How to Present Awareness Information on Large Public Displays?

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Abstract
In the last decade, a variety of systems that use large public displays to mediate awareness between members of distributed teams have been designed and evaluated. But due the diversity of applications and different evaluation methods the derived design recommendations are mostly inconsistent or even contradicting. The goal of this paper is to give a general recommendation regarding the type of information representation for group awareness systems independent from specific devices or applications. In this paper, we will describe an experimental study comparing an abstract and a concrete form of information representation regarding two factors: their suitability to provide awareness information and their disruptive effects on other activities.

1 Introduction

Since work becomes more complex and jobs require more specialized knowledge, the role of teamwork has gained significant importance within the last decades. Besides an immense increase in the use of work groups within companies (Guzzo & Salas, 1995; Sundstrom, 1999), also company-overlapping teams, where team members collaborate from remote locations, become more and more popular (Potter & Balthazard, 2002). But successful teamwork involves more than just people working at the same project or in the same room. To act as a team, the team members have to experience a special connection (the "team spirit"), they have to take over responsibilities and work towards a common goal. It is essential to share knowledge, to make decisions and to coordinate the activities of all people working in the team. As a result the importance and amount of communication is constantly increasing.

2 Supporting Awareness in Distributed Teams

In addition to explicit verbal communication, especially implicit communication in form of mutual awareness is an important requirement for a shared understanding and knowledge about ongoing and past activities within a team (Streitz et al., 2003). Mutual awareness usually leads to informal interactions, spontaneous connections, and the development of shared cultures-all important aspects of maintaining working relationships (Dourish & Bly, 1992).

Gaver et al. (1992) define awareness as the pervasive experience of knowing who is around, what sorts of things they are doing, whether they are relatively busy or can be engaged, and so on. Especially the information about presence and availability about remote colleagues are of high value during the daily work process. This is also confirmed by the findings of Nardi et al. (2000), who evaluated the use of buddy lists. They showed that people found it valuable to simply know who else was "around" as they checked the buddy list, without necessarily planning to interact with anyone.

In a shared work environment, information about presence and availability of colleagues are continuously available and picked up passively by those present. Teams which are geographically distributed, by their nature, are denied the informal information gathered from a physical shared workspace (Kraut et al., 1990). Hence, it is particular important to support the need of distributed teams for informal interaction, spontaneous conversation and awareness of people and events at other sites (Bly et al., 1993).

2.1 Desktop-Based Awareness Systems

In contrast to shared work environments, where no additional effort is required to maintain awareness, the members of distributed teams have to communicate the awareness information explicitly. The amount of information that is communicated is determined by the benefits the users gain and effort they have to undertake to provide the relevant information to their remote team members. This explains, why traditional communication tools, like e-mail or telephone, are only of limited aptitude for supporting awareness in distributed teams. Communicating the relevant information requires a comparatively high effort and therefore will be used only for things, which are considered to be more important, like time scheduling, task management or other work related subjects (Rohall et al., 2003; Bellotti et al., 2003; Gwizdka, 2002). Due to these shortcomings of traditional communication devices, a multitude of desktop-based applications for supporting informal information exchange between different groups and places emerged within the last decade. Two of the oldest systems are the graphical load monitors (Cadiz, 2003) and email biff tools (Cadiz, 2003). Others applications include small on-screen textual display objects such as scrolling tickers and fading message boxes, (Maglio & Campbell, 2000) small- to medium-size graphical tools similar to computer displays (e.g., MacLean et al., 1990), and ambient displays using physical objects to communicate information (Ishii & Ullmer, 1997; MacIntyre et al., 2001).

2.2 Awareness Systems for Public Spaces

Today, employees spend considerable time away from their own desk, working in meeting rooms, other offices or in the hallway (Lamming et al., 2000). According to estimations of Eldridge et al. (1994) and Whittaker et al. (1994), white-collar workers spend between 25% and 70% of their daily working time in conferences or meetings with colleagues. This continuous trend towards higher personal mobility within the workplace is also reflected in a change in development of awareness systems away from desktop-based solutions towards systems for public and semi-public spaces. With regard to the representation of the information these systems could be divided in two groups, either using concrete visualization techniques, e.g. VideoWindow (Fish et al., 1990) and MBone (Weiser & Brown, 1995), or abstract representations, like for example the Hello.Wall (Roecker et al., 2004) and Lampshade IPL (Hindus et al., 2001).

2.3 Abstract vs. Concrete Representation of Information

Both forms of information representations have individual strengths and weaknesses. Generally, systems using abstract visualization techniques are less obtrusive, need lower bandwidth and allow media remapping, so users may chose the representation device they like best (Pederson & Sokoler, 1997). In contrast, using concrete representation forms allows to provide more information at a higher level of detail (Reynard et al., 1998). Especially audio and video connections are presumed to offer a rich medium for communication and interaction, enabling distributed teams to cooperate as if they were in the same physical space (Gaver et al., 1992; Heath & Luff, 1993).

But in particular the usefulness of video-mediated awareness systems is widely challenged (e.g., Schmidt, 2002). According to Kuwabara et al. (2002) just exchanging high-fidelity audio and visual information does not necessarily lead to the construction of meaningful social relationships among people. They argue that a large amount of raw data might cause a cognitive overload in the mind of the receiver and recommend to use only symbolic representations of people. On the other hand, using abstract forms of representation requires users to understand and remember the semantics of the specific systems, while e.g. video-based awareness systems take advantage of the human strength to easily recognize faces (Goldstein, 1997).

3 Evaluation

In the last years, a number of individual awareness systems have been evaluated and recommendations for improvement have been derived (e.g., Hindus et al., 2001; Huang et al., 2002; Kuwabara et al., 2002). But for the development of future awareness systems it is not

sufficient to base general design decisions on the results of fundamentally different evaluations. Hence, the intention of this evaluation is to give general recommendations regarding the type of information representation for group awareness systems independent from specific devices or applications.

3.1 Concept

As mentioned earlier, one important and valuable piece of information for achieving awareness in distributed teams is the knowledge about the presence of the remote team members. As awareness information is usually delivered as a persistent secondary task, requiring users to rapidly and frequently switch between some other primary task and the notification task, the information should be presented in a subtle and non-distracting way.

Our goal was to evaluate abstract and concrete forms of information representation regarding two factors: their suitability to provide awareness information and regarding their disruptive effects on work. Therefore, we conducted a study where users were confronted with two different representations methods, but the same information and presentation device. It was compared with which form of representation the participants perceived better awareness of the presented information and which representation caused more interruptions.

3.2 Instrumentalisation

Since a considerable number of applications use continuous visual information as means for awareness support, we decided to use a simulated video connection between two remote locations as the concrete form of information representation. For the abstract representation the information about the presence of the remote team members was distilled from the video and symbolized through abstract patterns.

For the representation of the information we used a large public displays, following the current trend of providing peripheral awareness information in public and semi-public areas. But due to the general approach, we see no problems in transferring the result also to private places and smaller displays. The level of distraction was analyzed indirectly through the performance in a task the participants had to accomplish while perceiving the awareness information. The higher the level of distraction, the more the task performance should suffer.

3.2.1 Presented Information

To make the presented awareness information as realistic as possible, we started by observing the activities and movements within our own office space for several days. We found that approximately 10 times per hour someone was entering or leaving an office, and about 15 times per hour someone inside the office left his desk to get something out of a cupboard, to talk with colleagues or to use the whiteboard.

Based on these findings, we recorded a 23-minute video sequence showing a fictive office with five employees. According to our previous observations, we selected different types of team members: “Victor” had no desk in this office and entered the room only twice to talk with one of the persons inside. “Bettina” was leaving the office once, but was away from her desk three times. “Sonja” was outside the office for five times and walked around the office twice. “Matthias” left twice and moved within the room two times, and “Oliver” was leaving the office two and his desk three times. In addition, all team members made smaller movements at their desks, e.g. to pick up the phone or fetch something on the table. The frequency of movements increased gradually, so that the participants had some time to get used to their task and the faces of the people in the video. In the abstract form of representation, the presence of the team members was symbolized by different personal signs that were displayed for the time the person is inside the office.

We developed a special application to measure the effects of both representation forms regarding distraction and interruption. The program consists of a simple computer game and an interface to indicate the perceived changes in the presence state (see Fig. 1). The computer game was based on “Breakout” (Salen & Zimmerman, 2004) and designed to be particular sensitive to interruptions

and distractions. Similar to a pinball machine, the player has to avoid balls from falling down by returning them with a paddle. With a simple mouse click the game is paused and the program switches to the "awareness interface". Here, the participants can indicate the presence or absence of the team members by clicking on their picture or personal sign. A second mouse click resumes the game.

Fig. 1: Screenshot of the developed computer game (left); screenshot of the simulated video connection (middle); screenshot of the abstract representation using patterns (right).

3.2.2 Analysis

The performance in playing the game and in perceiving the presence information was analyzed through log files that were recorded during the whole evaluation. A purpose-build analysing software continuously tracked the state of every button and automatically generated a graphical overview of the button states. The software also tracked the number of lost balls and periods during which the game was paused to determine the task performance. These data was analyzed in various aspects, which will be explained in the results section.

In addition, a video analysis was performed, to find out how often and how long the participants had to look at the display to pick-up the presence information. The duration and frequency of glances to the display were used as indicators for the degree of interruption.

Besides these objective, performance-oriented criteria, we also aimed to acquire subjective user impressions as more intuitive measures of mental workload. According to von Rosenstiel (2003) the personal job satisfaction - and with it the acceptance of an awareness system - is also influenced by the relation between the subjective performance and effort made to achieve it. Therefore, we used different kinds of questionnaires to examine how the participants judged their own performance and how exhausting they found playing the game. If the method of presenting the awareness information influences the atmosphere and the concentration, there are probably differences in those subjective judgments depending on the representation technique.

3.3 Conduction

During a two-step experiment both sequences were shown to 47 participants. The participants were divided into two groups, which differed only in the chronological order of the presented representation sequences. While the first group started with the abstract representation and saw the concrete representation in the second step, the order was the other way round for the second group. To make sure that the participants would be able to keep concentrated at a constant level, the test consisted of two parts of 23 minutes each. During this time the participants were asked to play the game and to keep track of the presence of each of the five people in the fictive remote office. Perceived changes concerning the presence of each remote team member had to be adjusted in the "awareness interface" immediately.

After each test section, the participants filled out questionnaires, rating the recent representation concerning distraction and usefulness as well as their individual performance in playing the game and being aware of the remote colleagues. In the end, a third questionnaire was used to compare both representation forms.

3.4 Hypothesis

In the abstract representation form, all personal signs have their own specific position where they appear. Thus, the observer has an additional clue in form of the position to recognize status changes, simply by noticing that something changed at a given position. This is different in the concrete form of representation, as the people in the video are moving within the fictive office. Therefore, we expected more temporal misinterpretations of the presence states when people are in the office, but not at their desk. We also expect the subjective performance and effort in playing the game to be rated higher in the concrete representation form, because it contains more information and therefore should be more distracting. Compared with this, the subjective performance in maintaining awareness should be lower, as the participants should feel more confident with the video than with unfamiliar patterns.

Concerning the performance in maintaining awareness we analyzed various indicators without formulating an explicit hypothesis. We also did not formulate a hypothesis concerning the subjective performance in playing the game, as the effect of a higher distraction depends on the individual skill which is unknown. Only if the game requires very high mental resources, the performance will suffer from distraction, otherwise only the effort would increase.

4 Results

As mentioned in the beginning, our goal was to compare the different forms of information representation regarding their suitability to mediate awareness and regarding their influence on other tasks. To evaluate their ability to convey awareness information, we analyzed how accurate the information is perceived and how robust the representation forms are against temporal misinterpretation. As a measure for interruptions, we compared the performance in the game, and the number and duration of game breaks as well as the number to glances to the display. A detailed description of the evaluation can be found in (Memisoglu, 2004).

4.1 Analysis of Mediated Awareness

To evaluate the ability of both representation methods to mediate awareness information, we compared both forms regarding the perception of information changes and their robustness against temporal misinterpretation.

The quality of information perception was determined by the time users required to realize that a certain person has entered or left the room. Although the participants were asked to synchronize the "awareness interface" as fast as possible, there are two reasons why delays might occur. First, entering and leaving the office requires a certain amount of time. Hence, in the concrete representation there is no exact moment when the status of a person changes from "present" to "absent" or the other was round. And second, the participants might want to overcome a critical game situation before switching to awareness mode for changing the presence state. Therefore, we defined a goodwill period of four seconds. All perceived status changes during this period were counted as correct. Table 1 shows that the total number of unperceived changes within the goodwill period was significantly higher while using the abstract representation.

Presence	**Abstract**	**Concrete**	**χ^2**
Bettina	64	48	2,29
Victor	54	50	0,15
Sonja	122	81	8,28**
Oliver	96	66	5,56*
Matthias	70	60	0,77
All	**406**	**305**	**14,3****

Absence	**Abstract**	**Concrete**	**χ^2**
Bettina	31	12	8,4**
Victor	64	29	13,2**
Sonja	119	30	53,2**
Oliver	68	25	19,9**
Matthias	65	23	20**
All	**347**	**119**	**112****

Table 1: Total number of "present" persons that were not perceived within the goodwill period (left), and total number of "absent" persons that were not perceived within the goodwill period (right).
*** significant at 5 % probability, ** significant at 1% probability**

Besides a delayed perception of the presence and absence of certain persons, the awareness of the fictive remote team is also negatively affected by temporal misinterpretations. This happens for example, when a participant thinks a person has left the office and came back in, although that person was present all the time. While there is no significant difference for present persons, there were highly significant more temporal misinterpretations of absent people while using the concrete representation (see Table 2).

Presence	Abstract	Concrete	χ^2
Bettina	0	0	-
Victor	5	2	1,29
Sonja	1	3	1
Oliver	0	4	4*
Matthias	1	0	1
All	**7**	**9**	**0,25**

Absence	Abstract	Concrete	χ^2
Bettina	1	2	0,33
Victor	0	16	16**
Sonja	2	2	0
Oliver	1	1	0
Matthias	1	2	0,33
All	**5**	**23**	**11,6****

Table 2: Temporarily perceived as "absent" although person was present, summed up over all participants (left), and temporarily perceived as "present" although person was absent, summed up over all participants (right). * significant at 5 % probability, ** significant at 1% probability

As the observed frequency of movements in our office might not be representative for the average office worker, we also tested if the participants made relatively more mistakes in tracking frequently moving people than rarely moving ones. As shown in Table 3, there is no relation between the frequency of movement and the total number of unperceived presence changes.

	Bettina	Victor	Sonja	Oliver	Matthias
Number of Moves	3	5	9	5	5
Number of Unperceived Changes	155	197	352	255	218
Mistakes per Move	**51,67**	**39,40**	**39,11**	**51,00**	**43,60**

Table 3: Relation between frequency of movement and total number of unperceived presence changes.

4.2 Analysis of Task Performance

As a measure for the task performance we compared the performance in the game, and the number and duration of game breaks between both forms of representation.

The performance in the game was measured by the number of dropped balls and the duration of the longest game sequence without dropping a ball. While the participants dropped highly significant more balls in the concrete representation condition, there was no significant difference between both conditions regarding the duration of the longest game sequence (see Table 4). As game situations are common, where it is impossible not to drop a ball, it seems valid to conclude, that the representation method does not influence the maximum performance.

Dropped Balls	n
Abstract Representation	4707
Concrete Representation	5119
χ^2	17,3**

Longest Game Sequence	M	SD	t
Abstract Representation	88,801	41,228	
Concrete Representation	91,222	39,540	
Difference	-2,417	38,352	0,063

Table 4: Total number dropped balls of all participants, compared with a χ^2-test (left), and mean longest game sequence without a dropping ball over all participants, analyzed with a 2-tailed t-test (right). ** significant at 1% probability

The more often and the longer a person has to interrupt his work to get awareness of colleagues, the more his work suffers. Therefore, we compared how often and how long the participants had to

pause the game to look at the display. Table 5 shows that there is no significant difference between the abstract and the concrete representation, neither concerning the number of breaks nor their mean duration.

Breaks	n
Abstract Representation	717
Concrete Representation	715
χ^2	0

Mean Duration	M	SD	t
Abstract Representation	126	41,6	
Concrete Representation	106	33,5	
Difference	19,1	30	0,64

Table 5: Total number of breaks, compared with a χ^2-test (left), and mean duration of total break time in seconds, analyzed with a 2-tailed t-test (right).

4.3 Analysis of Gaze Direction

In the previous sections we observed the achieved results of the participants in the different tasks. The performance depends on the task-difficulty, which for some participants might be so high or low, that there is no measurable difference between the abstract and the concrete representation. Therefore, we also analyzed how often and how long they looked at the display. The more distracting the form of representation is and the harder it is to understand, the longer and more often the participants should have looked at the display. For the evaluation, we distinguished between "short glances" and "long glances". This differentiation was made because short glances interrupt work less than longer ones. As a long glance we consider every look at the display, which lasts longer than one second. Several short glances with less than a second gap between them were regarded as one long glance.

Number of Glances	Short	Long
Abstract Representation	7636	562
Concrete Representation	7814	510
χ^2	2,05	2,52

Duration of Long Glances	M	SD	t
Abstract Representation	24,0	16,8	
Concrete Representation	21,8	23,2	
Difference	2,19	29,3	0,07

Table 6: Number of glances to the display (left), and mean duration of long glances (>1 second), summed up per participant (right).

The intelligibility of the representation method will influence the time interval the participants have to look at the display perceive the information. Therefore, we also compared the duration of the long glances. For every participant we calculated the total duration of long glances, and compared the mean durations over all participants between the abstract and the concrete representation form. As shown in Table 6, there were no significant differences.

4.4 Subjective Assessment of Performance and Distraction

For the analysis of the subjective assessment of performance and distraction, we compared the frequency of participants favoring the abstract representation with the frequency of participants favoring the concrete representation using a χ^2-test. For each questionnaire item participants with no preference were removed for the analysis. The evaluation showed no significant difference in preferring one or the other representation form concerning effort and performance in playing the game as well as in maintaining awareness of the fictive remote team. Only in the final comparison significantly more participants rated the concrete representation more distracting than the abstract one.

5 Conclusion

The evaluation showed that an abstract representation has several benefits. Firstly, the abstract representation of the awareness information was rated significantly more often as less distracting than the concrete representation using video. Secondly, the performance in the game was less

affected through the abstract representation, as highly significant fewer balls were dropped while receiving the awareness information.
Comparing both representation forms, there is no significant difference in the frequency of temporal misinterpretation, where persons were perceived as "present" although they were "absent". However, there were highly significant more temporal misinterpretations of "absent" people while using the concrete representation.
In contrast, the recognition of persons leaving the fictive office was clearly better when using the concrete information representation. But regarding the collaboration of teams, being aware about a person entering the office and thus being available for immediate personal contact is usually more valuable than recognizing that someone just left the office. One may wait for a colleague to enter the office to talk to him or to schedule something. When a team member leaves the office, information about the reason and duration of his absence are usually more helpful than just knowing that he is gone. So in this specific application domain, it might even be seen as an advantage, that only the more valuable presence information is perceived. This is also reinforced by the fact, that in the final questionnaire significant more participants rated the concrete representation as more distracting than the abstract representation.
There was no difference in the duration of the longest game sequence between both representation forms, which means that the potential performance in the game was not influenced by the representation. But using the concrete representation the participants dropped highly significant more balls, which as to be regarded as an indicator for a higher degree of distraction.
The only advantage of a concrete form of information representation is that it does not need any practice to be understood. The logfiles proved that the participants made fewer mistakes while interpreting the concrete information. But since many office tools need some practice to make use of their full potential and as the effort to remember the patterns is rather low, this fact is not likely to outweigh the drawbacks of a concrete information representation.
Summing up the results, we come to the conclusion, that abstract forms of information representation are more suitable for large public displays than concrete ones.

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