Supporting Collaborative Learning with Augmented Group Awareness Tools

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Abstract

This article introduces the concept of awareness, which emerged in the field of computer-supported cooperative work and relates it to several psychological constructs. It reports the support of awareness by technological means and discusses potentialities of group awareness tools to support collaborative learning. A prototypical tool is introduced, which is intended to support online learning groups by indicating group conflicts. An experimental study is reported, which examined the benefit of this prototype regarding minority influence in learning groups. It shows that an augmented group awareness tool can lead to better individual and group performances in learning groups.

Keywords: Group awareness; computer-supported collaborative learning; visualization; peer learning; online discussion.

The Psychology of Awareness

The notion of awareness has originated in the literature on computer-supported cooperative work (CSCW). Although it is widely used, the term is ill-defined. On the most general level, awareness can be defined as adaptive knowledge about an environment (Endsley, 1995). Adaptive means that knowledge about an environment is not fixed, but must be updated over time to account for changes in that environment. Another defining characteristic of awareness is that it mostly is a by-product of taskwork to be accomplished, thus making it distinguishable from the concept of attention.

The first part of this article tries to take a look at this concept from the viewpoint of psychology. In other words, different types of awareness will be introduced, compared, and related to psychological constructs.

First, we suggest to distinguish between situational awareness and group awareness. Situational awareness is the perception of affordances in a non-social environment, whereas group awareness refers to the perception of other persons in an environment, their activities, and their products.

Situational Awareness

The concept of situational awareness has emerged from research on flight simulators, and now is often addressed in research on immersive virtual environments. From a psychological point of view, situational awareness is related to spatial cognition, i.e. it describes the sense of orientation that users have in virtual space. Situational awareness is often insufficient, and thus can be supported by the use of maps, grids, landmarks, and the like (Darken & Peterson, 2002; Wickens & Baker, 1995). The concept of situational awareness can be extended to encompass not only spatial navigation but also semantic navigation because similar feelings of disorientation have been reported (Conklin, 1987).

Another psychological construct that can be linked to situational awareness is presence (Steuer, 1992). Presence is the subjective feeling of "being inside" a virtual space and is often accompanied by a feeling of non-mediation. Presence is related to a number of psychological phenomena. For instance, high levels of presence are needed to experience anxiety in treatments of phobias (Rothbaum & Hodges, 1999). In order to facilitate presence and situational awareness, technologies should strive for vividness (e.g. stereoscopic sight and sound) and interactivity (e.g. rendering of head movements).

Group Awareness

Group awareness adds a social dimension to digital worlds. Many digital environments give no indication of the presence or absence of other users, their activities and their products. However, once such information is added to an environment, the actions that users perform are not only informed by spatial and semantic constraints, but also by social affordances. In other words, semantic navigation and spatial navigation will be complemented by social navigation (Dourish & Chalmers, 1994).

We have identified three different types of group awareness, each of which can be supported by technological means, and each of which can be related to other psychological constructs. In the following, we will briefly address these types of group awareness.

Awareness about the Presence of Others. The simplest type of group awareness is knowledge or perception about the presence (or absence) of others. Technologies can vary in how much they support this type of awareness. Whereas many digital environments completely lack this type of awareness, presence indicators can range from quite simple to rather sophisticated. In the simplest case the presence indicator just provides a list of who is currently visiting the same content, as can often be found in online discussion forums.

From a psychological point of view such presence indicators diminish anonymity in the group, and consequently can be linked to the psychological research on anonymity. E.g., while some researchers tend to regard anonymity as detrimental to group interaction (Kiesler, Siegel & McGuire, 1984), others have pointed out that anonymity can sometimes even increase normative influence in groups (Reicher, Spears & Postmes, 1995).

Another concept that can be linked to simple presence indicators is the notion of social presence (Biocca & Harms, 2002; Short, Williams & Christie, 1976), i.e. feelings of being connected to other people. According to social presence models, the more people feel connected, the stronger they will be responsive to mechanisms of social influence.

As described above, group awareness about the presence of others can be supported by simple "Who's online" lists, or by more advanced technological means. E.g., group awareness about the presence of others will be enhanced by providing some kind of virtual embodiment of users in an environment, i.e. the use of avatars. Avatars lend an identity to online users, thereby fostering issues of impression management and person perception.

Another feature that comes with (maneuverable) virtual embodiments is the use of personal space. The field of proxemics addresses the interpersonal distance that people express to manage social relationships. Jeffrey and Mark (2003) have investigated how people strategically position their avatars to engage in the same socio-spatial complexities that real-world environments offer (e.g. the emotional effects of crowding).

Even more sophisticated ways to support group awareness about the presence of others is provided if avatars have the ability to express facial and gestural cues. Blascovich (2002) has investigated the role of nonverbal behavior of avatars in social settings. For instance, his model of social influence in immersive virtual environments predicts that humans will violate interpersonal distances if they believe that a virtual person is controlled by a computer (i.e. an agent). However, if the agent shows high behavioral realism (e.g. by keeping mutual gaze), it will be treated like another human being in terms of interpersonal distance. Nonverbal behavior plays an important role in building interpersonal trust and attraction. Thus, this type of awareness technology adds another flavor to the social richness of virtual environments.

Workspace Awareness. A second type of group awareness is not only related to knowledge and perception about the presence of others, but also about the activities that others are engaged in. This type of awareness is sometimes referred to as workspace awareness (Gutwin & Greenberg, 2002). Workspace awareness is not coupled to embodiment, yet it distinctly enhances social interaction above the levels of the aforementioned presence indicators. While avatars lend an identity to social actors, workspace awareness tools introduce identifiability. The actions of persons become visible, and at the same time persons are responsible for what they are doing. In other words, identifiability is the mechanism that allows for norms and rules to come into play. Erickson and Kellogg (2003) have termed mutual identifiability as social translucence, and they suggested it to be the most important feature of tools for group awareness and social navigation.

Another psychological by-product of tools to support workspace awareness is social comparison. Seeing what others are doing provides individuals with a standard that strongly influences their own behavior. Both promotive and detrimental effects of opportunities for social comparison were demonstrated by Cress (2004) in a social dilemma scenario.

Augmented Group Awareness. The two general support mechanisms described thus far (presence indicators, workspace awareness tools) are somewhat similar in as far as they try to enrich digital scenarios to make them more like face-to-face settings. While this step is important to make online navigation social, we believe that the true power of awareness tools lies in a third type of technology support. Hence we call those tools augmented group awareness tools. Augmented tools provide groups with information that would be difficult or even impossible to gain face-to-face.

Augmented tools usually display information that has no physical equivalent. For instance, some tools provide information about the cognitive state of a group or its members. Moreover, augmented tools preserve information over time, either by storing awareness-related information, by integrating the past of an interaction into a single representation that reflects the current status in real-time, or by preserving the history of a digital objects to be used for later reflection about the design process.

Examples of augmented group awareness tools can be found in many commercial environments. For instance, online bookstores recommend specific products to customers based on the purchasing behavior of similar customers. An example for the non-commercial use of augmented group awareness tools are voting features of many group decision support systems.

As can be seen from these examples, augmented group awareness tools do not necessarily have to be technologically sophisticated. We call them augmented because they provide information that is not clearly visible in face-to-face environments (e.g. individual or collective recommendations in the bookstore examples, preference structures in a group decision support system). Augmented group awareness tools receive the necessary information to be displayed from two sources, either explicitly from deliberate user actions (recommendations, ratings), or implicitly from the behavior of other users within the environment. The difference between these two support types is commonly referred to as direct vs. indirect social navigation (Dieberger, 2003).

From a psychological point of view augmented group awareness tools can be related to the concept of higher-order cognition. For instance, tools indicating who knows what in a group could be linked to transactive memory (Wegner, 1987). Similarly, tools that describe other "cognitive states" of a group (e.g. conflicts, trust) would have a strong impact on metacognitive processes like planning, monitoring and evaluating the social interaction.

Augmented Group Awareness for Collaborative Learning

It was mentioned above that augmented group awareness tools are quite common in commercial environments, and sometimes in the organizational context of group decision support. However, few researchers have applied awareness tools to support collaborative learning scenarios. Soller, Martínez Monés, Jermann, and Muehlenbrock (2005) have cited some examples, however, many of the tools described in that paper, while technically being awareness tools, are not intended to feed back awareness information to a group, but only to inform researchers about patterns of interaction. The few reports on systems that employ visualizations for a group and its users (e.g. Barros & Verdejo, 2000) have focused on the level of technical implementation; however, an empirical investigation of augmented group awareness and its implications for collaborative learning was not undertaken until now.

In order to close this gap we developed a set of augmented group awareness tools intended to facilitate computer-supported collaborative learning. Like in many other group awareness systems, these tools are based on user ratings. In particular, they require learners to mutually rate their contributions made in an online discussion forum on several dimensions. The tools store, aggregate, and transform these ratings, and visualize the transformed ratings as a feedback to the group in real-time.

To test empirically whether such a tool does have an impact on group interaction and group performance we chose a typical educational scenario, which involved a group of learners with conflicting viewpoints. From a Piagetian perspective, conflicting viewpoints can lead to fruitful discussion, and serve as a basis for the co-construction of a solution on a higher level. In stark contrast to that, a host of social psychological research indicates that conflicts lead to detrimental effects, especially if the numbers of advocates for those viewpoints are imbalanced. In this case we have a majority-minority conflict, and it is a well-known effect that minorities have difficulties to exert social influence on a majority.

On this basis we adapted an augmented group awareness tool to the scenario of a majority-minority conflict and experimentally evaluated its potential to strengthen the influence of a minority to express its viewpoint and to exert social influence in an online discussion.

The tool rested on two principles. First, it made differences between viewpoints salient by graphically separating majority and minority contributions. By realizing that a discussion contains minority contributions illusions of unanimity could be prevented, and an awareness of the existence of a conflict should be raised. This feature was implemented by requiring subjects to rate their agreement with the contributions of the online discussion. The second feature of the awareness tool is intended to strengthen the minority influence by pointing out a minority's potential to introduce novel concepts to a discussion (Nemeth & Rogers, 1996). The tool required subjects to rate the novelty of contributions for the discussion, and visualized the contributions according to this dimension.

Thus, by making salient the existence of conflicts and by making salient the novelty of minority contributions it was expected that an augmented awareness tool will strengthen the impact that such a minority has on group interaction and group performance. This hypothesis was tested in an experimental study.

Experimental Study

Method

In the study, small groups of four learners each had to discuss and to agree on a conflicting physics issue in a text-based online discussion environment. Similar to the *informed minority* paradigm (Stewart & Stasser, 1998), information was previously distributed to the group members in such a way that one learner – the minority – had more meaningful information about the issue than each of the other three learners, which together constituted the majority.

Design. Two experimental conditions were compared, which differed with respect to the support learners received regarding the awareness of other group members' contributions during the online discussion. While learners in one experimental condition were only provided with an online discussion environment, learners in the other condition were additionally provided with a rating-based group awareness tool.

Participants. 64 students (26 males and 38 females, ages 19 to 31; M = 22.05; SD = 2.35) at the University of Tübingen were randomly assigned to the two experimental conditions and – within the small groups – to the minority or to the majority. They were paid for their participation. To prevent a very high level of prior knowledge physics students were excluded from participation.

Material. The application domain was comprised of physics concepts concerning light propagation.

The *instructional material* was taken from the web-based inquiry science environment WISE[1] module *How far does light go*. It consisted of several information segments supporting either the correct hypothesis that "light goes forever" or the wrong hypothesis that "light dies out". The information segments were distributed to the group members prior to the group discussion according to the informed minority paradigm of Stewart and Stasser (1998). While one learner in each group was provided with all information segments, which altogether support the correct hypothesis, the three majority members in each group were

[1] http://wise.berkeley.edu/

each provided with a subset of information that rather support the wrong hypothesis.

The *online discussion environment* used in both experimental conditions was developed at Knowledge Media Research Center in Tübingen as part of the groupware system VisualGroup (in its ongoing version renamed as Bebop[2]). It enabled the small groups to discuss in a text-based, synchronous, and anonymous way.

The *group awareness tool* provided to the small groups in one of the experimental conditions was embedded into the online discussion environment (cf. Figure 1). It consisted of (1) seven-point Likert rating scales that allowed learners to rate other group members' contributions with respect to (a) the agreement with a contribution, and to (b) the novelty of a contribution in the discussion, and (2) a visualization of the group members' mean ratings on each contribution, representing (a) the raters' agreement to a contribution along the x-axis of a two-dimensional graph, and (b) the rated amount of novelty of a contribution along the y-axis of the same graph. The visualization was personalized in that each learner could distinguish own contributions from other group members' contributions and already rated from unrated contributions.

The *test material* for assessing the knowledge of the learners consisted of two questionnaires given to the learners individually before and after the group discussion. It mainly collected the decision of the learners for one of the two hypotheses, the confidence of the learners in this decision, and an explanatory statement for the chosen hypothesis. Choice and confidence rate were used to calculate the correctness of the decision ranging from 0% (wrong answer and confidence rate of 100%) to 100% (correct answer and confidence rate of 100%). Furthermore, the learners' interactions with the discussion environment and with the group awareness tool such as content and time of contributions and ratings were recorded in log files.

Procedure. The experiment consisted of two crucial phases: an individual information phase, and a group discussion phase. In the first of these phases, learners received information about light propagation individually (10 minutes). While the information received was identical for

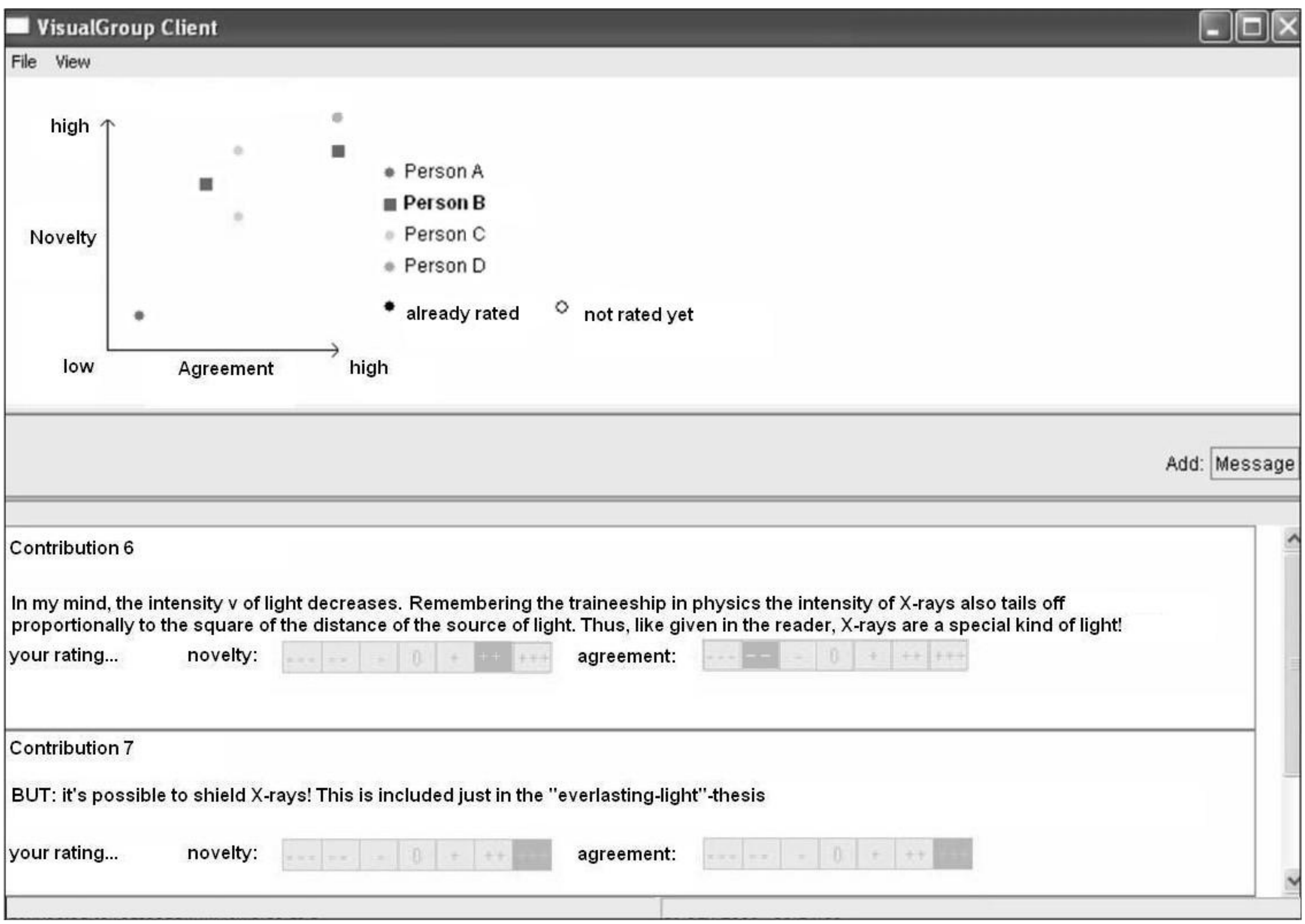

Figure 1: Group awareness tool with rating scales and visualization of mean ratings

[2] http://svn.kmrc.de/

all small groups of both conditions, it differed within the small groups according to the informed minority paradigm of Stewart and Stasser (1998) as described above. Subsequent to this phase and prior to the group discussion, the learners' knowledge was assessed by the first questionnaire. In the discussion phase small groups had to discuss on the basis of the information received and to agree on one of the alternative hypotheses. According to the experimental design of the study small groups in one condition were only provided with the online discussion environment, while small groups in the other condition were additionally provided with the group awareness tool.

Results and Discussion

Table 1 shows the means and standard deviations for the individual learners' correctness assessed by the questionnaire before and after the group discussion.

Table 1: Means and standard deviations of correctness before and after the discussion

Support		Without awareness tool: pre-discussion	Without awareness tool: post discussion	With awareness tool: pre-discussion	With awareness tool: post-discussion
Minority	M	80.50	78.63	78.88	78.38
(n = 16)	SD	11.24	32.51	17.17	36.18
Majority	M	29.92	37.17	38.33	74.58
(n = 48)	SD	21.31	36.89	15.55	36.02
Overall	M	42.56	47.53	48.47	75.53
	SD	29.34	39.76	23.75	35.51

As expected, learners with minority status – who were provided with all information available – performed at a very high level independent from the experimental condition they belonged to. In contrast, the performances of learners with majority status differed with respect to the availability of the rating-based awareness tool (cf. Figure 2). While majority members with awareness support almost achieved the post discussion correctness scores of the minorities, the scores of majority members without awareness support lagged far behind those of the other three groups.

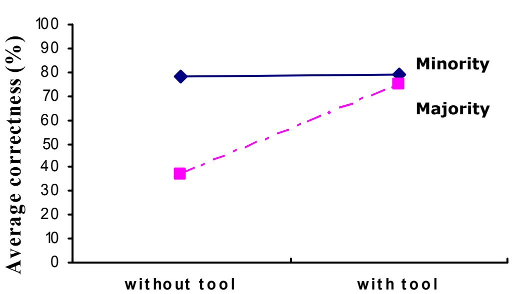

Figure 2: Post-discussion correctness as a function of awareness support and member status

A two-way analysis of variance with the factors *group awareness support* (with vs. without awareness tool) and *information-based group member status* (minority vs. majority) revealed a significant effect for *member status* ($F(1, 60) = 4.47$, $p < .05$) but only marginal effects for the factor *awareness support* ($F(1, 60) = 3.20$, $p = .079$) and for the interaction of both factors ($F(1, 60) = 3.29$, $p = .075$). However, a pairwise t-Test reveals a highly significant effect for *awareness support* indicating that learners who were provided with the awareness tool achieved much better performances than learners who discussed only by means of the online discussion environment ($t(62) = 2.97$, $p < .01$). As supposed, this effect can be ascribed to the learners with majority status ($t(46) = 3.56$, $p < .001$) while there is no difference between the correctness scores of the minorities ($t(14) = 0.02$, $p = .989$).

While these results demonstrate that an augmented group awareness tool can strengthen minority influence in collaborative learning scenarios, there are several open questions regarding how it exactly affects group discussions.

Preliminary analyses of the learners' discussion behavior indicate that learners who were provided with the awareness tool discussed marginally longer but wrote much less contributions than learners without awareness support. Particularly thematically less relevant contributions seem to have occurred much more in the condition without awareness support. This higher efficiency in the awareness condition is not surprising. Particularly the novelty dimension in the visualization might serve as a filter not only for repeated contributions of majority members but also for thematically irrelevant contributions. This efficiency might be further increased if the visualization was implemented navigable in such a way as to enable learners to access textual contributions by clicking on corresponding visualized contributions. Thus, learners might be able to focus on the visualization to a greater extend and to use it efficiently for processes of search and selection of information.

An important question that cannot be satisfactorily answered by means of the experimental study reported in this paper is whether the use of the awareness tool leads to better performance as a result of features of the visualization or merely due to attributes of the rating process. Rating of other users' contributions might encourage elaborative processes during reading because learners are required to read them attentively. On the other hand, it might increase the amount of invested effort during writing, because learners know that they are being evaluated. However, in the reported study subjective data indicate that within the condition with awareness tool those learners performed better who used the visualizations more often, while the number of given or received ratings had a less important influence on learning performances.

Presently, we are conducting a follow-up study, which enables the experimental differentiation between effects of the rating component and of the visualization component of a group awareness tool. Moreover, additional studies are necessary that replicate the results with different paradigms and tasks, in order to detect further scenarios in which augmented group awareness tools can enrich collaborative learning.

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