwhelming them." (Kraut et al., 2002, p. 155)

Awareness information is related to several levels and characteristics of collaboration and therefore different types of awareness can be addressed by supporting systems. The most relevant types of awareness addressed in this thesis are presented in the following section to give insights on different understandings of the term "awareness" for facilitating collaboration with different purposes.

2.2 Notions of awareness in collaboration

Over the years, awareness researchers have proposed several types of awareness to address various notions of the term relating awareness to the workspace and its actors, to the tasks comprising a common project, as well as to social relationships among collaborators. Many of the differentiations discussed in the following sections are primarily related to work groups in co-located settings. But since they illustrate important aspects of collaboration within work groups they also demonstrate connecting factors where awareness support and groupware systems may step in when workers are distributed. The following types of awareness are interrelated and overlap, and therefore cannot be seen as monolithic blocks but rather as coherent notions of awareness.

Informal awareness is "the general sense of who's around and what they are up to – the kinds of things that people know when they work together in the same office" (Gutwin, Greenberg & Roseman, 1996, p. 6). The information people collect about the presence of co-workers, their attitudes and rhythms facilitates chance encounters and casual interaction. In co-located settings such background information is gained almost effortlessly by a naturally given physical co-presence (Tee, Greenberg & Gutwin, 2009, p. 677). Gross (2013, p. 432) refers to informal awareness as "coexistence awareness" and describes it "as users' mutual person-oriented information on each other." Many researchers also refer to the effortless perception of environmental background information as "**peripheral awareness**" (e.g. Bly, Harrison & Irwin, 1993; Cadiz, Venolia, Jancke & Gupta, 2002; Pedersen & Sokoler, 1997). The peripheral perception of information provides an overview of the environment without distracting workers from their actual tasks. Hence peripheral (or informal) awareness preserves non-obtrusive guidance and orientation within a group (Gross, 2013). In CSCW informal awareness is supported, for example, through "media spaces" that connect distributed workers through permanent video and audio streams (cf. Bly et al., 1993). An early system based on

media spaces is the *Portholes* system that connects two work groups across different continents (cf. Dourish & Bly, 1992). A more detailed discussion of this system follows in Section 2.3.2.

Social awareness is characterized as "the information that a person maintains about others in a social or conversational context: things like whether another person is paying attention, their emotional state, or their level of interest" (Gutwin, Greenberg, et al., 1996, p. 6). During conversations people constantly get mutual feedback in the way they articulate utterances and by the verbal and non-verbal conduct of communication partners. Such multi-sensory feedback channels enable co-located workers to maintain social awareness (Gutwin, Greenberg, et al., 1996). But social awareness cannot only be obtained in situations in which actual conversations take place and therefore it has to be seen as a supporting aspect of collaboration in a broader sense. For example, Tolmar, Sandor and Schemer (1996, p. 298) characterize social awareness as "… awareness about the social situation of the members, i.e., awareness about what they are doing, if they are talking to someone, if they can be disturbed etc." Addressing the social relationships within working environments Bødker and Christiansen (2006, p. 10) refer to social awareness "as a conscious feeling of belonging, relatedness and care prompted by the environment." People working on common tasks for a longer period of time develop a sense of community and personal relationships with each other. Gross, Stary & Totter (2005) remark that social awareness involves taking on roles and perspectives of others and, besides providing a mutual understanding of each other, it also directs collaborators to follow common goals. Moreover, social awareness makes individual activities transparent and perceivable for others and thus captures social pressure and socially enforced competition (Gross et al., 2005, p. 341). Awareness systems that support social awareness generally gather environmental information about people's activities and habits to provide representations to remote colleagues. As an example, the *Break-Time Barometer*, reviewed in more detail in Section 2.3.3, facilitates common break-taking by indicating activities in public spaces on clock-like devices (cf. Kirkham et al., 2013).

Workspace awareness is maintained by "up-to-the-minute knowledge a person uses to capture another's interaction with the workspace" (Gutwin & Greenberg, 1996, p. 208). This notion of awareness involves actors, tasks and artefacts situated in a workspace as crucial factors for having workspace awareness. Elements and happenings outside the particular workspace are less relevant for this type of awareness, which marks an important distinction to social and informal awareness (Gutwin & Greenberg, 2002). The workspace is interpreted as the environment where several people are commonly executing particular tasks in common, either co-located or distributed. Workspace awareness is awareness about collaborators and their interactions among each other in and with the workspace. People gain an understanding of actions and events taking place as well as artefacts being used for collaboration. Through this up-to-the-minute knowledge about the characteristics of the workspace, workers are able to keep track of the history of events as well as to develop predictions about future actions of their co-workers. Workspace awareness is particularly obtained through bodily actions (movement, posture, position, etc.), the handling of artefacts and conversations among collaborators. Gutwin and Greenberg (2002) identify various effects of enhanced workspace awareness for successful collaboration: A high level of workspace awareness contributes to enhanced

management of coupling, which means that transitions between individual and shared work are smoother. Communication is simplified because the workspace itself is used as an external representation and therefore supports a higher efficiency of nonverbal communication. Furthermore, coordinating actions, anticipating upcoming events, and providing assistance to co-workers is supported through a higher degree of workspace awareness. An exemplary approach to support workspace awareness in shared workspaces of real-time groupware systems is to implement widgets to inform users about the activities of remote collaborators (cf. Gutwin, Roseman & Greenberg, 1996).

Task awareness is another notion of awareness that primarily concentrates on the particular task or project that is divided among several collaborators. To enable each individual contributor to maintain knowledge about the overall status of a group's work, members have to monitor each other's activities to accordingly align their own progress. Constantly following the activities of co-workers furthermore enables people to identify situations when colleagues are available for active collaboration or whether they would rather work individually. Hence, a high level of task awareness facilitates the coordination of workflow between collaborators (cf. Kraut et al., 2002). Kim and Kim (2007) remark that participants in their study on awareness systems required common access to recourses associated with particular tasks. Thus one objective of task awareness systems is to provide possibilities for exchange and common handling of task-related documents. Project management software is an example of a system that supports task awareness (cf. Gutwin, Greenberg, et al., 1996).

Artefact awareness is defined as "one person's knowledge of the artifacts and tools other people are working with" (Tee, Greenberg & Gutwin, 2006). Artefacts include several materials people use for work such as documents, drawings, tools, etc. Awareness about work-related artefacts facilitates monitoring and coordination of activities, triggers the interest of others, indicates the availability of co-workers and creates opportunities for initiating artefact-oriented conversations. While artefact awareness can be interpreted as a component of informal awareness and workspace awareness, it still differs from these types because it focuses on the visibility, representation and handling of artefacts within an environment to provide opportunities of interaction via these artefacts (Tee et al., 2009). Artefact-oriented awareness support is for example provided by the "*Artifact Buddy*" system that represents a shared document as the central part of collaboration via an instant messaging system (cf. Greenberg, Voida, Stehr & Tee, 2010).

In addition to the outlined notions of awareness several other types have been presented within the research field but do not appear as crucial within the scope of this thesis, and are therefore only referenced briefly. **Situation awareness**, for example, refers to the state of knowledge workers need to have to be able handle a complex system like an aircraft (cf. Gutwin, Greenberg, et al., 1996). **Group-structural awareness** comprises information about the organisational characteristics of groups, such as roles, status and responsibilities (cf. Gross et al., 2005). Regarding the problem statement of this thesis the characteristics of informal and social awareness appear to be most relevant to inform the design of a technology probe introduced in Chapter 5.

In the subsequent sections various awareness systems are reviewed ranging from early attempts in co-located settings via desktop-based systems for distributed awareness support up to metaphorical and artful representations of remote activities. The presentation of different approaches to the topic provides a deeper understanding of how the types of awareness are informed in practice by actual systems.

2.3 Scientific approaches to awareness support systems

Within the research field the term "awareness" addresses various aspects of the work environment. Whereas early approaches supported awareness in co-located settings and of highly demanding tasks, distributed workers often receive support via their personal desktop computers because a PC already encapsulates possibilities for collecting data, transmitting this data and displaying awareness information on the screen of a distant colleague. Systems that tend to focus on social relationships within a work group often make use of the common environment itself to gather data and present information directly in common areas. The subsequent sections follow this path and introduce different approaches of awareness systems to support collaboration as well as social relationships.

2.3.1 Early ethnographic studies in co-located settings

Two significant explorations can be identified as principal roots of awareness research. These studies mark the earliest examinations where technology-mediated work support does not solely focus on individual task support, but rather identifies that mutual awareness about the co-workers' activities and their social interactions provide important information sources for a successful collaboration (cf. Gross, 2013; Rittenbruch & McEwan, 2009). Both studies investigate the social character of cooperative work in different real-world settings. The work practices in the London Underground line control rooms were examined by Heath and Luff (1992), and the interaction between air traffic controllers was the subject of the second study by Bentley et al. (1992). The results, as well as the implications of both approaches, are summarized in the following sections.

Collaboration in the London Underground line control rooms
Heath and Luff (1992) found that prior contributions about technologies to support cooperative work do not address the social interaction that takes place in a work environment to a sufficient extent. They identified a "… gap between the naturalistic analysis of collaborative work in a real world setting and the design of technology to support CSCW" (Heath & Luff, 1992, p. 70). Heath and Luff attempted to bridge this gap by a sociological analysis of work practices, collaboration and task coordination in London Underground control rooms to inform the design of technology to support cooperative work. The data for the analysis was gathered by ethnographical methods such as video recordings of real-world work practices, field observations and interviews.

At the time of the study in the early 1990s, the setting in a typical control room of the London Underground was as follows: A line controller and the Divisional Information Assistant (DIA) shared a workplace in the form of a semi circular desk with various tools like telephones, CCTV[1] screens, a radio system, etc. Next to the controller and DIA, on a similar desk, signalmen had their workplace. In front of the two desks there was a fixed line diagram perceivable for the entire crew. While the diagram showed the real-time traffic movement a paper-based timetable was used to coordinate the traffic flow. Necessary adjustments to the timetable were marked on coated pages by the controller as well as by the DIA and communicated to the signalmen and others. These activities were undertaken in very close collaboration and relied on the possibility of a flexible division of labour to manage the challenging tasks and occurring crises; therefore the study focused on the mutual interaction between the controller and the DIA.

Both of them overheard the actions and conversations of the respective counterpart while they were engaged in completely different individual tasks. Still the DIA for example overheard conversations of the controller with the driver of a train and set actions without explicitly talking to the controller, even without waiting until the controller finished the call to the driver. Through surreptitious monitoring the collaborators were able to set conducts without explicit coordination, solely relying on the peripheral observation of the other's activities and the common availability of information displayed on the line diagram and CCTV screens. Heath and Luff (1992, p. 81) characterise these objects to be "… carefully designed to encourage a particular form of co-participation from a colleague, but rarely demand the other's attention. They allow the individual to continue with an activity in which they might be engaged, whilst simultaneously inviting them to carefully monitor a concurrent event." However, only through the interplay between the socio-interactional practices of the DIA and the controller, like monitoring each other's conduct or the implicit coordination of information, could the available technology unfold its supportive character.

Heath's and Luff's (1992) findings reveal that the tacit knowledge about the other's conduct is an integral part of the successful accomplishment of the individual task, but they also note that mutual awareness in this setting is harder to achieve when more collaborators, such as additional signal assistants, also have to be implicitly addressed. Since the controller and the DIA grasp the information about changes to the timetable peripherally and subsequently sketch this information into their own timetables, Heath and Luff suggest making the changes to the timetable immediately available for all collaborators. To achieve this they envision a screen to present the timetables accompanied by electronic pens to allow changes to be made them, so that adjustments to the timetable would be conducted in a similar manner as before – individually and independently - but would become mutually available for the crewmembers. More generally Heath and Luff (1992, p. 91) conclude that "… to facilitate individuals mutually to monitor their co-participants, technologies have to support a 'seamlessness' between public and private activities."

1 CCTV: closed-circuit television; used for video observation

Interface design for air traffic control

The second fundamental study to mention in terms of awareness research is the ethnographic examination by Bentley et al. (1992) on the work practices of air traffic controllers with the aim to inform the interface design of a reactive flight database[2]. Similarly to the previous study, an ethnographic approach was chosen to obtain deep insights into the real-world work practices of air traffic controllers because it was important to have an understanding of their actual work practices rather than of formal ones (Bentley et al., 1992, p. 123). One relevant constraint within this setting was that altering the interface of the database must not lead to major changes in work practices, because of expensive retraining and the complexity of tasks. Since prior attempts for a redesign of the interface failed because they were conducted primarily from a technical perspective, within this study the various aspects of the cooperation between the air traffic controllers are taken as the main contribution to inform the design of the interface.

The London Air Traffic Control Centre (LATCC) comprises 8 radar suites where each one is responsible for one or more radar sectors. Each suite is equipped with radar screens and communication facilities for calls to aircrafts and other radar suites provide a workplace for the chief controller, two radar controllers and two assistants. Besides the real-time information on the radar screen, paper-based flight strips are used by the controllers as a representational object for an aircraft. These flight strips carry several pieces of information about a flight such as the flight number, aircraft identifier, source and destination, heading, current height, airspeed, etc. (Bentley et al., 1992, p. 124). The flight controllers organize the flight strips on a flight progress board and thus obtain – together with the information on the radar screen – a detailed overview of the actual state of the sector.

Although each member of the crew in the radar suite has his/her own responsibilities and tasks to fulfil, the ethnographic study by Bentley et al. (1992) revealed integral aspects of teamwork within the practices of the crew. Since the controllers need to be highly concentrated on the task, collaboration cannot always be carried out by the explicit exchange of information. Rather, the controllers develop a tacit knowledge about what is going on in their radar suite, and thus about the conduct of their collaborators. The flight strips, especially, support this awareness about the local environment because they are used as a shared notepad by the entire crew of a radar suite and so illustrate the flow of actions that have been taken. Bentley et al. (1992, p. 127) identified that

> "… the actual performance of some manual activities, such as writing on the strips, manipulating them in the racks, coordinating by telephone with adjacent suites, and more, serve to keep the controller, and other members of the team, 'geared into' the work."

For example the checking of the information on a strip, as it comes out of the printer, and the manual placement of the strip on the rack mark important activities in terms of safety because through these manual actions potential problems can be identified early. One main objective in software development is to automate manual labour, but here the ethnographers studying the practices of flight controllers discovered that some manual activities are very critical for the successful elaboration of a task. Bentley et al. (1992) present two main findings of their

2 "A reactive data base is a data base where the information is continually updated either from external sensors ... or from concurrent inputs from different users." (Bentley et al., 1992, p. 123)

ethnographic study: Firstly, the conjunction of ethnographers and software developers gives both parties insights into the respective research field of the other and therefore supports the design of an interface that, on the one hand, fulfils the system requirements and, on the other hand, respects the actual work routines of the practitioners. Secondly, the manual intervention of objects can be an integral part of the implicit cooperation between co-workers and therefore should be retained by system design rather than replaced.

Findings from co-located settings inform awareness support across distance
The presented ethnographic studies by Heath and Luff (1992) and Bentley et al. (1992) reveal that implicit awareness about the work context and the activities of co-workers is an integral part of work environments were collaborators have to resolve time and safety critical tasks that require highly focused attention. The studies also showed that ethnographic examinations provide a detailed understanding of the actual work practices and how collaborators establish mutual awareness through implicit conduct. Whereas strong context awareness supports co-located collaborators in the accomplishment of highly demanding tasks, awareness support for spatially distributed co-workers serves slightly different purposes. When people are collaborating across distance, techniques have to be found that re-establish proximity on various levels. Therefore technology-driven awareness support systems provide task information across distance and contribute to a common understanding of the progress of tasks and relationships among distributed collaborators, which is the topic of the following section.

2.3.2 Activities of distributed collaborators on the personal desktop

Numerous scientific studies have been conducted in recent years to propose awareness support systems for the personal desktop. It would exceed the scope of this thesis to give an entire review of studies within the research field. Hence, a selection of examinations is presented that appear relevant to the problem statement of this work because they illustrate common design principles as well as different notions of awareness.
Major advantages of desktop systems are that there is no necessity to leave the workplace and the personal computer of office workers can be exploited to exchange and display information. Such systems that directly present awareness information in a limited space – the screen of a desktop computer - where the main task of the user is to do work, primarily support awareness about particular tasks or artefacts and also provide communication possibilities. Since the majority of these systems provide a connection between personal workplaces, the representation of an overall group status that also includes other areas of the environment appears to be a less important goal for such desktop-based systems. The following section introduces five distinct approaches to awareness support on the personal desktop followed by a short comparative analysis of the presented systems.

Awareness Widgets for real-time collaboration on shared screens
Gutwin, Roseman et al. (1996) investigated the use of awareness widgets on a shared screen, where participants worked together in real time on similar tasks. In addition to the main view of a groupware system that presented the common workspace, several widgets are introduced to support awareness about the co-workers' activities on the screen. A miniature view gives an

overview of the entire workspace –the main view only shows a clipped section of the entire workplace – and provides information on changes made by a collaborator in a different section. A radar view also displays the entire workspace but gives information about the other's location and the section of the workplace the collaborator is actually working on. In contrast a 'what you see is what I do' (*wysiwid*) view only shows the immediate context around the co-workers cursor and therefore provides detailed information about the other's interaction. Besides these single widget windows further widgets were applied to the main view window. 'Telepointers' show the position of a co-worker's curser and a 'teleporting' feature enables the user to easily observe the other's section. To provide additional information about the location of the colleague's actions within the workplace multi-user scrollbars accompany the personal scrollbars in the main view (Gutwin, Roseman, et al., 1996, p. 260). Although the system was tested in a side-by-side setting where the participants were able to talk to each other but did not see each other's workplace, the awareness widgets appear relevant to mention because they illustrate possibilities of how to implement awareness support in particular parts of a personal desktop, like multi-user scrollbars. For distributed settings, the system could be applied in conjunction with telephone calls or instant-messaging features to enable direct communication.
The study with nine pairs of participants revealed that especially the radar view and the miniature view were frequently used because they provided two benefits for the accomplishment of the task: On the one hand, they assisted the completion of the individual task and, on the other hand, gave additional information about the other participant in the workspace. Whereas the radar window provided a good overview of the entire workspace the representation in the *wysiwid* view was hard to interpret by the users because the animation was not smooth enough and therefore the detailed actions of the co-worker were hard to follow. Similar interpretation difficulties were reported for the multi-user scrollbar. Since the mental workload of integrating the information of the two axes was left to the user, the radar view was perceived as easier to interpret because the information about the other's location was already integrated by the system. In general, the majority of the users judged the radar view the most valuable addition to the groupware system (Gutwin, Roseman, et al., 1996, p. 263).

Informal representation of remote colleagues via sidebars

The desktop-based groupware system *Community Bar* developed by Romero, McEwan and Greenberg (2007) supports informal awareness and provides casual interaction possibilities for small groups[3]. The system is implemented as a sidebar on the screen of a personal computer and provides various pieces of information about so-called 'Places', which can represent different commonalities of collaborators like organisationally formed work-groups, task-related teams, or just an office or workplace. Although *Community Bar* represents a sidebar and therefore is positioned in the periphery of the screen it supports multiple sources of information and interaction techniques via so-called media items. These media items represent people as a video stream or photo of their workplace, public conversations as chat dialogues and several other group artefacts like web pages. A collection of media items, presented as tiles grouped as places, finally shapes the sidebar on the screen. Since space on the screen is very limited

3 Community Bar was tested in a field study of two groups consisting of 15, respectively 17 people (c.f. Romero et al., 2007, p. 91).

and primarily used for actual work tasks the size of the tiles is rather small but if something attracts the user a *Tooltip Grande* provides a larger presentation. Via a click on a *Tool Tip* the full view window opens and enables the user to fully engage with all features of the system (Romero et al., 2007, p. 90).
A field study with two user groups revealed, for example, that the transition from the periphery to the focus of attention is very critical. Changes have to be displayed clearly to be perceivable by the users but in a way that users are not disturbed or distracted. Additionally, if an event attracts the user's attention the information and interaction possibilities of the different views (tile, tool tip and full view), should actually become richer from stage to stage. Peripheral users – people who were not part of the core group – had difficulties in keeping the rhythm of the others because of the rather explicit communication among the core group members and therefore they reported feeling like outsiders. Overall Romero et al. (2007, p. 98) reason that the system cannot completely replace real-world richness in co-located settings but still is a valuable contribution to preserve aspects of group culture over distance.

A comparable approach to the support of peripheral awareness through the use of sidebars on the personal screen is represented by "*Sideshow*" (Cadiz et al., 2002). Although this system first of all provides awareness information about the individual tasks and schedule, instant-messaging services have been incorporated to provide information about other people's states, as well. Colleagues are represented by a static image and additionally their availability on *Windows Messenger* is indicated as well as their calendar for the day. Users of *Sideshow* reported that it is a benefit to have relevant information presented directly on the screen and they can therefore stay aware of information without giving up the focus on the main task. Nevertheless, users also noted that especially the notifications were experienced as distracting and demanded focal attention too intrusively (Cadiz et al., 2002).

Single line messages to inform people about common issues
The text-based messaging system *Tickertape* presented by Fitzpatrick, Parsowith, Segal and Kaplan (1998) supports awareness through displaying content from various information sources in one single line on the screen. These sources can be bidirectional chat messages between group members to support awareness among collaborators as well as unidirectional subscriptions to a newsfeed to support awareness of events and activities. *Tickertape* is based on the notification service *Elvin* which provides publish/subscribe functionality to enable the user to receive messages provided by the systems instead of having to collect the desired information manually (cf. Fitzpatrick, Kaplan, Mansfield, Arnold & Segall, 2002). To allow its users to distinguish between newer and older messages a time-out filter was implemented to fade aged messages into grey and finally let them disappear (Fitzpatrick et al., 1998). The single-line design of the messaging systems leaves enough space on the screen to enable the user to focus on the actual task at hand while still providing relevant information in the periphery.
Conducting a user study Parsowith, Fitzpatrick, Kaplan, Segall and Boot (1998) identified three major uses of tickertape: work, social activities and leisure. To support the accomplishment of actual work tasks *Tickertape* became an additional, lightweight communication channel for its users. Where setting up an e-mail to quickly obtain an answer to a question required some effort, *Tickertape* was perceived as a better tool for quick interactions. In terms of supporting

social interaction, *Tickertape* was reportedly useful for organizing informal meetings for lunch or coffee breaks among its users. For leisure, the system was used to display new or sports results (Parsowith et al., 1998). People subscribed to newsgroups for work as well as for leisure or entertainment reasons but reported spending less time just browsing the internet because of the practical subscriptions in *Tickertape* (Fitzpatrick et al., 1998). In summary, especially the lightweight design of *Tickertape* and its possibilities for organizing general groups contributes to a sense of community and cohesion.

Artefacts as central element of instant messaging

Greenberg et al. (2010) present "*Artifact Buddy*", a system that aims to support awareness of shared artefacts. Instead of the other awareness systems where interpersonal connections are most commonly addressed, this system puts digital artefacts like text documents or pictures as central objects of interest for collaboration. This is basically achieved by interpreting a document the same way a user – buddy – is represented in an instant messaging service. To achieve this Greenberg et al. (2010) implemented an extension of the *Microsoft Live Messenger* because it provides typical instant messaging (IM) functionality and it has a public API[4]. One team member acts as host and therefore is responsible for setting up the shared document, creating an IM account for it, loading the document file into the system and inviting the other collaborators to join an IM group on this document. Once set up, *Artifact Buddy* provides information about the host's editing activities, a chat dialog box for conversations about the task and enables the group to create different versions of the document. Via special commands users are able to retrieve the different versions of the document as a history of actions including the chat protocol. Group members are able to indicate that they are currently working on the document or, for example, requesting control by typing a particular sequence on the chat console, which is done automatically for the host account. By handling a document as IM Buddy and providing characteristic features, a work group is able to monitor the progress of the others and to coordinate joint activities. Making collaborative actions accessible then gives information about the availability of the artefact and colleagues, and interest is triggered by seeing the others' actions (Greenberg et al., 2010, p. 1).

Long-distance representation through video streams

The two distributed work groups of Xerox EuroPARC in Cambridge, England, and Xerox PARC in Palo Alto, California, were connected by the *Portholes*[5] system to establish a sense of community across a large distance (Dourish & Bly, 1992). The *Portholes* system consists of a group of servers that distribute the data to client interfaces running on the users' personal workstations. The typical client window comprises images of the remote colleagues, their workplaces and other sites of the environment, like common rooms, that appear to be supportive for facilitating group awareness. These images displayed in the client interface are accompanied by various other properties like the name of the co-worker, the room number,

4 Application Programming Interface. A set of routines and tools provided by the developer of a service to allow third-party extensions.

5 Although common areas of the work environment are part of the Portholes system, the information is mainly presented on the personal screens and therefore is discussed within this section while more public representations of work groups are addressed in the following section.

or an e-mail address, which additionally gives users the opportunity to directly send e-mail via the *Portholes* window. *Portholes* encompasses three different clients: A basic client displays a selectable number of sites and the corresponding properties. Another client provides the possibility to attach audio snippets to the images and send them to the remote colleagues. A third version is intended for implementation in public areas and therefore only displays images of such places; offices are not shown with this client. Messages within the *Portholes* system are either broadcasted, and therefore available for all users, or directed by specifying a particular recipient.

Users of *Portholes* reported liking the ability to actually see the remote colleagues and their environment. People working late at night or at weekends found company at the remote site through *Portholes* and thus felt less alone in their offices. Due to the time difference people at PARC, California, were pleased to see the sun rise in England and watch the start of the day there. Besides these positive responses, users also referred to shortcomings of the systems. The performance of the data transmission was rather bad and people had to wait for new images for quite a long time, which negatively influenced their motivation to use *Portholes*. Users also reported that the window of the client was too large and took up too much space on the screen to enable them to continuously use the system. But despite these shortcomings users experienced a higher level of connectedness and shared community with their remote colleagues supported by the use of the *Portholes* system (Dourish & Bly, 1992).

The presented desktop systems support awareness on various levels

These awareness systems for the personal desktop provide information about collaborators on various levels. The awareness widgets support real-time collaboration by informing the partners about the others location on the shared workspace as well as giving detailed information about current activities (Gutwin, Roseman, et al., 1996). The community bar comprises several media items like video streams, chat messages or websites to represent the activities and commonalities within a work group (Romero et al., 2007). *Tickertape* uses a single line to show chat messages as well as information from news feeds (Fitzpatrick et al., 1998). The *Artifact Buddy* provides chat possibilities and editing indication around a shared document (Greenberg et al., 2010) and finally the *Portholes* not only transmit pictures of co-workers over large distances, but also represent further information like e-mail addresses (Dourish & Bly, 1992). The comparison of the approaches reveals, that each system uses multiple sources of information to support awareness. Either one channel is used as the main contribution and enriched with further information or many sources are subsumed to accordingly represent the collaboration environment. Referring to this Romero et al. (2007, p. 94) state that "in a collocated physical environment, people use a wide array of rich awareness and interaction channels …" and conclude that "… CB's rich information and communication channels match expectations of increased awareness and interaction." The results of the studies clearly show that applying the characteristics found in co-located settings by providing awareness information from various sources to distributed collaborators, contributes to the establishment of a common ground and therefore a shared sense of community, at least to some extent, despite spatial distance.

The way these different sources of information are presented on the user's screen is very similar in most of the systems. Since users need to concentrate on accomplishing their main

tasks, awareness information is usually displayed on the periphery of the screen, via sidebars (Romero et al., 2007), small windows (Gutwin, Roseman, et al., 1996) or single lines (Fitzpatrick et al., 1998). A system that did not follow this pattern – *Portholes* – has been criticized by its users referring particularly to this point because the space on the screen is too limited to display application windows needed for personal tasks and relatively large windows to follow the activities of remote colleagues (Dourish & Bly, 1992). The common conviction to present awareness information in the periphery is illustrated by Romero et al. (2007, p. 92) as follows: "… while an informal awareness and casual interaction system should constantly display awareness information, it should do so in a way that attracts attention at only the right times." Analysing the various levels on which mutual awareness is beneficial for co-workers, the reviewed approaches show differences in the aspects of shared commonalties they address. Awareness widgets (Gutwin, Roseman, et al., 1996) provide their users real-time information of a commonly used virtual workspace, hence supporting workspace awareness (Gutwin & Greenberg, 1996, p. 208). A different notion of awareness is supported by *Tickertape*, where the single-line system primarily focuses on the tasks people have to accomplish and the artefacts they use for work (Parsowith et al., 1998, p. 139) and therefore facilitates task awareness as Kraut et al. (2002, p. 153) defined it. The support of artefact awareness is the main contribution of the *Artifact Buddy* system, which provides mutual awareness about joint work on a shared document (Greenberg et al., 2010). Another form of awareness – social awareness – is supported by the *Portholes* system because it not only provides information about the personal workplace and common tasks, but also illustrates activities in common rooms or outside views (Dourish & Bly, 1992). Therefore, it contributes to the support of social relationships among distributed collaborators.

Subsuming this review of desktop-based awareness systems, common design principles like the distribution of a broad variety of information from different sources and presentation in the periphery of the screen could be identified. Furthermore it could be shown how different forms of awareness, presented in Section 2.2, are addressed by different systems. Since the *Portholes* system provides additional knowledge about commonly used places of the environment it marks an appropriate transition to the following section where awareness systems are introduced that concentrate on the support of social awareness on a group level and therefore somehow are embedded in common areas of the environment.

2.3.3 Metaphorical representations of distant people

The presentation of awareness information regarding social relationships among group members somehow may be integrated into the environment instead of solely connecting people via their personal desktop computers. Collaborators regularly make use of common areas within an organisation, meet each other there and start informal conversations. Therefore it appears to be promising to retrieve data about these habits and represent them in some way in offices of co-located as well as remote workers, or to indicate activities of colleagues directly in common areas. Since the presentation of personal information in public areas is always confronted

with privacy concerns many approaches choose to transform data into metaphorical, abstract representations of people's activities.
The following section presents a selection of four studies that introduce different ways of representing people in different settings metaphorically. Although not all approaches connect remote workers and not all primarily concentrate on work environments, they still provide valuable contributions to this thesis in the way they address the particular problem setting.

Informal content of personal activities presented on large screens
Supporting social awareness via an intelligent large-screen display placed in the staff room of an academic department is the objective of the *Panorama* awareness system developed by Vyas, Nijholt, Eliëns and Poelman (2011). *Panorama* displays non-critical, non-work related content of co-workers' everyday lives, like personal images, videos or text messages. Additionally the system collects information about the surrounding environment through a camera, microphones and motion sensors to gather data about the amount of current activity within the department. The collected information stemming from nine distinct channels is presented via two display panes, a vertical and a horizontal one. This arrangement provides the feeling of "walking through a corridor" (Vyas et al., 2011, p. 2). The movement and liveliness of the presentation is oriented on the activity in the surrounding and comprises three levels. The more lively the environment, the faster the speed of the visuals and in this way the rhythm of the work group is represented on the *Panorama* display. Through the collection of two different types of information, personal content and automatically retrieved activity information, the system utilizes two aspects of social awareness. Self-reflection explicitly illustrates the members' individual contributions and casual encounters are implicitly initiated by the presentation of ongoing activities. *Panorama* was designed to provide a sense of community as an ambient display in the background but also to support chance encounters and become a topic of discussion and therefore move to the centre of attention (Vyas et al., 2011).
The analysis of a user study revealed different types of content posted to the system. People submitted casual yet still work-related pictures like photos of conference visits, humorous images of staff members, or pictures from old times. Besides these work-related images, some users handed in more private pictures like photos of their pets, funny clips or content related to personal hobbies. Text messages, though, were mainly used to communicate work-related content, like official announcements. The placement of the screen in the staff room of the department stimulated the curiosity of the staff members about the displayed pictures of others. They wondered who and what was shown on a picture and started discussing them during common lunch breaks for example. Through such discussions and additional textual announcements people learned more about the current activities of the department and about the personal activities of their colleagues. The content on the *Panorama* display certainly initiated conversations among the staff members and especially pictures of common activities from the past facilitated communication about such memories. Subsuming these results Vyas et al. (2011, p. 8) conclude that "Panorama provides a window into the unexamined background of sociality of workplaces, and novel perspectives on workplace rhythms and tasks."

Motion and scent connecting distant people

Strong and Gaver (1996) introduce three different approaches that support simple and expressive interaction possibilities and connect remote people through abstract representations. The first system, called *Feather*, connects travelling people with their relatives at home by signalling the travelling person's attention through representational objects. The travelling person carries a picture frame as a communication object and every time the traveller is holding the frame a signal is sent to a corresponding object at home. There, a soaring feather in a cone-shaped enclosure represents the incoming signal from the partner. A fan at the bottom of the enclosure controls the movement of the feather. By holding the picture frame the travelling partner explicitly expresses that he or she is thinking of the other one and the feather represents this in an abstract and lightweight manner (Strong & Gaver, 1996). The second approach, *Scent*, is quite similar to the first one. The travelling partner still uses a picture frame to indicate thoughts but on the other site, a bowl filled with essential oil is used to represent the remote person. This bowl is heated when the picture frame is held, thus the essential oil is vaporised and leaves a pleasant scent in the environment. The advantage of this system is that the representation of the remote person persists for a longer period of time and therefore it is more unlikely to miss the expression conveyed by the travelling partner (Strong & Gaver, 1996). The *Shaker* system comprises two devices that can be carried around by partners, friends or relatives to exchange tactile gestures. If one object is shaken the activity is transmitted to the other object in real-time and causes the receiver to shake proportionally. The aim of this approach is to encourage entertainment and lightweight exchanges among well-known people. Strong and Gaver clearly differentiate their designs from other more task-oriented awareness systems and note that "awareness can be seen as a process of picking up largely non-symbolic information that is not predictable nor clearly related to any particular goals" (Strong & Gaver, 1996, p. 30). The design of these systems addresses the exchange of moods and emotions to facilitate social relationships rather than the transfer of rich information used to accomplish tasks.

Artful representation of group activity on ambient displays

The *Hello.Wall* awareness system shows various types of information via light patterns on a wall-sized ambient display and therefore is characterized as informative art (Prante et al., 2003). The display contains 124 cells each comprising LED clusters to present information as well as short-range RFID transponders at each cell to connect to supporting *Personal Aura* artefacts. These artefacts can be configured to hold various sorts of information about the carrying person such as mood or availability (Röcker, Prante, Streitz & van Alphen, 2004). Additionally handheld *ViewPort* devices can be used to interact with the wall and retrieve further details of the presented information. In the lower areas of the wall, long-range readers are built in to recognize the users distance from the display and to present information according to three distinct interaction zones. When people are not in the range of the sensors the system is in the ambient mode and shows general information that is not related to an individual user. If someone is recognized within the notification zone, and thus is relatively near to the wall display, personal identification patterns according to the current setting of the *Personal Aura* artefact and/or notification patterns consisting of personal signs are presented, which are only known to the related person or a work group of which the person is part. To directly interact

with one of the 124 cells users have to come closer to the wall and enter the cell interaction zone. Individuals are able to create public and private codes and 'leave' them on the wall to be discovered by co-workers or visitors. In the ambient mode the system, for example, displays information that is captured from conversations and re-mapped to light patterns appearing as an atmospheric decorative element of the environment. For members of an organization the closer interaction zones provide possibilities for exchanging and exploring information through secret visual codes that only their colleagues may be able to decode. The objective of this system is to provide an ambient artful display that enriches the environment and furthermore supports team building and coherence among the members of the organisation (Prante et al., 2003; Prante et al., 2004).

For an evaluation *Hello.Wall* devices were deployed in the common rooms of two distributed work groups and the group members were equipped with *Personal Aura* artefacts and *ViewPort* devices. The walls gave an ambient representation of the activities in the remote environment when no one was close enough to enter the interaction or notification zone. If a collaborator entered one of these zones both walls indicated the presence of the person by overlaying the ambient display with a personal identification pattern that could be perceived peripherally. Users on the remote site were able to send a request for interaction via the *ViewPort* devices, for example, to have a video connection to their colleagues, which also was indicated by a particular pattern on the wall. The results of the evaluation show that it did not took long for users to memorize the different patterns. The participants also characterized the *Hello.Wall* as a good means of communication with their remote colleagues, which provided a pleasant informative representation of the ongoing activities at the remote environment (Streitz et al., 2005, p. 8).

Informing co-workers about break-time habits

The *Break-Time Barometer* system developed by Kirkham et al. (2013) informs collaborators about ongoing activities in social areas of the environment and therefore supports the coordination of collective breaks. The system comprises various sensors embedded in commonly used areas of the workspace to collect data that gives an indication of possible gatherings of colleagues. Power sensors are for example attached to kitchen devices such as a coffee machine or a microwave to recognize their activation. Environment sensors detect human activity within a proximity of about three metres by collecting data from a light sensor, a microphone, and from temperature and humidity sensors. Besides this automated data retrieval, users are able to deploy messages to the system via SMS or a mobile web app to manually indicate that they are taking a break and/or to actively invite colleagues to join them. To present the break-time information to users Kirkham et al. (2013) deployed a series of static devices in the shape of table clocks with a touch screen as the clock face in the offices of the work group members. The screen displays the history of the measured sensor activity so as to enable users to identify ongoing breaks as well as the most popular times for breaks. In addition to such peripheral indication of activity the system uses the activation information of the kitchen devices to display alerts about currently ongoing breaks on the clock face. Messages submitted by other users are displayed in a similar fashion on the clock and may inform the participants about future activities.

The *Break-Time Barometer* was tested during a period of two weeks in a research group with about 70 members in total. In interviews, users agreed that the clock design was experienced as appropriate and pleasant, but some were not able to clearly identify the different data sources. They linked the indicated activity mainly to the loudness level in a particular area and were less aware of the mixed collection of sensor data. Nevertheless, users reported regularly pursuing activities by clicking through the individual areas. Especially the dual functionality as clock and activity display was experienced positively because by glancing at the clock the participants were able to retrieve further information about the break-time activities. Although the idea was to support collective break-taking among the participants, some used the system in an opposite way to identify inactive places for taking a calm break. Since participants requested additional information about the observed area, such as who actually takes a break and what is discussed there, Kirkham et al. (2013, p. 81) recommend combining the general information about break times with possibilities for more detailed social connectedness.

Advantages and commonalities of these abstract embedded approaches

Similarly to the previously discussed desktop-based awareness systems the approaches presented in this chapter also provide awareness information on the periphery of perception to avoid distraction from current activities and additionally give possibilities for active, focused interaction. The *Hello.Wall* achieves this through the implementation of different interaction zones depending on the distance from its users (Prante et al., 2003), while the *Break-Time Barometer* distinguishes different levels of presented information regarding richness, where the lowest level just gives an indication of possible gatherings and the highest level displays actual invitation messages (Kirkham et al., 2013). Such smooth transitions from a peripheral observation of an occurring activity to direct engagement become a crucial factor for successful awareness systems because once a peripherally perceived change heightens a user's attention the system ought to be able to provide possibilities for more actively discovering the origin of that change.

In contrast to desktop-based awareness-support approaches, the systems introduced in this section are somehow embedded into the environment itself, and therefore present the retrieved information in an abstract, almost artful manner. Since the main objective of these systems is to illustrate the rhythm of a work group so as to enhance community building and group coherence, primarily by addressing the social relationships between collectively working individuals, the task-related exchange of rich information may be neglected, opening up creative ways for presenting the collected sensor data. Especially the *Feather* and *Scent* implementations by Strong and Gaver (1996) show how technology-driven awareness systems support social, emotional connections among people through abstract representations. Another beneficial effect of abstraction is the preservation of privacy. Since collected data is converted to a form that does not allow assignments to the individuals who caused the sensed activity, the abstract information can be published in public spaces without violating personal rights. *Hello. Wall* presents data on an ambient information display for visitors and through secret patterns for co-workers if they are within range of the sensors (Prante et al., 2003). The *Break-Time Barometer*, for example, uses microphone data, but transforms it – combined with data from other

sources - to visual representations on the clock face where the identification of the originator is no longer possible (Kirkham et al., 2013).
Systems that provide highly abstracted representations of co-workers' activities and additionally are directly embedded into the work environment may provide fewer interaction possibilities with the system itself than for example desktop-based systems. To bridge this gap many approaches make use of accompanying personal devices to enable the users to communicate more directly with their colleagues via the system and to retrieve more detailed information from the system with a lower level of abstraction. Such devices like smart phones or other artefacts explicitly designed for use within a specific system provide possibilities for interaction with ambient awareness displays whenever some content or activity heightens the focused attention of the user. Since static input devices like keyboards or touch screens may be difficult to encapsulate in an artefact, their combination with personal mobile devices enables the required interaction possibilities and allows for an abstract or even artful presentation of awareness information. Many of the previously described systems make use of accompanying devices for example to enable users to submit photographs for the *Panorama* display (Eliëns & Vyas, 2007) or to send messages to colleagues via the *Break-Time Barometer* (Kirkham et al., 2013). The *Personal Aura* artefact and the *ViewPort* devices represent examples of devices explicitly designed for the *Hello.Wall* to express personal information like emotion or availability and to retrieve more detailed information from the wall display (Prante et al., 2003).

This literature review of social awareness systems reveals that a common approach is to highly integrate the system into the environment, to use abstracted forms of presentation, to provide a pleasant experience and secure privacy, as well as to combine such systems with personal devices to enable direct interaction. The diverse concepts introduced in this section illustrate approaches that support awareness beyond the personal desktop and therefore indicate important aspects of awareness support on a group level.
This chapter followed the path of awareness support from settings of close collaboration in very demanding tasks via the support of awareness on the personal desktop between distributed workers up to the metaphorical presentation of awareness information in public places of the work environment. Whereas the previous section primarily concentrated on different notions of awareness and particular systems to support them in various ways, the following section focuses on techniques in information technology that inform the design of awareness systems.

2.4 Related concepts in information technology

The approaches to awareness support presented in the previous section incorporate various concepts of information technology regarding sensing environmental data, presenting information and embedding technology in the environment. The key concepts and terms that link the support of awareness in collaboration with recent developments in information technol-

ogy are illustrated in the following paragraphs to provide further insights into the technology-related aspects of awareness research.

Since the objective of this thesis is to design and evaluate an awareness system to support social bindings across workgroups on a group level, a promising approach is to collect data from public areas within the groups' facilities. **Ubiquitous computing** (*ubicomp*) appears to be relevant for achieving this because various types of sensors embedded into artefacts and tools used in common rooms provide activity data on the environment without affording the users to actively and consciously generate data. Ubiquitous computing "is fundamentally characterized by the connection of things in the world with computation" (Weiser & Brown, 1996). Collecting data from various distinct sources like coffee machines, microwave ovens, loudness sensors, motion sensors, etc. that are placed in an environment, connected and analysed may enable the transportation of awareness information across distance. These elements of ubiquitous computing allow for an effortless sensing (for the user) of environmental information in a similar way that collaborators in co-located settings gather awareness information through peripheral perception. Recent developments in the hardware sector have led to cheap and easy to implement platforms of microcontrollers and sensors. Raspberry Pi[6], Arduino[7] or Adafruit Industries[8] are just three among many platforms/suppliers of modern hardware that enables developers to easily integrate technology into the environment. *Hello.Wall* (Prante et al., 2003) and the *Break-Time Barometer* (Kirkham et al., 2013), reviewed in detail in the previous section, take advantage of ubiquitous computing to obtain awareness data. A rather critical position towards a too extensive exploitation of indiscriminate sensorial data is taken by Grudin (2002) who argues that

> "ubiquitous computing is the ultimate cleavage of action from the 'here and now'. Once a digital representation of an action reaches a network, it could surface anywhere on the planet at any future time. … Understanding our context-dependent social behaviours, designed through natural selection, is crucial in identifying the limits, opportunities and risks of context-traversing digital technologies." (Grudin, 2002, p. 77)

Regarding the automated retrieval of context information Chalmers (2004, p. 223) remarks that "context-aware and ubiquitous computing often concentrate on computational representation of context that span and combine many senses and media-rather than the social construction of context in interaction." This criticism of ubiquitous computing in regard to awareness support clearly shows that social relationships within groups go beyond technology-driven representations of collected data. Therefore the application of automated sensors within public areas of an organisation has to be conducted carefully and in accordance with the users' social worlds.

A related term is "**calm technology**" introduced by Weiser and Brown (1996) which refers to the potential of ubiquitous computing to be calm in the sense of not disturbing and not demanding permanent attention by users. "Calm technology engages both the centre and the

6 https://www.raspberrypi.org

7 https://www.arduino.cc

8 https://www.adafruit.com

periphery of our attention, and in fact moves back and forth between the two" (Weiser & Brown, 1996). Since peripheral perception is a key component of informal awareness, calm technology appears to be a promising approach for presenting awareness information in the periphery enabling the user to stay focused on the actual task at hand. Once a peripheral event attracts attention the user can switch the focus to engage with it and then go back to the previous task when the event is no longer of interest. Ensuring smooth transitions between peripheral and focal attention is a key component of calm technology (Weiser & Brown, 1996).

In modern organisations office workers spend most of their time resolving individual task on personal desktop computers. Especially in technology-oriented organisations, like the university department examined in this thesis, workers may not want to be confronted with computers in their common rooms because they have to operate them all day anyway. **Tangible user interfaces** (TUIs) allow direct interaction with physical objects and therefore enable designers to create devices that go beyond traditional interaction on a screen via mouse and keyboard (Ishii & Ullmer, 1997). TUIs "give physical form to digital information, employing physical artifacts both as representations and controls for computational media" (Ullmer & Ishii, 2001, p. 580). Implementing tangible user interfaces in awareness systems will yield to solutions that are computationally mediated but not perceived as computers in the usual sense (Ullmer & Ishii, 2001). Such devices may be deployed in public areas of organisations and be handled as usual objects, like many other things present (e.g. coffee machines, newspapers, board games, etc.) with the objective of representing remote collaborators' activities and providing interaction possibilities in some way. Another relevant factor of tangible user interfaces is that through their seamless integration into the environment they facilitates smooth transitions from the periphery to the foreground of users' attention (cf. Ishii & Ullmer, 1997). The concept of **embedded interaction** follows comparable principles. Whereas TUIs are used to design particular devices that do not appear as technology, embedded interaction means to directly integrate technology into ordinary objects to retrieve data about their usage (cf. Kranz, Holleis & Schmidt, 2010). This data finally can be analysed to provide information about ongoing activities and maintain awareness.

In order to make awareness information accessible within an environment where technology should not dominate the lives of its users, **ambient media displays** may constitute a promising concept for preserving the familiarity and the identity of the surroundings. Ambient displays use natural phenomena such as light, soundscapes or motion to present digital information (Ishii et al., 1998). "An ambient display resides in the periphery of a person's attention. The display calmly changes state in some way to reflect changes in the underlying information it is representing" (Stasko, Miller, Pousman, Plaue & Ullah, 2004, p. 19). By the use of the existing resources of an environment like walls, lights and particular sounds, change in the lightning of a room for example may be a consequence of change in information retrieved elsewhere and thereby represent a connection between remote locations. The representation of information in the periphery facilitates the advances of *ubicomp* strategies to inform people about events without requesting focal attention. The *ambient*ROOM (Ishii et al., 1998) is an early example of how awareness information can be presented in the background by the use of light and sound. The amount of unread e-mails is displayed by the loudness of different

soundscapes like birds or rainfall in conjunction with the lightning in the room. The number of other people's activities is illustrated through patterns of illuminated light patches projected onto a wall and furthermore a rippling of water in a tank informs about activities of distant loved ones (Ishii et al., 1998). The *ambientRoom* example offers various different opportunities for making use of the existing environment to maintain awareness about the personal workplace as well as about remote people through displaying information peripherally using familiar resources.

The concept of ubiquitous computing and related interaction strategies like tangible user interfaces and ambient media displays often have informed the design of awareness support systems in the research history, which resulted in various successful approaches to connect other people across distance. In summary for this thesis these techniques are utilized to automatically collect environmental data from public areas of three distributed work groups in a university department. The design of the technology probe, introduced in the subsequent chapters, is highly influenced by the strategies of tangible user interfaces in order to develop an artefact that integrates with the environment without being perceived as a computer. The technology probe comprises ambient information display techniques to peripherally inform users about ongoing activities and it provides direct interaction possibilities whenever an event attracts the users' focal attention.
These characteristics aim to re-establish some benefits of proximity illustrated in the first part of this chapter, facilitate the maintenance of awareness types like informal and/or social awareness across distance, and is derived from established scientific awareness systems successfully implemented in comparable areas. Before concentrating on the actual design, concept and evaluation results of the technology probe, the methodological approach of this thesis is outlined. The following chapter therefore presents mixed research methods applied in three major stages of the project: Initially, the users' demands and wishes for an awareness supporting system were sought acquired. Subsequently, users opinions on open design issues within the development phase were captured. And finally, test-period data retrieved from various sources was collected and analysed.

3 Methodology & Approach

The objective of this study is to design a *technology probe* that enables users to maintain social awareness across distance, which is based on empirical and analytical work. The design process is mainly driven by the principles of *participatory design* where the users' experiences and their daily routines play an important role and design is seen as a joint process among users, designers, researchers and other relevant stakeholders. *Participatory design* makes use of a broad repertoire of research methods to examine various aspects of the research subject and provides a wide range of techniques to support the joint design of technology (c.f. Sanders, Brandt & Binder, 2010). Within this study a selection of mixed qualitative and quantitative research methods was applied. Qualitative methods, such as *ethnographic interviews* were used to acquire a deeper understanding of the context in which the awareness system is applied and to understand the practices and needs of its users. Quantitative approaches were applied when the users' stance towards a specific question had to be examined and for automatically collecting *log data* from the *technology probe*. The *mixed methods* approach informed the design of the *technology probe* from many different viewpoints and allowed an examination of the social phenomena within and between the investigated work groups utilizing different perspectives (c.f. Tashakkori & Cressfield, 2008).

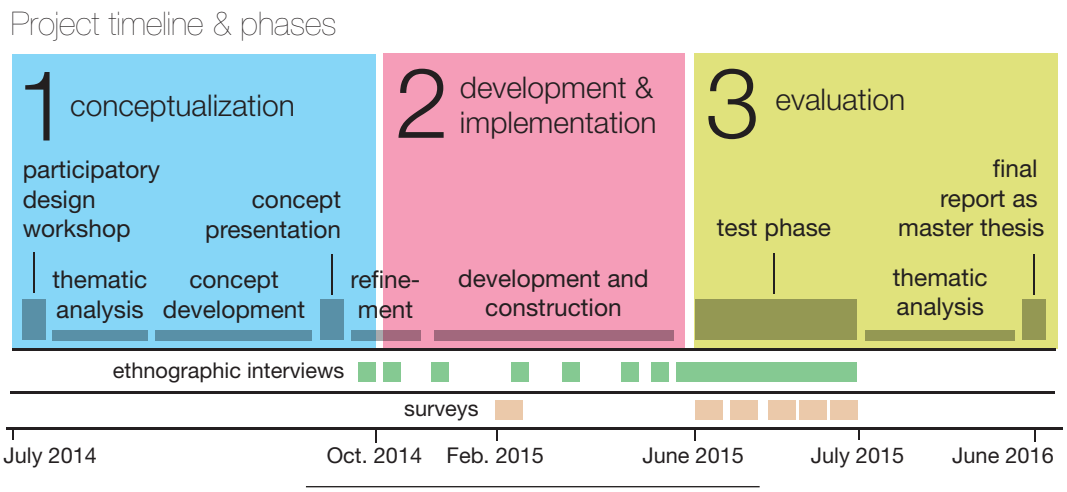

Figure 1: Project timeline illustrating work progress, milestones and conducted methods.

The first part of this chapter comprises the characteristics of the three distributed research groups that participated in this study. The following sections provide an introduction into theory and practices of participatory design, as well as a description of research methods used, combined with an illustration of how they were applied within the study. Figure 1 illustrates the timeline of the entire project comprises its three main phases, conducted methods and achieved milestones. A detailed description of the approach taken in this project is given in Section 3.5.

3.1 Department structure and site characteristics

The Department of Design & Assessment of Technology at the TU Wien comprises three distributed work groups at two different locations within the inner city of Vienna. The distance between the two locations is approximately 500 meters, equivalent to a walk of about 5 minutes. Although two of the groups are situated on the same floor of a building they can be treated as distributed because they do not have commonly used areas. These two groups use different entrances to their facilities and the only direct passage between them is locked almost permanently. The entire department comprises more than 80 employees in total[9]. An exact number unfortunately cannot be given, since there is a frequent change in the number of employees working as research assistants or tutors and some do not work permanently in the groups. Nevertheless, seven professors, 33 research and project assistants as well as approximately nine other employees (general staff, secretaries, technicians) can be considered to be permanently employed in the department. The 49 relatively constant employees are distributed to groups A, B and C[10] as follows: Group A comprises about 24 permanent members, in Group B about eleven people are employed constantly, and Group C includes approximately 13 permanent workers. Although everyone related to the department was in some way able to contribute to this examination and appreciated doing so, the permanent employees represent the core group of the department and are therefore the main subject of this study.

The technology probe elaborated within the scope of this thesis was deployed in a public area of the group's facilities to provide mutual information about activities in that area. Therefore, the location of commonly used rooms in the facilities of the groups plays a significant role because centrally located rooms are assumed to involve more people in mutual interaction than remote locations. Figure 2 illustrates the locations of commonly used public areas within each group's environment. The places with the highest colour intensity are the groups' kitchens and conference rooms where people are expected to meet frequently and spend time together. Middle-range intensities indicate the hallways of the groups' facilities. Here occasional encounters are assumed to occur. The rooms with low intensities are individual and team offices as well as laboratories. In this places people primarily work on their tasks and meetings might

9 Numbers retrieved from the campus software system of TU Wien (https://tiss.tuwien.ac.at/adressbuch/adressbuch/orgeinheit/1624) and the department website (http://igw.tuwien.ac.at) on 12th April 2016.

10 The actual names of the groups were changed to A, B, and C to ensure anonymity.

rather happen on purpose than by chance. The few rooms in figure 2 not filled with colour represent not commonly used or irrelevant places like storage-rooms or lavatories.

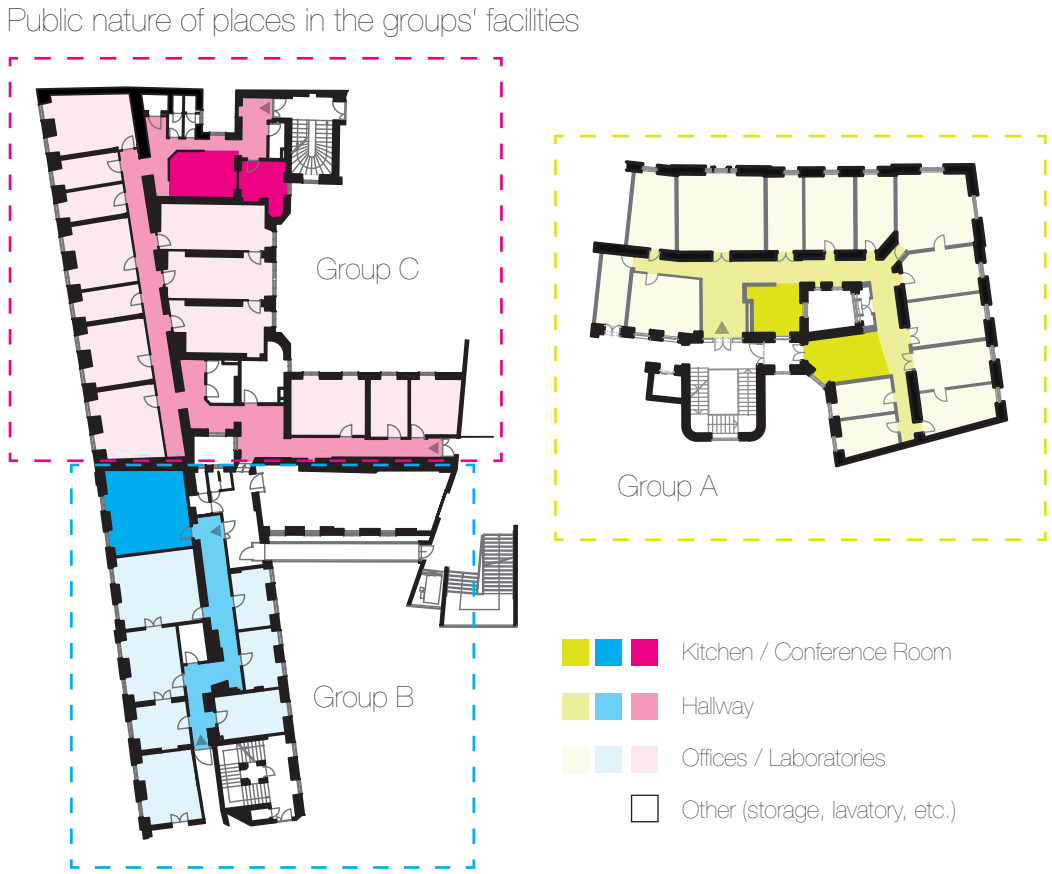

Figure 2: Public nature of places in the groups' facilities illustrated by colour intensities. Floor plans retrieved from GUT (https://www.gut.tuwien.ac.at/immobilienmanagement/grundrisse_objekte/) on 12th April 2016[11].

The room layout illustrated in figure 2 shows where in each facility the rooms are located that are assumed to be the main meeting points for the groups' members. The kitchen of group A is located very centrally as well as near the entrance. The room itself has no door, so it is not strictly separated from the hallway and therefore people passing by can easily recognize if there is some activity in the room or not. The conference room of group A is located a bit 'deeper' within the facility and is separated by a glass wall from the hallway (not shown in the plan). Since the kitchen is used as the main meeting point there are fewer informal gatherings in the conference room. Group B uses one room as kitchen, common room, library and conference room. The room is located next to one of the entrances and is, besides the hallways, the main meeting point for the group members. In the facilities of group C, the conference

11 Details and irrelevant building sections were removed from the original floor plans to provide a simplified illustration. Colour codes were added to the floor planes to indicate the public nature of places.

room is a separated area in the hallway that comprises a traditional conference table as well as a lounge area equipped with sofas for more informal gatherings. The lounge area is located next to the kitchen, which is in a separate room, but a large window allows seeing through from the meeting area into the kitchen and vice versa. The areas are located at the end of the main hallway near one of the entrances. The members of group C use both rooms/areas equally for common lunch breaks and informal gatherings[12].
This section outlined the most relevant characteristics of the department structure and size, the location of commonly used places within the groups' facilities and their likeliness for occasional gatherings. The chapter continues by giving an illustration of the principles of participatory design and applied research methods within this study.

3.2 Participatory design

In traditional computer-based system-development approaches designers, software architects and programmers usually follow the specifications given by their client. Whenever anything is unclear developers either consult the client, usually the management of an organisation, to refine the specifications or integrate their own perspectives on how problems could be solved and the system used. The actual needs and work practices of the users do not play a major role. Traditional system design is more oriented towards the economic (budgetary) goals of an organisation and the interpretation of work by the management than towards the social realities and daily routines of the workers. Kensing and Blomberg (1998, p. 168) refer to this as design "… where efficiency is emphasized over quality of work life." System design that neglects workers' individual needs and their well-established procedures for resolving tasks leads to deskilling and devaluation of human work (Muller, Wildman & White, 1993).
To integrate users into system design processes is an integral strategy, particularly in Scandinavian approaches. These countries have a long tradition in workplace democracy, where workers own the right to take part in organizational decisions concerning their work and changes to it. Regarding software design the partaking of users improves their knowledge of the desired system characteristics, provides realistic expectations of a system's use, reduces resistance of users to newly implemented systems and finally increases workplace democracy (Gregory, 2003). Through the principles of participatory design a strong relationship is built between those who design technology and those who have to use the resulting systems. Kensing and Blomberg (1998) note:

> "The participation of the intended users in technology design is seen as one of the preconditions for good design. Making room for the skills, experiences, and interests of workers in system design is thought to increase the likelihood that the systems will be useful and well integrated into the work practices of the organization." (Kensing & Blomberg, 1998, p. 172)

12 The common room usage habits are derived from personal observations conducted over many visits during my work on this study as well as from reports of the employees.

Active cooperation between designers and users provides deep insights into the use context for designers and conversely reveals new possibilities for how technology can contribute to this context for users. In participatory design projects workers contribute actively to the analysis of the needs and requirements to be satisfied by a system, the evaluation and selection of components, the design and prototyping as well as its organisational implementation (Kensing & Blomberg, 1998).

Participatory design follows the inquiry paradigm of constructivism (Spinuzzi, 2005). In constructivism realities are understood as mental constructs that are socially and experientially based and dependent on individuals and/or groups. Knowledge is gained particularly through the interaction between researcher and the object of research. The variability of socially based constructs of reality therefore requires inquiry through interaction between the involved people (Guba & Lincoln, 1994). In participatory system design people contribute in different roles and from different perspectives, as investigators, designers, users, clients and other stakeholders.
In recent years since the emergence of participatory design researchers and practitioners have developed a broad catalogue of tools, techniques and methods to facilitate user participation and engagement in system design. By the use of methods like observations, interviews and workshops researchers gain an understanding about the contexts and work practices of users where both technology and the organisation of work are in focus (Kensing & Blomberg, 1998). Approaches with ethnographic elements especially are often conducted and appear to provide holistic knowledge about the relations between technology and work practices (e.g. c.f. Kensing, Simonsen & Bødker, 1996; Muller & Druin, 2003). Sanders, Brandt and Binder (2010) introduced a framework of various participatory design tools and techniques derived from a selection of relevant studies. Tools and techniques are generally assigned to three dimensions: form, purpose and context. The form dimension differentiates between kinds of action taking place like making (e.g. collages), telling (e.g. diaries) and acting (e.g. design games). The second dimension encompasses the purposes of the tools and techniques regarding the participants' conduct. This dimension distinguishes between probing participants' experiences, priming them for detailed investigation, understanding their domain and generating ideas. Finally, the context domain describes how the tools and techniques are used. This depends on factors like group size, venue, relationships among the stakeholders, etc. (Sanders et al., 2010).

In CSCW and HCI participatory design principles play a relevant role in system design for understanding the interrelationship between technology and people's work practices. Kensing and Blomberg (1998) identify a number of contributions from CSCW to participatory design and vice versa. On the one hand, CSCW informs participatory design research on how collaborative technologies may be implemented and how cooperative relations can be established. On the other hand, participatory design principles contribute to CSCW to provide a deeper understanding of context and organisational relationships (Kensing & Blomberg, 1998, p. 182). Regarding HCI Muller and Druin (2003) note that participatory design bridges the gap between the world of technology and the world of the end users. In this field participatory design offers tools, methods and techniques for bidirectional exchanges between designers

and users where both of them profit in the end through systems that are actually usable and integrated into the daily workflow (Muller & Druin, 2003).

There is always a certain trade-off between the intensity with which users are able to participate in system design in the daily work tasks with which they are occupied. Individuals may not always be available because their schedules simply do not allow extensive participation in design projects, and not all users may be available together at a certain time. Therefore, participatory activities have to be planned carefully with respect to the users' schedules und motivation (cf. Sanders et al., 2010).
In this study several sessions and opportunities were used where one or more users participated. In the initial phase of the project especially, a participative workshop provided an understanding about the needs and wishes of the users for awareness supporting technology. Based on the findings of this workshop a system concept was presented and in feedback sessions such as discussions and ethnographic interviews the concept was refined in conjunction with the users. Within the development phase of the technology probe details of interaction possibilities and the appearance of the probe were finetuned based on survey results, ethnographic interviews and common prototyping in 3D-printing sessions. Finally, users used the probe within a test period of four weeks and identified strengths and weaknesses, as well as completely new and unexpected ways of interaction.
In this special setting of an academic department conducting multidisciplinary research in the field of HCI, CSCW and Applied Assistive Technologies (AAT) participants contributed to the study from three different perspectives: as users, as researches and as IT experts. In their user role they articulated their personal views, needs and wishes for the project, as well as their concerns and worries about particular system details. As researches they were interested in the approach taken, the results and the findings. And as IT experts they informed about promising technologies, gave advice on the implementation and provided expertise provided from their own domains. To gather insights from all three user perspectives, a mix of different methods was chosen to collect information in various ways.

3.3 Mixed Methods

Mixed methods research refers to the combined use of qualitative and quantitative research elements within a study. The combination of elements can take place at different points and for different purposes e.g. mixed methods, research processes, philosophies or designs (Creswell & Plano Clark, 2011). Therefore, many varying definitions of mixed methods research can be found that refer to each of these aspects differently. As a result of a comparison of multiple interpretations of mixed methods research Johnson, Onwuegbuzie and Turner (2007) introduced a definition that appears suitable for this study:

> "Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference tech-

niques) for the broad purposes of breadth and depth of understanding and corroboration." (Johnson et al., 2007, p. 123)

This definition does not limit mixed methods research to the combination of qualitative and quantitative methods, it opens up the possibility of combination throughout the entire process in planning, thinking and analysing. Although in this study the focus of mixed methods research is mainly apparent in the mixing of different methods, qualitative and quantitative viewpoints also influenced the analysis and findings.

Greene, Caracelli and Graham (1989) identify five purposes within mixed method evaluation design: triangulation, complementarity, development, initiation and expansion. Triangulation combines results from different methods or data sources to find convergence, corroboration or correspondence of the results. Complementarity means the use of the results produced by one method to elaborate or clarify the results of another. Development takes the results of one method as the basis for the development of further methods. Initiation means the illustrations of paradox and contradiction from one method, the questions or results from another. Finally, expansion provides an extension in breadth and range of a study (Greene et al., 1989, p. 259). In this thesis the mixed methods approach was mainly chosen for the first three purposes: triangulation, complementary and development. Triangulation of different methods provides views on the overall results from different perspectives (cf. Flick, 2010). The purpose of complementarity is apparent between the quantitative log data and reports in ethnographic interviews regarding the degree of use of the technology probe. Furthermore the results of the initial workshop and my experiences in the subsequent design process highly influenced the development and choice of the further methodological approach.

The latter part of the definition given by Johnson et al. indicates advantages of the use of mixed methods. A combination of methods leads to a wider range of information collected from different sources and contributes to a deeper understanding and elaboration of the research field. One benefit of quantitative approaches is the personal distance between the researcher and the object of research. Therefore, the risk of influencing participants and the data being biased is reduced. On the other hand, distance between the researcher and the research object results in a loss of context information that is a key contribution of qualitative approaches. Mixed methods research provides more evidence, enables researchers to use a broader catalogue of tools and techniques to collect data and provides a bridge between qualitative and quantitative worldviews and paradigms (Creswell & Plano Clark, 2011). How this is utilized within this thesis and which methods were particularly selected is outlined in the following parts of this chapter.

3.3.1 Participatory design workshop

Workshops are integral to participatory design, because they allow stakeholders in a project to communicate about shared goals, interests and strategies, and produce valuable outcome through joint action. Muller and Druin (2003) discuss various different workshop concepts and identify a number of general "claimed benefits" of workshops: participants develop new concepts that directly influence product design; people engage with the design process and

outcome; ideas from various individuals are taken into account and useful artefacts are produced to inform further design decisions (Muller & Druin, 2003, p. 24).
The planning of the participatory design workshop was basically informed by the generative tools introduced by Sanders (2000; 2002). These tools follow a *say-do-make* model to access the participants' experiences on different levels. The *say* level gives information about experiences participants are able to express in words, with the limitation that they probably only articulate experiences they are actually willing to share. The *do* level seeks to gain additional insights through the observation of the conduct of the participants. The third level finally gives an understanding of what people create from the various toolkits or materials. Investigations on the making of artefacts give an understanding of participants' thoughts, feelings and dreams that may not be expressed in the upper levels. Exploring all three levels of experience establishes a better understanding of and empathy with those who actually use technology (Sanders, 2002). Therefore, the participatory design workshop conducted in this study was structured into sequences of three different techniques to address all three levels of the *say-do-make* model.

As an initial method for this thesis a participatory design workshop was conducted to gain insights into the needs and wishes of the different groups, as well as to acquire knowledge of design implications that will further inform (in combination with other methods and an ongoing literature research (see Chapter 2)) the concept of a technology probe. The workshop was realized in collaboration with Noemi Steitz who did research in the same field for her Master's thesis. The aim of her work was to gain a detailed description of the context of the project, information on aspects that appear to be relevant, as well as the role technology could play to maintain awareness from the user perspective. Her work comprises a series of interviews including different group members with different backgrounds and functions within the department (Steitz, 2015). The resulting codes from her interviews build the basis for the mutually planned and implemented design workshop. Although we planned and conducted the workshop together, analysis of the collected data was done individually to ensure that each kept the focus on our individual problem setting.

Three brainstorm techniques in a lunchtime setting
To obtain valuable output from the workshop great effort was put into its detailed planning. Due to the tight schedules of the department members and their motivation for attending the workshop its duration was set to a maximum 1.5 hours and was scheduled at lunchtime. Since the meeting took place at lunchtime a variety of snacks and drinks was offered to create a comfortable atmosphere and a less work-related situation such as to maintain a high motivation of the participants. They were to have lunch together and additionally talk about an enhanced "linking" of the separate groups.

The workshop was structured into five different phases with a sequence of three different techniques. After a short introduction and completing consent forms the first technique was *jumpstart storytelling* where the participants were asked to tell short stories related to the project (Curedale, 2013, p. 44). These stories could include their wishes, particular fears or scepticism towards such a system as well as general thoughts about enhancing the group bindings. To support the storytelling cards with codes and phrases from Noemi Steitz's previously con-

ducted interviews were presented. This was intended to provide a better start to the matter by recalling different aspects that came up in the interviews. The *jumpstart storytelling* sequence was planned to take about 20 minutes of the workshop but exceeded this to about 30 minutes.

The second technique applied within the workshop was *starbusting* (Curedale, 2013, p. 150). Based on the discussions and stories of the first phase the participants were asked to articulate concrete questions they had in mind about such a system. To facilitate them a star with six interrogative parts of speech (Who? What? How? Where? When? Why?) on each peak was drawn on a white board. The participants were asked to start their questions with either one of these parts of speech, write them on post-its and put them on the wall at the end of the sequence. Since this part was done more individually the single questions were read out loud by Noemi Steitz and myself to present the questions to all participants.

Following *starbusting,* where questions were raised, the third sequence of the workshop was to generate design ideas through creating collages, drawings, mock-ups or artefacts (c.f. Sanders et al., 2010). The objective of this sequence was to answer some of the previously articulated questions as well as to provide suggestions about how the participants might imagine such a system. Several materials like coloured paper, a variety of different pens, stickers or modelling material were provided to release the creativity of the participants. These materials where positioned on two different tables, and the participants split up in two groups and discussed their issues within these groups. At the end each group presented its ideas to the other. Finally the workshop was closed with a short summary where the members recapitulated what they had talked about in the workshop and pointed out what was important to them.

Evidence from audio recordings, photographs and created artefacts

For the purpose of further analysis the workshop was audio-recorded in full length and photos were taken of the different actions like card grouping at the beginning, the final post-it filled star and the drawings and artefacts representing ideas. The most valuable parts of the audio-material were transcribed[13] using the *TiQ* transcribing system, a method especially for transcribing the data of group discussions and one perfectly suitable for the partial transcription of this workshop. With this method interruptions within the debates are marked and therefore how the participants react and respond to each other can be tracked in detail (Przyborski & Wohlrab-Sahr, 2010, p. 164 ff). The content of the pictures was rewritten to enable an easily readable presentation of the grouping of the cards and the handwritten questions. Within this conversion it was important to retain the original arrangement as it has been on the table or the white board, thus no formulations or affiliations were changed.

The initial workshop represents a decisive contribution to this thesis, because, on the one hand, users commonly reported on the work context, their wishes from and concerns about an awareness support system. On the other hand, participants also provided their views on how technology could facilitate the maintenance of awareness across distance. People contributed

13 In some sequences of the recording many people are debating at the same time and therefore these parts were not clear enough to be transcribed. In other parts, participants were talking about issues not related to the workshop and therefore such parts were also excluded from the transcription.

within this workshop as group, rather than on an individual level, a factor that was crucial for the success of the project since the objective was to support awareness on the group level.

3.3.2 Ethnographic interviews

Ethnographic approaches are frequently applied in awareness research to gain insights into the social realities of the participants and to develop an understanding of their particular work practices (e.g. Bentley et al., 1992; Cheverst, Dix, Fitton, Rouncefield & Graham, 2007; Heath & Luff, 1992; Tollmar et al., 1996). Hughes, King, Rodden and Andersen (1994) characterize ethnography as follows:

> "It is a naturalistic method relying upon material drawn from the first-hand experience of a fieldworker in some setting. It seeks to present a portrait of life as seen and understood by those who live and work within the domain concerned." (Hughes et al., 1994, p. 430)

Hughes et al. (1994) note challenges to ethnographic findings used to inform system design because results are presented in a discursive form and not as systematic as system engineers may wish. Nevertheless, they identified four different uses of ethnography within system design: *Concurrent ethnography* influences ongoing system design throughout the entire design process. *Quick and dirty ethnography* is used to obtain a general sense of the setting by applying brief studies. *Evaluative ethnography* seeks to verify or validate design decisions already taken. And *Re-examination of previous studies* informs initial design thinking (Hughes et al., 1994, p. 432). In this study ethnographic interviews were concurrently conducted to gather the participants' opinions on particular design issues. They were often applied in a 'quick and dirty' manner for occasional meetings and conversations. Furthermore, they were used to present actual design decisions to participants and to receive evaluative feedback.

Ethnographic interviews are characterised by non pre-structured conversations that are mainly conducted immediately and directly in the field. The structure of the interview is depends on the particular situation and is oriented towards the actual interests of the researcher. The advantage of ethnographic interviews is the proximity to the daily lives and routines of the participants, while settings of other interview forms may be perceived as artificial (Mey & Mruck, 2010).

Chance encounters used for ethnographic interviews

In this study ethnographic interviews were primarily conducted during the test phase of the technology probe to gather the personal opinions of the participants and thus obtain a sense of the role the technology probe actually plays in their daily lives. The interviews were mainly conducted with participants present during visits at the groups' sites to deploy and pick up question boxes (used for surveys conducted in the same period; see Section 3.3.4) and during occasional maintenance visits. During the test phase of the technology probe, I visited the groups almost daily and therefore the data collected from a multitude of ethnographic interviews provided a valuable contribution to the understanding of the probe usage.

Ethnographic interviews were not only conducted during the test phase of the technology probe, but also took place less frequently during the design phase of the probe. Encounters

were used to discuss details of the ongoing design process to ensure the users' engagement with it and to receive feedback on ideas. Besides the interviews conducted during chance encounters, some were done deliberately whenever users articulated major personal concerns on the probe and/or project. Then users were asked in scheduled meetings about their concerns so as to clarify the background the concerns and for together explore creating ideas for possible solutions.

Field notes instead of recordings

During and/or immediately after each interview field notes were taken to keep evidence on the issues addressed within the interviews. The notes included information about venue and date, spoken content, observations, the characteristics of the setting itself as well as the partners' attitudes towards the project, interviewer and/or other relevant aspects. Since especially during the test phase interviews were conducted almost daily, the notes taken resulted in a sort of diary of the entire test phase that provided not only a general overview of the test phase but also deep insights into details and particular issues. I decided against making audio recordings of the ethnographic interviews, because this would have disturbed the personal and informal character of the interviews and participants would have experienced them as more 'official' and artificial.

In addition to the participatory design workshop, which gathered the participants' ideas and wishes on a group level, the ethnographic interviews were used to collect evidence at the individual level. Throughout the design process, interviews were used to refine the concept to actually meet the participants' needs, and during the test phase they additionally had the evaluative function of validating and verifying the information collected by surveys. The 'quick and dirty' character of this method enabled users to articulate views and statements that they probably would not have expressed with such openness in an artificial, audio-recorded setting.

3.3.3 Technology probes

The term technology probe is derived from cultural probes (cf. Gaver & Dunne, 1999), which may be subsumed as various materials handed out to participants with the purpose of self-reflection and behavioural change. Technology probes follow similar purposes but the characterization is limited more to technological artefacts. Hutchinson et al. (2003) define technology probes as follows:

> "Technology probes are a particular type of probe that combine the social science goal of collecting information about the use and the users of the technology in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think of new kinds of technology to support their needs and desires." (Hutchinson et al., 2003, p. 18)

From the engineering perspective a technology probe must actually work in real-world settings, therefore the main functionality must be provided in a sophisticated way so that users actually can use it without dealing with major maintenance issues or non-implemented functionality. Simplicity and flexibility of use are the main characteristics of well-designed technology

probes that enable users to adapt the probe and/or use it in unexpected ways (Hutchinson et al., 2003). Although the characteristics of technology probes appear similar to the attributes of prototypes Hutchinson et al. (2003) identified a number of differences between them: Technology probes differ from prototypes in functionality because they provide one single main function (and other subordinated functions) whereas prototypes provide broader functionality. Technology probes have an open-ended character and offer possibilities for re-interpretation. Prototypes demand a more explicit way of use. The design of technology probes is not expected to change during the usage period. A lack of usability is seen as a means to provoke users to use the technology probe differently. In contrast, prototypes may be altered during the usage period to facilitate usability. Logging data of usage is crucial during the deployment of technology probes so as to be able to present results to the users afterwards, whereas this is not the primary goal for prototypes. Finally, probes are used in earlier phases of system design than prototypes (Hutchinson et al., 2003). Although the last distinction is not accountable for the technology probe developed in this thesis, it is still classified as a technology probe because the other requirements outlined above have been clearly met.

Three identical technology probes to facilitate awareness

The objective of the system design in this project was to find possibilities to maintain awareness across distance through technology. Hence, three identical technology probes were designed, built and tested. The design of the probes was driven by a participative character to ensure that the needs of the users were actually met. The probes were built with robust materials and of high quality, with technical parts hidden inside to enable users to concentrate on interaction and use. Within the test phase the users were invited to use the probes in whatever way they wanted and could imagine. The choice of the actual placement of the probes within the common rooms of the facilities was left to the users as were the ways of interaction and the amount of use and time spent with the probes. There were no obligations for users to actively engage with the probe along the test period, because it was of great interest for my work to see if people interacted with the probes, and if so, how they reacted to their deployment, and how they used them. To give further information about the probes' functionality, the collected data and the overall purpose, informative posters[14] were mounted in the groups' facilities near to the probes during the test phase.

The usage of the probes was evaluated by three methods. Ethnographic interviews and surveys with open questions were conducted to gather statements from users and sensor data was logged to obtain quantitative information about the amount and frequency of use. Although the probes use data from microphones and buttons, only button data was logged to avoid users having the feeling of being permanently monitored. Maintaining privacy for the users was very important and therefore I renounced logging microphone data. Furthermore, such data would have only provided information about the amount of activity in the surroundings, not about interaction and context, and therefore was of no interest for this work. The collected log data provided descriptive statistical data about the button use, which is presented in Section 6.1.

14 See Appendix A

The probes were deployed in a later phase of this work and are seen as the main contributing factor to it. Through the deployment of the probes users had the chance to explore different ways of facilitating awareness and the probes represented tangible, real, physical objects as sources for debate on the topic of cross-group awareness support. Through the use of the probes users were able to reflect on their initially articulated needs towards an awareness support system and to create further ideas of how the probes could be adapted in future work to address their needs even better. Details on design, functionality and overall appearance of the technology probes are given in Chapter 5.

3.3.4 Surveys

Surveys were used primarily to collect quantitative data in written form. One advantage of paper-based (and online surveys) is that the researcher is absent during the conduct of the method and therefore the participant is less likely to be influenced by the researcher. However, this advantage also implies a disadvantage of the approach: due to the absence of the researcher the survey situation cannot be controlled and the answers could be influenced by other factors unknown to the researcher (c.f. Bortz & Döring, 2006, p. 252). Nevertheless, another advantage of paper-based surveys in contrast to interviews is that data from many participants can be gathered in a relatively short time with relatively little effort. A crucial factor for successful surveys is a meaningful and comprehensible phrasing of questions because participants have no possibility of checking back to clarify uncertainties. Thus a paper-based survey needs to be carefully organized upfront. Information material has to be handed out to the participants to inform them about the purpose of the survey and its overall objective (cf. Atteslander, 2010).

Online survey to obtain user feedback on details of probe design

Two different techniques of surveys were used in this study, an online survey and paper-based surveys. During the design phase of the technology probe a brief online survey was conducted to gather users' feedback on the labelling of the buttons used to express a group's mood. The survey was designed using *Google forms*[15] and the link to the surveys was sent to the participants by e-mail accompanied by an information sheet[16]. Users were able to choose from 16 predefined moods and activities and additionally the form included an open field for further suggestions by the users. The easy-to-implement online survey opened the possibility for receiving quick feedback and ideas from the users on issues I was unable to resolve by myself. For the participants it took only a little effort to fill out the short survey and thus provide a valuable contribution to the project.

Paper-based surveys to evaluate the probes

In addition to the ethnographic interviews a series of paper-based surveys was conducted during the test phase of the technology probe. These surveys exclusively comprised open ques-

15 Google Forms is a service provided by Google to design and spread online surveys (https://www.google.com/intl/en/forms/about/)

16 See Appendix A.

tions to enable the participants to answer them freely with their own statements. Boxes with question cards were placed in the vicinity of the technology probes for a minimum of one to a maximum of three days for each set of cards during a four-week test phase from June to July 2015. The boxes contained multiple cards with two or three different open questions, as well as blank cards for giving other feedback, phrased in English and in German, so as to give the participants the opportunity to choose their preferred language. The questions were intended to collect experiences that give insights into the two main objectives of this study. On the one hand, they were used to gather information about how well the technology probe addressed the wishes and needs of the participants and, on the other hand, they brought insights to the key questions of the thesis and especially to what extent the technology probe supported awareness and behavioural change. The questions were related to the actual stage of the evaluation phase and therefore, especially in the first survey session, they mainly focused on the first impression, look and feel of the device, aesthetics and the clarity of functionality. Later, the questions concentrated more on changes in behaviour and how the probes influenced the exchanges between the groups. In the third week of the evaluation two survey sessions took place since this was the last week of June where the largest number of group members were still present before many of them left for the summer break. In the following week, the lecture-free period at the university started and therefore fewer staff who could give feedback on the probes were present at the institute. Nevertheless a 'light-weight' set of questions was deployed in the first week of July where closing-up questions were asked about the overall satisfaction with the technology probes and the group members were thanked for their participation. To enhance the motivation to actually fill out the cards the boxes were stuffed with some candy and the message: "Take the sweets and give some feedback!"

The paper-based survey method was chosen to have distance from the participants because previously conducted methods, especially the participatory design workshop and the ethnographic interviews, were characterised by close contact with the participants and through the surveys they had the chance to give feedback anonymously. The information gathered in the surveys therefore provided insights into use and appearance of the probe from a slightly different angle.

The collection of the afore-mentioned methods accompanied the entire design and evaluation process of the project. The *mixed methods* approach enabled views from different perspectives during the process and ensured that data and information were captured that were actually needed at a particular stage of the project. A *participatory design workshop* was organized to get the users together and generate initial ideas about an awareness support system. *Ethnographic interviews* accompanied the entire process of design and evaluation with the objective to permanently stay in touch with the users to obtain feedback and new ideas on design details. *Technology probes* were deployed in the common rooms of the groups' facilities to gather information about use and further design ideas provoked by real, physical artefacts. To evaluate the use of the probes a series of *paper-based surveys* were conducted to obtain additional information users perhaps may not have wanted to articulate in the interviews. The *mixed methods* approach provided mainly qualitative data from various sources. The scientific method used to analyse

the gathered qualitative data and the overall approach taken in this study comprise the topic to the following part of this chapter.

3.4 Thematic analysis of qualitative data

The qualitative data collected from the recordings of the workshop, the ethnographic interviews, the open questions from the paper-based survey were analysed thematically.
"Thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). Through analysing and interpreting the data at hand in iterative steps of coding and reflection, possibly themes emerged from the data. Although the themes were derived directly from the collected material, the role of the researcher within this process cannot be denied because themes were actively selected in relation to the researcher's interest and interpretation. A theme is characterized by relevant manifestations and patterns of response in the data. Typically, a number of representations related to a theme can be found. But since thematic analysis is a method for analysing qualitative data the number of appearances is not the only or most significant indication of an emerging theme and its importance to the research question. What is actually considered as theme finally depends on the judgment of the researcher (Braun & Clarke, 2006).
Braun and Clarke (2006) identify six phases of thematic analysis but they remark that analysis is not a linear process of moving through the phases, it is more recursive going back and forth between the phases to gain a dense description of the realities. Phase one comprises familiarization with the data. Reading the data actively and repeatedly enables the researcher to immerse him- or herself in the data. Transcribing verbal data could be a way to familiarize oneself with the data and to acquire a more detailed understanding of it. Phase two seeks to find initial codes within the data. Codes represent feature extracts of the data that appear to be interesting and can be described as basic elements of the data segment. Codes usually are generated by applying notes to the material, highlighting it in different colours or by using post-it notes to identify segments of data. Braun and Clarke (2006) advise to code for as many potential themes as possible and to get a broad representation of data through the codes and to preserve a little bit of the surroundings of the data in the codes to keep connections to the context. In phase three themes are identified within the codes by grouping different codes to related themes. Using mind-maps, tables or pieces of paper facilitate the identification of themes because codes may easily be moved around grouped and organized. In phase four the theme candidates found in phase three are reviewed and refined. Some themes may be combined to one bigger theme whereas others may be dismissed because they are not actually relevant. The refinement takes place on two levels. On the first level the codes are checked to see if they really fit the identified themes and on the second level the themes themselves are revised to see if they actually map the entire data set. In phase five the themes are finally defined and named as they are later presented in the report. In this phase the essence of each theme is determined and the aspects of the data and codes that form the theme are defined. Again the overall view is checked to see if the themes correctly illustrate the data in respect of

the research question. In phase 6 the final report is produced where each theme is described in detail. It is important to provide a concise, coherent, logical and interesting illustration of the interpretation of the underlying data (Braun & Clarke, 2006).

Especially the flexibility and openness of the method in terms of different types of data stemming from various sources appear to be convincing factors to use it for the analysis of qualitative data within this thesis. Thematic analysis was applied twice in this work at different stages of the process. The material of the initial workshop was analysed using this method as well as the evidence of the evaluation phase of the technology probe at the end of the project. The analysis of the materials followed the principles and phases introduced by Braun and Clarke (2006). For the analysis of the initial workshop the underlying material comprised transcriptions of audio-recordings and photographs, whereas for the analysis of the test phase field notes and written answers to open phrased of survey questions were the basic data sources. The process of analysis was quite similar for both and comprised multiple steps starting with the preparation of the data and familiarization with it. Coding, finding themes and refining them until a 'bigger picture' emerged from the data took three iterations in both analyses, but the actual conduct varied slightly.
In the workshop analysis the first iteration was used to identify thematically similar parts of the transcript by marking the most relevant and interesting parts in different colours. Segments marked in yellow stem from the first phase of the workshop, the card grouping and initial discussions. The phrases marked in green came up within the storytelling part of the workshop. Finally, the statements expressed in the presentation of the design ideas were marked in pink. By this colour coding, the statements can always be traced back to the method of the workshop from which they originate. After marking initial codes were written on the transcript and the segment was cut out. Within this first iteration the original cut-out segments of the transcript were grouped by possible preliminary themes. Within the second iteration step codes derived from the marked transcript segments were written on post-its and arranged to groups on a poster. To keep track of the origin of the codes numbers were written on the post-its as well as on the pieces of the original transcripts. Again every single code can be backtracked to a particular statement by a participant. By arranging the post-its more suitable themes arose than the initial ones, but these themes, too, were not sufficient for obtaining the intended significance. Finally, a third iteration step was necessary to build up the final themes, name and describe them. Some themes from the second step remained, some were named differently and some new ones were added. A few post-its were rearranged according to the new themes and a bigger picture of the essential sense of the data emerged. Furthermore, sub-themes were identified and named within this last iteration step. For every single step the arrangement was photographed to ensure ongoing evidence throughout the whole process.
The iterations in the analysis of the test phase data followed similar principles. Since the field notes and the survey statements were assignable to the single groups colour-coding was used to keep this information, if needed, for later. Interesting statements by users were highlighted in different colours in the material according to the group to which they belonged. When the highlighted statements were transformed to referring codes on post-its a second level of colour-coding was used to keep track of the origin of the data source. Pink post-it notes

were used for statements coming from a short pre-test of the technology probe in one of the groups. Green notes indicated data stemming from the paper-based surveys and codes on yellow post-its represented statements from ethnographic interviews. Additional information about the source of the data was noted in the corners of the post-its. Similarly to the analysis of the workshop codes and raw-data were numbered to ensure traceability. Moreover, the group code (A, B, C) was noted on the post-its as well as the date of the survey or field-note. This ensured traceability to the raw data as well as allowing recognition of possible indications for changes in statements between the single groups, on the one hand and in the time domain regarding the duration of the test phase, on the other hand. Again, the initial codes were formed to themes and refined until the themes appeared to map the data sufficiently.

Figure 3: Photographs of the workshop analysis process. The left picture shows the first iterations where pieces of the transcript were grouped. The right picture illustrates the resulting themes and codes.

The thematic analysis of the workshop and test-phase data provided a deeper understanding about the needs of the users in the first case and about the actual context of usage in the latter. The quality of the collected material was rich and it originated from different sources. Its volume allowed me to renounce computer-supported analysis and to use a traditional, non-automated, manual approach instead. This facilitated the immersion and familiarization with the data as well as it promoting creative ways of grouping and organizing codes to themes by manually manipulating them on a large poster. The following section illustrates this particular approach and shows how the applied methods and analysis of data contributed to the entire process of the project and system design over its full duration.

3.5 System design approach

The overall organization of this project followed a bottom-up design approach based on empirical data and can roughly be divided into three phases: initial concept development, technology probe construction and implementation, and final evaluation. As shown in figure 1 (p. 45) the entire project took about two years starting in July 2014 and resulting in this

thesis as its final report in June 2016. The three phases of this work were basically initiated and completed by achieved milestones (illustrated through thicker rectangles in the first line of figure 1) but they cannot be interpreted as completely separate and independent since they merge into each other.

Concept development, probe construction and final evaluation
The first method conducted in this project, the participatory design workshop, also marks the initial milestone for this work because it provided basic material about the usage context, the needs of the users and particular design ideas. The next step in the initial phase was a thematic analysis of the collected data where themes emerged that characterized the relevant factors for further design decisions. Based on these findings the concept of an awareness supporting system was developed and presented to the users for further feedback. The concept presentation allowed room for a lively discussion on the concept where valuable feedback was provided. Users identified many things they liked and saw their initial needs and wishes addressed by them, but they also used this feedback session to articulate concerns mainly about privacy issues. The feedback session was not only used to gather various user opinions, it also was used to elaborate together solutions to reduce privacy concerns and to further improve aspects of the concept that were already perceived positively. Therefore, the first phase was not clearly concluded with the end of the concept presentation, and merged with the development and construction phase during a refinement period after the presentation. In this refinement period the first ethnographic interviews took place to gain a better understanding of the likes, dislikes and serious concerns with respect to the concept introduced. In this period of the project it was crucial to commonly find solutions for open issues and to clarify possible discrepancies between my interpretation of the workshop data (which resulted in the concept) and user expectations.

Once the open issues were cleared the second phase of the project began by actually starting development, construction and implementation of the technology probes. This phase started with research on appropriate hardware pieces such as controllers, sensors and displays, and on possible materials for the construction of the probes. After identifying and procuring the necessary parts the existing construction plan of the probes was refined and the devices were assembled following this plan. The concluding period of the second phase included the programming of the devices as well as developing and customizing server-side services to enable communication between the probes. In the development and construction phase ethnographic interviews were conducted whenever issues arose that needed clarification together with the users. These interviews were conducted less frequently than in the evaluation phase which is illustrated by the fewer occurrences in figure 1. Since relatively minor issues and details were discussed in chance encounters the interviews in this phase were conducted rather briefly and in a 'quick and dirty' manner (see Section 3.3.2). In addition to occasional ethnographic interviews an online survey was conducted in this phase to obtain the user ideas about different group moods that were then printed as labels on eight buttons of the technology probes. A set of 16 moods and activities, based on the findings of a study on work group moods by Bartel & Saavedra (2000), was given from which to choose, as well as an open field where users could give additional suggestions. The construction and development phase was concluded by

a pre-test with about nine users of one group, which also marked the transition to the final evaluation phase.

During the evaluation phase the three technology probes were deployed in the groups' common rooms for four weeks from 8 June 2015 until 3 July 2015. Users were encouraged to handle the probes in ways they individually preferred, to locate the probes in places they thought most suitable and to interact with them as frequently as they wanted. No provisions were given about location, interaction and frequency of use so as to gain realistic insights about how the probes were incorporated into the daily routines of the users and their ability to facilitate social awareness across the groups. As figure 1 shows two methods were applied during the test phase to collect user feedback almost daily. Ethnographic interviews were conducted during visits to the groups and provided valuable insights about the personal attitudes of single users towards the probes. The written field notes resulted in a test-phase diary that illustrated changes in interaction and use during the four weeks of deployment. Five paper-based surveys with open questions were conducted to give users the possibility of giving feedback anonymously. Each of the surveys comprised a set of questions that were placed together with motivational sweets in a box near the probes. In each week one survey was conducted except for the last week in June where two surveys took place. First it was planned to deploy the boxes for one day and then remove them again. Thereby a new set of questions would have been indicated with a new appearance of the boxes. Since some participants complained that they were not able to fill out the question cards because they were not present on the day the first survey was conducted the duration of the following surveys was extended to two days (or even three days if participants requested). Information sheets in different colours were then used to indicate new sets of questions. In addition to this qualitative data the usage of the probes' buttons was automatically logged by the server application. This provided a good quantitative overview on the frequency of use. Finally, the data collected in the test phase was thematically analysed and the overall results and findings of the entire work are now outlined in this thesis, which also marks the concluding milestone of my work on the project.

My role as researcher

Since participatory design and ethnographic research methods require a relatively close collaboration between the researcher and the participants in the research objective, the role the researcher plays is a notable factor for the conduct of a study. Przyborski and Wohlrab-Sahr (2010) remark that there is always a trade-off between proximity and distance for the researcher. Close contact to the participants of a field study enables empathy for the researcher and affords the opportunity of actually understanding the context and comprehending the perspectives of the participants. Then again, distance from the field is necessary to allow the researcher to reflect upon the collected material from a research perspective (Przyborski & Wohlrab-Sahr, 2010, p. 60).

Within this study I engaged deeply with the users for the refinement of the concept, during the construction phase and especially in the test phase of the technology probe. The ethnographic interviews opened up possibilities for valuable and honest conversations with the users about their individual views and opinions towards the overall project and the technology probes implemented. Within these conversations I tried to assist the participants with clarifications on

functionality and my personal intentions for specific characteristics of the probes[17] to provide deeper understanding whenever requested. Nevertheless, I deemed it important to not actively suggest solutions for open issues at the outset, but to let the users develop their own ideas for possible adjustment within the interviews. Only if the interview partner could not imagine certain ideas spontaneously, general examples were given to provide a basis for further debate. The objective of this approach was to act as a contact person for the users whenever they had questions or ideas and to simultaneously collect valuable data, but not to influence users in their decisions and development of ideas.
Writing down the field notes right after the interviews provided the first opportunity for me to reflect upon the spoken content and convert it into results that finally influenced further design of the probes and my behaviour in succeeding interviews. As already stated in section 3.3.4 the survey conducted during the test phase also provided distance from the participants and enabled them to give feedback anonymously. The answers to the open questions of the surveys were screened immediately following each session but they were not explicitly addressed in detail in further ethnographic interviews. Rather, general patterns and trends identified in the responses of the surveys were sometimes became the topic of subsequent interviews.

A few words on reliability and validity
Validity and reliability in qualitative research does not follow the same principles as in quantitative research. According to Creswell (2009, p. 190) validity in qualitative approaches means to check the accuracy of the findings, and reliability refers to the consistency of an approach across different researchers and projects. To obtain reliability different procedures are suggested to be followed such as detailed documentation of the research process in terms of the collected data as well as the process itself and the steps taken within it. Transcripts have to be checked for possible mistakes and derived codes have to be reviewed to make sure that no shift between data and interpretation occurs. Regarding validity Creswell (2009) refers to various strategies such as triangulation, member checking, clarifying possible biases, presenting negative information as well, etc.
In this work the collected data e.g. field notes of ethnographic interviews, were described as detailed and as richly as possible, transcripts were done carefully following the principles of TiQ (see section 3.3.1) and steps and decisions taken were made transparent by explicitly describing them in detail within the sections illustrating the different methods and analysis, as well as in the outline of the overall approach in this section. The mixed methods approach followed in this study enabled triangulation across different data sources. Data from ethnographic interviews, surveys and sensor logs was combined to find commonalities as well as contradictions between the results obtained through different methods, and thus triangulation is one factor for validity. Member checking was done especially at the end of the first phase by presenting to the users the themes emerged from the analysis of the workshop to back check

17 Although the probe design was generally derived from the results of the initial design workshop and therefore mainly informed by the needs and wishes of the users, I introduced some details regarding overall appearance and the presentation of information and then presented these to the users and discussed them with them. To especially follow the participatory design approach the characteristics I brought in comprised the topic of the first ethnographic interviews to clarify if this met the expectations of the users.

these findings. Self-reflection on the gathered information (especially after ethnographic interviews) provided the chance to make possible biases visible that may have occurred through somehow influencing the participants.
The ethnographically informed mixed methods approach followed in this study in combination with detailed documentation of the data and the steps conducted, as well as ongoing reflection on the results allowed for an elaboration of a "thick description" following the notion of Geertz (1973). The rich and thick description of the context, the users' realities and expectations, as well as of the actual use of the technology probe, provided by the applied methods, is an additional contributing factor to the validity of the findings.

This chapter presented the methodological approach taken in this thesis to collect data, to analyse it and to design an awareness support system. In the first section the characteristics of the groups and their facilities were introduced followed by the principles of participatory design and mixed methods research. The theoretical background to the methods applied was also given and the actual approaches taken to collect material from various sources were outlined. A thematic analysis was conducted to reveal relevant themes found in the data of the initial workshop as well as in the results of the test phase of the probes. Finally, the overall approach and the combination of the individual methods was outlined, my role as researcher was disclosed followed by a brief discussion on validity and reliability. Having clarified in this chapter the methodology of this work on a theoretical as well as on a practical level, the actual results of the investigation conducted and the particular design of the technology probes comprise the topic of the following parts of this thesis.

4 Evaluation of System & Use Context

As already outlined in figure 1 the work on this project with the objective to design an awareness support system took about two years of conceptualization, development and testing. The following chapters of this thesis present the *awareness cubes* as the resulting system derived from the results of the conducted methods outlined in the previous chapter. The system comprises three identical devices realized as illuminated cubes that peripherally inform the users about ongoing activities in the other groups' common rooms and additionally act as tangible interfaces to enable explicit interaction. The cubes use colour coding for differentiating the individual groups on an ambient display and provide possibilities for expressing particular moods and/or activities of the groups via tangible buttons on the cube top. Further characteristics and details on design and functionality are outlined in Chapter 5 where the concept is presented comprehensively.

The contents of the following chapters are aligned with the project path and its three phases as illustrated in figure 1. As the work started with the participatory design workshop as the initial method for collecting information about the users' needs and the context, the results of the workshop and its analysis are outlined in this chapter because they represent the basis for further development and concept design. Consequently, the system concept, first feedback from users, the entire development and construction of the technology probes and the detailed software implementation and functionality are topics of Chapter 5. Finally Chapter 6 comprises the results and findings of the test phase including the analysis of data from ethnographic interviews and surveys as well as a descriptive illustration of the log data retrieved from button use.

The following sections provide a detailed description of the conceptual phase of the project, which is the basis for the development of the *awareness cubes*. The main results in this phase come from the participatory design workshop conducted together with my colleague Noemi Steitz. Hence, results of her work are outlined first in this section, followed by the results and findings of the workshop which was analysed individually.

4.1 Earlier work as basic point of entry

Before illustrating my own results and the designed system itself, I would like to refer to preceding research on this project done by my colleague Noemi Steitz (2015) because her results and findings from interviews build the basis for the commonly conducted participatory design workshop. Regarding the users' views on and requirements of technology, Noemi identified various relevant characteristics that are briefly subsumed in the following paragraphs. Interview partners expressed different attitudes towards awareness-supporting technology, ranging from scepticism over neutral stance to positive expectations. The difficulty in finding good working solutions and the overall necessity of such a system were topics within the interviews. In terms of content to be supported, a major desire of the participants was daily informal awareness of the others followed by the exchange of work-related information. As main characteristics for a possible future system group members indicated practicability and appropriateness to the context, as well as supportiveness and helpfulness in use. Furthermore, a system was to facilitate easy interaction and information flow, and was to be inviting and somehow pleasurable as well as offering concrete utilization with casual usage options. In addition to the interviews, Noemi set up a technology probe in the form of large touch screens in two of the groups. The probes comprised various possibilities for common drawing as well as for audio and video conferencing (Steitz, 2015). The results and especially the codes from Noemi's interviews were used to facilitate the initial phase of the commonly conducted design workshop where users were asked to articulate their views on the project as stories. During the workshop the cameras, mounted on the screens of Noemi's probe, triggered lively debates about privacy issues, which are also manifested in my results and findings presented in the subsequent section.

4.2 Results of the participatory design workshop

As illustrated in Section 3.3.1, the participatory design workshop comprised three techniques for gathering information about the users' wishes and needs regarding support of awareness, as well as design ideas about a future system. The workshop took place during the lunch break of the participants, and it took about 1.5 hours. The process was structured along the three techniques of *jumpstart storytelling* and card grouping, *starbusting* (Curedale, 2013) and *generating ideas* (cf. Sanders et al., 2010), as presented in this section. The atmosphere of the workshop was relaxed and casual, which helped participants to provide valuable and spontaneous contributions.

Initial storytelling and card grouping for immersing into the matter
In the first step of the workshop participants were asked to tell short stories about the project in order to get different individual viewpoints and opinions for further debate. Cards with printed codes and representative sentences from Noemi's interviews were arranged on the tables as reminders of the interview content and for helping people to get into the first task

and develop stories. Blank cards were also provided to allow the participants to create new codes and statements that appeared to be important for them. Participants immediately started grouping cards and bringing them to an arrangement that appeared reasonable to them. Figure 4 shows participants doing the grouping of cards and table 1 illustrates the overall resulting groups of cards.

Figure 4: Participants arranging cards with interview codes to support storytelling.

Group 1	Awareness of presence /rhythms/activities Automatic information management/handling/overview Creating group identity/feeling Exchanging/sharing work status/ideas/expertise/interests Using synergies/potential
Group 2	Screensaver problematic (added card) Design for intermittent use (added card)
Group 3	Viability/stability Simplicity
Group 4	Sustainability Viability/durability Energy consumption
Group 5	Balance Personal contact Contact/communication/interaction facilitation Connecting/relationship building

Group 6	Collaboration support Participation/group involvement facilitation voluntariness
Group 7	Sharing Exchange/sharing organizational issues Exchange/sharing availability information Asking/helping
Group 8	Movability Conventions of usage Maintenance/responsibility Placement/usage Disturbance/intrusion Consideration of time issues/retreat Time/effort needed Integration with own devices No supplementary effort Flexibility/configurability/individualization
Group 9	Pleasure/play/artistical Fun & lightness Necessity/sense/meaning Somehow connected to desk (added card) Incentives/reward (added card)
Group 10	Surveillance Trust Privacy Feeling of safety/no surveillance/confidence/control

Table 1: First workshop result. Groups of cards with codes from Noemi Steitz' (2015) interviews. Users grouped them by themes to support storytelling.

After people finished the grouping of the cards they used the arrangement for telling stories and talking about various aspects they characterized as important for supporting awareness across the groups. In addition, participants often referred to the touchscreen probe they were using to articulate issues they experienced, as well as emerging ideas like P5[18] did in a statement that addresses concerns about the camera attached to the screen, but also refers to a possible presentation of content that could be beneficial for all:

> *"If there is a light of video camera running and you don't know who are you connected with this is very strange but I really like the potential for the exchanging organisational issues and things like that. Basically there is e-mails coming and coming and coming and that was reading into detail. Maybe that's a way to put the big headlines somewhere so everyone has them in the back of their heads and yeah for*

18 Names of participants are coded to ensure anonymity.

like information asking there's the same questions over and over again and maybe this is a place to just post them for like quick answers." (P5)

Since the initial debates were primarily about the touchscreen and the attached camera, which was experienced as uncomfortable, P7 suggested removing the camera because *"my impression is that the camera makes more trouble than it adds value to the whole thing"* (P7). P8 confirmed the statement by noticing *"… many conversations there really started at least around 'are we being watched now?'"* Although the majority of participants agreed upon the concerns about the camera and the uncomfortable feelings caused by it, P2 suggested a possible solution that allowed video conferencing but also respected privacy by mounting *"… a mechanical shutter in front of the camera lens so you just slide it and you have your privacy."*

Although, the dominant topic in the first phase of the workshop was the touchscreen and the camera, various comments referred to other aspects such as possible content to be exchanged or participants' motivation for engaging with a future system. Regarding possible content, two main uses were stated. Some participants preferred to exchange 'light-weight' informal pieces of information as P3 characterized as follows: *"… you can share something which is digital but still entertainment which we don't do via e-mail, Facebook post in work time …"* Others referred to benefits of exchanging work-related content as well, like P1 *"… I would like to have the video option just in case because I imagine that it could be a way for people who are just sitting in meetings, you know, if we brought in the screen in here."* Regarding motivation and engagement, participants suggested to *"… put up pictures that say write something or to start some actions"* (P4) or to indicate new content through *"… a light that is glowing if there is something going on and is off if there is nothing"* (P6). Independent of the uncomfortable feelings caused by the camera, some participants perceived the large screen itself as distracting or even inappropriate for the common room area. P5 compared the settings to bars were TVs are mounted: *"I don't know, like sitting in a bar and there's a television somewhere I keep looking over even if it's football and I'm not interested at all and just keep staring at the television …"* Since the first phase was clearly characterized by discussions on the previously used touchscreen and the services provided by it, in the next phase the participants were asked to generate questions to open up the discussion for additional topics and aspects.

Phrasing questions to address various aspects of awareness support

Participants mostly phrased the questions individually accompanied by occasional rumour and consultation about open issues regarding the workshop technique itself, as well as the content and purpose of the questions. Each question was written on a sticky note and put on the whiteboard where a star was painted on it with six interrogative pronouns on its peaks. Participants where asked to start their questions with: *Who, What, How, Where, When* or *Why*. As outlined in Section 3.3.1 the method is called *starbusting* (cf. Curedale, 2013) and the different interrogative words were to support the participants for reflecting about the project from different points of view. Within the twenty minutes of this workshop technique the participants phrased a great variety of questions stemming from the interrogative words, which resulted in a filled star on the whiteboards that illustrated many different aspects of the participants' understanding of awareness support. An illustration of the resulting star with the questions is given in figure 5.

Figure 5: Resulting star with questions and statements from participants

As figure 5 shows not all questions really start with one of the suggested interrogative words and some of them are more statements than questions. Nevertheless, these are things that appeared to be important to participants and were assigned by them to the relevant interroga-

tive words. The majority of questions and statements were phrased referring to the *How?* and *What?* words.
The questions using *How?* words mostly refer to aspects of functionality of a future system and the interaction with it. Participants asked for *"immediacy"* and indication of new content or activities. A *"balance between availability and unobtrusiveness"* in terms of sharing content such as upcoming events and activities also appeared to be important for the users. Personal meetings were to be facilitated and the *"rhythm of the groups"* was to be represented somehow by an awareness support system.
Questions assigned to the *What?* word mainly addressed possible content to be shared via a future system and motivational factors for users. The information that could be used to represent the groups and facilitate awareness were key contributions within these questions. Regarding content and use people referred to the nature of group life and respecting social aspects of it. Users asked for some kind of *"added value"* that the system was to bring to their lives and an object was suggested as representative for the groups.
Questions referring to the *Who?* word focussed on people using a future system, its acceptance and the overall necessity of an awareness-supporting system. Concerns about additional effort a system may require, e.g. by needing a facilitator in each group, were stated as well as questions about who actually would want to use such a system. Users remarked in one statement that *"technology cannot substitute humans"* which represents a rather critical point of view.
Respecting the characteristics of the common room environment and the social life taking place there were also important in questions using the *Why?* word. Users were wondering, *"why so much technology is needed for the basic need of communication."* Again it was articulated that a large screen is distracting and a device with *"personality"* was suggested. Another questions addressed various reasons for connection such as competition among the groups to motivate the group members to engage with a system.
Only one question was phrased for each of the remaining *When?* and *Where?* words. Users asked, *"when should someone use this system?"* which may be related to special times of the day such as coffee or lunch breaks. The right location of a screen was the topic of the only question using the *Where?* word, which may be linked to questions regarding the obtrusiveness of a large screen.

The *starbusting* technique clearly opened up additional aspects of awareness support, enabled participants to imagine support techniques that go beyond the former touchscreen system and gave them the possibility to articulate personal concerns and criticism for a future system. In the next phase of the workshop these open topics were used as a basis for generating concrete ideas about how users could imagine interacting with a future system, the features that would be important for a supporting device and the content that could be exchanged through it.

Generating ideas for a future system
To support the users in generating ideas a variety of materials such as pens, stickers, coloured paper or modelling material were placed on two tables and the participants split in two groups to express their needs through using the creative materials. This resulted in drawings and collages addressing several aspects the users were discussing in this part of the workshop. Figure 6 illustrates a selection of ideas organized as collages on the tables.

Figure 6: Pictures from the workshop illustrating participants' ideas

The technique of actively and commonly *generating ideas* was accompanied by lively discussions on the desired characteristics of a future system. Since the participants were split up in two groups on different tables each group developed individual ideas. At the end of the *generating ideas* part of the workshop the groups presented their ideas to each other, informed the others about envisioned possibilities and mutually gave feedback, which led to further discussions.

The pictures in figure 6 show pieces of papers organized in groups or positioned as single signs representing different ideas that emerged in discussions during the workshop. In the top left-hand picture one sign requests to integrate the system into common lunches somehow. Users suggested to have lunch together but also to share their lunch with others. Referring to this P6 stated: *"… video could be part of this like having lunch at different places but together still …"* Quite similar to the question raised earlier in the workshop, another sign asks about the benefit of an awareness support system. P3 referred to this in the presentation of ideas: *"… what can we see as benefit or what could motivate us? So we found out things like procrastination is a benefit …; so if you urgently need to do something useless."* Other benefits were characterized as *"… pragmatic benefit like if you play with it that you can get coffee free or whatever"* (P3). These ideas and articulated benefits are references to informal exchanges and content a system could support. Furthermore, users saw possibilities for getting to know new people and, in addition, P4 suggested to: *"… not only get to know the people but also the projects that are going on in different groups so that you can collaborate more in these aspects …"*

In the top right-hand picture participants illustrated ideas about the visibility of content depending on hierarchy. The idea was that professors, assistants, colleagues abroad and students

should get access to different levels of content depending on their roles in the department. Similarly, on one single piece of paper users suggested to use the system to follow the groups' activities from far away, e.g. while travelling to conferences. Other cards refer to characteristics of technology and representation, e.g. providing possibilities for *"controlling output devices of other groups"* such as printers or having an avatar for representing the groups. In the summarizing presentation P6 described the avatar idea in more detail:

> *"And then we also talked about how to see if there is some activity and if there is no activity for a long time how to provoke you to do something. And one idea was, like a flower that's dying of dryness or something, and if you do something it gets more water again or so." (P6)*

The bottom left-hand picture shows a collage representing ideas for work-related support as P6 summarized in the presentation of the ideas: *"… share work-related things like links, literature, other stuff you might have to share …"* A desired connection from the public area to the personal desk and vice versa is also represented in this picture in figure 6. Random pop ups were suggested to be used to present content and that the system could provide web access to public areas to be connected to the personal desk.

The bottom right-hand picture in figure 6 shows ideas, which are in contrast to work- related aspects. The arrangement in this picture refers to users' wishes for playful competitions among the groups through casual games. Coffee counters were suggested as well as counters for miles walked representing specific activities that could be used for competitions. P6 suggested playing games via the system and characterized the ideas as follows: *"Or you could have playing a game together, a game that's easy to interrupt and resume again."* The idea was to play games where it is possible to make one move and then wait for a certain time before making the next. Therefore, the gameplay could include different people and be played over an entire workday. A link to the personal desktop was suggested here as well.

Other pieces of paper not shown in figure 6 comprised ideas for using a physical and/or ambient presence display to indicate activity. One collage addressed the problems experienced with the video camera again, and blinking lights were, for example, suggested to indicate an active video connection. Regarding the ability to control devices of other groups on one card, users articulated the idea to use 3D-printers to 'send' things to the other groups through remote printing. P2 illustrated this in more detail: *"… why not have a 3D-printer connected to both locations and you get objects. … Printing out … birthday presents?"*

The transcript of the audio recording revealed further ideas and discussion on the topic such as a gratification system for frequent users. This idea was rejected again because the group of participants that developed this idea also found that a gratification system would be in contrast to the freedom of choice everybody should have to use an awareness support system. In addition, P3 identified specific uncountable exchanges happening within one group but not really across the groups:

> *"… in our group we randomly exchange things like someone reads a paper for the one; the other one goes and buys food for that, and I mean uncountable types of exchanges are taking place and actually this is not shared with the other group." (P3).*

Regarding the effort technology would require to support informal, social awareness, participants stated that low-tech solutions that are cost- and resource efficient could be used to

trigger further actions and they would not need to put special effort into it. P1 suggested a solution *"… that is low effort but taps into things that we do anyway. Just picking up on the machine idea. We can have a cup of coffee anyway …"*

The three techniques applied in the participatory design workshops produced results on various levels. In the beginning participants were primarily talking about the touchscreen they were using previously and issues they had with the attached camera. The second technique provided a greater variety of contributions through phrasing questions regarding different aspects of awareness support assigned by six interrogative words. The last step of the workshop was to generate ideas about a future system. People used different materials to express their expectations and debated on them in a summarising presentation. This section provided an overview of the participants' statements and created artefacts regarding relevant aspects for supporting awareness, and the following section presents the interpretation of the gathered data.

4.3 Workshop findings

The data collected in the workshop was thematically analysed to get a deeper understanding of the users' needs, desires and concerns regarding awareness supporting technology. Three iterations of coding and refining finally revealed eight different themes in total each comprising several subthemes that illustrate the findings from the workshop. These themes allow very clear insights into what the members of the groups expect from a system that brings them closer together, how they can imagine using it, the content they want to share through such a system, why they want to have it at all and how they want to communicate through it. Figure 7 provides an overview of the resulting themes and subthemes. The detailed codes and their final assignment to these themes can be found in Appendix B.

Social / Community / Relationship

This theme is about the social life and community in the groups. It describes how the group members perceive themselves and others in the group and how they experience the members of the department as a group. It points out things that are missing in the current situation as well as hopes that are given towards a more socially connected future. It could clearly be identified that the members of one group don't even know all the members of the other groups and vice versa. So there is a desire to *get to know people* of the other groups better that are already vaguely known and to get to know new colleagues. P3, for example, referred to this problem when presenting ideas at the end of the workshop:

> *"… we realized that we don't know everyone because people – especially the younger generation – are not settled at the Technical University, are changing quite often. Every year there are new people, there are people going, there are visitors; so we don't know everyone … And then we just came to the conclusion that the best part about this project is all the time we are getting together to talk about how to get together and it's fun we have a workshop on that." (P3)*

Figure 7: Themes and subthemes as results from a thematic analysis of the workshop data

It has also been stated that *personal relationships go beyond simple communication* and scepticism was articulated as to whether technology was really able to enable establishing personal contact. Reports from participants revealed that there was already contact among members across the groups but rather on an individual level. Participants had concerns that technology would not be able to support contact on the group level because only having another communication channel (in addition to e-mail, Skype, etc.) was not seen as sufficient for establishing a common group spirit. The wish to have a *common group spirit* to enhance the group bindings was identified as another sub-theme. Remote groups should have a feeling of the rhythm of the others and social relationships should be facilitated and strengthened. Participants would like to be aware of the other groups and *having a sense of their presence*. If colleagues cannot be next

door because they are located in different buildings, participants would at least like to have a representation of the others to keep in mind that they actually exist. This representation could possibly be a physical one, a real object that is representative of the others. If a system can manage to bring the groups closer together and establish a common group experience members want to have a *personal benefit* from it, for example, through knowing their colleagues better on a personal basis, but also the projects they are engaged in and their actual tasks.

Content

This theme is about the different types of content that could possibly find a place in a future system. It shows what sort of information the participants like to share with their remote colleagues. Generally, participants wanted to *share information*, but often they did not articulate in particular what is meant by information. Nevertheless, it can be said that there seems to be a difference in the amount of information ranging from short pieces to more complex content. A more specific type of content is expressed through the suggestion to share *personal* pieces of information, such as short videos of a person's life to show what is going on and what somebody is doing at the moment. This would provide information on private activities and therefore could contribute to establishing personal relationships. A different type of content is *work-related information*. People would like to exchange things about projects they are currently working on to get feedback from different perspectives, as well as help on open issues. Such things can be links, references, expertise, ideas or interests.

For most participants it would be very important to share *funny things*, for example, exchange jokes or entertaining video clips. This is what they often do in their own kitchen talks and what they would like to share with others. Another suggestion was to present different types of content to different "types" of co-workers dependent on *hierarchies*. This would ensure that, for example, the head of the group could not see if he or she was part of a joke. This suggestion was discussed by research and project assistants in the workshop but was seen more as a fun functionality of a future system than as a serious request. Filtering content depending on the role of group members would definitely harm the facilitation of group spirit.

Other forms of possible content are short *announcements* or triggers for real meetings. For example, dinner plans could be shared by the system. Here the system would be used to organize personal meetings, remind the users to get together and keep a common schedule of informal activities. P6 illustrated this possibility: *"… there was a picnic organized, playing, gaming, the things you already have … How could you announce this?"*

Activities

The activities theme is somehow related to the content theme but has a different focus. The content theme describes types of information to be possibly exchanged whereas the activities theme focuses on actions the participants want to do commonly, supported by technology. It is quite obvious that the participants want to *share and exchange* various things. This goes beyond just talking to each other or texting messages. People want to establish uncountable types of exchanges, for example doing their colleagues a little favour or sharing organizational things. In addition to sharing various things or pieces of information participants would like to be able to *inform* other group members about their activities or to invite them to personal

meetings through a future system. This is somehow similar to the request for announcements illustrated in the content theme.
Another possible activity within breaks could be *playing games* against the members of a remote group. This perfectly fits the entertaining types of content mentioned in the content theme. People could imagine having playful competitions in various forms such as coffee counters that illustrate the coffee consumption of the different groups somehow or to directly implement gaming functionality, such as a chess game, in a future device.
In contrast to playing, some participants would like to use the system to *collaborate* with colleagues that are at conferences. The objective here is not primarily to connect to colleagues from other groups but rather to members of one's own group who are temporarily abroad. Such functionality is normally provided by groupware systems where the focus is on enabling remote colleagues to work efficiently rather than on facilitating social relationships.
A possible activity for establishing a common rhythm of the groups would be to have *virtual lunchtime meetings*. This could support the exchange of informal, fun content as well as more formal work-related information. Participants suggested setting up a stream for the lunchtime seminar already taking place on a regular basis in order to facilitate more frequent lunchtime meetings and also enable colleagues currently abroad to join the stream.

Motivation
This theme shows how the members of the department could be motivated to use technology to improve the social bindings between the groups. The theme points out several important aspects regarding the motivation of use, which can be seen as critical for a successful system.
Participants claimed that the use of a system should be *voluntary*. Everybody who is working there should have the free choice to use it or not. There should not be any form of punishment or disadvantage if someone refused to use it. This is slightly in contrast to a reward system some of the participants wanted to have. On the one hand, people should be motivated in some way to engage with a future system, but no one should be forced to use it.
As already mentioned, some statements required some kind of *reward* for using the system. Participants suggested providing possibilities for earning credits for playing with it or getting free coffee, dependent on frequency of use. It seems that people want to have a bonus just for using the system as such and not for the result of contacting other people and exchanging something. P3 referred to this form of motivation when summarizing some generated ideas: *"We had this discussion that the best two persons that communicate … get from the least, the worst two people on the list, a free food or something like that."* This leads to the assumption that some participants could see the implementation of such a device as a burden and might be afraid that it could require too much effort.
Similarly to the content and activities theme *fun* is also a sub-theme here. People want to do something useless, primarily entertaining. Especially in their coffee or lunch-breaks they do not want to be confronted with serious work-related content. They identify procrastination as a benefit here. This indicates that technology that is somehow embedded in the common rooms where users take their breaks from work should facilitate the exchange of content and activities users are engaged in in this context, which appears to be rather informal and lightweight rather than serious and task related. Another sub-theme is *competition*, which could be

interpreted as a fun element as well but does not really fit with procrastination in the breaks, despite competition here being meant as part of a game people play against each other. The chance to win something or to have a higher score in whatever seems to be a motivation factor for users. The actual game itself appears to be less important than comparing each other on a specific level. A little counter that shows differences and gives the chance of a little competition such as presenting the number of miles travelled or coffees drunk could also be just as motivating as the implementation of more complex games like chess. Therefore, the main reason for motivation is *entertainment*. The members of the groups would like to have something playful that provokes an interaction. Quite similar to the entertainment sub-theme is the *encouraging* sub-theme. The system has to encourage people to do something, be inviting and be an incentive. It somehow has to get the colleagues from their workplace to the place where the system is installed.
In contrast to entertainment, some participants could imagine being motivated to use a connecting device because it could *support collaboration* with others. This is similar to the exchange of work-related content, but was mentioned less frequently as a motivating factor than entertainment reasons. In terms of motivation, work-related aspects may not play such an important role because there are already services (e-mail, Skype) that participants frequently use to exchange formal content.

Effort
This theme shows how much effort the groups want to put into the use of a connecting device. The theme gives information about maintenance aspects as well as about the willingness to leave one's personal desk to meet colleagues.
Participants wondered about the supplementary effort such a device may bring and if it perhaps needed to be *facilitated or maintained*. A system should be cost- and resource efficient so that users did not have to spend time on keeping the system running.
The results clearly show that people would like to have a supporting system and even would like to have a reward for the use of it but they *do not want to put any extra effort* in it. They want the system just to be there, work properly and cost as little time and money as possible. Successful technology assists the users in their practices and supports their activities and therefore the required effort should be rather low. But, as the motivation theme shows, it should also include incentives for its use because the sole perspective of better relationships among the groups did not seem to be sufficient to motivate users to put efforts into a supporting system. To lower the amount of effort a system or device has to *be integrated in or combined with other devices* to save time and avoid that users have to leave their desks for every single interaction. It should bring some form of awareness of the others to the personal desk. This is a strong contrast to the encouraging sub-theme in the motivation theme where people reported that a system had to encourage them to be active and get in contact with others.

Initiation
Initiation is how the first step of getting into contact could look and what is important in establishing a connection because there is a difference in the participants' statements between already having communication and the act of establishing and initiating communication. The *initiation* theme is therefore related to the motivation theme.

The participants want to *be notified* if there is some action or if there is new content. This could be a first step that provokes interaction. In the former touchscreen system they reported having problems in identifying new content because the screensaver of the operating system was activated too often. Therefore, participants wanted to be notified about new content but these notifications should fit somehow to the break-time character of the setting and therefore it should not be too obtrusive. People wanted to be reminded of the system by *playful nudges* like a sound that is being played if someone in another group is making a cup of coffee. Another possibility would be a blinking light if there were some action going on in the other group's facility. Another starter could be the presentation of *excerpts of actual content*. This would make people curious about the details and start an interaction.
A future system should have *no idle mode* because this would signal that the system is running but there is no particular action in the other groups that could be displayed. This would prevent the initiation of an interaction. A screensaver should for example be avoided. In idle times pictures that encourage people to use the system could be presented instead. Comments from P8, P4 and P5 underline problems experienced and possible solutions:

> *"… I felt that the screensaver was problematic because it didn't invite any kind of interaction with the system it rather gave this impression of 'out of order'." (P8) "Maybe you should put up pictures that say: 'write something' …" (P4) "It could grasp some of the information that's in the system like – I don't know – there is a notification … and just display if you click me, you will [see] whatever someone left for whomever." (P5)*

Communication process
In contrast to the initiation theme, this theme describes situations when the communication has already started and is established and running. It collects different types of communication as well as questions regarding the recording of messages or conversations.
Many contributions addressed different types of communication (regarding content and context) and most of them showed the *need for informal communication*. Participants expressed their desire for unserious forms of conversations even though a system should also provide possibilities for formal exchanges. The reason why they wanted rather informal communication is that there simply are enough ways to communicate formal things like e-mail, phone calls, etc. Furthermore, referring to the fact that they would like to get to know their colleagues better it was stated by P4 that *"… it's also easier to have serious conversations if you have unserious conversations before because then you know the person you are talking to."* A future system should also enable the members of the groups to *set up spontaneous contacts more easily*. This is also a reference to the desire for informal exchanges although it is not explicitly mentioned here.
Regarding the *recording* and/or saving of messages and content it has been stated that this is *not really natural for kitchen talks*. A chat protocol doesn't really fit into the social circumstances of a lunch break. Users reported that kitchen talks have 'flying' and 'light-weight' character and therefore should not be stored or protocolled because this would not fit the kitchen context. Nevertheless, users also stated that they were afraid to miss something when they were not present and a system should obtain the content somehow, which is in contrast to the informal characteristics of break-time conversations. Obviously there is a trade-off between keeping the content of the communication process available for later use and considerations regarding

privacy and adequate handling of communication. Similarly to this the participants think that it is tricky to *ensure that someone really received a personal message*. There has to be some form of confirmation that people really receive content such as text messages or pictures. Like in face-to-face meetings there has to be a response somehow to confirm the receipt.
Furthermore, for communication aspects a future system could provide the possibility to *start or trigger different levels of communications*. This could range from informal to formal conversations or as a starter for the use of other channels or devices. For example, this could be a personal meeting or other activities as presented in the activity theme.

Technology
This is certainly the theme with the largest amount of single references and codes, which is understandable because the objective of the workshop was to gather ideas for a future technology for supporting awareness. It shows many different aspects such as privacy issues or being sustainable and forms a first picture of the characteristics of a device that is to be designed within this project.
The planned device should *fit into the environment*. It has to be easily available but also it must not be intrusive. The device should fit the situation of *kitchen talks* and therefore it could somehow have personality, which was not explained in further detail. It should support the natural group rhythm but it should not distract either from work or from break-time conversations. This, for example, indicates a peripheral device that enables users to concentrate on their actual activity and only requires engagement if it attracts the user somehow. Furthermore, it should not raise uncomfortable feelings like a camera or a huge screen does, for example.
A device for connecting the groups has to be *sustainable*. As mentioned before it should not require any effort but also should be ecological. The power consumption should be as low as possible and the times it is really running should depend on the actual interaction that takes place. In times of low activity the power consumption should also be as low as possible in terms of sensing and displaying.
It emerged very clearly that the device should be very *simple* but stable. A low-tech solution that does not need much effort in terms of maintenance but presents the activities of the groups in a way that establish a feeling of community was desired by some participants. As a low-tech solution the implementation of a telegraph was discussed by P9, P3 and P1, which was not meant to be a serious suggestions but rather an example for a very low-tech and simple approach from which the groups could benefit: *"Maybe we need a minimally technological solution like … a telegraph."* (P9) *"Yeah, I would also like …"* (P3) *"A telegraph?"* (P1) *"Yeah, we should have a telegraph."* (P9). In addition to simplicity, to some extent the device also had to be *flexible and moveable*. Here it is important to connect it somehow to other devices like desktop computers to reduce effort and to place it at different locations wherever it is needed.
The most important part within this theme is that users should *have full control of the provided* functions. The system has to be designed in a way that it is very clear in every situation if a connection is established and to whom it has been established. In terms of built-in microphones or cameras, it has to provide the possibility to disable sensing and recording completely, for example, through the use of a mechanical shutter. Thus the privacy of the group members

is respected and they can establish a form of trust towards the system because they have full mechanical control of all the critical functionality.

Summarizing: a simple, playful, low-effort solution is envisioned

The workshop provided a perfect occasion for beginning my work on the design of an awareness system for these groups because it revealed valuable insights into the users' needs and the break-time context within which the system should be embedded. It is very obvious that there is a wish for a better social connection and the facilitation of a stronger group feeling. Users want to get to know the people in the remote groups better, as well as the ones in their own groups and thus want to benefit from enhanced relationships on an informal level. It is crucial to provide representations of the groups within a supporting system to facilitate a sense of awareness across distance. Referring to the suggestions of the workshop participants this representation could possibly be a physical object or a virtual avatar. The group members would like to use a future system mainly for exchanging entertaining, casual and fun content like they regularly do in *kitchen talks* within their own groups. But, in addition, users also want to have possibilities to exchange more serious, work-related content which possibly could be taken from already established formal channels; perhaps a future system just has to link these channels together and present the content in a useful, comfortable and sophisticated manner. The motivation to use such a system could also be achieved in a playful way. For example, people suggested possibilities for earning credits through the use of the system to keep motivation high. However, people do not want to make any extra effort for the use of the system in terms of maintenance or time. Therefore it is important that a future system provides benefits for users but keeps the required effort by them as low as possible. As already mentioned, the character of communication should be informal but with additional possibilities for sharing references, links and other more formal and work-related matters. An awareness-supporting device should fit into the daily routines of the group members and also should be sustainable, stable and ecologically efficient in terms of power consumption. Many users would prefer a simple, low-tech solution that enables communication easily and also provides functionality for common gameplay and competition. It also has to ensure in every circumstance that the privacy of the users is respected and that they have direct control of all implemented features at any time. Automated sensing needs to be indicated in some way and users need to be able to turn off features whenever they want to. This analysis outlines many different characteristics of a future system envisioned and expressed by the users themselves. The characteristics that were emphasized in particular and how the designed technology probe addresses some of the more relevant wishes and expectations regarding awareness support are presented in the following chapter.

5 Awareness Cube Concept & Development

The themes from the analysis of the participatory design workshop suggest various points of reference for designing an awareness-supporting system or device. A future system has to follow principles of simplicity and effortless interaction and use but also should provide features to exchange rich content that may be entertaining and/or work related. To follow these wishes, experiences and requirements two concepts were elaborated derived from the findings of the initial design workshop. One of these concepts had to be discarded due to environmental reasons outlined in the following paragraphs. The second concept, however, appeared to be feasible and therefore was further elaborated for practical use resulting in the *awareness cube* technology probes, which is presented in detail in the following sections of this chapter.

Since an earlier concept addressed a variety of themes from the workshop and the reasons for its rejection highly influenced the design of the *awareness cubes* it is sketched briefly. The first system concept comprised projectors for displaying information and electronic pens for generating content and interacting. The projectors were supposed to be mounted above the kitchen tables of each group and therefore would display information directly on the table. The mounting on the ceiling would put the technology in the background and the device would hopefully be perceived as less intrusive and distracting than a large screen. Whenever the system is turned on it turns the kitchen table into an interactive zone for exchanging various types of content among the groups, yet still keeping the main use of the table (for lunch, etc.). If users turn off the system it would not influence the kitchen life at all, apart from the projector being present on the ceiling. As input and interaction devices electronic pens would have enabled the users to generate and exchange content for various purposes such as funny drawings or personal notes and invitations. In addition, content from personal devices such as smartphones, tablets or laptops could be integrated with the system and shared through it. Therefore, users would have been able to exchange playful and entertaining content as well as more serious work-related content. To respect the privacy of the users cameras, microphones and other sensors could be easily turned off via a remote control designed as penholder. This ambitious concept had to be discarded for two reasons. Firstly, the needed equipment would have been rather expensive, especially in relation to its usage time during a test phase of a few weeks. Secondly, it would not have been possible to mount equipment on the ceiling above the kitchen table due to reasons of workplace safety. Such mountings have to be authorized by the employer – the TU Wien – to ensure safety at the workplace of the group members.

This shows that there are further organizational, financial and environmental limitations than those elaborated by the users in the design workshop. Unfortunately, users' wishes and expectations are not the only criteria that have to be respected within the design of technology for supporting awareness across distance. To integrate these limitations another concept was envisioned that is also based on the findings of the workshop but tends to follow users' desire for simplicity.

5.1 Awareness cube planning and design

As an alternative to permanently installed equipment (projectors) and a system that comprises multiple devices (electronic pens, smartphone, etc.) the *awareness cube* concept, illustrated in figure 8, realizes the support of social awareness through relatively simple devices that allow flexible placement in the groups' facilities. The basic idea of the concept is to sense the current activity in the common room and present this information on equivalent devices in the kitchens or common rooms of the remote groups. Hence three cubes were constructed – one for each group. Thus the *awareness cubes* are representatives of the groups by indicating the presence of remote colleagues and showing the current degree of activity. As workers peripherally follow the activities of co-located colleagues and therefore obtain awareness about the rhythm and social relationships within a work group (cf. Kraut et al., 2002), the *awareness cubes* collect activity information and transport the captured information to the kitchens of the other groups. In this section the *awareness cube* is presented in detail, comprising the overall aesthetics and appearance of the devices, how awareness information is collected and presented and further possibilities for direct interaction via the buttons on top of the cubes.

Before the cubes were actually realized the concept was presented to the users for discussing the cube idea with them, getting feedback from them, and for commonly developing further ideas for interaction. The concept presentation and discussion marks a relevant milestone in the project (see project timeline, figure 1, p. 45) because the *awareness cubes* are based on the findings of the design workshop this was an opportunity to investigate if the concept actually met users' expectations. Furthermore, the discussion was used for debates on open issues such as the detailed functionality and use of the buttons, and new ideas to resolve these issues were commonly elaborated. Although the feedback of users was mainly positive and the majority of them liked the idea of an ambient display and interaction via simple buttons, some concerns were expressed. Especially debates about privacy issues and the possibility of being observed by the device were very lively and could not be completely resolved in this session. Since it appeared to me that some topics remained open for some users of one group after the presentation, although it clearly was the minority of the users, I asked for an additional meeting with them to further clarify the concerns and find satisfying solutions. The implementation of the *awareness cubes* only makes sense if each group is participating in this project and the system is not completely rejected by one of the groups for whatever reason. Therefore, a very detailed description of the functionality of the devices was given to interested users and compromises

were found that enabled all three groups of the department to use the cubes with positive engagement.

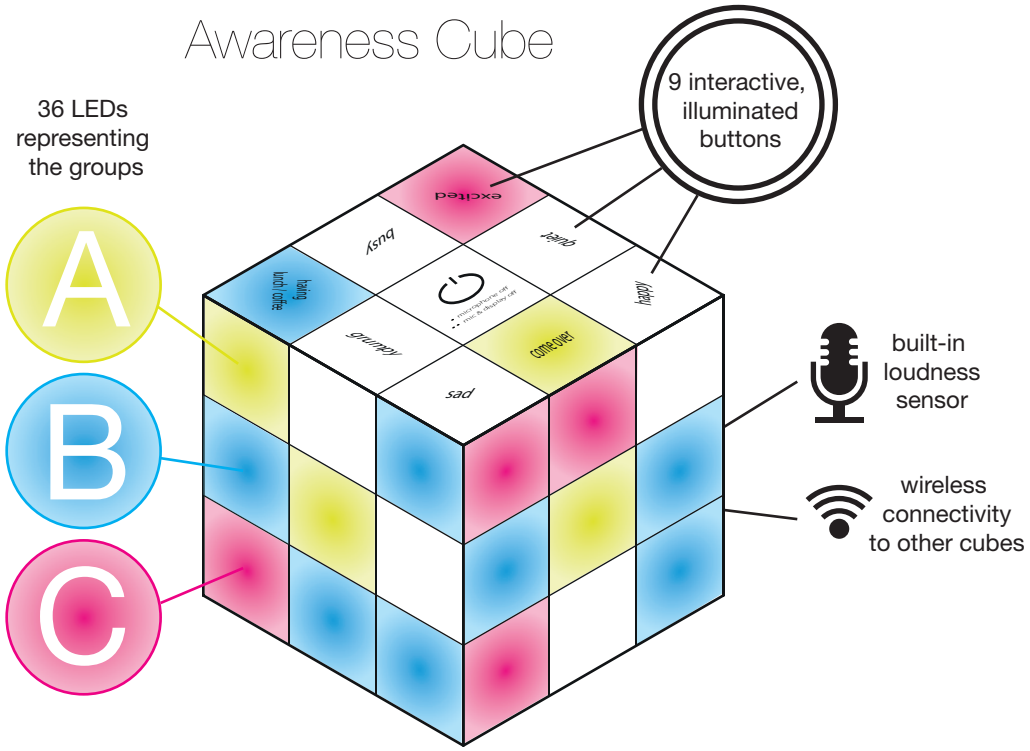

Figure 8: *Awareness cube* device comprising LED lights, interactive buttons, loudness sensors and wireless connectivity

Unobtrusive artefact aesthetics and appearance

As illustrated in figure 8 the *awareness cubes* are designed as ambient cubic displays for presenting awareness information with additional tangible interfaces in the form of buttons to provide explicit ways of interaction. The cubic design comprises LED lights mounted behind a semi-transparent surface and all technological components such as sensors and controllers are housed in the cube so that the aesthetics and the appearance of the devices have little commonalities with familiar technology such as computers, screens, keyboards, etc. Since the group members are using electronic devices very frequently for their work tasks they do not want their common rooms to be equipped with similar technology because the common rooms are used as places of communication and deflection from work within break times. Therefore, a design was chosen for the awareness supporting devices that is different to the technology with which the users are already familiar and the *awareness cubes* would not be perceived as interfering in the social life in the common rooms. The artefact is designed to fit to the environment and liveliness of the common rooms, presenting awareness information as

an ambient display in the background and providing possibilities for explicit interaction via its buttons. One main objective of the design is that users perceive the devices as comfortable and robust connecting objects rather than as an intrusive and distracting technology. For example, the presentation of awareness information through the LED lights also follows the principle of unobtrusiveness by providing smooth transitions of the illumination when changes in the amount of activity occur. The size of each cubic device is about 15 x 15 x 15 centimetres, which is just large enough to house the needed equipment inside the cubes. This size also provides variability of the cubes' placement in the common rooms. They are small enough to be put directly on a kitchen table without taking up too much space, but they can also be placed elsewhere at a more peripheral location such as on a windowsill. Furthermore, when the *awareness cube* is placed in the periphery of the common rooms, the device with its side length of 15 centimetres is still large enough to be recognized from larger distances. The only visible connector of the cube is its power plug, which also limits the variety in positioning – the cubes need to be placed near (in a range of 2.5m) a power socket. All data is transmitted wirelessly as this appears to be more comfortable for the users since connecting a number of cables would heighten maintenance effort. For the same reason, power supply through batteries, which would mean that the cubes could operate without any cable, was rejected because the users would possibly forget to charge the *awareness cubes* and the system would be out of order many times. In summary, the unobtrusive cubic design of the devices is unique in comparison to devices with which users are already occupied; it is also calm in terms of fitting the specific environment of the groups' common rooms and because the cubes are designed to work almost effortlessly.

Microphone data for visually presenting awareness information

The loudness level of the cubes' surroundings is used as basic indicator for activity in the common room of each group. It is presumed that the loudness level in the kitchen or common room corresponds to the liveliness of the activities of people present. Therefore, loudness appears to be a promising data source to inform the remote groups about ongoing activities in the common room and it furthermore appears to be a relevant source of awareness information because noisiness in the kitchen is also a good indicator for common break taking of co-located colleagues. The loudness level is measured by a built-in microphone and is algorithmically transformed to normalized intensity values[19]. This means that the loudness level is described as a value between zero and one and only these changing levels are used to present the activity information. To handle microphone data in this way is crucial for meeting users' insistent requirements for preserving privacy. Therefore, the microphone is neither used for recording of audio material nor for interpreting the collected data semantically regarding spoken content, type of activity, etc. Each sample of raw microphone data is only used to analyse the loudness within a given spectrum and is discarded as soon as the next sample is available. Ensuring that collected data could never be related to individuals for every state of the system was a crucial point brought up by some users from one group in the discussion following the concept presentation. Since the system cannot be successful if a group of users rejects it because of security concerns, the audio data is handled as outlined above and the detailed

19 Details on the algorithm and functionalities are presented in Section 5.4

algorithmic use of audio material was made transparent and presented to the users to resolve such concerns.

The retrieved intensities of loudness in the cubes surroundings are used to visually display this awareness information via LEDs on the cube's sidewalls. Each group is represented by its individual colour on the *awareness cube* (see figure 8) and therefore users can easily identify to which group the indicated activity is related. Each sidewall of the cube comprises a 3 x 3 matrix of LEDs and thus 36 LEDs are available in total on the sidewalls to display the activities in the common rooms of all three groups. For displaying nuances of activity and changes in the liveliness in the common rooms the intensity levels correspond to a particular number of LEDs. Thus more LEDs per group are activated if the intensity of noise is higher. In addition, the intensities are coupled with the brightness of the LEDs. By using a different number of LEDs and varying brightness for changes in loudness the *awareness cube* is illuminated more intensely the higher the activity in the groups becomes. Smooth transitions between changes of loudness lead to glowing effects in the illumination and the cube is perceived as an ambient display representing the rhythm of activity by flowing changes in its illumination. Since the activities of all three groups are presented on each cube the activity of one's own group is also perceivable through the cube's illumination. Through this the indicated activities become comparable by matching the self-produced intensity of LEDs on the cube to the intensities shown in the colours of the other groups. Sensing loudness information and transforming it to visual representations is the automated, passive form of supporting awareness across distance that the cubes provide. This allows the cubes to stay in the background, to be perceived as an ambient display, yet still providing a connection to remote colleagues by indicating their activities.

Interactive Buttons for exchanging particular group states and/or activities

In addition to the peripheral presentation through illumination, a more active and explicit form of exchange and interaction is provided by the nine buttons mounted on the tops of the cubes. These buttons are arranged as a 3 x 3 matrix and each of them includes one LED. Thus, the top of the *awareness cube* has a similar appearance to the sidewalls, but the single 'tiles' of the 3 x 3 matrix are illuminated buttons and not 'only' lights. The combination of a button with its corresponding LED enables the users to express something particular through the button and this expression is indicated on the other *awareness cubes* through the corresponding LEDs on the buttons. Since this simple concept of indicating something through the pressing of buttons allows various ways of use and different forms of expressions, the details were left open for the concept presentation to elaborate ideas together with the users. The analysis of the participatory design workshop showed very clearly that users prefer something simple and playful. In addition, the surface of the cube represents a 3 x 3 matrix and therefore the suggestion to use the buttons for playing Tic-Tac-Toe games across the groups was obvious. In the discussion after the concept presentation many users stated that they liked this playful element, but they also had concerns about how the game could be played with three players. In addition, some of the users remarked that it was relatively easy to achieve a tie game when both players were concentrated; however, the fact that there were three players and and that the particular opposite was not known, were considered to be interesting factors.

As already outlined in one of the previous paragraphs some users had serious concerns about how the concept guaranteed the users privacy and how the collected audio data was handled in a safe and secure way. To enable users to shutdown the *awareness cube* in times when they did not want any form of activity going on in their common room perceivable for others via the *awareness cubes* – even if no relation to individuals, types of activity and/or content was admitted – an ON/OFF switch was demanded. Since the suggestion of simply cutting the power supply of the cube in such situations did not satisfy the users and an additional 'hidden' switch at the bottom did not appear to be useful, it seemed promising to use one of the buttons on the top for switching the cube off. If one of the nine buttons had to be reserved as an ON/OFF switch, playing Tic-Tac-Toe would no longer be possible; so a use of buttons and alternatives had to be found. A combination of the users' statements in the workshop and literature research showed ways for alternative uses of the remaining buttons. Sharing and exchanging things, informing others and making announcements were frequently articulated wishes in terms of content and activities to be shared through an awareness supporting system. A study on work group moods by Bartel and Saavedra (2000) introduces different moods as collective properties of work groups and consequently, representing the overall mood of a work group could be a beneficial aspect of the *awareness cubes*. Therefore, I suggested labelling the eight remaining buttons with different moods to enable a more detailed expression of the group status in addition to the automatedly collected loudness information. This idea was a topic in early ethnographic interviews to obtain user feedback and to clarify which expressions could be promising for representing the moods frequently experienced by these three groups. In addition, to involve all users, an online survey was conducted to collect suggestions for particular expressions. In this online survey 16 predefined mood options primarily based on a circumplex model of mood (Larsen & Diener, 1992 as cited in Bartel & Saavedra, 2000) could be chosen by the users and an additional open field was provided to enable the users to give their own suggestions for additional moods that may be special for these groups. Figure 9 shows the predefined mood options and their related dimensions, their frequency of selection, as well as the individual suggestions from users.

The diagrams in figure 9 illustrate a wide range of moods referring to many dimensions, with a slight preference for moods from active and positive dimensions such as *high activation*, *activated pleasant* and *pleasant*. Especially in the suggestions given by the users themselves more moods from the *unpleasant* dimension such as *"sad"* and "*depressed"* were named as useful to be put on the cubes' buttons. Since there were only eight buttons available to be labelled with moods the predefined options and additional suggestions were grouped in eight expressions of moods and activities respecting the frequencies and the dimensions. The buttons were to enable users to express their favourite moods, but were also to provide moods from opposing dimensions such as positive ones and negative ones. The resulting eight mood labels for the *awareness cubes'* buttons, their origin from moods in the survey, the total number of references in the survey and their dimension are illustrated in table 2.

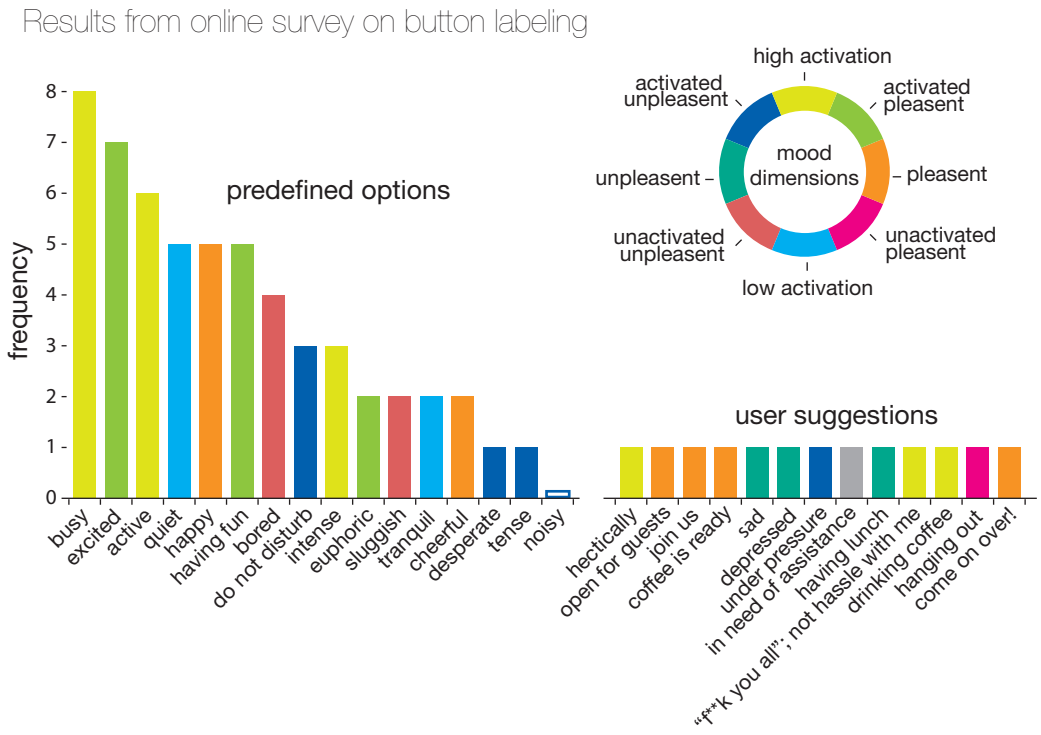

Figure 9: Results from online survey for button labelling to express group moods.

Button label	Origins	Freq. sum	Dimension
busy	busy, active, hectically, do not disturb	21	high activation
excited	excited	7	activated pleasant
quiet	quiet, tranquil	7	low activation
happy	happy, having fun, euphoric, cheerful	14	pleasant, activated pleasant
come over	open for guests, coffee is ready, come on over, bored, join us, in need of assistance	9	pleasant
sad	sluggish, depressed, sad	4	unpleasant
grumpy	"f**k you all", tense	2	unpleasant
having lunch/ coffee	having lunch, drinking coffee, hanging out	3	

Table 2: Final button labelling based on survey results and mood dimensions

The discussion following the concept presentation led to a very specific use for the buttons on the *awareness cubes*. One button is used as an ON/OFF switch to meet the users' requirements regarding possibilities for active privacy control by disabling the built-in microphone. The ON/OFF functionality is provided by the central button on the top of the cube and works in two steps. Pressing the button once switches off the audio sampling through the microphone

and disables outbound data transfer. Inbound data transfer is still enabled in this mode, which allows the presentation of awareness information from the other groups. Pressing the ON/OFF button a second time, switches the cube completely off and no information is sent to or received from other cubes. The mood buttons are arranged around the central ON/OFF button and enable the users to express explicit moods that are actually related to frequent experiences and activities of these particular groups.

Possible future system extensions for personal workplaces and mobile use

The findings of the participatory design workshop revealed that, in addition to a system implemented in the common rooms, users would like to have awareness information directly on their personal desks or while they are travelling and commuting. Therefore the entire system concept also comprises possible solutions to address these wishes, which have been elaborated as future extensions to the concept but have not been realized within the work on this thesis because this would have exceeded the scope and feasible effort of this work.

A 'little workplace brother' of the *awareness cube* was introduced in the concept presentation to illustrate possibilities for extending the awareness support system from the kitchens and common rooms of the groups to the personal workplaces of the employees. This smaller cube would have one third of the side length (approx. 5cm) of the 'large' *awareness cube* and would be connected directly to the personal desktop computers of the group members. The small cube comprises one LED on each sidewall to display the activity in the common rooms of the groups and one illuminated button on its top for sharing personal expressions or indicating individual participation from the desktop. The workplace cube would have no microphone and therefore would not automatically sense its surroundings so as to ensure privacy for the workers, and it would use the internet connection of the desktop computer for communicating with other cubes. The little cube would enable the group members to experience the activity and rhythm of all three groups not only in the common room but also on their desktops.

In addition to the little workplace companion of the *awareness cube* a virtual representation through a web-service and/or smartphone app could provide information about the group activities for colleagues who are currently not present at the groups' facilities. A virtual cube, similar to the physical ones placed in the common rooms, could present the loudness information on a webpage or mobile app to indicate activities and virtual buttons could be used to share personal expressions when people are not at work. Such services would enable the group members to stay connected to the social life in the work groups even when they are not actually present. It would somehow delocalize the awareness support system from the groups' facilities, the workers' presence at their offices and usual work time because people could stay connected at any time and in any place. A desire for a permanent connection to colleagues was not explicitly expressed in the workshop but people stated that they would like to stay in contact with currently travelling colleagues.

A concept closely related to relevant workshop themes

The *awareness cube* concept illustrated in the preceding pages is mainly influenced by the findings of the participatory design workshop and limitations regarding costs, environmental aspects and feasibility. Not each aspect, wish and expectation expressed by users in the workshop could be directly addressed in this concept but the most relevant and frequently stated desires

are included in this system concept. Regarding the *social / community / relationship* theme from the workshop findings, especially the wishes to enhance the group spirit and having a sense of presence, are directly addressed by the cube concept. In terms of the *activities* and *content* themes, the cube concept enables users to share and exchange group moods and activities via the buttons and, although the buttons are labelled accordingly, they could also be used for other, more playful purposes. The 'having lunch / coffee' and the 'come over' buttons allow users to make announcements and invite their colleagues for common activities. Regarding the themes representing the *motivation* of the users and the necessary *effort*, the system can be used voluntarily and there are no obligations for using the cubes. The design of the cube artefact and the representation of the groups through illumination of the object are intended to appear pleasantly, be encouraging and inviting to the users. The system operates relatively effortlessly in terms of needed maintenance and the concept illustrates possible integration with other devices. Regarding the *communication process* and the *initiation* of communication, the cubes facilitate possibilities for notifying remote colleagues about activities and group moods; they support more informal types of exchange but may act as trigger for other contacts through enhanced awareness such as more frequent personal meetings for lunch, for example. Regarding the theme on *technology*, the workshop participants stated, for example, that a future system should fit into the environment, which is achieved by the *awareness cubes'* unobtrusive design. Further expectations towards an awareness supporting technology such as simplicity, flexibility and full control by the users are also clearly met by the cube concept.

The *awareness cube* concept for linking three remote workgroups comprises simple devices with an unobtrusive design that automatically sense the loudness level in their surroundings and display these values via LEDs on the devices' surfaces. In addition, for direct exchanges, the buttons on the top of the cubes are labelled with moods and activities that are directly related to the actual social life in these groups. Possible extensions complete the system enabling use on personal desktops and while travelling, which could be realized in future endeavours. Within the scope of this thesis the *awareness cubes* were implemented as presented in this section to support social awareness across distance in the work groups' common rooms or kitchens. Details of the cubes' construction, used materials, installed hardware and an illustration of the software implementation is given in the following parts of this chapter.

5.2 Hardware components and assembly

After work on the concept was finished and the last major issues were resolved together with the users, the phase of planning the system and its associated devices merged into the phase of constructing and implementing the three *awareness cubes*. In this phase decisions on electronic components such as controllers and sensors had to be made and appropriate materials had to be found for the construction of the cubes. This section outlines the construction of the cubes beginning with their 'interior', namely the chosen controller, LEDs, microphone, and

their assembly. The presentation of the electronic components is followed by an illustration of the materials used and the construction of the devices.

For sensing the loudness in the common rooms the *awareness cubes* use the *Adafruit Electret Microphone Amplifier*. For displaying the loudness levels and mood expressions 45 *Adafruit NeoPixel Mini PCB* RGB-LEDs are mounted as five strips of nine LEDs on the cubes' surfaces and nine push buttons are placed on top of each cube for expressing the group moods. As microcontroller for handling the input from the microphone and the buttons, as well as the output to the LEDs, the *Arduino Yún* appeared to be promising because comprehensive software libraries are available to program these components and WIFI for connecting the three cubes is included in this controller[20]. Figure 10 illustrates the assembly of the components schematically. In addition, a detailed circuit diagram is given in appendix C.

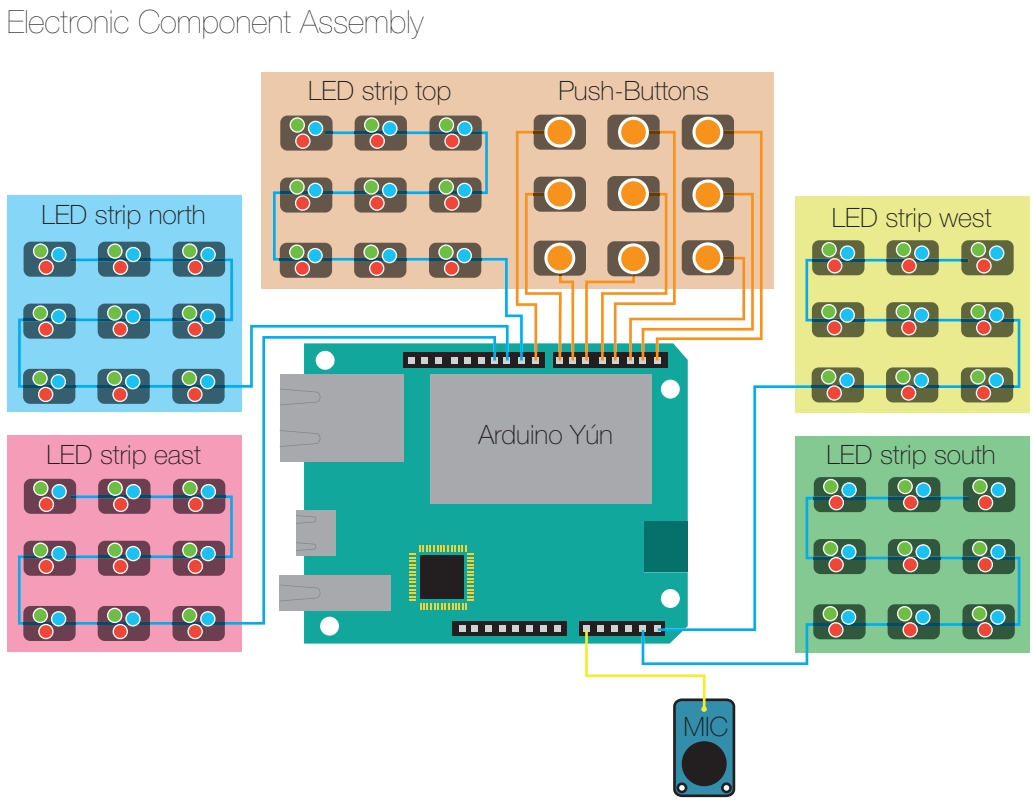

Figure 10: Schematic assembly of electronic components including LEDs on four sidewalls and the cube's top, push buttons on top and the build-in microphone.

20 Product links for further information (accessed on 17 May 2016):
Arduino Yún: https://www.arduino.cc/en/Main/ArduinoBoardYun
Adafruit NeoPixel Mini PCB: https://www.adafruit.com/products/1612
Adafruit Electred Microphone Amplifier: https://www.adafruit.com/products/1063
Push Buttons: https://www.conrad.at/de/drucktaster-250-vac-15-a-1-x-aus-ein-sci-r13-40a-05bk-tastend-1-st-701057.html?ref=detview1&rt=detview1&rb=1

The **Arduino Yún** microcontroller board is the central electronic component of the assembly illustrated in figure 10 and handles the microphone and button input, the output to the LEDs and the transmission of activity information to the other cubes. The *Arduino Yún* is frequently used by designers of prototypes and technology probes as well as by artists because it provides possibilities for connecting several components easily and setting up projects very quickly. The microcontroller board comprises two processors for different purposes. The *ATmega32u4*[21] processor handles data from the I/O pins of the microcontroller and therefore, in this project, it is responsible for audio sampling, addressing the five LED strips and handling button inputs. The processor works with a voltage of 5V, comprises 20 digital I/O pins, twelve analogue input pins and a USB connector for programming the board. It operates with a clock speed of 16MHz, has a flash memory of 32KB and a SRAM memory of 2.5KB. The second processer, the *Atheros AR9331*[22], supports an *OpenWrt-Yun* Linux distribution and is primarily responsible for network connections through WIFI and/or Ethernet interfaces. This processor also has a clock speed of 16MHz, but to support the Linux system it is equipped with a larger flash memory of 16MB and a DDR2 RAM memory of 64MB. In addition to WIFI and Ethernet interfaces the architecture comprises a USB host connector and a SD-Card slot. Communication between the two processors is facilitated by the so-called *bridge library,* which enables *Arduino* sketches to communicate with the network interfaces of the Linux distribution, run shell scripts and receive data from it (cf. Arduino LLC, 2016). In this project the loudness and button data is processed by the *ATmega32u4* processor, respectively the *Arduino*, and handed over via the *bridge library* to the Linux system, which transmits the data to a server application (see Sections 5.4 and 5.5 for details).

The **Adafruit Electrect Microphone Amplifier** (Adafruit Industries, 2015b) is used for audio sampling and therefore is the main sensor for collecting awareness information. The microphone senses audio data between 20Hz and 20KHz and includes an amplifier with adjustable gain. It is recommended to use the 'quietest' power supply available to have as little noise in the signal as possible and therefore it is connected to the 3.3V pin on the *Arduino Yún* as well as to the ground pin. It is important to note that the microphone also has to be connected to the AREF pin of the *Arduino* to get a reference voltage for analogue input (not illustrated in figure 10; see circuit diagram in appendix C). Finally, the OUT pin of the microphone is connected to an analogue input pin on the *Arduino* to allow successful audio sampling (cf. Adafruit Industries, 2015b).

For displaying awareness information in different colours five strips of **Adafruit NeoPixel Mini PCBs** are connected to the digital pins of the *Arduino Yún*. These components are RGB LEDs and can be lit in a 24-bit colour range of the RGB spectrum. The LED pixels are mounted on a small PCB[23], with the size of 8x10mm, and already include the driver of the

21 See ATmega32u4 datasheet for further information: http://www.atmel.com/Images/Atmel-7766-8-bit-AVR-ATmega16U4-32U4_Datasheet.pdf

22 See Atheros AR9331 datasheet for further information: https://www.openhacks.com/uploadsproductos/ar9331_datasheet.pdf

23 PCB: Printed circuit board

LEDs as well as soldering pads for connecting a number of pixels to form a strip of LEDs as illustrated in figure 10. Through the ability of chaining these components to a strip only one digital I/O pin on the *Arduino* is needed to address a series of LEDs (cf. Adafruit Industries, 2015a). The *Adafruit NeoPixels* operate with a voltage of 5V and thus can be supplied with power directly by the *Arduino's* 5V power pin. In this project nine *Adafruit NeoPixels* are chained and each strip of LEDs represents one sidewall on the *awareness cube.* As illustrated in figure 10 the sidewalls of the cubes are named after the compass directions north, west, south and east to be able to distinguish them. In consequence, the LED strip on the top is named after its position on the top of the cube. This naming convention is used through the entire process of construction and implementation of the cubes and can be found, for example, in the labelling of wires, etc. Each of the strips is connected to one digital I/O pin on the *Arduino Yún*, to its power-supplying 5V-pin and to the ground pin (not illustrated in figure 10; see circuit diagram in appendix C). Between the digital I/O pin on the microcontroller and the data input of the first *NeoPixel* on a strip a 470-Ohm resistor was added to avoid spikes on the data line that could possibly damage the first *NeoPixel* (cf. Burgess, 2013).

Nine **push buttons** on the top of the cube are used for expressing the current mood or activity of a group. Since the buttons cannot be connected as chains as easily as the *NeoPixels*[24] each of them was connected to one of the I/O pins on the *Arduino Yún* as well as to the 5V power-supply pin and to the ground pin. To ensure 'clean' logical input values a 470-Ohm resistor was added between the ground pin on the *Arduino* and the button pin. Then the input signal is tapped between the resistor and the *Arduino's* ground pin. The signal has to 'overcome' the resistor before it is detected by the input of the *Arduino* and thus false signals are avoided.

All components described above are mounted inside the cubes to ensure that the *awareness cubes* are experienced comfortably as ambient displays and unobtrusive objects and are not perceived as interfering technology. In addition to the components introduced above, a so-called 'breadboard'[25] is used for connecting the single components easily and to facilitate a better overview of the large number of different wires. Finally, a standard USB cable is used to supply the entire system with power. The particular assembly of the components inside the cubes, as well as their construction and materials used are presented in the following paragraphs.

5.3 Technology probe construction and materials

The exterior of the *awareness cubes* basically comprises three different materials serving different purposes. Firstly, it is important to build the cubes from materials that are easy to work with and flexible enough to be able to handle necessary adaptations. In addition, they have to

24 Various resistors would be needed to identify which button was activated.

25 A breadboard helps to easily connect wires without the need of soldering. In this project it is mainly used for connecting multiple components (LEDs, buttons) with the power supply of the Arduino Yún and its ground pin. The wires from the components are plugged into the breadboard, which is also connected to the power supply of the Arduino.

be robust enough to carry the cubes themselves as well as the built-in equipment. Robustness is important to ensure sophisticated functionality over the entire test period without damages that would affect proper and comfortable use. Meeting certain aspects of aesthetics is another requirement for the choice of appropriate materials. The *awareness cubes* are supposed to be experienced in a comfortable way and therefore adequate materials have to be used to ensure pleasant illumination and a comfortable tactile experience with the buttons. The construction process, materials used and their composition are presented in figure 11. In addition to the overview in figure 11, a detailed construction plan of the *awareness cubes* can be found in appendix C.

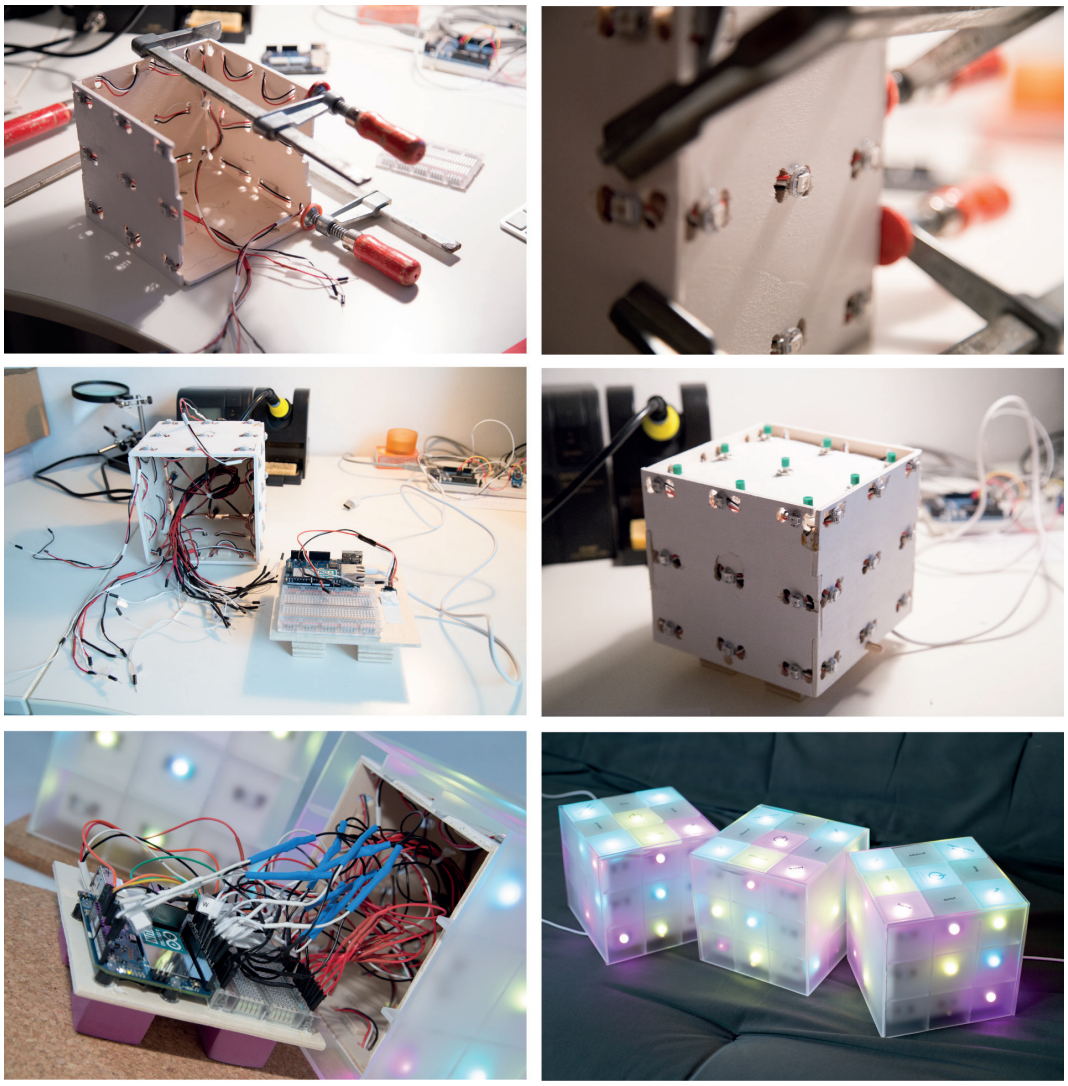

Figure 11: *Awareness cube* construction; a: assembly of wooden sidewalls; b: LEDs mounted on the sidewalls; c: inner cube and bottom plate with microcontroller and breadboard; d: finished inner cube; e: opened cube with transparent Plexiglas shell; f: three completely finished and illuminated *awareness cubes*.

Wooden scaffold to house electronic components

The scaffold of the devices is made of wood and represents the inner bearing part of the cubes. Wood perfectly meets the requirements described above: It is robust enough to hold the electronics and the material can be treated and adapted very easily by cutting, drilling and gluing. The wooden plates are 4mm strong; hence they are relatively lightweight but still strong enough to serve the purpose. Four identical wooden panels are composed with glue and form the sidewalls of the cubes as shown in figures 11a and 11b. The panels have two drilled holes for each LED to pass through the wires of the LEDs strips. Thereby the entire wiring of the strips runs inside the cubes to present a plain outer surface to the users. As figure 11b shows only the LEDs themselves reach out of the cubes' walls. To hold the single LEDs in place they are glued to the wooden panels with hot-melt adhesive. On top of the cube a further wooden panel with nine holes for the push buttons is attached and each push button is screwed to this panel so that only the activators of the buttons protrude from the enclosure. The bottom plate holds the *Arduino Yún* microcontroller, the microphone and a breadboard for easily connecting the single components. Two holes in the bottom plate are used to pass through the power cable for the microcontroller and to place the microphone sensor outside the enclosure to achieve clearer signals. The bottom plate is held in place and locked by wooden dowels that are passed through holes in the sidewalls. Wooden blocks glued to the bottom plate are used as stands for the cube. As figure 11e shows, these blocks are covered with paper stripes in the colours assigned to the single groups to identify and help memorize one's own colour more easily. The outer surface of the wooden scaffold is painted in white to provide a brighter appearance and to facilitate reflection of the LEDs' light. The side length of the inner wooden cube is 13cm, which is the perfect size to incorporate all the electronic components, as illustrated in figure 11c and 11e. The components fit exactly inside the cube without wasting too much space and, in addition, the drilled holes for the LED wires ensure proper ventilation to prevent overheating of the components.

Plexiglas surfaces for a pleasant appearance

To achieve a sophisticated presentation of awareness information the inner wooden cube is covered with semi-transparent Plexiglas. This allows the light of the LEDs to be perceived slightly blurredly, and in combination with smooth transitions of changes in illumination the semi-transparent Plexiglas facilitates glowing light effects on the *awareness cube*. These effects are illustrated in figures 11e and 11f. Another relevant factor for the choice of semi-transparent material, instead of clear glass, is that the remaining electronic parts, the LEDs, cannot be clearly identified as such. Hence, this material facilitates the experience of the *awareness cubes* as supporting objects where complicated technology is not placed in the foreground regarding the artefacts' appearance. Similarly to the construction of the inner cube, four plates of Plexiglas with a size of 15 x 15cm are used for the sidewalls of the cubes. To achieve the planned distance of 1cm on each side between the LED attached to the inner cube and the outer surface, bars were cut out from a large Plexiglas panel. These 1cm bars were glued to each sidewall plate at a distance of 5cm. Thus the surfaces of the cubes appear as small tiles with a size of 5 x 5cm each holding one LED in their centre. The Plexiglas is about 4mm thick, which provides a very robust tactile experience of the material. It does not easily bend or twist and

therefore the *awareness cubes* do not appear fragile at all. The relatively hard and robust material, as well as the stable construction of the cubes, is supposed to support confident and active use.

3D-printed button caps for tangible interaction

As shown in figure 11d, the buttons themselves are relatively small and since they are supposed to cover the entire top surface of the *awareness cubes* a cap had to be designed that is able to cover a LED and has a size of approximately 5x5cm, similar to the tiles on the sidewalls. Since the button cap demanded a unique design, 3D printing appeared to be promising for finding a form that resolves the open issues of accurate size and placing the LED. For expanding the size of a button a funnel was designed and 3D printed that to be attached to the small button and has the needed size of 5x5cm on its top. The funnel design also allows the LED to be placed in it and the wires of the LED strip can be passed through small slots in the funnel. The top of the funnel has a small edge of a few millimetres for gluing a matching Plexiglas plate on it to provide a similar appearance to that of the top side and the sidewalls of the cubes. Figure 12 shows a detached button funnel to illustrate its design and construction.

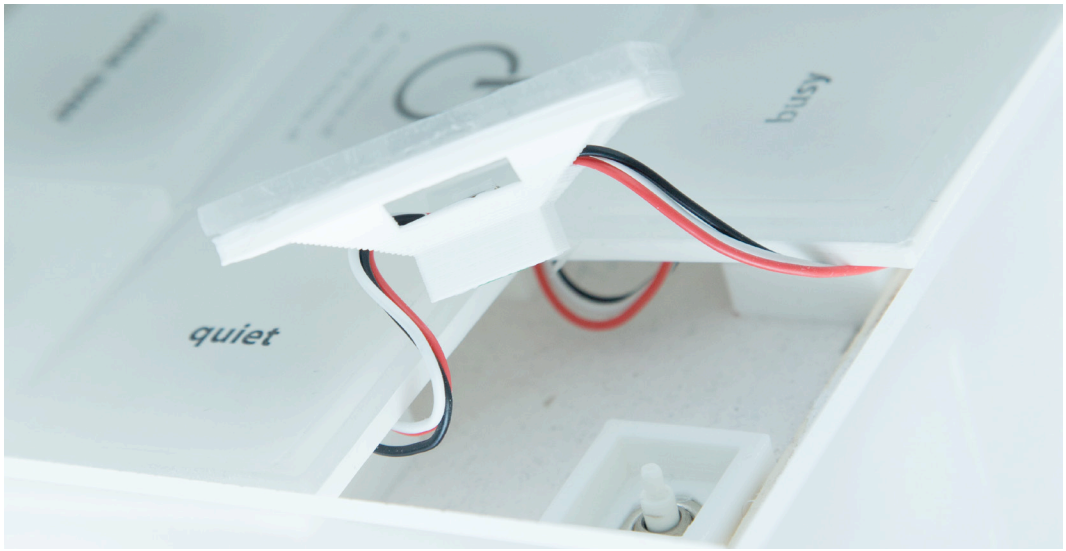

Figure 12: 3D printed button cap with LED wires and Plexiglas cover.

First tests with 3D-printed funnels attached to all nine buttons of the *awareness cube* revealed that the expansion of the buttons' size leads to instable handling of the buttons. The expansion from a 0.5cm surface to a 5cm surface made the pressing of the buttons wobbly and inaccurate in terms of tactile feedback. To resolve this issue, guiding enclosures for the funnels were designed and attached to the top plate of the inner cube as shown in figure 12. In this way the button can be pressed more exactly and only little movement is allowed while pressing it.

Sophisticated and compatible electronic components used in this project such as the *Arduino Yún* microcontroller, the *Adafruit Neopixels,* the microphone and the push buttons ensure exact sensing and presenting of awareness information as well as comfortable tangible interaction with the technology probes. In addition pleasant design and appearance of the devices in

combination with robust construction support pleasurable and even careless use of the *awareness cubes*. The specific electronic components and materials were selected to construct devices that are experienced comfortably and invite their users to play and engage with them. Besides robust construction and the appealing appearance of the materials, good feedback on the pleasant tactile surfaces and the interactive buttons, the actual functionality and the programming of the devices is also a relevant factor for successful implementation. Details of the components, materials and the construction of the technology probes were illustrated in this section, the algorithms that make these probes interactive and connected are presented in the following part of this chapter.

5.4 Client software implementation

The awareness support system presented in this thesis basically comprises three clients and a web service to which the clients are connected. The three *awareness cube* clients collect awareness data in the form of the surrounding loudness level, transform the raw data to intensity values, display the intensities via the LEDs and transmit this information to a web service. In addition to handling loudness levels, the clients also handle interactions via the push buttons, display these interactions and send them to the other *awareness cubes* via the web service[26]. The clients are programmed using *Arduino Software IDE* (Arduino LLC, 2015a), which comprises a text editor for writing the code as well as functionality for compiling the code and uploading it to the microcontroller. The IDE also enables the programmer to use external libraries to provide further and particular functionality. The resulting programmes, based on C/C++ programming language family, are called sketches and are organized by the IDE in a so-called sketchbook (cf. Arduino LLC, 2015a).

A basic *Arduino* sketch comprises two important functions[27]. The setup() function is called once when the sketch starts and it is basically used to initialize variables and to set up the mode of the microcontrollers' I/O pins (Arduino LLC, 2015c). The main function of an *Arduino* sketch is called loop(). This function loops continually as long as the board is running and is used for controlling the board, responding to input data and generating outputs (Arduino LLC, 2015b). Since the main function is constantly repeating through the entire lifetime of a program (as long as the board is supplied with power) control structures and mechanisms such as simple if-conditions, etc. have to be used for handling changes in input data and for updating output data. Although the loop() is the main function of *Arduino* programming the environment allows expanding programs through the use of individual functions for better structuring specific tasks and facilitating a better overview of the programs' functionality. In the sketches of the *awareness cubes* the main loop() function is rather short and mainly responsi-

26 The web service is presented in detail in Section 5.5.

27 Further details of functions, variables and structure of Arduino programs are provided in the reference guide: https://www.arduino.cc/en/Reference/HomePage

ble for iteratively calling up individual methods, handling audio sampling, data transformation and the presentation of data. The following paragraphs of this section illustrate one iteration of the main loop and therefore give an overview of the programming functionality of the *awareness cubes* and the computing processes from audio sampling to lighting up the LEDs, as well as the handling of the buttons. A reference to the actual source code of the *Arduino* sketch is provided in appendix C.

Audio sampling via the built-in microphone

The *awareness cubes* perform audio sampling to gather input data as a basis for presenting awareness information. In order to find a meaningful sampling rate for collecting the audio signal various aspects regarding relevant frequencies were identified. Firstly, human voice is a promising indicator for activity in the cubes' surroundings and therefore its frequency range between 500Hz and about 2KHz provides a good basis for audio sampling. Secondly, the telephone system includes frequencies up to 4KHz and since the basic content here is human speech this is also a useful indicator for the sampling rate (Salomon & Motta, 2010, p. 959). For transforming analogue signals to a digital representation the Nyquist-rate suggests choosing a sampling frequency twice as high as the highest frequency in the original signal to ensure that no information of the original signal is lost (cf. Salomon & Motta, 2010, p. 741). Following these basic principles of relevant frequencies and sampling of analogue signals, as well as minor limitations on the microcontrollers' architecture for setting interrupts, the sampling rate in this project is 9615Hz. Using this sampling rate means that frequencies up to almost 4800Hz can be sampled without loss of information, which includes the range of human speech and exceeds the sampling rate of telephone systems.

To achieve 'clean' samples, no other processes are allowed to be handled by the microcontrollers' processor while audio sampling is conducted. This can be guaranteed through the use of interrupts. Whenever audio sampling is performed all other tasks are interrupted until the sampling is finished. To enable the microcontroller to also still fulfil other computing tasks, such as driving the LEDs, the audio sampling cannot be constantly repeated. Pauses between single samples are used to ensure that all open tasks can be handled accurately. Hence a timer is used to trigger the audio samplings. This timer is basically a counter related to the clock frequency of the *Arduinos' ATmega32u4* processor (16Mhz) and is set to a specific value (20832) that triggers audio sampling approximately three times per second[28]. As soon as the buffer with audio data is full and the sampling is finished a flag is set to trigger further treatment of the data.

Fourier Transform of audio data to get spectral representations

First tests with the sampled audio data showed that simply identifying peaks in the loudness level is not sufficient for a sophisticated presentation of activity. Since 12 of 36 LEDs on the *awareness cubes'* sidewalls are assigned to each group and therefore used to display activity information from one group, using solely the loudness information from the audio signal leads

28 Additional information on using timers and interrupts is given in the following sources (accessed on 24 May 2016): http://playground.arduino.cc/Code/Interrupts; https://arduinodiy.wordpress.com/2012/02/28/timer-interrupts/; http://modelleisenbahn-steuern.de/controller/atmega8/18-7-adcsra-atmega8.htm;

to uniform representations on these 12 LEDs. Depending on the setting of a threshold there are two different possibilities for activating the LEDs. Either a certain number of LEDs is lit depending on the actual loudness level or all 12 LEDs are activated with their brightness corresponding to the loudness level. A combination of both number of LEDs and brightness depending on loudness levels is also imaginable but the illumination depends only on one single source – loudness. Since there are two dimensions available for presenting the sampled audio data – number of activated LEDs and their brightness – each sample is transformed to achieve additional sources to fill each dimension with different data.
Hence a Fourier transform is performed on the audio data as soon as a new sample is available. This transform produces a spectral representation of the audio signal that can be interpreted as a set of sine waves of different frequencies (Eidenberger, 2012, p. 23). Through the Fourier transform of each audio sample the spectrum can be divided into different areas of frequencies, and since there are 12 LEDs assigned to each work group each of the 12 LEDs is used to represent information from one specific part of the spectrum. In total, frequencies from 300Hz to 4800Hz are covered in 12 so-called frequency bins[29], and for each bin the average intensity of the signal is computed which is finally used to control the brightness of the corresponding LED. The Fourier transform enables obtaining intensity information from different frequencies and thus the two dimensions of LED brightness and LED count now representing different types of information. The number of LEDs is used to represent a specific range in the frequencies of the audio signal and the brightness of each LED represents the average intensity of the signal in the specific frequency range. Fourier transform is highly suitable for audio signals because of its similarity to human processing of audible information. Hair cells in the cochlea of the human ear map frequencies to specific fibres of the auditory nerves quite similar to the convolution of sampled audio data by trigonometric functions (Eidenberger, 2012, p. 42). The actual transform of audio samples is conducted by the application of a FFT library developed by *Open Music Labs* (2014).

Representation of loudness intensities via LEDs

The resulting data from the Fourier transform is used to compute normalized intensity values of the loudness levels following the principal approach of a code template developed by DiCola (2013). In this template, the average magnitude of a target frequency window is computed, converted to decibel values and finally normalized. The normalization in the *awareness cube* sketch comprises a range of values between 0 and 100 as a consequence of the microcontrollers' limited memory size[30]. In addition, an equalizer is applied to slightly supress the values in two frequency bins between 675Hz and 1425Hz because this is the main frequency region

29 Frequency bins (values in Hz): [300; 675], [675; 1050], [1050; 1425], [1425; 1800], [1800; 2175], [2175; 2550], [2550; 2925], [2925; 3300], [3300; 3675], [3675; 4050], [4050; 4425], [4425, 4800].

30 Such unusual ranges for normalized values are used in the entire program because the memory of the Arduino Yún is very limited. The application of comprehensive libraries for Fourier transform and wireless communication makes the sketch to be programmed very efficient regarding the use of storage space. Since floating-point variables consume a greater amount of space than integers, values are scaled up to a range between 0 and 100. This leads to a truncation of digits and very slight differences in LED intensity or colour values. But these effects are not critical for the purpose of this application and furthermore such minor inaccuracies are presumed to even go unnoticed by users.

of human speech and therefore the LEDs assigned to these two bins would be lit up almost permanently with full intensity.
As already outlined, audio data is sampled approximately three times a second and therefore changes in the intensities of the loudness are likely to occur frequently. To avoid distracting flashing of the LEDs, which would be a result of reacting to every single change of intensity, a threshold is used for displaying changes smoothly. Through the application of this threshold the setting of the LED is only altered if the change in the intensity is significant enough to be larger than the previous intensity plus/minus the threshold. If such a 'major' intensity change occurs, the corresponding LED light fades to a value between its previous value and the new one. As illustrated above, 12 LEDs are assigned to each group and lit up in the corresponding group colour (yellow, blue or pink; see figures 8 and 11). This means that 12 LEDs are directly driven by the built-in microphone and illuminated in the same colour. The remaining 24 LEDs get their values from the other *awareness cubes* and are lit up in the other groups' colours. The LEDs representing the three groups are intermixed and distributed across all four sidewalls to facilitate the presentation of awareness information in all directions. Since each of the 12 LEDs assigned to one group is coupled with a specific frequency bin the LED is only activated if the intensity in that bin is higher than the threshold, otherwise it is not lit up at all. If the LED is activated, its brightness is directly related to the intensity value and therefore the brightness of one single LED represents the intensities of a particular frequency range.
Since the *Adafruit NeoPixels* require RGB values, a conversion is conducted from the HSV colour spectrum, which uses intensity values, and the RGB spectrum needed to address the LEDs. The conversion algorithm is derived from a template by DiCola (2013) and performed in the *CubeArea* class that was especially implemented to handle the *awareness cube's* illumination. The class is an extension of the original class from the *Adafruit NeoPixel* library and stores a set of nine *NeoPixels* representing the cube surfaces as illustrated in figure 10. Besides collecting a set of LEDs to an area on the cube and converting values between different colour spectrums, this class is responsible for setting the colour value for a single LED and for fading between two values.
Finally, the assignment of LEDs to frequency ranges and controlling their brightness depending on intensities in combination with carefully adjusted thresholds and smooth transitions between different values allows the illumination of the cube to be perceived comfortably and unobtrusively.

Push buttons indicating group moods and activities

Another functionality that operates independently from audio sampling and the presentation of activity information is the exchange of group moods and activities via the tangible button interface on top of the cube. For handling the button activities a listening function is called up within the loop() function that constantly observes if a button is pressed. If a button action is detected it is handled similarly for all buttons except the central ON/OFF button.
In this case an additional function is called up, which is responsible for the switching of the cube in two stages. If the ON/OFF button is pressed once a flag is set that disables the audio sampling. This means that the *awareness cube* is no longer sensing any audible information from its surroundings. Thus no activity is transmitted to the other cubes. In this mode the device

only displays incoming awareness information from the cubes in the other groups. If the ON/OFF button is pressed a second time the presentation of information is also disabled and the device is completely deactivated. Although no information is transmitted in any direction the connection to the server remains active (without transmitting anything) to provide information that the technology probe is working. This is important for maintenance reasons because if the probe is not connected to the server for a longer period it may become disconnected from the power supply or stop working properly, which would necessitate remedial action. Pressing the ON/OFF button again reactivates the *awareness cube* in full functionality.
If one of the remaining eight buttons is pressed its current state is checked – whether activated or not – and the opposite of the current state is processed. Thus if the button is not activated the LED in its cap is lit and a message is sent to the other cubes. Conversely, if the button is activated the LED is turned off and a message is sent to inform the other cubes about the deactivation.

The three *awareness cube* clients are definitely the most relevant part of the entire awareness support system developed within the scope of this thesis. The devices sense awareness information in the form of loudness intensities in their surroundings and display this information on LEDs on their sidewalls. In addition, a tangible button interface on the top of the cubes allows users to interact with each other more actively. Since the awareness information has to be exchanged in some way among three cubes another relevant part of the system is the web service that is responsible for stable connections and proper information exchange. The characteristics of this service and how awareness information is exchanged among the cubes is presented in the following section.

5.5 Connecting the technology probes using the Spacebrew web service

For connecting the cubes a web service had to be found that met certain basic requirements. It needed to be flexible for exchanging different types of information, assure stable connections between the devices and provide libraries for the *Arduino* microcontroller boards in order to connect the clients with the server application. A comparison between several candidates revealed that the selected service – *Spacebrew* – met the outlined requirements sufficiently and only few adaptions were necessary to provide a satisfying exchange of awareness information among the technology probes.

"Spacebrew is an open, dynamically re-routable software toolkit for choreographing interactive spaces. Or, in other words, a simple way to connect interactive things to one another" (Trichenor et al., 2012). This statement on the *Spacebrew* website provides a brief overview on the purpose of the service – connecting devices. The service basically follows a publish-subscribe approach for exchanging information. Thus clients register their outbound data channels as publishers for transferring data to the server and subscribe to other publishers available

on the server to grasp incoming data. *Spacebrew* uses *WebSockets* as the communication protocol to exchange data between clients and the server. The protocol is layered over TCP[31] and is designed to enable two-way communication between browser-based applications and servers without opening multiple HTTP[32] connections. WebSockets basically rely on string data types for exchanging data between clients and server applications (cf. Fette & Melnikov, 2011)[33]. To enable developers to use different data types *Spacebrew* generally supports the exchange of Booleans, ranges and string values. Although these values are re-mapped to string values again internally by the *Spacebrew* library such possibilities provide higher flexibility for developers by reducing effort for manual data type conversions in the individual client program. The latest *Spacebrew* server application is written in Node.js[34] and a variety of libraries and guidelines are provided for clients such as the Arduino Yún used in this project[35]. For connecting the clients' publishing and subscription channels the *Spacebrew* server application provides an intuitive web interface where clients can be coupled with each other (cf. Trichenor et al., 2012).

To be able to use *Spacebrew* to connect the *awareness cube* clients some adaptations had to be made to the server application, the hosting server environment and the library provided for the *Arduino Yún*. *Spacebrew* provides a public web server for client connections, which enables developers to set up connections very quickly and test if these connections work as they are supposed to. Nevertheless, since this server is publicly accessible and clients can be connected and disconnected via the web interface, this setting did not appear to be appropriate for long-time use in the cubes' evaluation period. The server application, therefore, was installed on a server environment only accessible by the three *awareness cubes*. *Heroku*[36] was selected as the hosting platform for the server application because its use is free and it supports the Node.js implementation of the *Spacebrew* server application. Since connections between publishers and subscribers of the clients have to be made manually via the web interface of the server application, connections are usually lost if one client is no longer available. The server application provides the ability to register clients in a list so as to re-establish the connection as soon as a client is connected to the server application again. Unfortunately, this functionality identifies the clients by their name and their IP-address. Since the IP-address of the *awareness cubes* is likely to change after the device is restarted the *Spacebrew* server application had to be adapted to ensure the re-establishment of connections under any circumstances. This was achieved by identifying the cubes solely by their assigned names (A, B, C); this could be considered a weak

31 TCP: Transmission control protocol. A specification is given in the following resource: https://tools.ietf.org/html/rfc793

32 HTTP: Hypertext transfer protocol. Further details of the HTTP/2 standard can be retrieved from the following resource: https://tools.ietf.org/html/rfc7540

33 Further information on WebSockets is provided by the following resources: http://websocket.org; http://www.w3.org/TR/websockets/

34 Node.js is an event-driven javascript runtime. Further information can be found on the Node.js website: https://nodejs.org/en/

35 The Arduino Yún library for Spacebrew can be retrieved via the following resource: https://github.com/julioterra/yunSpacebrew

36 Further information about services of the platform can be found at the Heroku website: https://www.heroku.com

approach for the original public *Spacebrew* server, but in the server setting used exclusively for the *awareness cubes* it resolved the issue sufficiently. Furthermore, logging functionality for messages regarding button activities were added to the server application. Every time a button is pressed and a corresponding message is passed through the server the application triggers a log entry for this message that is tapped by the *logentries*[37] service implemented at the *heroku* server. This service records the log messages of the button activities and provides possibilities for later analysis of log data, which is presented in the following section of this thesis. Besides these minor adaptations to the *Spacebrew* server application the library for the *Arduino Yún* also needed to be changed in some of its functions to work more efficiently. As already mentioned, the flash memory of the microcontroller's *ATmega32u4* processor is very limited. Unfortunately, the *Spacebrew* library is rather comprehensive and other libraries and resources also need to be stored on the processors' memory. So, the library's scope was reduced to the minimum needed for establishing connections and transmitting messages.

For sending information to other cubes all three *awareness cubes* register an individual publishing function at the *Spacebrew* server application, and for receiving data from the other devices each cube subscribes to the publishing function of all other cubes. Basically two types of messages are exchanged between the cubes. One message type is used to inform other devices about changes in the loudness intensities sensed by the microphone and the second type comprises button activities. As a consequence of the limited computing power and memory of the microcontroller not every single change detected in the loudness intensities is actually transmitted to the other cubes. As outlined in the previous section, audio sampling is conducted three times a second and significant changes are displayed via the LEDs. For transmitting these changes to the cubes in the other groups the timeframe is expanded to one second. If there is any significant change in the loudness level within one second this change is sent to the other cubes. The message that is sent comprises three characters, and an exemplary message for changes in loudness intensities is formatted as follows: 'MB8'. In the first character the data source is coded and in case of microphone data the letter 'M' indicates the microphone as the data source. The second character defines the cube the message is coming from and so one of the identifying letters 'A', 'B' or 'C' is used. The last character of this message indicates the number of LEDs that need to be activated. Since two parameters – brightness and number of pixels – are used for directly displaying the loudness information from the individual microphones built-in to save storage space[38], messages are kept as short as possible and therefore the intensity is mapped to the corresponding amount of pixels. Nevertheless, careful fading from one intensity to another allows a more comparable perception of the remote information than for the local one. Messages representing button activities are formatted in a similar way, but comprise four characters. A typical message indicating button activity may look like: 'BC71'.

37 Futher information is provided at the logentries website: https://logentries.com

38 In addition to the use of integers instead of floating point variables, string messages used for exchanging data between the cubes are kept as short as possible because string data types consume much storage space. As already mentioned, the Arduino sketch needs to operate as effectively as possible in terms of storage space. In the latest version of the program about 87% of the controller's storage was used. Experiences gathered during the implementation process showed that every use of program storage space beyond 90% leads to unstable behaviour of the microcontroller, which is not acceptable.

Again, the first character provides information about the data source; here button data and therefore the character 'B' is used. As for the message informing about loudness activity the second character identifies the cube from which the activity is originating. The third character contains the number of the button for lighting up the correct LED on the remote *awareness cube*, and finally, the fourth character informs the remote devices if the LEDs need to be activated or deactivated. This value is either 0 in case of deactivation or 1 if the LED needs to be activated. Each time a new value for a button is set the corresponding LED is directly reacts to it. This means that the last activity is overridden and the current information is displayed on the button. If one group presses a button the corresponding buttons on all three groups are lit up in this group's colour. If another group presses the same button at a later time the previous information is lost (overridden) and all buttons indicate the new information. The simple formatting of the messages allows effective handling of storage space, and this format is easier to process for the clients since each character contains a specific type of information.

The development and implementation phase of this project comprised the design and planning of an awareness support system derived from findings of the initial participatory design workshop, as well as the construction and implementation of technology probes, their functionality and a server application that enables communication between the devices. The *awareness cubes* represent devices that are unobtrusive and facilitate the presentation of awareness information in the background as ambient displays. The actual presentation of this information via colourful LEDs is implemented in a way that provides a comfortable and pleasant experience of the devices by using smooth transitions between different states. In addition to the representation of remote colleagues in the background the *awareness cube* concept allows direct interaction among users through a tangible button interface on the cube's top. For this, nine buttons are labelled with mood and activity expressions referring to the actual social realities in the particular groups. The selected mood information is indicated by LEDs mounted on 3D-printed caps on the buttons. The awareness information comprising loudness levels in the cubes' surroundings and group-based mood expressions is exchanged via a flexible web service that follow publish-subscribe principles. This section provided a comprehensive overview of the design, construction and implementation of the *awareness cube* devices and the completion of these devices marks the end of the implementation phase of this project. The third major step to take in the project was to test the system during a period of four weeks to collect feedback from users and to gain insights about the system's actual ability to facilitate awareness across distributed work groups.

6 Test Phase & System Evaluation

The main objective of this thesis regarding the technology probes is to gain insights on how users deal with them, how they interact with the devices and how the *awareness cubes* may possibly influence the social life in the common rooms of the work groups by representing remote colleagues' activities. To achieve such findings the technology probes were implemented at the work groups' facilities for a period of four weeks and evaluated following different scientific methods as outlined in Chapter 3. The objective of this evaluation was to gather data from different sources and to resolve the research questions of this thesis through the thematic analysis of the collected data. The test period was intended to provide understanding of how the probes address the users' experiences articulated in the initial workshop and furthermore to give insights on the main research question of this work, namely how this technology facilitates and maintains awareness across distributed work groups. During the four-week test phase data from three different sources was collected. The interaction via the cubes' buttons was logged by the server application to provide an overview of the frequency of use and to illustrate how the level of use and engagement possibly changed throughout the test period. This quantitative data is presented in the first part of this chapter descriptively in the form of various diagrams that illustrate the frequency of use. In addition, a series of paper-based surveys and ethnographic interviews were conducted to collect statements directly from the users in order to understand their engagement, motivation and individual interaction with the devices. The results of the surveys and interviews are presented in the second part of this chapter followed, in the third part, by the findings of a thematic analysis.

6.1 Quantitative log data of button interaction

During the four-week test period of the *awareness cube* an extensive log-file, filled with data of button activity, was generated. This log data reveals the users' interaction via the nine buttons on top of the cubes and gives information on the frequency of active interaction among users. Information about the use of the buttons across the entire test phase is given by the log data as well as information about the probe usage at specific times of a day. In addition, the quantitative data is a relevant contribution to this work because data was collected continuously and automatically and so provides an overview of the active engagement with the cubes' buttons,

as shown in figure 13. Furthermore, it accompanies qualitative results, presented in Section 6.2, which provide deeper insights into the motives of the users.

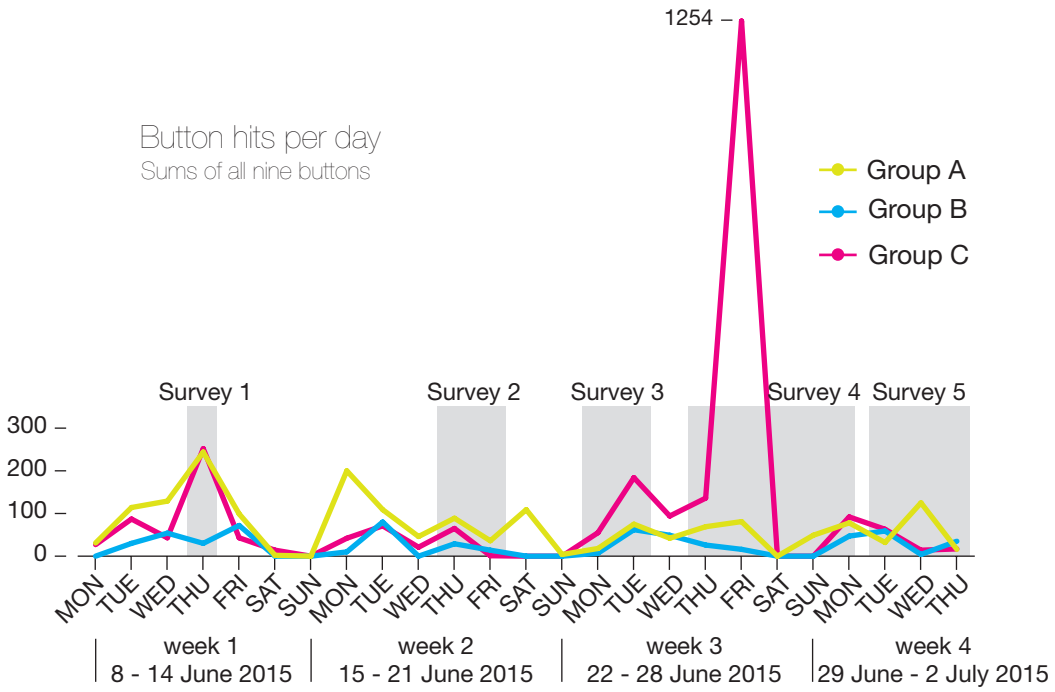

Figure 13: Sums of button hits per day by the three work groups over the entire test phase.

An overview of the button usage over the entire test period of four weeks is illustrated in figure 13. The diagram shows the sum of all button hits per day for each work group. The days where surveys were conducted are highlighted in the illustration to recapitulate the schedule of the test phase on hand and to highlight possible relationships between button use and surveys. The diagram clearly shows that there is an increasing use of the buttons on the day of the first survey, but for the following four surveys there is no significant increase in button use. The first survey may have reminded the users to engage with the devices and therefore possibly led to an increased button activity. At the beginning of the second week of the test period the button activity again increased slightly and after that, from the middle of the second week to the end of the test phase, button use was relatively constant in all three groups with moderate frequencies between only a few hits (less then ten hits per day) and more frequent use (more than 150 hits per day). As figure 13 illustrates, the most frequent button use took place in group A, followed by group C (with one major outlier in week 3[39]) and Group B. Obviously, the buttons were not used on weekends, because usually no one is present on these days, but the constant frequency of use on weekdays is not really decreasing until the end of the test phase, which

39 The outlier in the button use of group C on Friday, 26 June, is not an error produced by possible malfunction of the cubes or false logging. The exhaustive button activity took place during an ethnographic interview with one user and therefore the high value on that day was verified through observations.

could be an indication of continuing motivation of the users, and needs to be analysed in more detail using qualitative surveys and interview data (see Section 6.2).

Another interesting perspective of the time domain is the relationship between button activity and the time of the day, and this is illustrated in figure 14. The diagram illustrates that the buttons were used relatively constantly by all three groups over the usual working hours between 9am and 6pm. Again, the graph of group A shows the most frequent use, compared to the other groups.

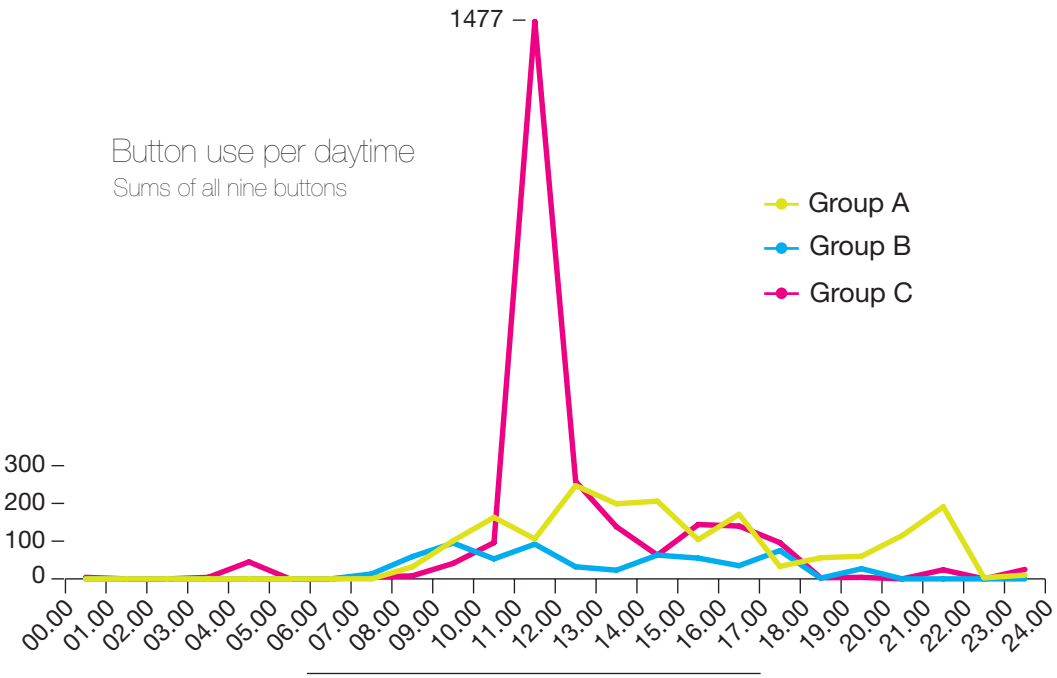

Figure 14: Sum of button activity of the three work groups related to daytime.

As figure 14 shows, in group A the buttons were hit most frequently at lunchtime and then rather constantly in the afternoon. The increased use in the evening is related to one particular day, where perhaps a special event took place at the group's facilities. The button activity of group B starts in the morning and is rather constant throughout the entire day, but generally at a lower level than the frequencies of the other groups. In group C the button activity started to increase mid-morning (the outliner discussed above took place at lunchtime), decreased slightly after lunchtime and increased again in the later afternoon towards the end of the usual working hours. The constant use throughout the day may be an indication that the cubes are not only used in commonly taken breaks by some group members, but may be used on other occasions, too, for example, while boiling water for tea or waiting for the coffee to be ready. Again, this has to be examined in detail using the qualitative interview and survey data. An interesting detail is also revealed by the graph of group C in figure 14. The *awareness cube* of this group also attracted users at night time between 4am and 5am since there is a small but

recognizable peak in the graph, which is possibly produced by highly motivated group members or security staff.

As outlined in the theoretical part on methods (Section 3.3.3), one relevant characteristic of the technology probes is to enable possibilities for re-interpretation by the users and thus allows or even supports alternative uses. Exactly this phenomenon could be observed for the use of the buttons. From the beginning of the test phase the buttons were not explicitly used to express the groups' moods and activities labelled on the buttons; on many occasions they were used entirely differently, and this is described in detail in the presentation of qualitative results. Because of the alternative use of the buttons the log-files provide no information at all about the popularity of the individual buttons. Since the buttons were used alternatively it cannot be determined from the quantitative data which moods or activities were more likely to be expressed by the users and which appeared less appropriate for daily use. Nevertheless, interesting information for one specific button – the ON/OFF button - can be retrieved from the log-data because this button provides a different functionality to that of the others and was used as intended most of the time.

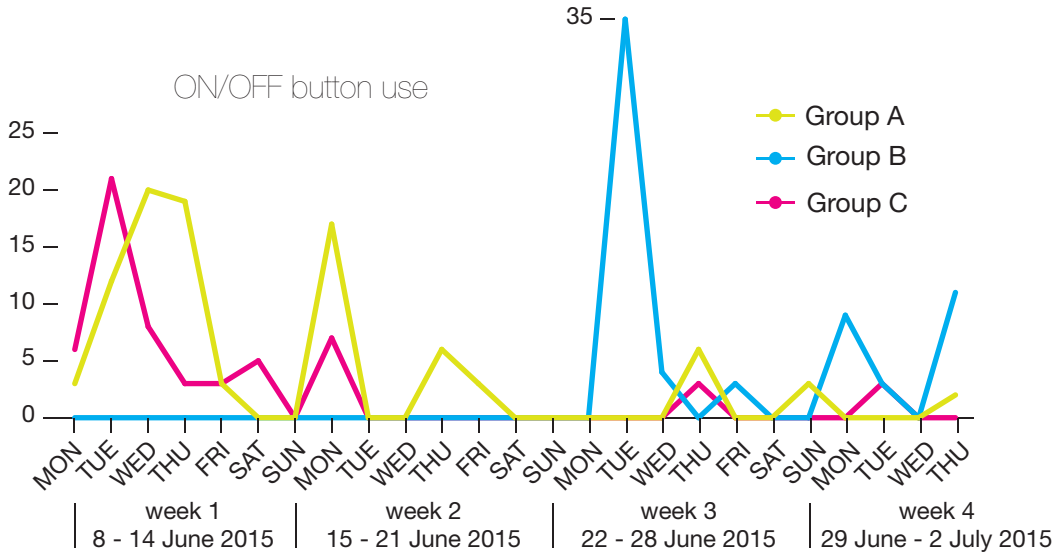

Figure 15: Frequency of the ON/OFF button use by the three work groups.

Figure 15 illustrates that groups A and C used the ON/OFF button relatively frequently at the beginning of the test phase with the use decreasing towards the end. From the middle of the second week onwards the ON/OFF button was used very rarely by these groups. Interestingly this is different for group B. This group did not use the button at all for the first two weeks of the test period. The ON/OFF button was used for the first time on 23 June after 15 days of using the technology probes and then very extensively on that day followed by decreased use on the remaining days of the test phase. Due to limited computing power, the *awareness cubes* stopped operating occasionally (more frequently on some days), had to be restarted manu-

ally and were not active between failure and restart; the fact that the device at group B was not actively switched off for half of the test period is noteworthy[40]. Recalling that especially members of group B insisted on the implementation of an ON/OFF button, the fact that this group did not use it at all during the first 15 days is astonishing.

The presentation of quantitative log data collected from button activities illustrated how frequently the users interacted actively via the cube buttons. It could be shown that the use of the buttons decreased after initial curiosity but then the buttons were used constantly throughout the test phase. An illustration of the buttons' use related to time of day mainly revealed that there appear to be various occasions for hitting buttons, and especially in the afternoon the buttons are used constantly. Interesting results were presented regarding the use of the ON/OFF button which dropped significantly in groups A and C after the first week, whereas group B started to use the ON/OFF button in the second half of the test period. The quantitative log data only provides information on the active use of the buttons; there is no information about the passive use of the *awareness cubes* as ambient display in this data. Passive use of the technology probe as well as motives for alternative use of the probes' buttons is the topic of the following sections where the results of the surveys and ethnographic interviews are presented.

6.2 Results of paper-based surveys and ethnographic interviews

Two qualitative research methods were used within the test phase of the technology probes to obtain direct feedback from users. A series of five paper-based surveys was carried out during the four weeks of testing the probes. The open questions addressed various issues regarding the actual stage of the test phase. In the first weeks the overall appearance of the devices and the clarity of the provided functionality were the subjects of the questions. Towards the middle of the test phase the surveys were used to gather information about specific experiences with the presentation of information and how people interacted with the devices in different situations. At the end of the test phase the questions targetted the identification of possible changes in user behaviour and were used to collect reports about occasional visits to other groups, possibly provoked by the *awareness cubes,* for example. In addition to the five surveys, ethnographic interviews were conducted during the test phase almost daily. Visits to the groups' facilities, for deploying the survey boxes or for maintaining the *awareness cubes,* were used to be able to talk to users and discuss possible issues, resolve open questions and generate ideas for further improvement of the probes. These interviews enabled a deeper understanding of individual experiences and different ways of use and interaction. The combination of

40 Users possibly pressed the ON/OFF button when the cube was not active and logging was not possible, but in such situations the probe's display is usually frozen and/or the ON/OFF button is lit up in red colour indicating malfunction. Therefore possible failure is noticeable for the users.

paper-based surveys and ethnographic interviews enabled users to give feedback on a comfortable personal level as well as anonymously through the surveys. The detailed questions of the surveys and the results of the two methods are presented in the following part of this section. The presentation of the results, comprising relevant statements by users, is structured on the four weeks of testing the technology probes and therefore feedback collected from the interviews and surveys is included according to the actual period of the test phase.

Short pre-test at the group A site

A few days before the actual test phase started a pre-test session was conducted with group A. The main objective of this session was to test the available network connection. Users of group A were curious about the novel devices and provided valuable feedback. The main topic of this first short feedback session was the behaviour of the LEDs on the buttons and the overruling of other groups. The button LED always presents the latest state: If group A hit a button just after group B hit the same button only the expression of group A was indicated on the button and the expression of group B was overridden. The statements of ten users participating in this session comprised opinions on this behaviour of the button LEDs. There was some regret that the buttons only showed the last state and that information from the other groups was lost. Others, however, interpreted this behaviour as a challenge and a possibility for playful use – they identified opportunities to 'take over' the buttons and to 'turn off' the others' buttons through activating buttons on their own cube. Other statements, for example, referred to differences in the labelling of the buttons. Six of them are labelled with moods and two are labelled with activities and some users stated that this might eventually not be appropriate. Additionally, users suggested indicating the frequency of button hits by higher intensities of the light or showing LED activity (such as blinking) in relation to the actual label. Some users wondered whether the device might lose its attractiveness after some time and might not be used anymore, but others also stated that the *awareness cube* was optically beautiful.

Week one – initial curiosity

In the first week of the test phase one survey (S1) was conducted comprising three questions regarding the identification of the groups, the labelling of the buttons and the experience with the LEDs.

> *S1-Q1: How easy or hard is it to identify the different groups? Please characterize situations when you can easily or hardly identify to which group the actual display on the cube belongs.*

Many users stated that a short learning process was necessary but the poster mounted near the cubes facilitated this. People mentioned that the poster was helpful for learning the colours. Participants also stated that the colours were easy to distinguish and since there were only three different colours there were no major problems in assigning them to the groups. One user addressed the overruling behaviour of the buttons and found that *"it's a bit misleading that only the latest button press gets the group colour set, earlier info is lost"*. Another argued that the groups generally did not have colours and therefore it was rather hard to identify them on the *awareness cube*.

> *S1-Q2: How do you experience the presentation of the activity by the LED-lights on the cube? When is the changing light perceived pleasantly and when is it disturbing?*

Some users referred to the nice design of the cube and its pleasant appearance as ambient display. One user characterized the presentation via the LEDs as *"[v]ery pleasing impression by dynamic dimming"*. Another, however, mentioned that the *"position of the lights [is] not clear on the sides"* and asked, *"do they mean anything?"* Other users were also not sure whether there was a specific meaning behind the positioning of the LEDs, and one requested *"more variations on places of lit LEDs"*. The changes in perception were not reported to be disturbing and some users mentioned that the *awareness cube* afforded being explored from all sides, and thus the activities could be discovered in more detail by coming closer to the device.

S1-Q3: Which of the moods or activities on the buttons do you think are useful to express a common group-mood and which are less useful? Why do you think some are more suitable than others?

People reported that the buttons labelled with "having lunch/coffee" and "come over" were activities and therefore did not really fit the other labels. Some of them (primarily users of group C) experienced this as positive because these activities were related to group life, whereas the other moods were perceived as too personal to express it on a group level. One user noticed that the buttons labelled with activities demanded active deactivation, which often could be forgotten. To some users the button labelled "quiet" was unclear because the built-in microphone already measured the loudness levels. One user stated not using the moods at all, but only the light effects.

S1: Other comments

On the cards for other comments statements where given, that were not topic to the questions. One user suggested that the cube could make a noise to be recognized more easily. Another user referred to the representation of remote colleagues: *"Really like seeing it when it is lit up – that others are around!"* The override functionality of the buttons was also addressed here by mentioning that it *"could be good to see, e.g., all are eating lunch"*. On one card a user reported that the cube "*creates a 'sense of presence' of others and 'connectedness with them'"*. Furthermore, users experienced the *awareness cube* positively as an early prototype, but unfortunately as technically rather somewhat unstable.

In interviews conducted during the first days of the test phase many people were curious about the *awareness cubes* and reported enjoying playing around with them. The actual placement of the cube was the subject of debate in group C, since it could be placed in the kitchen as well as in the lounge area, where the latter was deemed to be more appropriate. Some users of group B and group C stated that they had to be quiet now in the common room because the device was sensing the loudness. Such statements only came up in the first two days of the cubes' implementation.

The rather frequent system crashes caused by limited computing power of the microcontrollers were a relevant topic within interviews with members of group B. They reported that the device stopped operating frequently but this did not appear to be a major problem. Users of group B remarked that they simply restarted it and did not experience this as too annoying. They seemed to actually take care of the device and actively engage with it, although in many cases, by maintaining it.

Another topic of the first interviews focussed on the uncertainties about a possible relation with the display of loudness information on the sidewalls and the buttons on top, as well as the position of the LEDs assigned to each group. People asked how the illumination was generated and if the assignment of LEDs to the three groups was fixed or somehow created dynamically. Some users reported that a number of LEDs appeared to be activated permanently and asked if background noise could possibly cause this. Regarding the assignment of the LEDs to the groups one user requested more flexibility and movement in the illumination to achieve a livelier experience.
Already the first week of investigation showed that the buttons of the *awareness cube* were not solely used to express the groups' moods and/or activities. People reported using the buttons to draw colourful patterns with it on the top of the cube with no attention to the actual labelling of the buttons. Some users even tried to play TIC-TAC-TOE games via the buttons and used the ON/OFF button (always lit up in the group's own colour) as a joker. Users also envisioned a more flexible interaction via the buttons by using powerful displays instead of single LEDs to be able to configure the labelling of the buttons individually.
Regarding the appearance of the *awareness cubes* many users characterized the devices as *"funny"* and *"interesting"*. Furthermore, the simplicity of the devices and their ability to present something in the background were characterized positively during the interviews. One user remarked that the cube easily tipped over because the stands were mounted too centrally on the bottom plate and suggested placing the device on a special plate with placeholders for the stands to achieve better stability.

The first week of investigation was mainly characterized by curiosity and uncertainties about specific behaviour of LEDs and buttons. Especially during the interviews many questions from the users could be answered and the functionality of the devices was explained in detail to interested participants. In general, the devices were experienced as funny and interesting and users also referred to possibilities for exploring the devices actively. Although users had to deal with occasional system crashes, most users reported experiencing the novel awareness system positively.

Week two – creating patterns with buttons
The question cards in the second week of the survey (S2) addressed individual experiences with the devices as well as possible situations in which the microphone needed to be turned off or the device needed to be switched off entirely. The survey was conducted in the middle of the second week and thus users were supposed to be able to report personal experiences with the *awareness cubes*.

> *S2-Q1: Do you experience situations in which the cube causes an uncomfortable feeling? Please characterize such situations and illustrate possible changes to the cube to avoid such feelings.*

In group C, two cards with this question were filled out both answering the question very briefly with *"no"*. The users of the other two groups stated that they did not experience uncomfortable situations so far. One remarked that the entire presentation was very unobtrusive

and the cube did not appear uncomfortable. Another user, for example, used this card to express liking the device and that it was good to be able to actively connect with other groups.

S2-Q2: What comes to your mind when you see the activities of the other groups presented on the cube?

Here people primarily expressed that they were interested in what was going on in the other groups. Many users stated here that they identified colour patterns generated by buttons instead of meaningful messages and some even tried to answer with other patterns. One user stated beeing interested in the activities and then eventually pressing a button. Regarding the activity display on the cubes' sidewalls users reported wondering who was causing the activity and people were curious about what was going on, in particular, for example, if they were also having lunch. Obviously not all uncertainties could be resolved after the first week as one user still reported having difficulties in mapping intensities and therefore stated: *"that any reaction I see is just a presumptuous interpretation."*

S2-Q3: In which situations do you turn off the microphone to avoid the presentation of your activities on the other groups' cubes? Please characterize such situations.

In the answers to this question users of all three groups reported that there was no need to turn off the microphone so far. Some stated that they *"don't care about the mic"* or remarked: *"Why would I? No such situations"*. This was remarkable, considering that especially group B requested the possibility of turning off the cube, and in the early days of the test phase some users stated that they had to be quiet now because of the microphone. However, one participant of group B stated not knowing that turning off the microphone was possible, and another explained that the *awareness cube* did not differentiate between conversations and background noise and therefore there had not yet been any reason to turn the microphone off. Only one user of group C answering this question remarked that this function could be useful for internal meetings.

S2-Q4: When do you turn the cube completely off (microphone & display) and when do you turn it back on after such a phase?

People reported that they never turned off the cube completely, only after a system crash when it needed to be restarted[41]. One user from group B stated that no situation came to mind where the cube needed to be turned off completely. In group C, one participant reported shutting down the cube only once for testing the functionality but never again. Another user of group C stated that eventually nobody felt responsible for turning it off.

S2: Other comments

In the second week of the test phase the 'open' cards were used to suggest further enhancements to the cube and to report about experiences and observations made throughout the first two weeks. One user suggested presenting the loudness differently using an increasing

41 After a system crash the device needs to be disconnected from its power supply to be restarted. Switching it off via the ON/OFF button would not resolve this. Users were informed about this in the first days of the probe's implementation but obviously this information did not reach all of them.

number of LEDs from the bottom to the top of a sidewall; another requested *"more patterns"* and a button labelled with 'Hi'. On one card a participant wrote that *"the cube has more potential than it seemed at first and its interaction potential should be explored a bit more"* and suggested creating a larger cube that provided more possibilities of communications such as short exchanges as notes. Another user referred to the labelling of the buttons by mentioning that "happy" and "excited" as well as "sad" and "grumpy" were rather similar and could be subsumed to one button to make room for new labels. The "quiet" label was still reported to be unclear, but "busy", "come over", and "having lunch/coffee" were experienced as useful.

The alternative use of the cubes' buttons for creating colourful patterns was a relevant topic within the interviews of the second week of investigation. The interviews revealed that some users expressed the actual mood or activity as it was labelled on the buttons, whereas others were only interested in creating patterns and did not care about the labelling. Some users reported that they played TIC-TAC-TOE games and used the ON/OFF button as a joker. One of these users liked the implicit character of the game because the opponent was unknown but gameplay was still initiated. The user remarked that no one would really invite local colleagues to play TIC-TAC-TOE spontaneously and therefore the spontaneous establishment of the game was seen as a benefit. A participant from another group also liked the playful character of devices and could imagine focussing on this in future versions of the system. In particular, playing correspondence chess or other games was suggested to enable possibilities for competitions between the groups.
Other users suggested providing more flexibility for the button use through mounting small displays on the button caps. This would enable users to exchange short messages via the buttons and lead to more dynamic content than the fixed labels allow. Although these users would like to exchange written messages they also stated that possibilities for playful use should still be provided. Regarding possibilities for exchanging richer content than just moods one user imagined coupling the microphone with a button to record spoken messages and sending them to the other groups.
Participants who used the buttons according to the labels printed on them reported that they tried to invite people to come over but could not say if some actually visited other groups following the invitation on the *awareness cube*. Once two users from different groups were present in the common room of group B and as I entered to place the boxes for the survey they immediately started to report about their experiences with the cube. One reported sending a pattern to the other but unfortunately the other did not realize that. Asked if the user visited the other group because of the cube the user answered "no". Referring to the "having lunch/coffee" button users again recommended turning off the LED on this button after some time, because the state would no longer be correct and it was easy to forget to turn off the button manually.
When asked about their experiences with the activity display on the cubes' sidewalls most of the participants characterized it as comfortable ambient display but one user suggested using the sidewalls of the cubes to display patterns generated by the buttons. Thus the most favourite patterns could be 'stored' on the sidewalls for some time. Regarding the construction of the cubes, the stands were again a topic in the interviews, and users experienced the device as

somehow wobbly and unstable on the one hand, but on the other hand, participants remarked that they thought the cube would not actually tip over.
Remarkable feedback was given by a member of group B, reporting that the stance towards the project had changed completely. Users in this group were rather sceptical and almost rejected the project in the beginning because they worried about possible additional effort and obligations to contribute something to the project. The user remarked that they experienced the *awareness cube* as funny and there was no rejection anymore. The user emphasized that the changes were an effect of continuing conversation between the group's members and myself.

The second week of the test phase was characterized by more routine in the use of the cubes. Initial uncertainties were able to be resolved and users started to find alternative ways of interacting through the devices – especially by using the buttons differently. Interestingly, the different use of buttons – expressing moods by some users and drawing patterns by others – did not really lead to reports about major confusions or problems interpreting the expressions through the buttons. Regarding the actual purpose of the *awareness cubes* – to socially connect distributed work groups – one user stated that the system changed something but could not describe the change in more detail. The ability of the cubes to provoke changes in the social relations between the groups was addressed by the survey conducted in the third week of the test phase.

Week three – talking about the others' activities
During the third week of the test phase two surveys were conducted addressing changes in individual behaviour of the participants in their own facilities as well as possible enhancements in survey three (S3) and asking participants about their relation to other groups in survey four (S4).

> *S3-Q1: Do you remember circumstances in the last two weeks in which the presence of the cube led you to act differently in the common room than the weeks before, when the cube was not there? Please give a description of such situations.*

Most participants reported that their behaviour did not actually change but many stated that the *awareness cubes* were discussed with their local colleagues as the following statement shows: *"Other than excitedly interacting with it and discussing things related to the cube, no. I mean, nothing outside of the cube directly changed."* Other users reported that when they were looking at the cube it was reflecting their own mood. Some users of group C reported that they produced different noise levels for testing the illumination of the cube and for communicating with the other groups. One user referred to frequent system crashes and provided a funny statement reporting getting down on to the ground more frequently to unplug the cube from the power supply to reboot it.

> *S3-Q2: Should the cube offer less or even more possibilities to get in contact with the other groups? Which possibilities would you suggest and how would you like to use it?*

Participants of group A primarily suggested implementing functionalities to provide information about who in particular was interacting with them on the other side. This could be achieved by transmitting sound to be able to identify people present at remote common rooms

by push-to-talk functionality or by connecting the cubes to the smartphones of the employees via Bluetooth. In general, people would like to have more reciprocal turn-by-turn interaction, such as possibilities to invite people or the ability to ask why people were in a particular mood. In two statements on these cards users of group B argued that the *awareness cube* did not really establish contact between the group members, it rather provided an impression of the others' state. One user of group B suggested saving the state in case of a system crash and another stated that the cube was useless as it was, but unfortunately did not go into any detail about this. Users of group C provided two contributions to this question and suggested using the buttons of the cubes primarily for playing games such as TIC-TAC-TOE.

S3-Q3: Did the number of your visits to the common room change in the last two weeks? Why do you visit the room more or less frequently?

Here almost all participants who filled out the cards stated that the number of visits did not change. One user reported that visits to the common room sometimes took longer because people met there and talked about the *awareness cube*. Another participant reported curiously investigating the activities on the cube while waiting for coffee to be finished. Only one user reported visiting the common room especially to look after the cube approximately once per day.

S3: Other comments

Two participants referred to the sweets provided with the questions cards in the survey boxes. One thanked for the sweets and another asked if there were any vegan sweets. Other referred to the project and stated *"very nice project"* or remarked that it was funnier and more useful than assumed.

S4-Q1: If you think back to the time before the cube has been installed. Did your personal image of the other groups change? How do these changes look like?

Most participants stated that the personal image of the other groups did not really change. Nevertheless, two users provided differentiated feedback referring to the connectedness of the work groups remarking the following: *"Not personal image but certainly increased awareness that they are there! Not so much out of sight, out of mind as before. More 'in mind'"*; *"Not really. But the cube made it even more clear how important it would be to have more contact within the institute"*.

S4-Q2: Did your relationship to the other groups change somehow in the last weeks? Which changes did you recognize?

Many participants reported that the relationship did not actually change but the *awareness cube* invoked conversations within the groups and between members of different groups. In many of these conversations users reported wondering who was on the other side and asking people of other groups in personal meetings if they were, for example, playing TIC-TAC-TOE at a specific time. One user remarked that more perception of the others was achieved through this, and another stated that the relationship got "warmer". In one statement a user remarked

that there was a better feeling of connectedness than before and another noted that there was more interest in the activities of the others.

S4-Q3: Do you undertake particular actions (calls, visits) after you perceived the activities of the other groups via the cube? Please characterize such actions.

Here one user reported being too busy to actually visit the other groups but still liking the playful character of the device. Similarly, another participant stated reiceiving no calls or visits but playing games by pressing the buttons. Another answered this question very briefly with "no" and one user added, *"The cube is too far away from anything"*, but unfortunately gave no further explanation.

S4: Other comments

The open cards of this survey were primarily used to provide suggestions for further enhancements of the devices. One user suggested that the activity display on the sidewalls should provide information about the type of sound in some way. Another participant stated again that the "quiet"-button was unclear, characterized the activity display as "super" but too arbitrary and remarked that the activity display was a good indication for seeing if someone was present in another common room and if direct interaction would be possible. Another comment on an open card characterized the *awareness cube* as a nice-looking device but suggested implementing easier possibilities for getting into contact with others. This user also stated that background noise might influence the activity display and suggested attaching a sensor to the coffee machine or the printer and using these devices as data sources for activity information.

Similarly to the survey statements, in the ethnographic interviews conducted in the third week of the test phase many users reported regularly talking about the cube. In conversations with local colleagues people wondered about the origin of a particular activity or a pattern on the cube's top and who in the other group may have produced it. When meeting collaborators from a remote group people reportedly asked if they remembered a specific activity or pattern and probably knew who was interacting on the other side. One user would have liked to know who was sad on the other side and comfort the colleague. Another participant mentioned talking about the cube to a colleague from another group with which the participant usually did not have contact.

As in the previous week people used the buttons on the cubes top for creating patterns and playing TIC-TAC-TOE as well as for expressing moods and activities. One user whose main interest was in creating patterns reported constantly pressing buttons in the hope of getting a reaction from someone in another group, but unfortunately this happened very rarely. The participant explained feeling like a castaway sending messages and waiting for a ship to cross the way. Situations where light activity was indicated on the sidewalls and possibly someone was passing the *awareness cube* in a remote group but did not recognize the signals were reported to be very frustrating.

In some interviews users remarked that they could imagine using the cube for a longer period of time because it represented a nice background display and needed no effort. However, one participant stated that for long-time use the system needed to be more flexible and provide

different possibilities for exchanging things. Only expressing fixed moods and activities might get boring after some time. Generally, observation and interviews showed that users more frequently restarted the devices in cases of system crashes than at the beginning of the test phase. They seemed to care of the *awareness cubes* and appeared to be motivated to keep the system running.

The data gathered in the third week through the surveys and interviews shows primarily that people were having conversations about the cube – not only with local colleagues but also with remote ones. Especially the results of the surveys show that people rather did not actively undertake particular actions such as calls or visits evoked by the *awareness cube,* but they clearly reported that the cube facilitated the connectedness between the groups. In interviews, some users remarked that they could imagine using the cube for a longer periods of time because of its unobtrusiveness and effortlessness. Furthermore, users provided detailed suggestions for future enhancements regarding more flexible exchanges of content.

Week 4 – suggesting enhancements

Due to the fact that the last week overlapped with lecture-free time between terms, the fifth survey comprised more general questions regarding users' opinions on the project. The test phase was completed on Thursday, 2 June 2015, because on the following Friday group A borrowed the *awareness cubes* to serve another purpose.

> *S5-Q1: What is your personal opinion on the "linking the groups" project at the end of this test phase?*

Here users articulated that the basic idea was good but they also suggested enhancements and pointed out shortcomings of the system. One remarked: *"Overcoming geo-distance is hard. Coming over needs a good motivator. Maybe having lunch together 'in the middle' could be an option. Awareness of others did def. increase through the cube."* Another participant regretted that the information on the buttons was lost after restarting the cube. Some users stated that the approach was interesting, but further playful possibilities of use would be appreciated. One user stated that there was relatively less actual benefit, and another commented that the cube was not useful, but unfortunately without giving any reason.

> *S5-Q2: How satisfied are you with the way how the cube represents the other groups? Would you change anything to it and how would these changes look like?*

Many users reported liking the representations of the other groups through colours. Although, one remarked that there was no indication if the activity was produced by only one (very loud) person or by a group of people being present in the common room. Some users requested exchangeable button labels and one suggested using displays for the buttons instead of one LED. Another user would appreciate if the code were more stable and furthermore suggested that the cube could actively set some actions.

> *S5-Q3: Could you imagine using the cube beyond the test phase? What effects do you think it would possibly cause if it would be installed permanently?*

The majority of those who answered this question could imagine using the cube for a longer period of time. Some remarked on the positive characteristics and effects of the cube such as *"seeing how active others are is fun"* or *"just keeping a sense of awareness and connection"*. One user reported that the *awareness cube* did not disturb and that it was a nice toy and an eye-catcher, whereas others stated that the cube would become an ambient artefact and part of the inventory, but they characterized this as a positive development. One user remarked that the cube would need new features because the attraction might decrease if the features stayed the same.

S5: Other comments

In the last survey of the test phase there were only a few contribution on the open cards. One card was used to congratulate for the good job and another suggested publishing the source code for developing further playful concepts.

The ethnographic interviews in this week comprised many statements, opinions and suggestions that were already topics in the weeks before. Thus the feedback started to repeat itself somehow. Two users from different groups reported that there was slight confusion about the button use. One user reported using the buttons according to their labels and receiving an immediate response. Confusion arose, however, because the expressions were contradictory and not really making sense. In a conversation between the two users it could be resolved that the other user was only creating patterns instead of serious answers. Both users remarked that the *awareness cube* changed something. They could not describe the change in particular but both meant that it was something overarching all groups. Other users reported to still be playing TIC-TAC-TOE games and asked for common rules they said they did not know if everyone was playing by the same rules. However, it seemed that the establishment of common rules was not very relevant to users. Participants reported that they were somehow surprised that many people were still using the device because some had been rather sceptical at the beginning of the test phase, but after four weeks the cubes were still being used frequently. People also remarked that some of their colleagues had changed their stance towards the project from scepticism and rejection towards active use and a more positive attitude.

The contributions in the last week primarily comprised suggestions for future enhancements like more flexibility for the buttons. Furthermore, people stated in interviews and surveys that the project had developed positively and actually contributed to more connectedness of the distributed groups. People could even imagine using the system for a longer period of time if some enhancements were implemented.
Overall, the surveys and interviews conducted in the four-week test phase revealed remarkable developments in different aspects of the project. After initial curiosity in the first week accompanied by some uncertainties regarding the cubes' detailed functionality people became familiar with the devices, and especially during the second week many participants started using the cube in their own way – by creating patterns with the buttons or playing TIC-TAC-TOE. The twofold manner of use consolidated in the third week of the test phase. In that week conversations about the cube within and across the groups increased. These conversations were primarily used to identify the interaction partner of a specific prior situation. In the

final week of investigation users provided relevant and interesting ideas for possible enhancements of the *awareness cubes*. Especially the fixed labelling of the buttons was criticized and users requested more flexibility for exchanging content. After this chronological summary of the data collected during the test phase the results from an analysis of this data are presented in the following parts of the section.

6.3 Findings from test phase

The data gathered during the design phase through applying two different scientific methods – paper-based surveys and ethnographic interviews – was analysed collectively for obtaining deeper insights of the developments during the test phase regarding various relevant perspectives of the project. The findings presented in the following part provide an understanding of how the design and implementation of the *awareness cube* actually mapped the wishes and expectations of the users elaborated in the initial workshop. Another relevant contribution of this analysis, regarding the leading research question of this thesis, is to reveal how the presented system facilitated and maintained connectedness between the groups, social relationships, common activities, mutual interaction, subsumed as supporting social awareness across distributed work groups.

Similarly to the analysis of the initial participatory design workshop, the analysis was conducted thematically (see Section 3.4 for methodological details) in three iterations of coding and categorizing the material. Eight basic themes are the result of these iterations and provide a broad-ranging overview spanning several fields associated with the project, as well as deep insights into the particular areas of the system's design. An illustration of the resulting themes is given in figure 16 and the themes are presented in detail in the subsequent paragraphs.

Device design & concept
This theme encompasses several perspectives regarding the particular design characteristics of the technology probe. Feedback about the general perception of the artefact is part of this category, but there are also references regarding the construction or weaknesses of particular parts.
The *handling* of the "quiet" *button*, for example, confused users in several ways because many were not sure if quiet meant a request to the other groups or if it was an expression of a group's own status. If used for the latter participants saw no sense in this expression because the noise level was already captured by the microphone and displayed on the other cubes by the LED lights. Users also asked if the "quiet" button put the cube to a mute mode. Therefore some participants reported not using it at all. Also the ON/OFF button was not used very frequently because people could not imagine specific situations in which it would be necessary to switch the cube off. Furthermore, the button seemed to hamper the ability to play TIC-TAC-TOE because its LED was always activated showing the group colour and therefore had to be used as a joker in the game. At the very beginning of the test phase some of the participants considered the expressions on the buttons somehow related to the display on the sidewalls

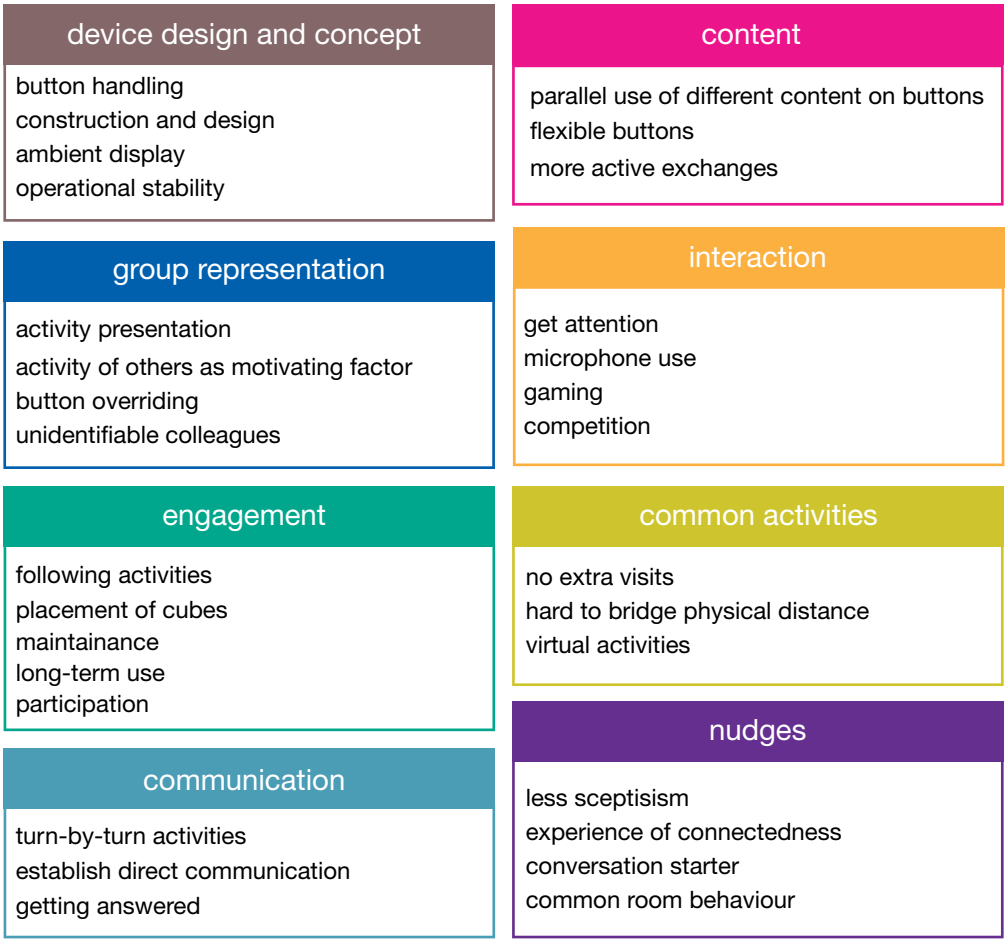

Figure 16: Themes emerging from the common thematic analysis of paper-based survey and ethnographic interview data.

of the cubes. Initially, it was not clear that the buttons and the illumination had no functional relation to each other, but this misinterpretation was resolved relatively quickly.

Regarding the presentation of the noise level on the sidewalls, the participants emphasised the light as unobtrusive and pleasing. Especially the smooth transitions between the levels and the combination of colours were characterized as comfortable and the cube was perceived as an *ambient display* in the background. The fixed assignment of LEDs to the groups was an issue as well as the form of presentation. Therefore some users requested more "movement" of the lights and flexibility of the display.

Additionally, users addressed issues concerning the *stability of operations* of the technology probe, like frequent system crashes, frozen LEDs on the sidewalls or worn out buttons. The major problem users had to deal with after a system crash actually was not the restarting process, which could be done relatively easily, but rather the loss of information from buttons –

button lights were reset after a restart. Thus users requested a backup functionality to be able to restore the previous state.
In terms of the *construction* itself, a few users worried that the cube could tip over when the outer buttons were pressed too hard, but generally the design of the artefact was rated as simple in a positive manner because it was experienced as something that was somehow attractive, did not have to be used actively and could be put in the background as an ambient display. People appreciated the twofold possibilities of using the *awareness cube* passively as an ambient display as well as actively by interaction through the buttons.

Group representation
This theme illustrates how the groups and their activities were represented through the illuminations on the cube. It shows how users perceived others' activities on the *awareness cube*.
Since the *activity presentation* by the LEDs was closely bound to the characteristics of the artefact itself, many statements regarding presentation were quite similar to the ones regarding the design of the object. The presentation was perceived as unobtrusive and ambient – it did not make one focus on it, but presented something in the background. The groups could be identified easily by the different colours although they had to be learned in the first days of the test phase. Overall the cube reportedly provided a sense of the activity of the others and participants stated that they had fun following the activities represented by the illumination of the cube.
Another subtheme describes the *experience of remote people* facilitated by the cubes. Unusual activities (background noise caused by open windows) were discussed across the groups and identified as such and therefore this phenomenon was not seen as major problem. The activity display served different purposes. The changing light caught the attention of participants and motivated them to press buttons. But users also used the changing light as an indicator for the presence of a colleague on the other side and the possibility for direct interaction. Contrasting the second purpose, people suggested fading out the lights over a longer period of time in order to get a sense of past activities and reduce the chance of missing something interesting. One participant even wished to have a mobile app accompanying the cube to be able to have the representation available on the smartphone and therefore everywhere.
Regarding the *overriding behaviour* of the expressions on the buttons the participants had different opinions because the buttons had been used very differently. Those who were only interested in expressing themselves via patterns favoured the overriding because that enabled them to "paint" simple but clear patterns. If the buttons faded or showed more than one colour at the same time the clarity of a pattern would be lost. This behaviour was also important for playing TIC-TAC-TOE games via the buttons. For those who liked to express their (or the group's) mood via the buttons the overriding turned out to be a problem because the initial information was lost and furthermore it was not recognizable if more than one group was in the same mood at the same time. For them it would be a major improvement if each button could indicate the expressions of all three groups at the same time by either fading through the colours or having one LED built in for each group. If the buttons were able to represent all three groups, commonalities could be identified more easily, like having similar lunch times or times when they were busy – and so they would metaphorically be able to see if they were

doing something "together". Due to the moods represented on the buttons some participants signified that they wanted to take care of their colleagues, in terms of wanting to know why they were in a particular mood and, for example, comfort them if they pressed the "sad" button. One participant also reported not wanting to override the common group mood by a personal expression.
Although the groups were distinguishable through their colours, because of privacy reasons neither the activity display nor the expressions on the buttons gave information about who in particular caused an action or how many people were present. The representation of *unidentifiable colleagues* led to discussions within the individual groups and even across the groups about who in particular was in the indicated mood or was responsible for a specific pattern. Hence, on the one hand some group members were curious about who was responsible for an expression or activity, on the other hand, however, some reported to be excited about not knowing in detail because it was a fun element of the communication.

Engagement
This category accompanies the representation category discussed previously in terms of personal engagement of the users, their willingness to interact through the *awareness cube* and their interest in it. It encompasses different sources of motivation for using the system, expectations for future developments and findings that address different forms of effort related to the system.
Regarding the need to *follow the visual representations* on the cube, some participants wished that the cube would, for example, make some noise if there was some change in the activity so as to be able to follow the actions more easily. The cube should somehow call the attention of the users more actively to reduce their need to explicitly "wait" for something to happen. Some users even wished to have one cube in their offices to be able to permanently follow the indicated activity. People stated that it still needed a certain effort to walk over to the kitchen to see the activities on the cube and it would be more comfortable to have the representation directly in the office. Furthermore, at least some button lights should be turned off automatically according to the participants because they were not correct after some time like "having lunch", for example.
There were also discussions about the best *placement* for the cube in the common areas of the facilities, which can be taken as an indicator that people were actually interested in the devices and were thinking about different aspects of the setting. Although such statements as mentioned above show that some users could imagine that higher flexibility in terms of placement would be useful, it was also stated that batteries – which would eliminate the necessity for placing the cube near a power socket – would demand too much effort in taking care of charging them and so regularly maintaining the technology probe.
The rejection of any *maintenance* obligations (revealed in the analysis of the initial workshop) has to been seen in the context of a possible permanent implementation of the cube. Regarding the technology probe's test phase its weaknesses were widely accepted and users also showed willingness to maintain the cube by regularly restarting it as well as actively asking for assistance in rare situations of severe malfunctioning. Ironically, some reported that it was even healthy to get down on the ground to pull the power plug and restart the device. Overall

the users actually took good care of the *awareness cubes* especially in the second half of the test phase when they became more and more familiar with them. Nevertheless, there were many statements indicating that people required a more stable device for long-term implementation. Regarding the provided functionality users showed initial curiosity that evened out a little bit after the first week and stayed relatively stable in the remaining test phase. Although there were no reports that people interacted with the cube less frequently towards the end of the test phase, some participants stated concerns that the cube might become boring in a *long-term implementation* because the functionality was not flexible enough. The participants could imagine using the device permanently but then the system had to provide more features and more flexibility in terms of interaction and communication possibilities, which leads to the following categories.

Communication

This theme characterizes how the participants used the *awareness cubes* to communicate with their remote colleagues and also how the cubes' features may be enhanced to enable more sophisticated communication possibilities.

First of all, participants tried to find ways to *establish a direct communication* line to the others via the cube. Some did that by drawing patterns and waiting for an immediate response, which reportedly indeed happened and patterns were then drawn turn by turn; others sent out a kind of Morse code via the buttons to indicate that they were there and wanted to communicate. Following the participants' statements there had to be a way to initiate communication somehow and ensure that their remote partners got notified of such an invitation because people mentioned that they never knew if anyone actually recognized a new pattern or an invitation via the "come over" button.

Once a communication was established – a sent invitation found a response – the participants would like to have a form of synchronous communication that enables turn- *by-turn activities* like pattern drawing, playing TIC-TAC-TOE, answering questions expressed through the buttons, or even using the cube as a Walkie-Talkie. Especially in terms of doing simple Q&A exchanges someone suggested labelling the buttons pairwise to be able to respond to a "come over" invitation by a simple "OK" or "YES". Others also wanted to have a more sophisticated solution where they would be able to ask back why they should come over and therefore know what was going on in particular on the other side that might be interesting to join.

This category clearly shows that people like to communicate with each other in a rather simple but still coordinated manner, which is provided by the cube in a very basic way and would have to be improved for long-term implementation.

Content

Since the previous theme characterized various forms of communication the technology probe already supports or should support in a future version, the present theme focuses on the content exchanged via the *awareness cubes*. Within this theme there are two major sub-themes, which address the already mentioned playful component, as well as the possibility of expressing the group's state via the buttons.

After some days of the test phase several users began to exchange patterns through pressing the buttons, which led to confusion among those who used the buttons to express moods; but

the longer the test period lasted the easier it became for all participants to use the cubes for *both types of content in parallel.* As soon as the "rumour" that the buttons could also used for creating patterns reached the majority of the users, it no longer appeared to be a problem. If there were confusing mood expressions activated like "happy" and "sad" at the same time people started to interpret such things as playful patterns but nevertheless used the buttons to express moods if they wanted to. The ethnographic interviews showed that there were users who only made patterns with the buttons and did not care about the moods at all, as well as are others who primarily used the buttons as intended, i.e. to express the group's state. Furthermore, some participants mixed these types of content and did both. There were no statements at all requesting an elimination of one content type for the benefit of the other. However, each "content group" developed several ideas for supporting their particular type of content throughout the test phase, which overall can be subsumed as a request for more flexibility – for both types. In terms of the button labelling, users suggested combining buttons they perceived as similar (like "happy" and "excited" or "grumpy" and "sad"), which gives the possibility of putting other expressions on the buttons. People also requested an additional "tired" label on one button instead of a rather rarely used button like the one labelled "sad". Some users also identified a discrepancy between the buttons labelled with several moods and the two buttons labelled with activities. While some people reported that it was not suitable to combine activities with moods and that it would be better to only use moods, others stated that "moods" were too individual for them and that "activities" were better. Beyond suggestions for improved button labelling a certain request for more *flexibility of the expressions* emerged throughout the test phase. Buttons should not only provide a predefined text, but also give users the possibility to exchange the labels perhaps via dynamic displays on the buttons. Besides more flexibility in labelling, people who used the buttons for mood expressions also could imagine using them for simple messaging like exchanging notes or short text messages. Therefore suggestions to build in a Walkie-Talkie function to support spoken messages came up as well as preferences for text-based messaging only, which would be less personal than voice-recordings. Those users who primarily used the buttons for drawing patterns or playing games clearly requested possibilities for drawing more patterns and wished to have a history of patterns on the sidewalls instead of the loudness information or to be able to draw patterns on the sidewalls as well.
Besides the exchange of various content types via the buttons, people also gave suggestions regarding the noise capturing and its presentation on the sidewalls. Some suggested using the sidewalls for *more active exchanges* like pattern histories or gaming. Others although suggested using the signals of different sources like printers or the coffee machine to represent the activity.

Interaction
This theme is related to the two previous themes, communication and content, but focuses on how things are exchanged and how people interact through the device. In general, the theme points out the importance of an entertaining component for such a device, originating from many mentions about playful ways of interaction.
The analysis of the test phase data revealed that the *awareness cube* invites curious investigations of the others' activities, for example, while waiting for the coffee to be brewed. People actively tried to produce sound patterns to *call the attention* of remote colleagues and start interaction.

For example, there were reports about participants doing a barrage of catcalls in front of the cube to increase the intensity of the light as well as specifically producing noise in specific rhythms to achieve a certain variety in the illumination. These results show that some participants *actively used the microphone* to interact with the others, which goes beyond the intended functionality of the microphone to just passively collect the noise of the surroundings and display it on the LEDs. Furthermore, the initial scepticism about the microphone decreased clearly. On the day the technology probe was implemented many participants worried that they had to be quiet in the common room because the cube was listening and thus were hindered in their interaction with each other. Just after a few days of implementation, nobody mentioned such worries anymore.

There were manifold statements regarding interaction that demanded a playful manner of use in terms of implementing several games, which could entertain the users during their visits in the common rooms. *Gaming possibilities* in whatever form would definitely be a motivating factor for a long-term use of the cube, as can be seen from the pattern-drawing attempts via the buttons. The pattern-drawing utilization by some participants fits statements where people requested more support for "meaningless interaction". Some participants even interpreted the overriding functionality of mood indication on the buttons as a playful component. Through this feature it became possible to *match each other* somehow and to be able to deactivate the others fields – in a playful, charming way – by first setting and then resetting all the buttons. Playing TIC-TAC-TOE games seems to be an extended form of pattern drawing, because people reported starting to play by simply trying (and hoping that the other recognized the game) and the longer the test phase lasted users even developed individual rules about how to handle the central ON/OFF button. However, it could not be really clarified if all the players agreed on the same rules until the end of the test phase. Interestingly, people stated that playing via the cube with their remote colleagues was easier than with people present of their own group because it happened more spontaneously, which underlines the cube's ability to be a connector between unknown players.

Common activities

Common activities is a less extensive but nevertheless important theme that emerged from the analysis. It is about activities the group members do (or can imagine doing) in common where the technology probe can be used as an initiator or supporter for such activities.

For example, there were *no verified reports that people visited* one of the other groups because they had been invited via an activated "come over" button. Two main reasons can be identified to explain this: First of all, the few people who reported having visited colleagues (this always happened on a personal level) in other groups already did that before the technology probe has been implemented and did so too during the test phase and so it was not necessary to have an activator like the cube. Those who did not visit others before – and had no personal relationships with people in the other groups - saw no reason to be more sociable because of the cube. A representation of the others and interaction via the cube seemed to be enough for them. The second reason is, that it takes time and effort to walk over to the other's facilities to visit somebody there. People were too busy and said that there was no time for visits or they just did not know exactly what was going in the other group and whether joining them would

be worth the effort. This is also related to the request for a possibility to ask back why someone should come over as outlined in the communication theme. A "have lunch in the middle" button was also suggested to reduce the effort for the visitor and allow people to meet at a predefined place in the middle.
Since it was hard to trigger actual physical common activities, people reported occurrences of *virtual common activities* performed on the cube itself. The representations of the noise level were characterized as a good indicator for seeing if direct interaction were possible, perhaps in the form of a game. Another common activity related to the cube was the established rule set for the TIC-TAC-TOE game (not all were commonly used except for the treatment of ON/OFF button) as well as requests for a push-to-talk functionality. Besides more interaction related commonalities some content-related statements could be found in the data regarding common activities. Participants characterized the labels "sad", "happy" and "grumpy" as too personal and therefore not really suitable for a common expression at the group level, whereas "having coffee" and "come over" where characterized as good labels to trigger common activities (although they did not lead to actual visits).

Nudges

Nudges are little impulses a change in an environment – like the implementation of a technology probe – might bring, and since direct effects from the implementation of a certain technical artefact on a social environment cannot be deduced the term "nudge" seems to be highly suitable for characterizing those small changes people reported during the test period.
As reported before, the probes evoked curiosity when they were actually implemented at the groups' facilities. However, between the presentation of the concept and the day of the probes' implementation, participants were rather sceptical as to whether this idea would be able to fulfil their needs. This scepticism comprised security issues as well as little conviction that representing the noise level of the other groups' kitchen via LED lights could really support awareness. This *scepticisms changed* completely, at least for some participants, as the results show. People explicitly mentioned that the cube *"is funnier and more useful than expected",* there were reports that people who initially opposed the whole concept started to press buttons and participants who raised severe concerns in terms of security and privacy regarding the microphone explicitly mentioned within ethnographic interviews that their minds changed completely and they did not really see a necessity for turning off the microphone anymore. So there was definitely a shift in some users' opinion during the test phase.
Regarding the cubes' objective for supporting awareness, participants reported that they *experienced a connectedness* to unknown people and a long-term use would even increase this. People reported that there was more perception of the others, and the technology probe provided a sense of presence of the remote colleagues through the illuminated LEDs. The cubes' implementation led to curiosity about what was going on in the other groups and, in particular, interest in what colleagues were doing at the very moment. On a meta-level, people reported that the technology probe made clear that having contact was important. There were several statements pointing out that the cube actually increased awareness: one participant mentioned that the groups became closer and the relationship became somehow warmer. Others perceived some change because of the cube but could not really characterize what changed in

particular. Only a few participants reported that the cube did not change anything and their relation to and perception of the other groups stayed the same as it was before.
Besides these nudges in terms of awareness, connectedness and representation of the others, the technology probe *triggered conversations* within each group and even across the groups. Within the groups people were reportedly debating and wondering about the activity and/or person who caused a particular activation of LEDs – both on the sidewalls as well as on the buttons. There were also reports of conversations about the cube and that it was *"always a conversation starter"* for debating cube-related things like its functions, but also for discussing things related to the other groups like a pattern or a game. Across the groups the conversation (during occasional meetings and visits) were quite similar and the main objective here was to find out who was responsible for a particular pattern, against whom one had been playing for several hours ago and what was meant by an expression via the buttons. These reports, showed that conversation across groups was mainly used to clarify incomprehensible button communication, but also lead to conversations about gameplay and created patterns between people formerly unknown to each other.
Referring to a survey question about changing *behaviour in the common room* or the number of visits to the common room, the participants mainly reported that they perceived no change at all. The majority reported that the cube did not disturb or cause an uncomfortable feeling, and could become part of the inventory; it was nice to have it in the background, but it did not really cause individuals to change their behaviour. This particular question especially addressed initial concerns regarding the feeling of being observed by the cube, and therefore it can be interpreted as positive that there was not really a negative aura created by the cube. One participant began thinking about his own mood, which surely is a nice nudge that emerged through interaction with cube.

The thematic analysis of qualitative data collected throughout the test phase of the technology probe revealed eight relevant themes describing various aspects of the test phase, the use by the participants and how the *awareness cubes* supported awareness across the three distributed work groups. The findings show that simplicity is an important factor for users but – a little bit in contrast to the findings from the initial workshop – people were actually willing to put a little effort into the use of an awareness support system because they identified some benefits such as increased connectivity between the groups. Besides the possibility of exchanging short message snippets – here provided by the mood buttons – people were highly motivated to exchange playful content. Most users could imagine using the system for a longer period of time if it were more flexible in terms of interaction and exchange of content.

The thematic analysis marks the completion of a comprehensive process within this project that started with the evaluation of context and gaining an understanding of user needs, wishes and expectations towards an awareness support system. Therefore an initial workshop was conducted to elaborate design ideas together with the future users. A thematic analysis of the data collected in the workshop yielded a system concept that was presented to and discussed with the users. Necessary adaptations of the system were elaborated in a participatory way together with users to be able to address the expectations of all three groups and therefore be able to implement a system that actually suited their daily routines. Three technology probes

were constructed to serve as ambient information displays with tangible button interfaces on their tops that allowed direct and active interaction between the users. The design of the *awareness cubes* mainly followed the principles of simplicity and unobtrusiveness to fit into the casual and comfortable environment of common rooms and break-time situations. The system was implemented at the sites of the three work groups for a period of four weeks to gain insights into its ability to support social awareness across distance. Within this test phase, the use of the devices' buttons was automatically logged to provide a quantitative overview of the various usage frequencies. To gain a deeper understanding of the use of the devices, user motivation for different types of usage and possible changes in the perception of remote colleagues, paper-based survey and ethnographic interviews were conducted throughout the test period. Again, the data was analysed thematically and eight themes were identified characterizing different aspects of the technology probes' usage that represent – together with findings from previous stages of the project – a relevant contribution to a final discussion for resolving the research questions outlined in the introductory chapter of this thesis.

7 Discussion

The preceding chapters of this thesis presented awareness research in CSCW and HCI from various perspectives, related awareness research to recent developments in technology to maintain and facilitate awareness across distance. A collection of research methods and the principles of participatory design were introduced to illustrate scientific techniques for the development and evaluation of awareness supporting technology primarily following a qualitative research approach. The application of the participatory design approach led to an awareness support system, the *awareness cubes*, which is based on the wishes and expectations of its users and was envisioned and developed in close collaboration with them. The previous chapter illustrated the three phases of system design from exploring the use context, developing the *awareness cubes* and finally testing the devices in a real-life setting. The data collected during this process allows relevant insights into users' handling of the system and their interaction with it and the system's ability to support awareness across distributed work groups. In this chapter the presented findings are discussed on several levels and from different viewpoints. First, a relation to earlier findings found in relevant literature is given. Second, the methodological approach is discussed and the benefits of the chosen approach are illustrated as well as lessons learned during the process. Third, relevant aspects emerging from the results are discussed, the research questions of this thesis are resolved and this work's contribution to the research field is revealed.

Establishing a common ground through alternative ways of use

The objective of this project was to facilitate awareness across distributed work groups on the group level and therefore the *awareness cubes* were created as physical objects with tangible interfaces intended to be placed in the common rooms of three work groups. The basic idea of the approach was to provide similar cues of awareness across distance as they can be found in a co-located setting. Co-located workers perceived activities of others in the hallway or in the common rooms peripherally and decided if they wanted to actively join these activities or if they rather wanted to work independently on their individual tasks. As illustrated in Chapter 2 the establishment of a common ground is a relevant factor for successful communication in co-located settings. People follow their partners' conduct more easily through interpreting gestures or emphasis in their speech (cf. Kraut et al., 2002). One relevant contribution of technology for supporting awareness across distance is to re-establish supporting characteristics that are given naturally in co-located settings by physical proximity, such as a common ground for communication. The *awareness cubes* facilitated the establishment of a common ground among its users in different ways. People frequently exchanged patterns or played TIC-TAC-TOE games through pressing the button on the cubes' top and thus developed a common ground

via this way of use. These alternative ways of use emerged throughout the test phase of the technology probes and indicate the establishment of a common ground since there was an informal agreement across all groups on this alternative use. Members from different groups even developed rules for playing TIC-TAC-TOE on the cubes. Regarding the intended use of the buttons to express current moods and activities, a common ground was harder to establish because users could not really assign the expressions to individuals and wished to have more information about the state, which was not supported by the cube. Possibilities for asking back why a group was in a particular mood or if an activity was still in progress would have facilitated the establishment of a common ground for this way of the buttons' use.

Supporting informal and social awareness through passive and active use

Regarding the types of awareness supported by the *awareness cubes* two can be clearly identified: informal awareness and social awareness. Informal awareness provides knowledge on actually present co-workers, the actual rhythm of a work group, and the up-to-the minute characteristics of the environment. Informal awareness is primarily maintained through peripheral perception and interaction with the environment and, according to Gutwin, Greenberg and Roseman (1996, p. 6), "informal awareness is the glue that facilitates casual interaction." The *awareness cubes* support informal awareness primarily through displaying the other groups' activities peripherally on the cubes' sidewalls. Users reported that it was funny and interesting to follow the activities of their remote colleagues on the ambient display and therefore they got a sense of the other's presence. The common rooms of the individual groups appeared to be extended somehow to those of the others through this connection. Displaying the activities of remote colleagues in the background did not distract users from their actual conduct but allowed them to sense the presence of others peripherally and therefore gain informal knowledge about distant colleagues. This knowledge enabled users to initiate more active interaction via the *awareness cubes* buttons. People reported using the activity display as a basic indicator for direct interaction.

The transition from passive use of the cubes as an ambient display to more active use for direct interaction with colleagues can also be seen as a transition from the support of informal awareness to social awareness. One characterization of social awareness refers to information on the other's emotional state, if a conversation partner is paying attention or showing interest (Gutwin, Greenberg, et al., 1996). This particular characteristic cannot really be addressed by the *awareness cubes* because there is no transmission of such rich information representing the emotional state of a user, and furthermore the expressions on the buttons were related to the state of an entire group. But a more general notion of social awareness sees this type of awareness as the feeling of relatedness and belonging to a group or organization (Bødker & Christiansen, 2006). Findings of the test phase show that users wanted to know more details about expressed moods or activities (if they identified an activated button as such and not as part of a pattern). People asked who was responsible for a particular expression and further wanted to know why such colleague was in the expressed mood. This came out very clearly as one user stated wanting to comfort a "sad" colleague. Through the expression of moods and activities via the buttons people got a vague indication of the actual situation at the remote site. Their request for a functionality that enabled them to ask for the reason of a specific state was

an indicator of an increased feeling of belonging to a social environment, and therefore for social awareness in a general sense. But not only the intended use of the buttons for expressing moods and activities but also the alternative uses for more playful exchanges were indicators for connectedness. People drew patterns with the hope that remote colleagues might see these patterns and possibly respond with another pattern, which was also accountable for playing TIC-TAC-TOE games.

The combination of a desktop-based and a public system

In Chapter 2 a collection of relevant scientific approaches in awareness research were presented in detail. Besides early approaches, systems were introduced which supported awareness on the personal desktop (e.g. Fitzpatrick et al., 1998; Greenberg et al., 2010; Gutwin, Roseman, et al., 1996; Romero et al., 2007) as well as more ambient systems which provide rather metaphorical representations of remote people (e.g. Eliëns & Vyas, 2007; Kirkham et al., 2013; Prante et al., 2003; Strong & Gaver, 1996). The initial concept of the *awareness cube* system, as presented in Chapter 5, comprised a combination of devices implemented in the common rooms of the work groups with services or devices for the personal desktop or even mobile use. For reasons of feasibility only the devices for the common rooms were actually realized within the scope of this thesis, but findings from the test phase show that some users wished to have awareness information directly on their desks. The *awareness cubes* in the common rooms provided mutual information about activities in a particular room and therefore support awareness on a group level. However, some users wanted to follow the group activities on their desks and even wanted to interact with other people directly from workplace to workplace, which possibly would lead to a support of awareness on a rather personal level. Having a representation of the other groups directly on the personal workplace or on a smartphone would eliminate the need to join the common room and therefore being somehow active in gaining awareness information. The wish for a personal awareness device or service application also illustrates the tension between necessary effort for maintaining awareness by visiting the common room and further improvements of the connectedness between the groups by presenting information at the workplace. Therefore, possible future extensions of the system for personal desktops would have to be designed in a way that facilitated the feeling of connectedness on the one hand but also kept users motivated to engage with the system, and required little effort for maintaining social relationships on the other hand.

Consequent user participation leads to trust in the system

Following the paradigm of participatory design, where users and designers are jointly working on the design, planning and implementation of a future system (cf. Kensing & Blomberg, 1998), facilitated the development of a highly tailored system that is based on the users' expectations and needs. The participation of users was most relevant in the first steps of this project where their experiences and wishes articulated in a design workshop and other informal conversations led to a detailed description of the systems' context and how users could imagine to engage with a future system. Without this knowledge it would not have been possible to implement a system that fulfilled the users' needs, on the one hand, and gained users' trust in the system. Having trust in the *awareness cubes* was an important factor regarding the privacy and security concerns expressed by some users at the beginning of the design phase of the

cubes. Especially the participatory design approach and the methods used allowed for close proximity to the users and established a certain level of trust. Based on this level of trust, the transparency of the system's functionality and the participation of users, critical concerns regarding privacy and security were resolved. Moreover, users spontaneously reported that their attitude towards the whole project shifted because of a multitude of conversations with me where the details of the system became more transparent and their concerns directly led to adaptations. The importance of resolving issues regarding privacy and uncomfortable feelings caused by observations is shown in a study by Riche, Simpson and Viller (2008). Due to continuous video recording a subgroup of participants stopped using the coffee room and only came back sporadically after adaptations were made to the system. This shows that resolving such concerns before implementation of a system is relevant for the engagement of the users. Users participated in the design and development of the *awareness cubes* in different stages but how and when they were actually able to participate depended on their individual schedules. Since they had to achieve their personal work tasks it was difficult for them to contribute to every single detail of the system. Therefore the 'quick and dirty' ethnographic interviews, which were conducted whenever relevant decisions had to be made, allowed the users to participate in the project without spending an excessive amount of time on it. Many interviews were conducted very briefly but still provided relevant contributions for detailed design decisions. Nevertheless the 'quick and dirty' characteristics of these interviews, especially in the early stages of the project, unfortunately were sometimes not documented adequately and therefore there was not evidence for a few decisions that were made based on such informal conversations with users. For example, a variety of possible materials for the *awareness cubes*' surface was presented to some users and the majority voted for the semi-transparent Plexiglas. Thus the selection of the material was based on user participation, but unfortunately the process was not documented. For future attempts a seamless documentation of such small details of the design process from the beginning on would be relevant for being able to provide evidence for all commonly taken decisions.

Mixed methods as promising approach to reach (almost) all users

The selection of mixed methods for evaluating the technology probes allowed insights on various levels. People provided relevant contributions in ethnographic interviews and illustrated their motives for using the probes on a personal level. The paper-based surveys were intended to provide possibilities for users to give feedback anonymously and address issues, which they perhaps would not have wanted to address in face-to-face conversations. Whereas in interviews mainly positive developments and possible enhancements of the system were discussed, negative attitudes towards the project and the *awareness cube* were subject of the surveys. Unfortunately, most of the users who characterised the system as "useless" did not provide further reasoning for their opinion and obviously those users avoided interview situations or at least they avoided making such concerns subject to interviews where it could have been discussed in more detail. As mentioned above a certain level of trust was established with the majority of the users throughout the work on the project but obviously this could not be achieved for all users. More detailed reasoning for such superficial criticism would have been a relevant contribution to this work for allowing further understanding of the experiences and attitudes of

users. Although the methods were chosen carefully and provided relevant information on the technology probes' use, negative experiences are as relevant as positive ones and users have to be motivated somehow to provide further reasoning for criticism. Nevertheless, the carefully selected methods enabled the collection of rich data from various sources, which finally led to a "thick description", as Geertz (1973) characterized it, of the use of the *awareness cubes*. An indication for achieving such a "thick description" was repeating contributions in interviews and surveys towards the end of the test phase. Users appeared to have given reports from all relevant perspectives and therefore no entirely new issues emerged in the last few days of the test phase.

From 'effort' to 'engagement'

Two central analyses were applied to the qualitative data collected throughout the project. The first analysis after the initial design workshop elaborated themes that described the use context and the second analysis after the test phase of the technology probes identified different ways of use and the participants' motives for using the probes as they did. It appears reasonable to discuss the most relevant findings from these analyses to illustrate how the *awareness cube* system met the users' expectations, and to identify possible changes throughout the process. Figure 17 illustrates the themes emerging from the two thematic analyses side by side. Coherence between certain themes are indicated by the attributed colours.

Regarding technology, users envisioned a simple and flexible device that somehow fitted into the environment. In interviews and survey statements users characterized the *awareness cubes* as attractive artefacts, with simple and funny functionality. The cubes' appearance and their ability to act as ambient displays supporting passive use as well as interactive devices supporting active use facilitated the devices' embedding into the environment. This embedding let the device be perceived as a 'natural' object or as part of the inventory, as one user described it. In terms of content exchanged through the system people had manifold ideas from work-related to personal content. The test phase clearly revealed that probably the most relevant type of content for a system in this particular setting was a playful one, as users found their own ways to exchange playful things such as colourful patterns. A closer look at the communication themes of figure 17 reveals differences between the workshop theme and the test-phase theme. The system provided possibilities for simple exchanges like group moods and activities but the test phase showed that this approach reduced the communication abilities too much. People would like to have had more turn-by-turn communication to be able to ask back and clarify possible uncertainties in interpretations of expressions. In terms of activities people found playful virtual common activities such as TIC-TAC-TOE games, but there were no common physical activities triggered by the cube besides conversations about the system. The most remarkable shift between the themes of the initial workshop and those of the final test phase relates to the 'effort' and 'engagement' themes. Whereas it appeared to be very important for the users to avoid any kind of possible additional effort the system might bring in the beginning, this attitude shifted towards actual active engagement with the system in the test phase. People explicitly stated in the workshop that there was not to be any need to maintain the devices, but they were regularly restarting the *awareness cubes* in cases of system crashes and did not see major problems in doing so. Perhaps there is a certain difference in imagining the

theoretical use of future device and the use of a real object that is actually present in the environment and brings benefits and so can be afforded a certain amount of care. Another factor for this shift might have originated in the ethnographic participatory design approach. The users' motivation for interpreting a system to which they contributed personally as beneficial and not as an additional burden might be an effect of that particular approach.

Figure 17: Comparison of workshop themes and test-phase themes to illustrate coherence of certain themes and development throughout the project..

In the introductory chapter of this thesis two blocks of research questions were presented that represent the main objectives of this work. One block is related to the *awareness cube*'s ability to support social and informal awareness across distance and the other block addresses reports and indication of changes in user behaviour, their perception of remote colleagues and the relationship between the groups. The entire process of system development and evaluation revealed insights that contribute to resolving these questions. For some of them the analysis of

collected data provides very clear answers; for others, resolution is more complex and answers can only be given indirectly and implicitly, such as for behavioural change of users.

Awareness through peripheral representation and direct interaction

How does technology with elementary functionalities and interaction possibilities support and maintain awareness between distributed work groups in informal, non-work related settings?

The findings from the evaluation of the test phase and the initial workshop show that especially in informal environments such as common rooms simplicity and pleasant appearance are relevant factors for successful technology. Here the representation of the overall rhythm of a group is more relevant than exchanging more explicit things in order to achieve higher efficiency for resolving tasks. In the given setting the characterization of technology as 'simple' comprises easy to interpret functionality that provides effortless use. Effortless means that technology is somehow self-explanatory in terms of its use and furthermore does not require too much maintenance effort. The pleasant appearance of the technology in this setting means that technical components are hidden to the greatest possible extent and the appearance is somehow inviting and motivates users for further interaction. But the pleasant appearance and simplicity also mean that the technology represents something in the background without demanding permanent attention of the users. The literature review provided in Chapter 2 as well as findings from the initial design workshop show that successful awareness systems need to be able to operate in the background and only draw the focal attention of users when something relevant is happening. For example, when someone peripherally observes the conduct of local collaborators the *awareness cubes* provide information of distant people in the background. Statements by participants clearly show that the simple representations of their remote colleagues' activities through illumination on the devices sidewalls are perceived as entertaining. People interestedly followed the movement of light that represented distant colleagues and wondered about the origin and background of this activity. The illustration of remote activity reportedly led to a feeling of increased connectedness, and therefore awareness, among the groups. The design as an ambient display provided a representation of the other groups that could be followed actively as the focus of user attention or more passively as an information source in the background. The abstraction of the loudness information displayed via LEDs left room for speculations about the actual activities of distant colleagues and led to further conversations and debates.

The findings regarding interaction through the tangible button interface were twofold. Again, simplicity was appreciated and especially the alternative use of the buttons for generating patterns and TIC-TAC-TOE motivated people to interact with users from other groups. But people using the buttons as intended for expressing moods and current activities reported that the interaction was too elementary. People requested possibilities for more mutual turn-by-turn interaction. Regarding the support of awareness the buttons clearly led to interaction across the groups and people reported on their hope that others might see new patterns or join a TIC-TAC-TOE game.

The combination of the peripheral representation of the other groups via the LEDs and the possibility for active interaction via the buttons kept users motivated to follow the activities

of their colleagues and to join interaction whenever something interesting occurred and thus awareness was supported on two levels. A representation of others was necessary for generating awareness and the abstraction of the activities even heightened curiosity on the part of the receiving party. Further possibilities for direct interaction, via the playful use in this setting, contributed to maintaining awareness because engagement and the initiation of interaction can be seen as an expression of interest in other people.

Connectedness on a playful basis

What benefits (or disadvantages) for informal exchanges between distributed work groups can be related to the implementation of such artefacts?

Generally, during their test phase the *awareness cubes* achieved that users from all three work groups reported experiencing more connectedness among the groups. Some users desctibed relations between the work groups as closer and warmer, which is obviously a benefit of the informal exchanges through the system. The representation of others' activities in the informal setting of the common rooms allowed users to follow the others' conduct and interact with each other on a non-work related basis. Soon users developed playful ways of using the devices, started to wonder which colleague was pressing buttons at a given moment, and conversations about others actions were started within the individual groups and also across groups to clarify uncertainties. User reports show that the implemented awareness system brought people who hitherto had not known each other together on an informal basis and somehow reminded users that there actually were distant colleagues belonging to the same organisation and that through supporting this in the common rooms users were able to get in contact without following a specific work task. Whereas people reported experiencing more informal connectedness there were no clear indications that the benefits of informal exchange lead to an increase of other exchanges and interaction related to work tasks and cross-group collaboration. To be able to identify such effects the *awareness cube* system would need to be implemented for a longer period of time, and include suggested adaptations.

Talking about the system and the others but no significant action beyond

How do noticeable changes in the conduct of the group members occur that reportedly were provoked by the implemented awareness system?

How does the implementation of the awareness system affect the daily routines of the group members in their local common room?

Which follow-up actions are reportedly triggered through the preceding use of the artefacts?

How does the system influence the perception of and relation to the distant groups?

For this set of questions answer cannot be given explicitly since changes in the behaviour of people may be influenced by many factors and therefore cannot directly be related to the *awareness cube* system. Furthermore, the test period of four weeks allowed identifying indications of changes but these would need to be investigated in a long-term evaluation.

People reported that the *awareness cubes* triggered many conversation within groups and also across groups. With local colleagues people wondered who was responsible for action of other groups indicated on the cube. They imagined what the others were doing at the very moment. In conversation between people from different groups uncertainties were clarified and people were asked if they recognized a specific pattern or who was playing TIC-TAC-TOE. People showed interest in the representations of others and spent time watching their activity and interacting via the buttons, but there were no reports of action beyond this.
For example, no visit to other groups took place explicitly because of an activated 'come over' button. Uncertainties about detailed activities and who was responsible for the invitation kept people from overcoming physical distance. To motivate users to follow up on such invitations more information would have been appreciated about the purpose of the invitation. The only reported follow-up actions were conversations about the cube when people met occasionally, even conversations between people who previously were not frequently in contact.
According to user statements the *awareness cubes* enabled the groups to move closer together in an informal social relationship. For the majority of users the perception of and the attitude towards the other groups did not change radically, but people liked having a representation of others and therefore the system contributed the feeling of belonging to a common entity. People, for example, reported that others were not as "out of sight" as before.
Although the most significant changes in the behaviour of the group members was an increased number of conversations within and across groups the cubes did not provoke any other actions such as visits or common lunches. To achieve this the awareness system would need to provide further possibilities for mutual interaction and allow people to clarify uncertainties so that they really could be sure that someone on the other end invited them on purpose. Such functionality would probably lead to further activities provoked by the awareness system.

Especially the second block of these research questions focussed on changes closely related to the investigated groups, the behaviour of their members and activities taking place that appeared to be special for these groups. The first block, however, addressed more general findings regarding the support of awareness in an informal work environment. Although the system was designed particularly to serve the needs of these three work groups and is based on the actual working context of its users, the process revealed insights that appear to be valuable in a more general sense.

Curiosity and excitement through anonymity
The great majority of scientific approaches on awareness research in CSCW are based on a personal level, where two or more individuals are somehow connected. Interaction mostly takes places between people who know each other or the presented systems at least allow identifying the interaction partner at some level of the system. The approach taken in the present work focused on the support of awareness on a group level and one relevant factor for this awareness supporting system was that it provided no possibility for uncovering the identity of an interaction partner. There is no retraceable information in the loudness display about who is producing the noise or how many people are present. Information is collected, presented and understood as the representation of a group and not of individuals. Equally, the labels on the buttons refer to the actual state of the group and not so much to the state of individuals,

although people might have used them accordingly. Glaser and Strauss (1964, p. 670) refer to this as "closed awareness context", where the identity of interaction partners is not revealed. One benefit of treating awareness information this way is to obtain privacy, which is always a relevant factor when transmitting data generated by human beings across distances. And another interesting benefit is the way users were dealing with this fact, which indicates motivating factors for awareness systems on a group level. Participants in this project constantly wondered about the identity of the interaction partner, which at first sight may suggest revealing it, but they actually started wondering about the displayed activities. Although they wanted to know who was on the other side, they identified this as a fun element that facilitated curiosity and left room for speculation. Finally, the hidden identity of interaction partners led to curiosity and generated excitement about the system and the conduct of the others.

Tailored systems for supporting social relationships

The system development process of this project led to a highly tailored system that was embedded in the environment of the investigated work groups. The design of the resulting *awareness cubes* was based on the expectations of its users and the interaction possibilities were related to the daily routines of these particular groups. Therefore this particular approach may not be generalizable and successfully applicable for other work groups even for similar organizations. But the fact that successful awareness systems need to be highly tailored to the needs of the users is one outcome of this work that is generalizable. Without the continuing participation of the users the design of the system most certainly would not have met the expectations and affordances of the users in a way that allows satisfying use. Although the system is highly tailored and was development jointly with its users, the test-phase findings suggest a series of adaptations, which would result in even higher customization towards particular usage contexts. Especially systems that are closely bound to the social realities of their users and furthermore are supposed to facilitate social relationship need to be highly embedded into these realities and developed to enable users to interact with each other through the system in a way that appears natural to them. For systems that support informal and social awareness this can possibly be achieved either by highly tailoring a system for use in a specific context like the *awareness cubes* were, or by providing a highly configurable system where users can pick modules that fit their purpose (cf. Kling, Crawford, Rosenbaum, Sawyer & Weisband, 2000). Especially recent developments in technology towards easy-to-implement components such as the Arduino or Raspberry Pi microcontrollers, as well as the availability of sophisticated sensors and displays facilitate the design and implementation of tailored concepts such as the *awareness cubes*.

Within this discussion the most relevant findings for resolving the main research questions of this work were illustrated. In addition, interesting developments that emerged during the process of investigating the context, developing the *awareness cubes* and evaluating their use were presented, which provide insights beyond the matter of the main research objective but are still valuable factors for the outcome of this thesis and the development of the project. A concluding chapter finally subsumes the main contributions of this work and provides an outlook for possible future endeavours.

8 Conclusion & Future Work

Awareness support in CSCW and HCI encompasses a great variety of scientific approaches and systems facilitating different types of awareness for different purposes. Different notions of awareness support can be identified ranging from very task-oriented approaches following the objective of maximized efficiency for resolving tasks over artefact-oriented approaches that put the common manipulation of an artefact in the foreground up to more social and relationship building notions of awareness like informal or social awareness.

The *awareness cube* system elaborated within the scope of this Master's thesis addressed the latter notions and therefore aimed at supporting social relationships across distance in order to achieve a better perception of connectedness across distributed work groups. The system, implemented at the three work groups of the Institute of Design & Assessment of Technology at TU Wien, is designed following the principles of participatory design. All relevant decisions regarding the concept of the system its design and its implementation were made jointly with its users in order to be able to present an awareness supporting technology that is closely related to the expectations and desires of its users. A highly tailored system, realized in form of three cubic devices that represent remote activities and provide possibilities for direct interactions, resulted from this process. The possibilities to actually use the *awareness cubes* in two different ways can be identified as major cornerstones of its awareness supporting abilities. Passive use as ambient display in the background allows the users to keep track of others activities and therefore provides a sense of presence of remote colleagues in the periphery of one's perception. Once something raises a users attraction and the users attention shifts from peripheral to focal attention the system provides possibilities to directly interact with remote colleagues by actively pressing buttons. The four week test phase of the system revealed that users do not exclusively use the buttons as intended but rather found alternatively more playful ways of use as they started to generate colourful patterns and playing TIC-TAC-TOE games. The ability of the technology probe to allow such alternative ways of use revealed valuable insights of the users' handling of the devices. Although the different ways of use appear somehow competing – some were using the buttons for expressing moods and activities and some were doing patterns – this was not reported to be a major problem for the users themselves. After some time they were able to distinguish somehow between expressed moods and patterns and even if uncertainties occurred users did not perceive them negatively. This may be an indicator that for these groups the actual content of exchange was not so relevant

than the overall possibilities to be able to exchange something and interact with each other. Since it was clear from the beginning on that the system supports informal exchanges people interpreted the system as additional rather playful communication channel for meaningless but funny exchanges. Through the visual representation of others and direct interactions the *awareness cubes* reportedly enhanced the feeling of connectedness among the groups which led to increased awareness of others presence in the common rooms, similar to the perception of local colleagues making noise in ones surroundings. Furthermore the *awareness cubes* provoked lively discussion within groups and even across groups about the origin of activities, patterns and mood expressions. These discussions appeared to be a result of the anonymity of individuals the system obtains because people were constantly wondering who of their colleagues caused a particular activity but not in a negative way. The fact of not knowing seems to be an exciting characteristic of the system that leaves room for speculations. Although the system led to conversation among the group members there are no reported actions provoked by the *awareness cubes* such as personal meetings and common lunches. People reported that for overcoming physical distance they need to have certainty about what is going on at the other side or if an invitation is meant seriously.

Besides the presented findings concerning these particular groups the evaluation of the *awareness cube* shows that a "closed interaction context" (Glaser & Strauss, 1964) where partners have no information on the identity of their opposite may facilitate curiosity and finally can lead to excitement. This indication could be utilized by future systems that support awareness on a group level where the bindings between work groups are to be facilitated instead of relationships among individuals. Another relevant aspect for awareness systems that support social relationships appears to be a great degree of customization. Since the success of such a system relies on its ability to fit into the daily routines of its users it needs to be tailored. Presumably the *awareness cubes* can hardly be applied to other contexts in the same way as they worked successfully for these groups. But the fact that the system is highly tailored to its context can definitely be generalized. Thus systems that aim to support social relationships and awareness of distant people, which is closely bound to social realities, either need to be tailored towards the actual use context, or they need to be highly configurable (cf. Kling et al., 2000) to provide the users the freedom of choice for selecting satisfying components.

Although the *awareness cubes* provided a better feeling of connectedness and facilitated awareness their possibilities for direct interaction were subject to debate and suggestions for further enhancements. Users clearly articulated that they wished to have a very simple form of exchange but the provided possibility for expressing moods and current activities via buttons was characterized as too elementary for longer use. The results show that people actually liked expressing moods and activities and they even found new ways of interaction through the buttons, but for a long-term implementation of the system concerns were raised that the limitation to eight predefined expressions was too restrictive. Throughout the test phase users began to develop further ideas as to how direct interaction could be realized in a simple but flexible way. Resolving such issues could be a relevant task for future work. People appreciated the simplicity of the cube concept but especially for direct interaction possibilities there was a certain demand for retaining simplicity but adding more flexibility for exchanges. There

were numerous suggestions as to how the buttons could be altered to achieve this. Basically these user suggestions can be subsumed into two main directions. Firstly, people requested possibilities for more mutual turn-by-turn exchanges to be able to clarify uncertainties. Thus the cube could provide possibilities for answering questions with yes or no. Secondly, there was a request for more flexible exchanges in a more general sense. People suggested using the buttons for recording short audio snippets and sending them to remote colleagues. Others wished to be able to display text messages on the buttons and hence the buttons would need to contain a high-resolution display. For future enhancements of this particular system it would be relevant to improve the flexibility of exchanges and to maintain the ability for simple, playful and alternative use scenarios.

From a research perspective various directions for further explorations are conceivable. The *awareness cube* system showed that it facilitated awareness across distance for the test period of four weeks. It would be very interesting to see how the system performs in a long-term evaluation, including the suggested enhancements, and to explore its abilities to contribute to the social relationships across the groups when the devices become established components in the groups' common rooms. An important factor here would be to somehow keep users motivated and to investigate if the feeling of connectedness with the remote groups actually was a motivating factor, in addition to the entertainment through the system that kept users interacting with others.
Since the *awareness cubes* are highly tailored to the context an implementation in different environments would probably not be successful. But to satisfy the user request for more flexibility this could lead to a configurable system, especially regarding the interaction possibilities of the buttons, and subsequently it would be interesting to deploy an enhanced, more flexible version of the system in other context to investigate its ability to support awareness in different environments, as well as to explore the extent of the configurability needed for such systems.
In a more general sense the concept of supporting awareness on a group level would also be an interesting research objective to be explored in further detail. Especially the observations within this work regarding the effect of anonymity, which led to a certain amount of excitement in this project is a fascinating development that could be explored in future attempts to gain deeper understandings of the interplay between closed awareness contexts and curiosity about unknown interaction partners.

The *awareness cube* system was designed jointly with its users, which led to an awareness supporting system realized as an ambient display with tangible interfaces for direct interaction. The findings show that simplicity, flexibility and customization are relevant factors for the success of this particular awareness system. Overall, the work in this thesis finally underlined various benefits of participatory design approaches, which lead to identification with and trust in the system. Whenever social relationships and daily routines of users are the most relevant factors for the success of a technology, designers need to focus on the actual use context, the expectations of users and their participation to be able to envision solutions that actually fit the daily lives of users.

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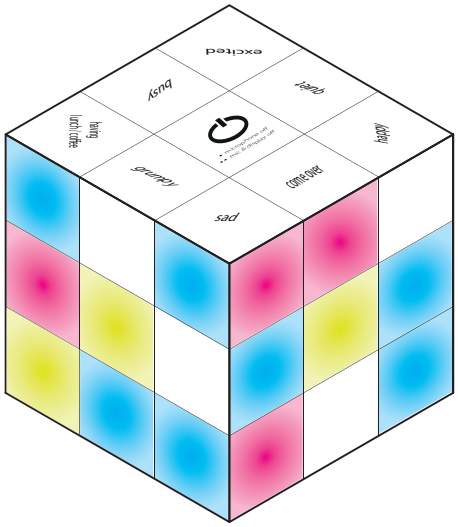
Vyas, D., Nijholt, A., Eliëns, A. & Poelman, W. (2011). Exploring Community Building with an Awareness Display. In: *Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments (PETRA '11)*. New York: ACM.

Weiser, M. & Brown, J. S. (1996). The Coming Age of Calm Technology. Retrieved 15 July 2015, from http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm

Appendix A User Information*

* In the original user information sheets the work group logos were used to identify each group. For keeping anonymity they were exchanged with the characters A, B, and C.

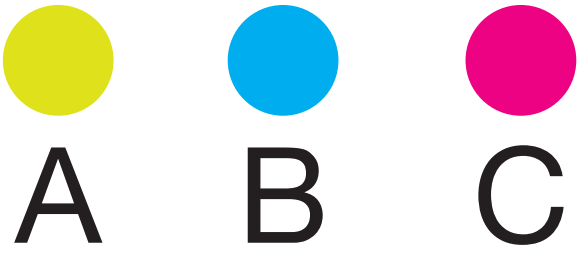
awareness cube: prototype information



Trial period: 8 June to 2 July 2015

Weekly survey by short paper-based questions.

Colour assignment:



general information

The awareness cube is an artifact that will be placed in the kitchen/common room of each group of the Institue for Design & Assessment of Technology to provide an abstract representation of the current activities in the kitchens/ common rooms of the other groups. By illuminating a certain number of tiles in the corresponding colour, the activity of each group is indicated by the cube. Therefore, the cubes measure the loudness level in the room via a built-in microphone. The buttons on the top of each will be used to express a particular group status or mood. The purpose of the cube concept is to enhance awareness about the other groups and to act as a reminder that there are spatially separated colleagues following similar goals.

illuminated tiles

The cube comprises 36 tiles on its side surface with built-in LED lights. Since there are three different groups, twelve tiles are assigned to each group to display the loudness level of the cube's surroundings. The number and brightness of the illuminated tiles depends on the frequency of the signal and its intensity in terms of loudness. Each group can be identified by it's individual colour - see above.

buttons

The buttons on the top of the cube can be used to express the overall group mood or activity. After a button has been pressed, it lights up on all of the cubes in that group's colour that initiated the expression. The mood expression can be deactivated by pressing the button again, or it can be overriden by another group if that groupt also presses the button.
The central button turns the cube off in two steps. The first mode turns off the microphone and the outbound connection of its data. The second mode turns off inbound connections, too, and therefore does not display any activity.

data transmission

The cube sends out data for two different actions via its WIFI connection. On a significant change in the loudness level a message is sent to a server containing the type of sensor (microphone), the ID of the cube (A, B or C) and the number of LEDs to activate (0-12). If a button is pressed, a similar message is sent out containing the type of sensor (button), the ID of the cube (A, B, or C), the number of the button (0-8) and the state of the button (0 or 1).

privacy

The button actions are logged by the server for a later analysis. There is no recording or logging of any microphone data and no transmission of speech (just intensity values)! There is no personalization of any sensor data!

For further information contact:
Gerfried Mikusch
gerfried@mikusch.net

about the linking the groups project

The Institute for Design & Assessment of Technology comprises three work groups which are located in different buildings. Within each group there is frequent exchange and communication among the colleagues, but there is less contact at the group level besides official meetings and occasional conversations on a personal level. The objective of the "linking groups project" is to enhance and support informal exchange for all members at the group level.

Awareness Cubes @ IGW

8 group mood / activity buttons

Button actions are displayed on all cubes in the group's colour that initiated the expression.

Buttons always show the last expression - moods / activities can be overridden by other groups!

ON/OFF Button & Status LED

2 step shutdown:

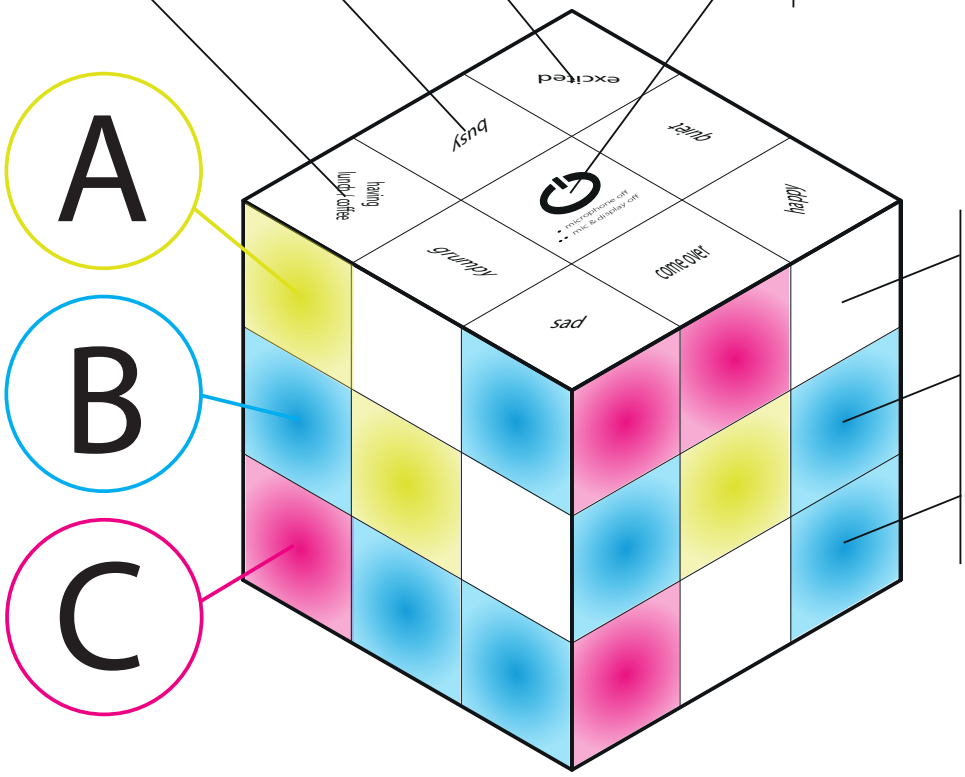
1st push turns off microphone and outbound data transfer. (Lower Brightness on LED)

2nd push turns off display and inbound data transfer.

Status LED: connected & active

no server connection

startup & setup sequence



Illuminated tiles display the loudness level of the cubes' surroundings.

Changes in loudness are sent out to remote cubes at the other groups.

Each group can be identified by its individual colour.

Troubleshooting A: Pull the power plug and plug in again in cases of:

- Orange or Red Status LED for longer than 3 min.
- Weird behaviour: strange or no illumination, buttons not working, etc.

Troubleshooting B: Send an E-Mail to gerfried@mikusch.net in cases of:

- other Exceptions & Problems
- Troubleshooting A does not work ;-)

for further information contact: Gerfried Mikusch
gerfried@mikusch.net

about the project

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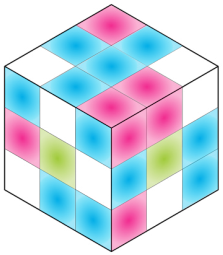
about the cubes

The awareness cube is an artifact that is placed in the kitchen/common room of each group of the Institute for Design & Assessment of Technology to provide an abstract representation of the current activities in the kitchens/common rooms of the other groups. The purpose of the cube concept is to enhance awareness about the other groups and to act as a reminder that there are spatially separated colleagues following similar goals.

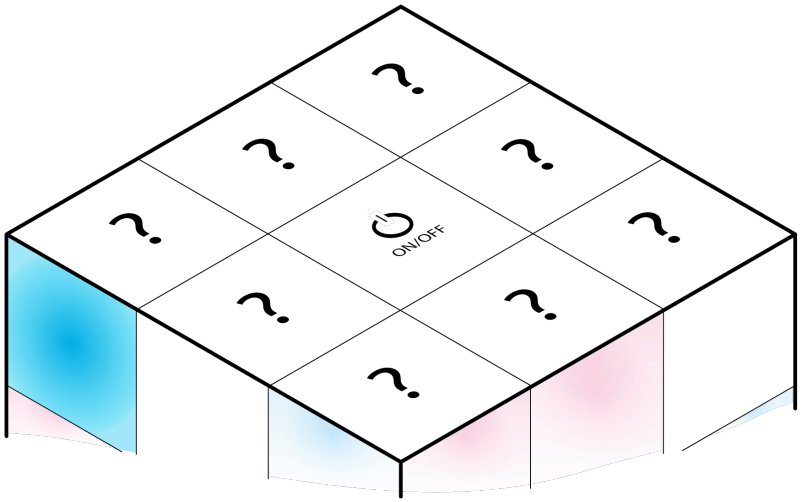
privacy

The button actions are logged by the server application for a later analysis. There is no recording or logging of any microphone data and no transmission of speech (just intensity values)! There is no personalization of any sensor data!



awareness cube

group-status buttons - online survey



group status buttons

9 buttons are mounted on top of the awareness cube. The central button switches the cube on and off and the remaining 8 buttons can be used to express a particular group status or mood e.g. "we're having fun right know" or "we're busy, please do not disturb".

Since you as members of the three work-groups know best the most suitable expressions for your group-status or group-mood, please give personal suggestions and/or vote for some predefined suggestions via a short online survey.

Here is the link to the survey:
http://goo.gl/forms/D0VLcl2bnm
The survey is active until February 25th 2015!

The eight statements mentioned the most will be printed on the buttons and should enable the groups to give a more detailed impression of their acutal activity than is already automatically done by the loudness sensor and the LED-lights.

I'm looking forward to receiving many interesting contributions and appreciate your participation. Thanks!

Gerfried Mikusch

contact: gerfried@mikusch.net

about the project

The Institute for Design & Assessment of Technology comprises three work-groups which are located in different buildings. Within each group there is frequent exchange and communication among the colleagues, but there is less contact at the group level besides official meetings and occasional conversations on a personal level. The objective of the "linking groups project" is to enhance and support informal exchange for all members at the group level.

about the cube

The awareness cube is an artifact that will be placed in the kitchen/common room of each group to provide an abstract representation of the current activities in the kitchens/common rooms of the other groups. By illuminating a certain number of tiles in the corresponding colour, the activity of each group is indicated by the cube. Therefore, the cubes measures the loudness level in the room via a built-in microphone (there is no sensing or recording of speech by the cube! The microphone only measures loudness!). The buttons on the top of the cube will be used to express a particular group status or mood. The purpose of the cube concept is to enhance awareness about the other groups and to act as a reminder that there are spatially separated colleagues following similar goals.

Appendix B

Themes & codes

Participatory Design Workshop: Thematic Coding

Social/Community/Relationship

Getting to know people
- Get to know people (23)
- Get to know new people (20)

Personal relationship is more
- Relation between groups beyond simple communication (24)
- Personal contact better than via technology (35)

Having a sense of presence
- Know that other people exist (12)
- Physical sense of copresence (64)
- Metaphor object that is circulated (98)
- Getting in contact easier (112)
- Awareness of others (106)
- Representation of others by virtual animal (group hamster) (63)

Personal benefit by better social connections
- Get benefits from others (45)
- Benefit from others knowledge (108)

Enhance group feeling and bindings
- Share rhythm of the group (91)
- Relationship building (10)
- Sense of being a group / community building (25)
- Connecting the groups together (13)

Content

Not clearly defined (Information)
- Exchange information (115)
- Exchange short infos (83)

Personal
- Daily video from real life (102)

Work related
- Exchanging ideas, interests, expertise (167)
- Work related things, links, literature (16)
- Know about projects in other groups (21)

Playful/funny
- Fun pleasure (employee of the month) (46)
- Exchange entertaining things (3)
- Funny posts (19)

Filtered content
- Different content access by hierarchy (48)

Announcements
- Share events, dinner plans (100)

Activities

Virtual lunchtime meeting
- Lunch once a week with camera (97)
- Lunchtime video (86)

Inform others
- Show something (84)

Exchanging/Sharing
- Exchanging something (9)
- Uncountable types of exchange (26)
- Sharing organizational (87)

Announcements
- Announce activities (85)
- Facilitate in-person meetings (104)

Playing games
- Gaming, battling each other (11)

Collaborate/stay in touch
- Collaborate with colleagues far away (22)

Motivation

No obligations
- Free choice of using it (42)
- Voluntariness (113)

fun/entertainment
- Playful stuff to provoke interaction (36)
- Miles travelled (to conferences) (38)
- Coffee counter (37)
- Urgently need to do something useless (32)
- Procrastination as a benefit (31)

Encouraging
- Provoke you to do something (62)
- It has to get you from your desk (66)
- Incentive (28)
- Inviting (109)

Reward
- Get free coffee as reward for playing with it (33)
- Earn points (34)
- Earn free coffee by being active (41)
- Earning and spending credits for helping someone (40)
- Get benefit / gratification (117)

Competition (95)

Collaboration support (114)

Initiation

Notifications
- Notifications for interesting things (17)
- Notification of new content or action (1)

Playful reminders
- Awareness by playful low-tech coffee counter (43)
- Sensor at coffee machines playing a sound (44)
- Notification is there is anything going on by a light (67)

No idle mode
- Inviting pictures that say: “do something” (29)
- Screensaver hides the actual content (73)
- Screensaver signals “out of order” (49)
- Show clickable content for further actions (30)

Communication process (aspects)

Formal vs. Informal conversations
- Informal conversations (2)
- Something for not serious communication (phones, e-mail for serious) (6)
- Balance of formal and informal communication (15)
- Unserious communication starts makes serious communication easier (7)

Reception of messages
- Reception (confirmation) of asynchronous messages is tricky (8)
- Make sure message reach the others (104)

Trigger/Start for more
- Start/trigger for other conversation levels (4)
- Technology as trigger or reminder (22)

Recording of messages (text) is not natural for kitchen talk (5)

Make spontaneous contact easier (14)

Technology

Fit into the environment
- Fitting to social kitchen life (101)
- Availability vs. intrusiveness (92)
- Device with personality (93)
- Natural group rhythm taken into (99)
- Do not disturb (90)
- Screen is distracting (96)
- Screen draws attention on it (81)
- Screen as unobtrusive as possible (105)
- Uncomfortable to have a screen in your back (76)
- Distraction from personal talks by "changing" screen (27)

Sustainability
- So much light is going to the screensaver (74)
- Greenhouse stat (39)
- Sustainability, energy consumption (57)
- Save energy, ecological (111)

Simplicity
- So much technology for a basic need (94)
- It should be simple and stable (110)
- Step back from touchscreen toward low-tech (72)
- Stability, viability, simplicity (55)
- Low tech solution in terms of costs and effort (69)
- Minimally technology solution like a telegraph (65)

Placement/Location (Flexible/moveable)
- Movability, flexibility (60)
- Displacement (54)
- Integration of other devices (61)

Surveillance/Privacy (full control for users)
- Don't know who you are connected with (78)
- Believe that camera is on all the time (80)
- Observed by camera (79)
- Be watched, privacy (75)
- Felt watched by camera (77)
- Privacy (70)
- Question of privacy (47)
- More control over video camera (59)

- Trust, feeling save (118)
- Open close eyes for camera (on/off) (50)
- Red light on camera is not sufficient (53)
- Time delay, blink, or acoustic prompt when camera is on (52)
- Self image for camera (51)
- Mechanical shutter for camera (82)

Effort

Maintenance
- Supplementary effort (maintenance) (58)
- Need for facilitator (103)
- Cost and resource efficient (68)

Personal engagement
- Low effort to make (115)
- No extra effort (88)

Time efficiency (integration with other devices)
- Integration with own devices to save time (56)
- Combining to desktop – not necessary to go to the screen (71)
- Awareness at the desk (89)
- Connection between screen and workplace (18)

Test phase: Thematic coding

Device design and concept

Button handling
- Quiet unclear, because sounds are already captured by mic (83)
- Quiet is somehow unclear (97)
- Quiet button unclear; never used it (277)
- Quiet button as request to others or as expression of own situation; unclear (163)
- Quiet button unclear. Does it put the cube to mute? (32)
- Turning off cube for reboot (183)
- ON/OFF is fixed for playing TIC-TAC-TOE; advantage for each player (167)
- More Groups think they win TIC-TAC-TOE because of ON/OFF button (108)
- ON/OFF button is not needed (207)
- Points on the ON/OFF button are not clear; use suns (115)
- Thought that the buttons on top are related to the display on the sides (105)
- Unclear that the sides present noise; not moods (85)
- LED illumination related to labelling (2)
- Button history not recognizable (7)
- Earlier info on button is lost (69)
- Not sure about override (66)

Construction and design
- Simple design is positive (104)
- Cube is simple (33)
- Cube is funny (25)
- Cube is funny because of ambient design (117)
- Cube is an eyecatcher (309)
- Cube itself is a nice design (73)
- Looks beautiful (11)
- Possible damage by users (31)
- No big problem if one button does not work (120)
- Busy button wears out (65)
- Cube wouldn't actually tip over (141)
- Cube could tip over when outer buttons are pressed (21)
- Stands have to be on the outer corners; more stable (116)
- A tablet with placeholders for the stands could make it more stable (22)
- Nice game but little use (303)
- Playful character of cube (106)
- Use cube for other projects (42)
- Haptic feedback for buttons is good; touchscreens are everywhere (103)
- I would not memorize more buttons (256)
- Nine buttons are sufficient (208)

Ambient display
- Cube is funny because of ambient design (117)
- Works well as ambient display (54)
- Pleasing impression by dynamic dimming (72)
- The light does not disturb (76)
- No impression of hectic through smooth transitions (80)
- Light is quite unobtrusive (79)
- Same 3 LEDs on one side are always on (29)
- Boring that the LED position for one colour is always the same (35)
- The LEDs appear fixed (56)

- Display volume from quiet to loud; increasing (175)
- Better intensity of loudness/noise level (296)
- More variations on places of lit LEDs (94)
- LEDs should move somehow (36)
- LEDs good, but the impression seems to random (279)
- Wonder about position of lights and what they signify (55)
- Meaning of position of lights unclear (53)
- How does the illumination work (28)
- Random light up of single LEDs or fixed position? (23)
- Visual representation of noise level makes sense (314)
- Colours are distinguishable (68)
- Pleasant combination of colours (92)

Operational stability

- A prototype has its weaknesses (45)
- You can see something despite crash (43)
- System crashes frequently (23)
- Unstable prototype problematic (160)
- Restarting is one form of interaction (27)
- Restore last status after crash (236)
- Error indication would be good (87)
- Feedback after crash requested (24)
- Good as prototype but too unstable (88)

Group representation

Activity presentation

- Presentation is unobtrusive (176)
- Cube presents something in the background (34)
- May become more an ambient artefact in the future (301)
- Impression that own group has more LEDs on the cube than others (165)
- Display should remember history; short back hall (101)
- I does matter that group info is presented; not other unrelated things (143)
- User seems satisfied even when there is not transmission (44)
- Mobile app to accompany it (298)
- Groups do not have colour; therefore hard to assign them (91)
- Easy to identify groups by colours (71)
- Colours learned with the help of the poster (90)
- It takes a little time to get used to the colours (74)
- The info sheet gave good orientation (52)
- Info sheet was important to learn the colours (89)

Experience of remote people

- Cube provides sense of the state of others (229)
- I like the representation of others (293)
- It is fun to follow when there is something going on (75)
- I like seeing that others are around (64)
- Seeing how active others are is fun (300)
- Nice to see that there is something going on (118)
- Activity of others motivates to be more active too (190)
- Activity of others motivates to press a button (191)
- Some LEDs seem to light permanently; background noise? (23)
- Background noise by open window (287)
- Nothing particular comes to my sense when I see the activities (178)

Button overriding
- Different intensity on buttons; more activity/less activity (1)
- Want to know why others are "sad" and comfort them (244)
- Want to ask why others have a particular mood ("grumpy") (219)
- Do not want to override group mood by personal expression (243)
- I do not deactivate expressions of others by overruling (242)
- Personal mood could be interpreted differently at other groups (129)
- Let them think they have won (the TIC-TAC-TOE game) (111)
- Would be good to see all groups on buttons (102)
- Could be good to see that all are eating (67)

Unidentifiable colleagues
- Talks about who could be present at the other group (198)
- Try to imagine who is on the other side (171)
- Curious about who did the other pattern (188)
- Wondering who is on other side (272)
- Connect via Bluetooth (voluntarily) to be able to know who is present (91)
- Would be nice to see who is who (294)
- You play although you do not know against whom (121)
- Contrast of wanting to know who is on other side and excitement of not knowing (206)
- It is not possible to distinguish if there is only on person or the entire group present (306)

Engagement

Following activities
- Cube should make noise (58)
- Cube should call attention via sounds (146)
- Additional sound to recognize changes (220)
- Each cube seems to think they use the cube more than the others (238)
- I knew the group colours after one day (51)
- Group colours have to be learned brief (50)
- Cube affords exploration from all sides (57)
- I did visit the common room because of the cube (228)
- Cube is small and therefore affords to come closer to explore (93)
- Problem to care to switch off moods/activities (124)
- Turn off button lights automatically in the evening (159)
- Button lights should go out automatically; having lunch is not correct after some time (113)
- Bad button labels: come over, having lunch; need to be deactivated (60)
- No necessity to read label when different illumination (3)
- People passing by; little interaction (128)
- Now and then use; not for particular reason (232)

Placement of cubes
- Nice to have one cube in the office; see more; not necessary to go to lounge (166)
- Place the cube directly in the office (316)
- Interest for placement of the cubes (21)
- Talk to others about changing position (127)
- Uncertainty about best location (16)

Maintainence
- No battery because it needs to be charged (18)
- No motivation to service the network if broken (14)
- Maybe nobody feels responsible to turn the cube completely off (194)
- People take good care of restarting the cube (290)
- Crashes not very annoying; we have to do something with it then (26)
- Wants to help to solve the problem (46)
- I put myself to the ground to pull the power plug (235)

- Turned it once off for testing (195)
- Someone restarted the cube (20)
- Required help to fix connection problem; per E-Mail (19)
- Participant shows that one button has to be pressed (119) special that it works (156)

Long term use
- If features stay the same it might get boring (317)
- Less interest after some time (10)
- Initial curiosity has decreased (161)
- More actions from cube (307)
- Little interest for prototype (15)
- Expanded use imaginable because of low effort (241)

Participation
- Little motivation to fill out question cards (47)
- Reported from research perspective (41)
- Good atmosphere while talking (30)
- Hard to get to talk to someone (125)

Communication

Turn-by-turn activities
- Turn-by-turn pattern drawing between groups (162)
- Groups do patterns and change them mutually (130)
- Sent pattern and got direct response (137)
- Groups do symmetric patterns (110)
- Other group answered with pattern (38)
- More turn-by-turn activities (226)
- Reaction is just a presumptuous interpretation (169)
- Sent invitations via "come over" but got responses that did not fit (245)

Establish direct communication
- Not known if the transmitted "code"/pattern is seen by others (205)
- Morsing: hope to get response by indicated activities on sidewalls (261)
- Desperately morsing; feeling like a castaway (260)
- Sent morse code via button over minutes in the hope to get response (259)
- Tried to generate particular noise levels to communicate with others (225)
- I press the button and hope that others see it (218)
- Request for other possibilities of contacting (224)
- Possibility to easily establish contact is missing (285)
- Exploit the interactive potential more (186)
- Possibility to invite someone to play (225)
- Cube should offer more possibilities to get in contact; little games (237)
- Want to have a "hi" button which can be pressed rhythmic every 20 sec. (112)
- Pattern has been sent to group B; not recognized (135)
- One can see something but there is no contact (230)
- No actual way to get contact (238)
- Large cube with more possibilities to communicate (188)

Get answered
- Want to be able to ask back why I should come over (221)
- Would be really happy if someone would answer once (262)
- Record messages so that colleagues can hear them later (145)
- Pairwise labelling of buttons with questions and answers (285)
- How long does it take until the information is received (204)
- Used "come over" for invitation before events; no valid visit (148)

Content

Different types

- In group A buttons are used to express moods (239)
- OK, that buttons are used differently (199)
- Use buttons for moods and patterns (147)
- More drawing with buttons than exchanging meaningful messages (170)
- Others also make nice patterns (177)
- Report that only one uses buttons for mods, others just do patterns (134)
- Rumour gets around that buttons are used for patterns (203)
- Pressing buttons to do patterns (142)
- Drawing patterns with buttons (37)
- Playfulness and exchanging messages (153)

Flexible buttons

- How can you be happy and sad (222)
- Confusion about happy + grumpy, because of too correct usage of buttons (252)
- Two activities; rest adjectives (6)
- Combine similar buttons to get new ones with other expressions (196)
- "sad" will not be used very often (86)
- "tired" button instead of sad (194)
- "happy", "excited" too similar, as well as "grumpy" and "sad" (164)
- moods are too individual; activities are better (98)
- "having lunch" and "come over" not suitable; activities not moods (99)
- None of the labels are suitable to express moods (84)
- Unfortunately not all labels are suitable (302)
- Missing label "tired" (61)
- Button labelling makes sense, but is used differently (163)
- Mixture of moods and status is OK over all (81)
- Good button labels: happy, busy, excited, grumpy, quiet (59)
- For long term use more than predefined text on buttons necessary (152)
- More dynamic by display instead of LED on buttons (100)
- Exchangeable label via digital display (295)
- I do not use moods, just illumination (78)
- Exchange short text messages (150)
- Exchanging notes (187)

More active exchanges

- Request for more patterns (197)
- Show pattern history on sidewalls (139)
- Use the cube to present other things (40)
- Coffee machine produces good signals (286)
- LEDs should give info about type of sound (drilling, etc.) (277)
- Sensor for coffee machine or printer as data source (288)
- Presentation of loudness not so important (288)
- Cube should not play sounds. It is already noise here (209)
- Speaking more personal (barrier) than texting (151)

Interaction

Getting attention

- Curious investigative tasks while waiting for coffee (230)
- There is a certain urge to press something (210)
- Excitedly interacting (212)
- Interaction more important than representation (138)
- Someone did a barrage of catcalls in front of the cube (48)

Microphone use
- Could imagine to turn off the mic while internal meetings (193)
- Do not care about mic (192)
- No need to turn off mic, because cube does not distinguish between talks and other noise (182)
- No secrets; not necessary to turn off mic (173)
- Do not know that mic can be turned off (180)
- Never turned off the microphone (172)
- No situation required turning off the mic so far (181)
- Information about kitchen usage/behaviour of others (157)
- Fear of surveillance by microphone (156)
- We have to be quiet now (13) (17)

Gaming
- Curiosity to play around (12)
- Button labelling does not matter (140)
- Labelling does not matter so far (39)
- Funny form of interaction (201)
- Focus on colour games and meaningless interaction (167)
- Thesis too serious; no playful component (312)
- Gaming as motivation for longer use (133)
- More playful possibilities of usage requested (131)
- More playful components (236)
- Develop playful concepts (318)
- Games on cube would be entertaining (313)
- Seem to have fun playing TIC-TAC-TOE (109)
- Someone did a TIC-TAC-TOE game (49)
- Spontaneous playing harder within own group (122)
- Gaming by trying (123)
- Button overruling as gamification (4)

Competition
- Rules/strategies for TIC-TAC-TOE emerged (249)
- Possible to shut others down (8)
- Match each other through overruling (5)
- Win prices through games (132)

Common activities

No extra visits
- "have lunch in the middle" button requested (292)
- No extra activities initiated by the cube (284)
- Use the cubes of other groups too, but did not come over because of cube (257)
- Too busy to actually go over (276)
- Too much effort to come over; not sure if there is really something going on (149)
- Overcoming physical distance is hard. "Come over" needs a good motivator (291)
- No visit at other group because of the cube (136)

Virtual activities
- LEDs are good to see if someone is present and a direct interaction is possible (280)
- Not sure if moth side are aware of playing; maybe one playing and the other doing patterns (251)
- Rules for TIC-TAC-TOE but not commonly used (250)
- Request for push-to-talk function (223)
- Possibility to exchange messages; walkie-talkie (144)
- Pressed the "quiet" button and it got quiet at the others kitchens (126)

Common expressions
- "sad" is rather private. Not suitable for workplace (82)
- Bad for common expression: "sad", "happy", "grumpy", "excited"; too personal (96)
- Good labels: "having coffee", "come over"; common activity (95)

Nudges

Less scepticism
- Nice to have it in the background (202)
- Cube is funnier and more useful than expected (231)
- Those who were against it started to press buttons (258)
- Some people's opinion changed completely (254)
- Initial scepticism and rejection eliminated (253)
- Atmosphere towards the project changed positively (158)
- Surprised that cube is still in use (264)
- Cube has more potential than it seemed first (185)

Experience of connectedness
- Curiosity what is going on over there (179)
- Now interested in what others do (274)
- Cube made clear that contact is important (281)
- Feeling of connectedness with "unknown" people (189)
- In longer use the cube will bring more connectedness with other groups (315)
- Cube creates connectedness with others (63)
- Cube creates a sense of presence of the others (62)
- More perception of other groups (270)
- Use it further to keep sense of awareness (299)
- Certainly increased awareness that they are there (265)
- Cube changes something but cannot be identified in particular (247)
- Cube does change something; not told what exactly (155)
- Not so much out of sight and mind as before (200)
- Nothing outside the cube did change (215)
- Personal image of others did not change (282)
- Feeling of more connectedness than before (289)
- Relationship to other groups did not change (283)
- Relationship got warmer (271)

Conversation starter
- We talk about the cubes an our activities (273)
- Initiating personal conversations because of interest (275)
- Talked about cube and played around with it (234)
- Not acted different but talked about cube (252)
- Longer stay in common room for talks about cube (231)
- More conversations about groups within the group through the cube (248)
- Discussing things related to cube (214)
- Cube is always a conversation starter (297)
- Cube triggered conversation with parts of the other groups (267)
- Cross group conversation about what was meant by expression (268)
- Cross group conversation about who played two hours ago (269)
- Cross group conversation about activities on cubes (240)
- Real conversation about incomprehensible button communication (246)
- Cube gave the occasion to start conversation about pattern with unknown (211)

Common room behaviour
- Would become part of the inventory (310)
- Cube does not disturb (308)
- Used to have equipment around (77)

- No uncomfortable feeling caused by cube (168)
- No change of behaviour in the common room (233)
- Cube is nice but does not change behaviour (263)
- Looked at the cube but did not act differently (216)
- No change in common room visits by the cube (229)
- Cube evokes curiosity (260)
- Use for procrastination of work (224)
- I am thinking about my mood now (217)

Useless information (missing reasoning)

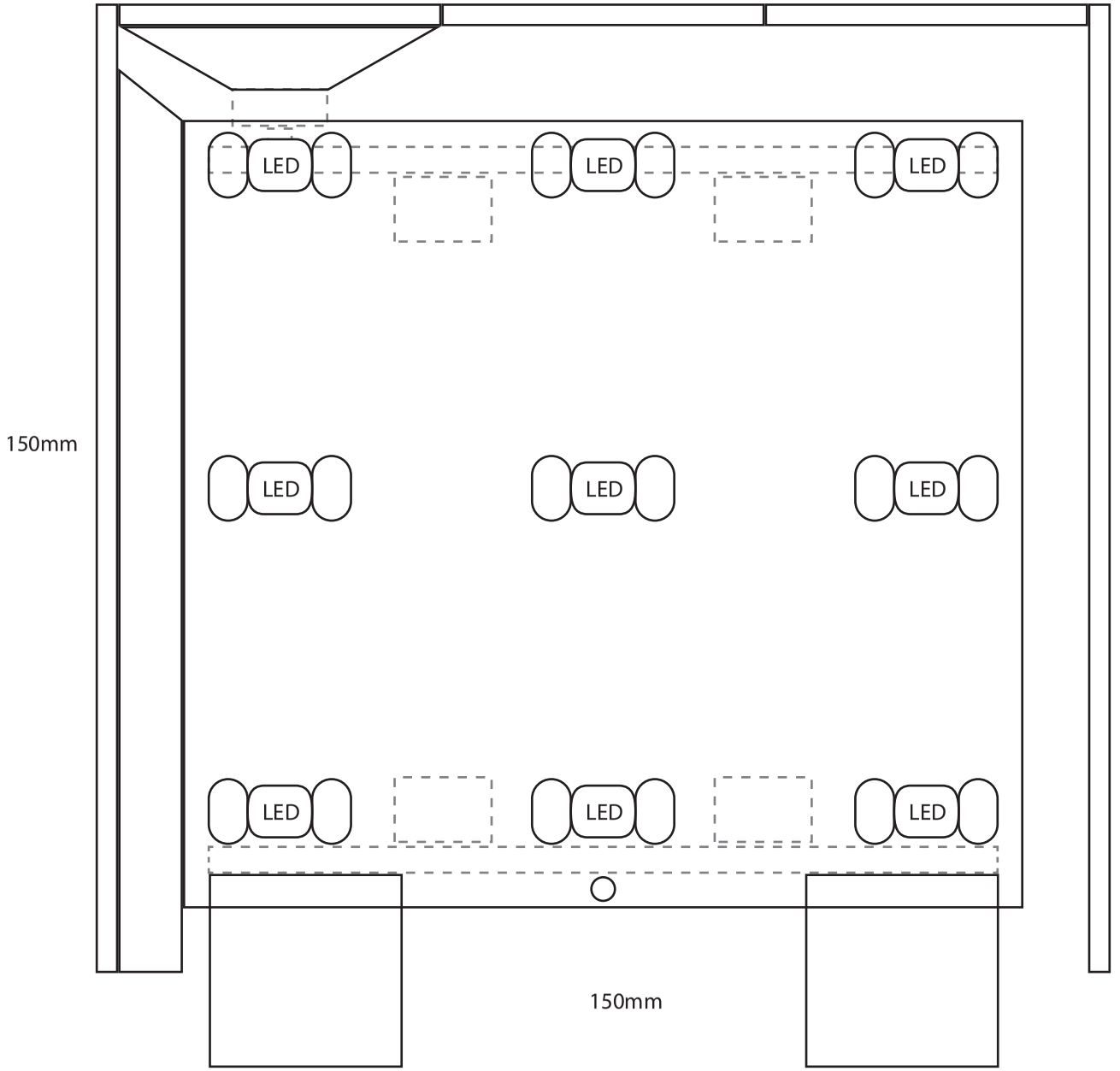
- Can not imagine to use it further (311)
- Presentation by LEDs is useless (70)
- The cube is no use (304)
- The cube is senseless as it is (237)
- The cube is useless (305)
- Cube is interesting (31)

Appendix C

Awareness cube construction & implementation

awareness cube

side view



Plexiglas 3,5mm

wood 4mm

awareness cube

inner side plate

wood

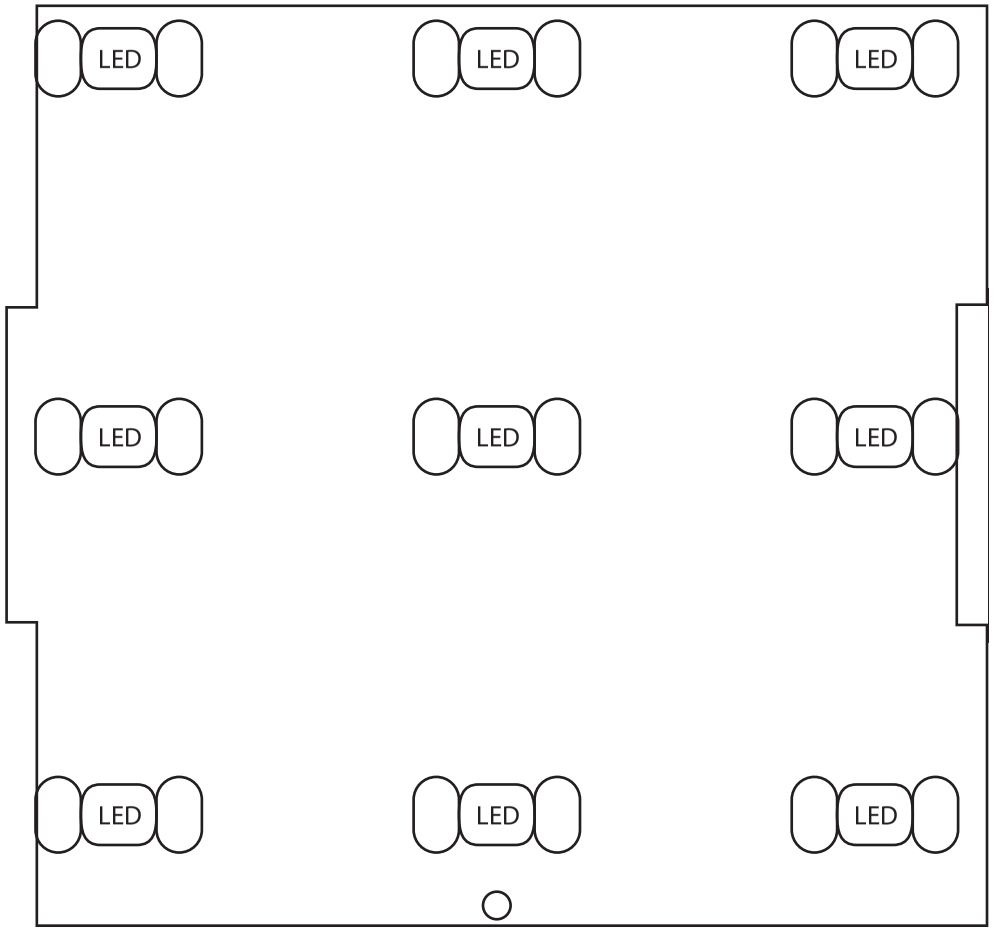
4 pieces

cable tunnel

6x10mm

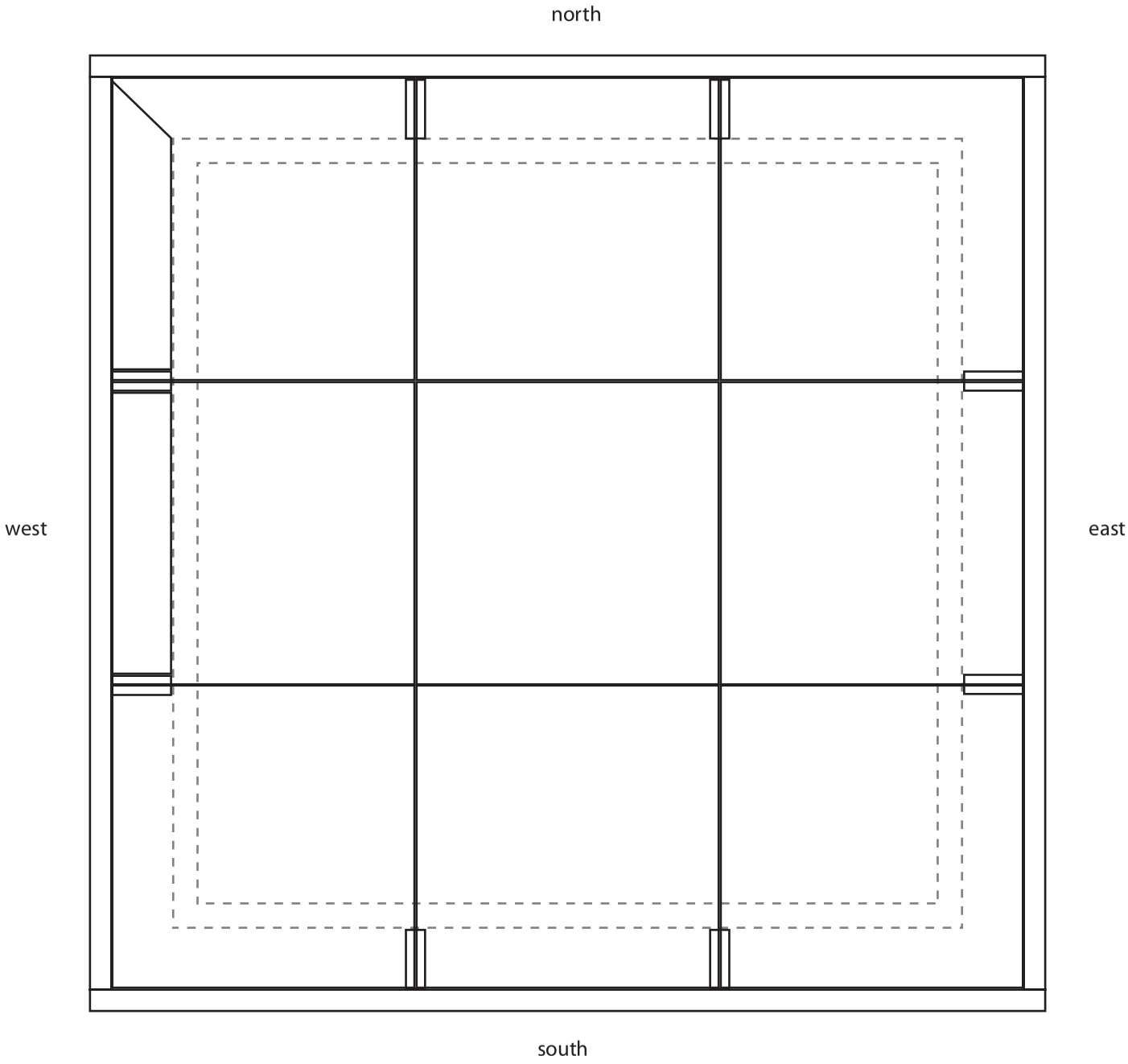
bottom lock hole

4mm



awareness cube

top view



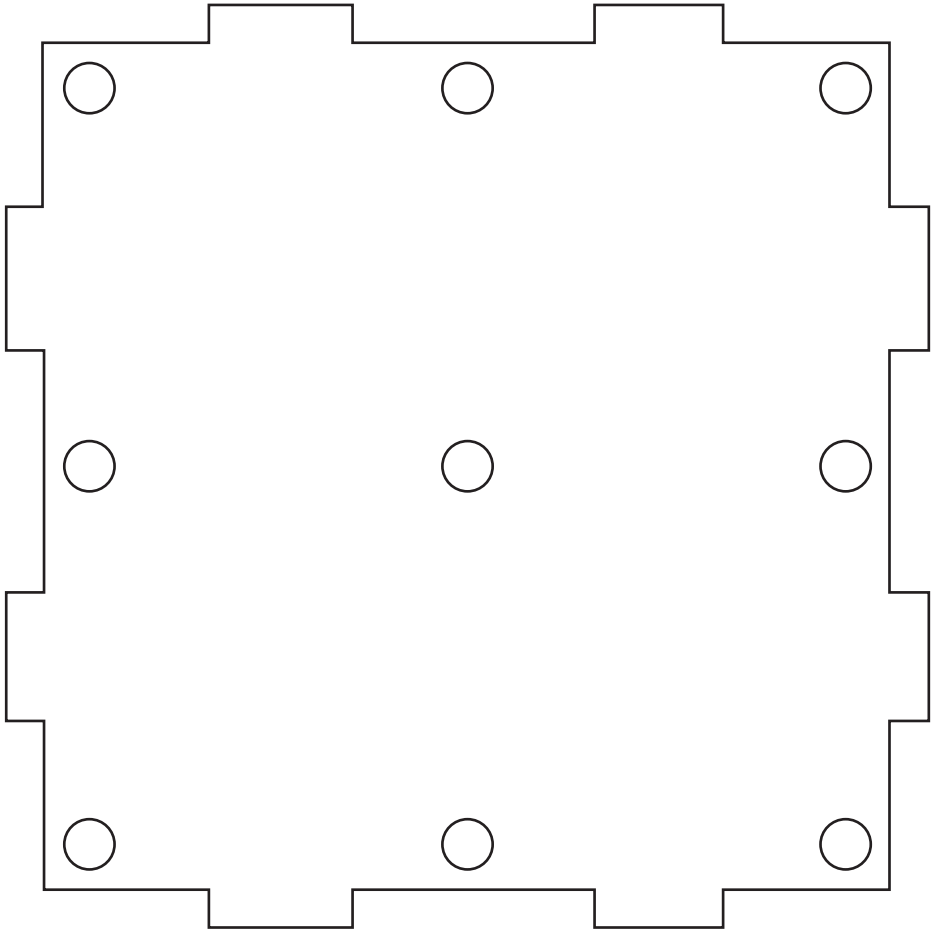
awareness cube

inner top plate

wood

button mount hole

7mm



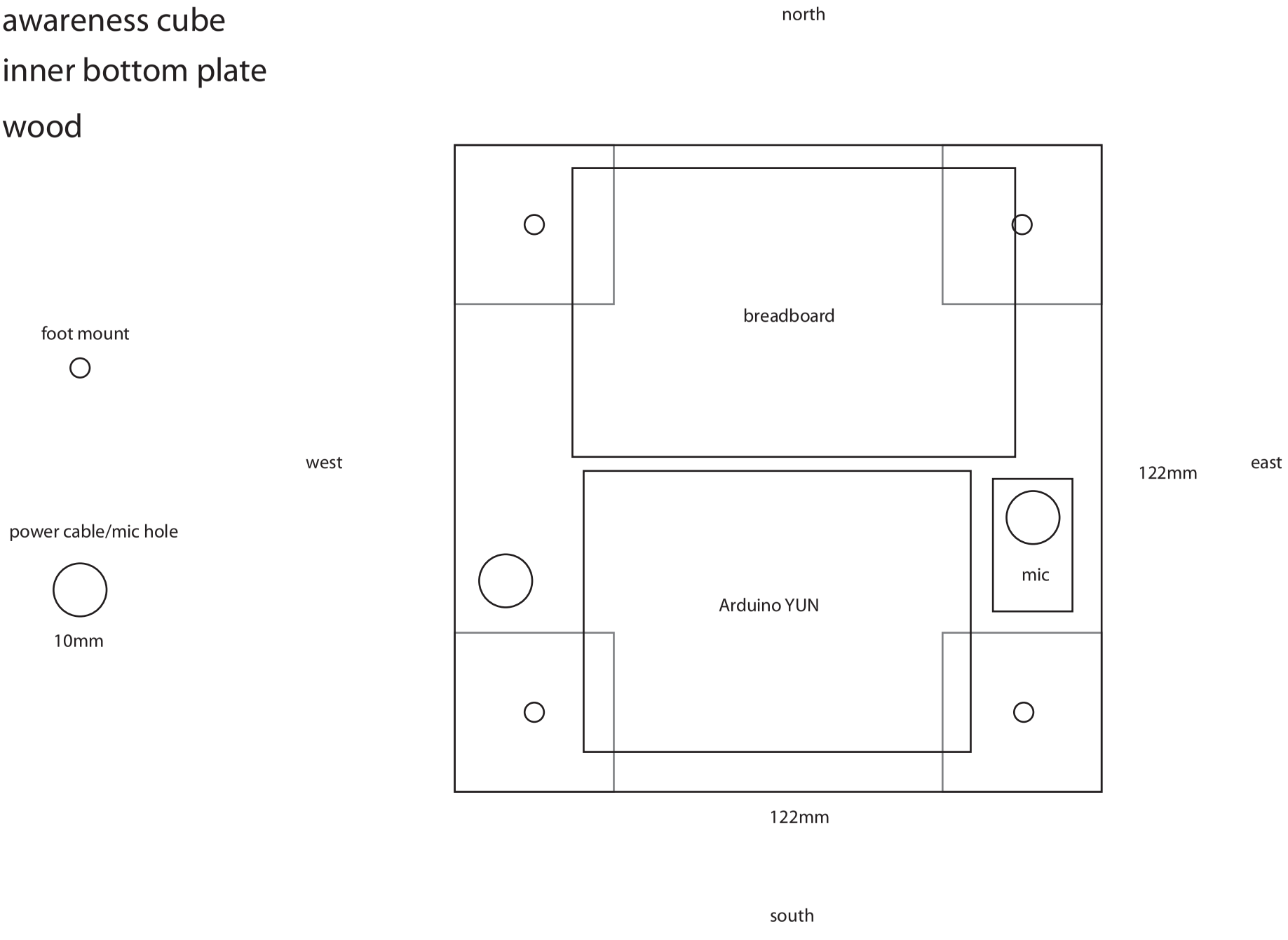
122mm

122mm

awareness cube

inner bottom plate

wood



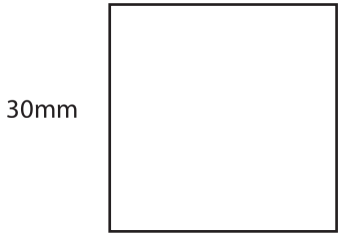
awareness cube

other parts

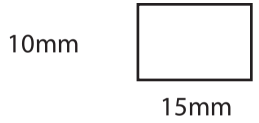
wood

stand
12 pieces

10mm wood



inner plate holdings
8 pieces

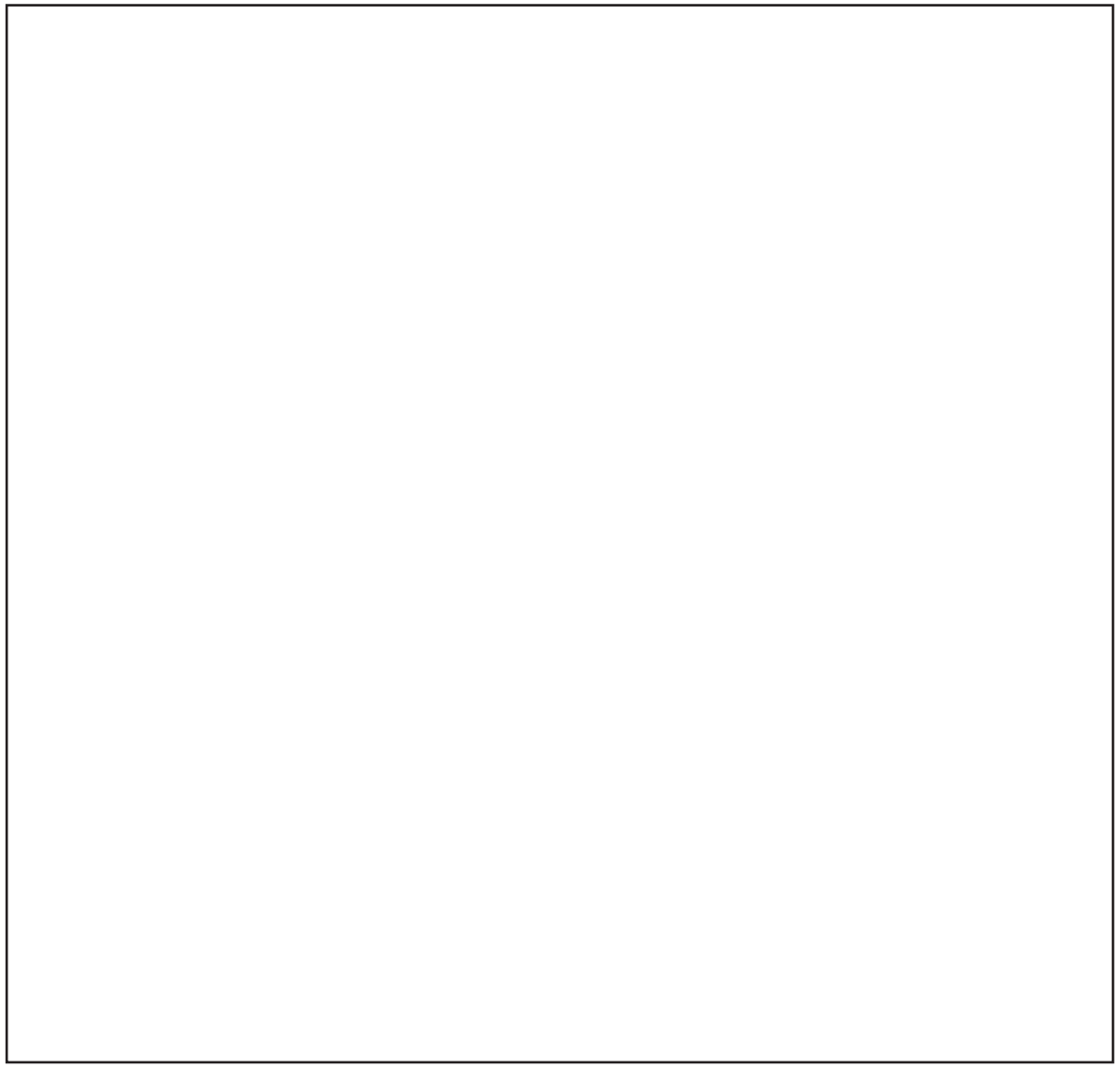


awareness cube

north/south side plate

plexiglas

2 pieces

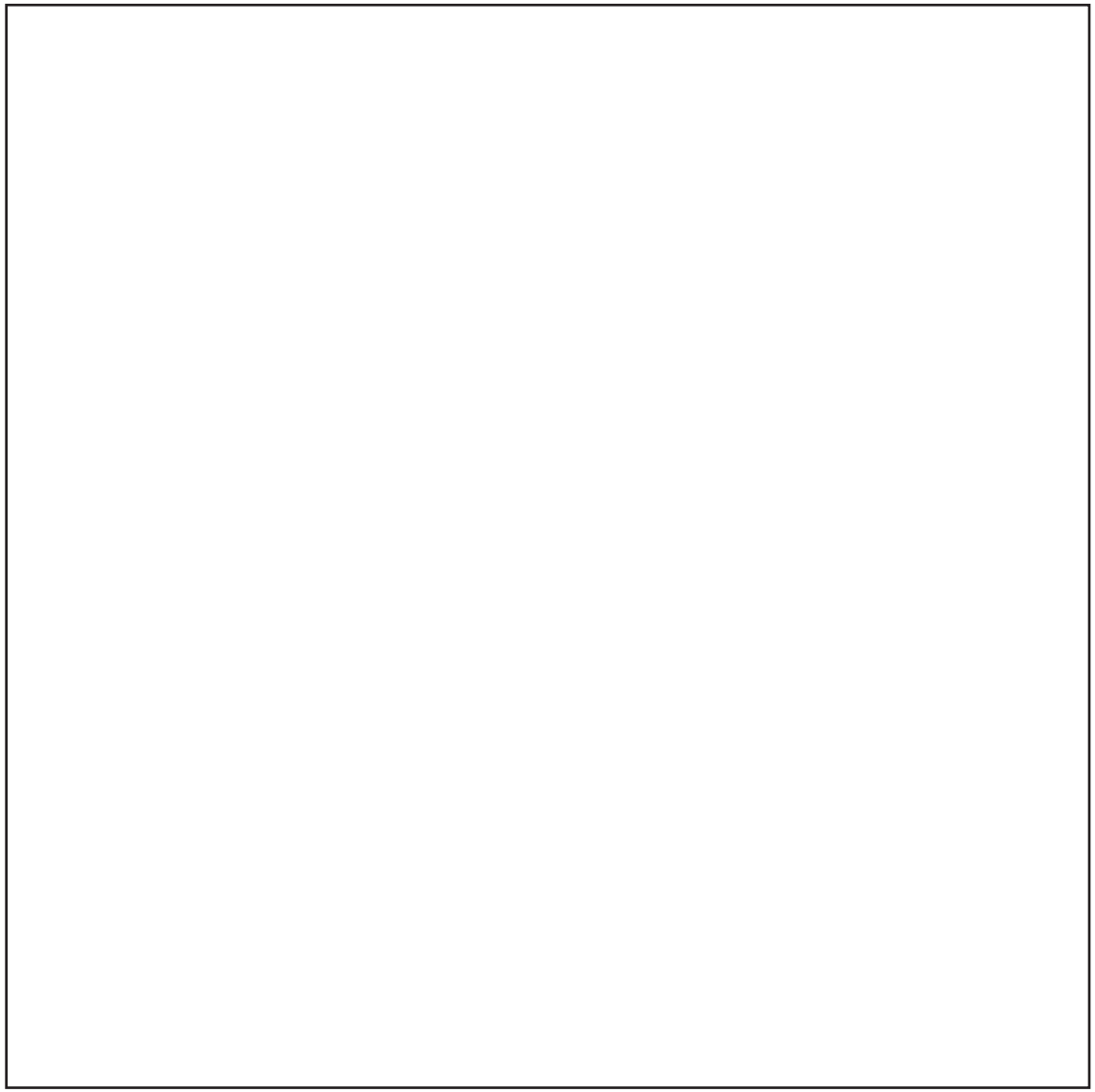


awareness cube

east/west side plate

plexiglas

2 pieces

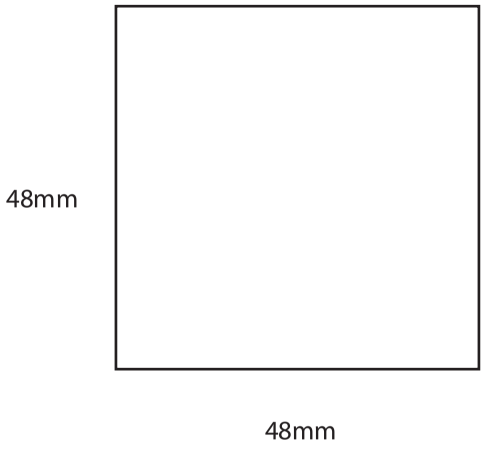


awareness cube

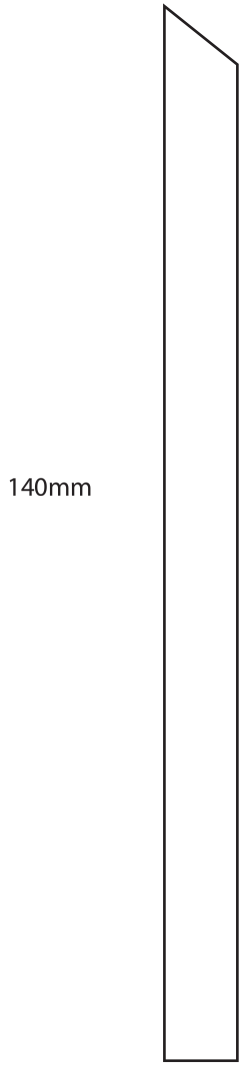
other parts

plexiglas

button plates
9 pieces

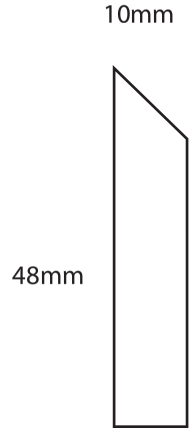


vertical
8 pieces

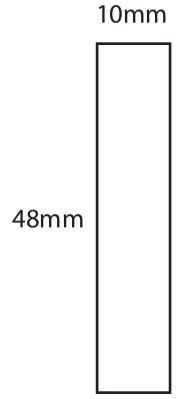


plexi-wood connectors

horizontal outside
16 pieces



horizontal inside
8 pieces

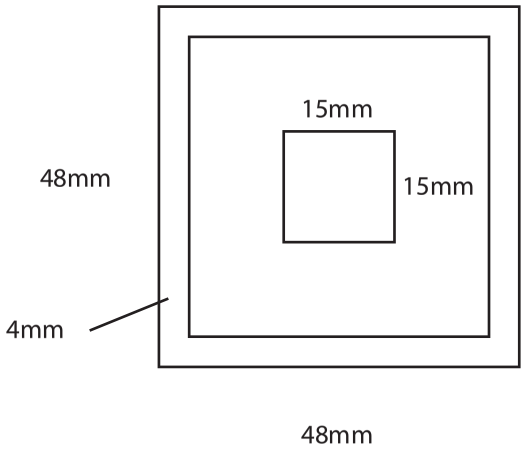


awareness cube

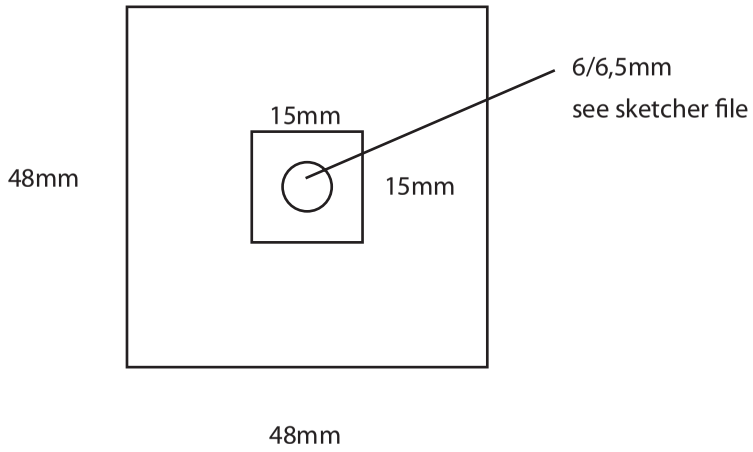
funnel

27 pieces

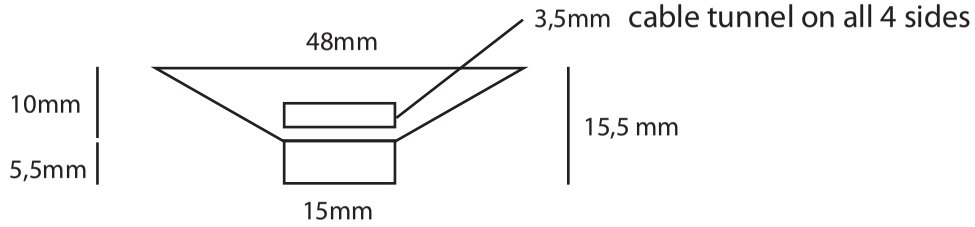
top

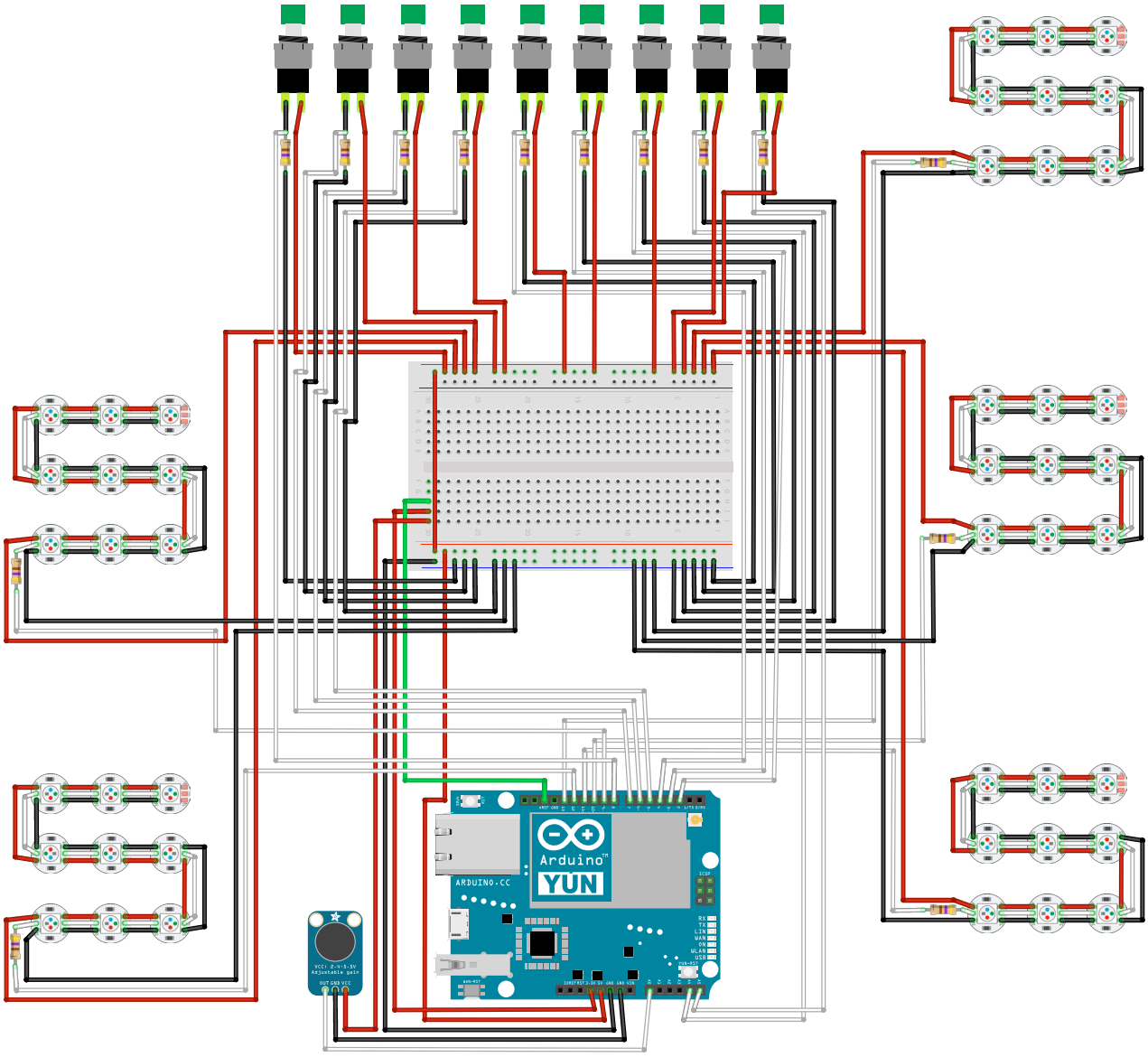


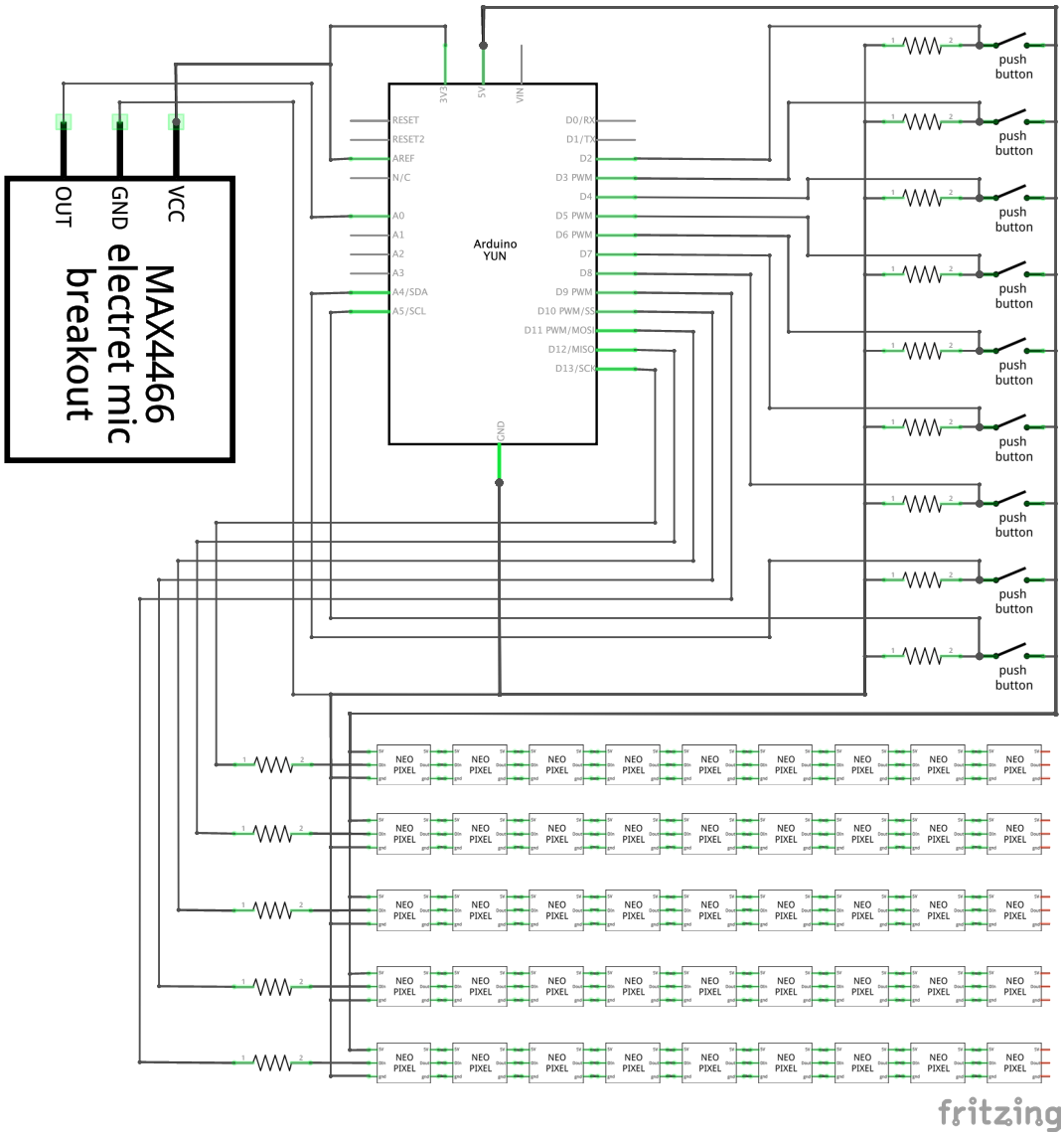
bottom



side




Arduino
YUN
ARDUINO.CC
fritzing


MAX4466
electret mic
breakout
OUT
GND
VCC
Arduino
YUN
RESET
RESET2
AREF
N/C
A0
A1
A2
A3
A4/SDA
A5/SCL
3V3
5V
VIN
GND
D0/RX
D1/TX
D2
D3 PWM
D4
D5 PWM
D6 PWM
D7
D8
D9 PWM
D10 PWM/SS
D11 PWM/MOSI
D12/MISO
D13/SCK
push
button
NEO
PIXEL
fritzing

Awarness cube - Program code

The programm code of the awareness cube project can be downloaded from the following source:

https://github.com/jerimuc/awarenessCubes

Information on used libraries can be found on the following web pages:

Adafruit NeoPixel library: https://github.com/adafruit/Adafruit_NeoPixel

Arduino FFT-Library: http://wiki.openmusiclabs.com/wiki/ArduinoFFT

Spacebrew library for Arduino Yún: https://github.com/julioterra/yunSpacebrew

Spacebrew Toolkit: http://docs.spacebrew.cc