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Supporting controversial CSCL discussions with augmented group awareness tools

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Abstract This paper describes the development of augmented group awareness tools that take mutual user ratings of their online discussion contributions as input, aggregate these data, and visually feed these data back to the members in real time, thereby informing participants about how the group as a whole perceives their contributions. A specific group awareness tool was experimentally tested in a CSCL scenario using online controversies about a physics domain. The learning material was distributed across group members to create a situation where an individual minority member with a scientifically correct viewpoint faces a majority favoring a plausible, but incorrect viewpoint. It was hypothesized that in unsupported CSCL groups an incorrect majority would dominate a correct majority, whereas in groups that were supported by an augmented group awareness tools minority influence could be strengthened by making minority contributions salient. The paper reports results in support of this hypothesis, and discusses the mechanisms leading to the benefits of group awareness tools for collaborative learning.

Keywords Awareness · Social influence · Social navigation

Introduction

Since the early 1990s the notion of awareness has figured quite prominently within the field of CSCW (computer-supported cooperative work). The concept of awareness is notoriously vague, but there is some agreement that it refers to the perception and knowledge of contextual variables about the material and social world that surrounds a person or a group

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(Endsley, 1995). This paper seeks to empirically explore the question of whether the concept of awareness can be fruitfully adapted and applied to the field of computer-supported collaborative learning (CSCL).

There is huge diversity in how the term awareness is employed in the literature, and several attempts have been made to categorize this field (e.g. Carroll et al. 2003; Christiansen and Maglaughlin 2003; Gross et al. 2005). A general distinction we would like to draw is between situation awareness (Wickens and Baker 1995) and group awareness, with the former being knowledge and perception about the material environment surrounding a person (e.g. about spatial cues while navigating real or virtual worlds), and the latter being knowledge and perception about the social environment surrounding a person (e.g. being informed about the presence, the state, or the activities of other persons in real or virtual environments).

Group awareness

Group awareness is comprised of several elements, among them knowledge and perception of who is there, where other persons are located, where they are looking at, and what they are doing (Gutwin and Greenberg 2002). It is evident that group awareness is easily available in face-to-face (FTF) scenarios. However, once group members are spatially separated, group awareness has to be facilitated by means of technological support. Consequently, the use of group awareness technologies has become widespread in digital environments, ranging from lists of active users in online discussion forums (who is there) over avatar embodiments in virtual environments (where are they located, where are they looking at) to video screens, shared scroll-bars in collaborative editors, activity indicators, timelines, and other widgets used in shared workspaces (what are they doing).

The idea of using technology to foster knowledge and perception about the social environment (i.e. about the group and its products) is at the heart of our own research on group awareness. However, the tools that we develop differ in two important respects from classical CSCW-related group awareness tools. Our first extension with respect to group awareness refers to the type of information that participants perceive about their group. As group awareness is a natural by-product of FTF interaction, many CSCW approaches try to re-establish FTF conditions by technological means. Most examples of group awareness tools refer to feedback about behavioral variables like seeing who is there, seeing where someone is located, and seeing what others are doing. While providing FTF-like conditions by technological means is a legitimate goal for systems designers, we would argue that the true power of technological support can be shown only if technologies give rise to kinds of interaction that actually surpass FTF levels to some degree. Consequently, we suggest the notion of augmented group awareness tools, where augmentation means that such tools provide information and feedback that would be difficult or impossible to yield in FTF interactions. More specifically, augmented group awareness tools feed back information about social and/or cognitive variables (instead of behavioral ones), i.e., variables without physical equivalent like knowledge, attention, attitudes, preferences, attractiveness, or emotions.

Giving feedback about social and/or cognitive variables is a common practice in the field of social navigation research (Höök et al. 2002). Social navigation involves capturing, aggregating, and transforming user-generated data in ways that influence the navigation of other users. Social navigation tools are not designed to foster collaboration within real groups, but to inform individuals via data that were generated by an anonymous collective. A common distinction in related research is between direct and indirect social navigation.

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In indirect social navigation a tool captures behavioral data (e.g. Web page visits) without requiring explicit user input. For instance, online bookstores often employ indirect social navigation to recommend products on the basis of the purchasing behavior of customers who bought the product one is currently inspecting. In contrast, direct social navigation tools mostly focus on social and/or cognitive data, and they gain such data by requiring users to explicitly express their opinion about entities in an environment. E.g., the system MovieLens requires users to rate a number of movies on which basis other movies are automatically recommended (Konstan and Riedl 2002).

Augmented group awareness tools are a hybrid between classical group awareness tools and social navigation mechanisms. Augmented group awareness tools collect information that originates from the group a person is interacting with (not from an anonymous collective) and focus on knowledge artifacts that directly emerge out of interaction (not on external entities). These features are similar to classical group awareness tools. However, the idea of capturing non-observable variables (e.g. attitudes, opinions) through user ratings, and the idea of aggregating and transforming such rating data in order to influence individual behavior is borrowed from the notion of direct social navigation. More specifically, the class of augmented group awareness tools that we have developed require participants to mutually rate contributions in an online discussion on two different dimensions, and the ratings are aggregated, transformed, and fed back to the group. Furthermore, the fact that participants do not rate a set of pre-established entities, but rather mutually assess their contributions as the discussion unfolds, distinguishes augmented group awareness tools from classical voting mechanisms in group decision support systems (Lim and Benbasat 1993). As a consequence, augmented group awareness tools provide a unique affordance to online interaction because participants get an up-to-the minute, real-time feedback on what the group as a whole thinks about the products it generates.

A second extension of classical group awareness research that our work is exploring relates to the application of group awareness tools to the field of CSCL. Why should collaborative learning benefit from augmented group awareness tools? At least three reasons come to mind. First, computer-supported collaborative learning can be described as joint negotiation of meaning and understanding (Baker 1994; Roschelle 1996). Given the fact that negotiators need contextual cues in their construction of a situation (Bazerman et al. 2000), it is important to provide contextual information. Augmented group awareness tools inform learners with respect to what their group thinks about its products. Learners can use this information to identify crucial elements of interaction (i.e. discussion contributions) in order to assist the negotiation of meaning. Second, augmented group awareness tools (at least those based on direct social navigation principles) do not only improve the perception of social variables in a group, but also offer new opportunities for participation. While the main part of interaction among learners is to be found in their discussion contributions, the rating mechanisms of augmented group awareness tools add an extra layer to participation. Moreover, actual discussions are often dominated by a small number of learners, and the rating mechanism provides an additional platform for less active learners to contribute to the meaning making process. Rating online contributions is comparatively effortless, and allows multiple learners to "voice their opinion" in parallel. Third, augmented group awareness tools provide a new metaphor with respect to learner guidance. On one hand, it is assumed that CSCL environments should foster learner autonomy. However, there is general agreement that groups often suffer from a lack of structure in interaction. On the other hand, attempts to structure collaboration explicitly (e.g. through scripted cooperation) are often criticized because they might interfere with exploratory strategies, thus leading to learner reactance (Dillenbourg 2002). Augmented

group awareness tools might provide a middle ground between these two extremes. They are designed to engender autonomous, but well-informed learner actions.

Until now, very few attempts have been made to use group awareness tools for CSCL (see Soller et al. 2005, for an overview). Many CSCL applications in this area focus on feedback about behavioral variables like learner activities (e.g. Kimmerle and Cress 2008; Kreijns et al. 2002), or provide feedback not to the group, but rather to external observers. However, a recent study by Janssen et al. (2007) uses augmented group awareness tools for feeding back information about cognitive and social variables in a group, i.e., about the existence of group conflicts. Their system, called Shared Space, uses indirect social navigation principles, i.e., an intelligent agent automatically codes and interprets online discussions by checking for about 1,300 content markers, and the results of this analysis are fed back to the group in real time.

Our tools have a similar focus on conflicting information in a group, however, in contrast to the approach taken by Janssen et al. (2007) our scenario relies on direct social navigation principles (i.e. explicit ratings from learners). The general tool class we envision for our work entails support mechanisms for both synchronous and asynchronous forms of online group discussions. The basic idea here is to require learners to rate the written contributions in an online discussion on one or more pre-defined dimensions (e.g., agreement with a contribution; relevance, comprehensibility, coherence, or originality of the contribution). The tool itself performs three functions. First, it takes the learning ratings as input data for computation. Second, it aggregates and/or transforms these data. For example, an aggregation could be performed by computing arithmetic means of ratings of standard deviations of ratings, or any other statistical procedure. And third, the tool visually feeds back these aggregated rating data to the group.

Depending on situational characteristics of groups designers can develop specific instantiations of this general tool class in order to support CSCL. The design process involves choosing rating dimensions, determining aggregation and transformation mechanisms, and deciding on the feedback format. The overall goal of an augmented group awareness tool is to provide contextual information that assists the meaning making and negotiation process of a group. Therefore, augmented group awareness tools should enable learners to easily see and absorb what the group as a whole thinks about the contributions in a discussion. For example, a tool using "relevance" as a rating dimension could visually represent the discussion contributions according to their relevance, thereby making salient those contributions and topics that merit further attention for a group.

Minority influence in collaborative learning

We have set out to explore the usefulness of augmented group awareness tools by developing an instantiation of the general tool class that is specifically tailored to a particular CSCL scenario, namely, the case of controversies and conflicting viewpoints. According to educational theorizing, controversies and conflicts are often seen as important antecedents of collaborative learning (Doise and Mugny 1984). Some collaborative learning methods are even explicitly designed to engender controversial discussions among learners, e.g., Structured Controversy (Johnson and Johnson 1979). Despite the potential of controversies to facilitate elaboration and negotiation among learners, there might be some pitfalls to these methods. The social psychological research literature points at various deficiencies of controversies because they can give rise to patterns of social influence that might be detrimental to a group's functioning, particularly if the sub-groups advocating the viewpoints are of different size. For instance, there is an abundance of social psychological

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literature that points at the difficulties that minorities in a group have on influencing conflicting majority viewpoints (Asch 1956), especially if the task at hand is not demonstrable (i.e. a particular viewpoint cannot easily be proven to be a correct one). If this robust finding is applied to collaborative learning one can only assume that controversial discussions in a learning domain are also prone to the influence of a majority, irrespective of the validity or justifiability of the majority viewpoint.

Generally, the suppression of minority viewpoints would be detrimental to collaborative learning because it prevents groups from gaining divergent, flexible perspectives on a particular domain. These detrimental effects of lacking minority influence are exacerbated when the minority holds a scientifically correct viewpoint that fails to influence an incorrect majority perspective. Given that collaborative learning requires the joint construction of a shared understanding it could well be the case that in such a scenario the minority would rather comply with the incorrect majority perspective than vice versa.

In the context of group-decision making these patterns of social influence are often investigated in a quantifiable manner by employing so-called hidden profiles (Stasser and Titus 1985) with an informed minority. In these scenarios a minority group member receives unshared, critical information that should lead to a different, but better group decision quality than the shared pieces of evidence that the majority members receive. In addition to the general finding that groups are often unable to uncover a hidden profile (i.e., identify the best alternative), studies employing an informed minority have shown that groups focused less on critical (minority-held) information when the task did not appear to be demonstrable (Stewart and Stasser 1998), that minority influence was even more diminished when groups were using an anonymous group decision support system (McLeod et al. 1997), and that the discovery rate of the best decision alternative (out of three) was only 10% using an informed minority (Brodbeck et al. 2002).

However, social psychology has also outlined several conditions that should lead to enhanced minority influence. These beneficial principles are crucial because they informed the particular design of our augmented group awareness tool. An important antecedent for minority influence stems from the theoretical distinction between normative and informational influence (Deutsch and Gerard 1955). The influence of a majority on the minority is mostly normative, i.e., minorities often conform to the majority viewpoint because of social pressure. Minorities can counter these effects by exerting informational influence, i.e., they must appeal to the need of majority members to arrive at a valid conclusion, and they need to be persuasive in advocating their viewpoint (Wood et al. 1994). From related research literature, three principles can be derived that contribute to an enhancement of informational influence. First, the focus of group interaction should be on the arguments brought forth in interaction, not on the persons advocating the arguments. Focusing on the messages is likely to increase their elaboration which in turn leads to systematic message processing focusing on the quality of arguments (Martin et al. 2007). Our specific awareness tool instantiation addressed this principle by providing visual feedback with respect to the contributions of a message (not with respect to the authors of those messages). Second, studies have indicated that groups often exhibit a tendency to disregard or ignore minority viewpoints (Hastie et al. 1983; McLeod et al. 1997), thus leading to biased processing of information. This detrimental effect can be weakened by feeding back information about the attitudinal discrepancy among minority and majority contributions, thereby precluding false consensus. In other words, the cognitive conflict among messages (not necessarily among persons) should be made salient. This principle is addressed in the design of our awareness tool by requiring learners to rate their agreement with the online contributions of their co-learners. The tool aggregates the agreement rating

for each contribution by computing arithmetic means, and visually feeds this information back. As a consequence, average minority contributions (receiving comparably low agreement ratings) and average majority contributions (high agreement ratings) are visually separated, thereby serving as a constant reminder that a cognitive conflict still exists. Third, the literature on persuasion suggests that attitude change is more pronounced when arguments are novel than when they are already known (Vinokur and Burnstein 1976). At the same time, Moscovici (1976) and other theorists on social influence emphasize that minorities can often be seen as sources of innovation. It can be concluded that minority influence can be increased by making salient their potential for innovative solutions. This principle was implemented in our augmented group awareness tool by requiring learners to rate the novelty of discussion contributions. One should expect that the average novelty of majority contributions is rated as relatively low (because majority arguments are shared and tend to be redundant), whereas minority contributions should yield high novelty ratings, thereby being made salient in the visual feedback.

In sum, the specific design of our augmented group awareness tool should foster informational influence in a group. In the specific scenario that we use (a controversy with solutions of different quality, a correct minority facing an incorrect majority) this should lead to strengthened minority influence. Messages of the minority should be processed more carefully, should be elaborated more deeply, and should be at the focus of group discussion. If the task of a CSCL group is to make a decision among two competing viewpoints, strengthening minority influence should lead to better decisions as a rough indicator for better learning. An experimental study tested these assumptions.

Method

In the study, small groups of four learners used a text-based online discussion environment in order to come to an agreement on a conflicting physics topic. Similar to the *informed minority* paradigm (Stewart and Stasser 1998), learning material, consisting of pieces of evidence, was previously distributed across the group members in such a way that one learner—the informed minority—received information that should lead to a scientifically correct viewpoint on the issue, whereas three other learners (majority members) received information that should lead to a plausible, but incorrect viewpoint.

Design

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

Participants

Sixty-four 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.

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Materials

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

The instructional material was taken from a translated module of the web-based inquiry science environment WISE (Linn and Hsi 2000), addressing the topic "How far does light go." The entire pool of learning material consisted of six pieces of evidence concerning light propagation. Two pieces of evidence were in line with a scientifically plausible, but incorrect viewpoint ("Light dies out"), whereas three pieces of evidence were supporting the scientifically correct viewpoint ("Light goes forever"). A sixth piece of evidence was irrelevant with respect to the conflicting viewpoints.

The six pieces of evidence were distributed across the group members prior to the group discussion according to the informed minority paradigm of Stewart and Stasser (1998). The three majority members received four pieces of evidence each: two (shared) information pieces supporting the incorrect viewpoint; one (unshared) information piece about the correct viewpoint; and the irrelevant piece of evidence. Taken together, the information distribution in the majority was identical to a hidden profile, i.e. each member would be more likely to prefer the incorrect alternative based on shared information, whereas a group's preference should shift towards the correct alternative if the unshared information pieces were pooled during discussion. The fourth member of the group (informed minority) received all six pieces of evidence, which would tend to lead to a preference for the correct viewpoint.

Prior tests revealed that this type of information distribution predicted learner preferences quite accurately, i.e., independent learners who received the same material as the minority tended to favor the correct viewpoint, whereas learners who received the same material as the majority, were biased in favor of the incorrect viewpoint.

The online discussion environment used in both experimental conditions was developed at the Knowledge Media Research Center in Tübingen as part of the groupware system VisualGroup (in its current version renamed as Bebop). It enabled the small groups to discuss in a text-based and synchronous way. Contributions were listed sequentially in temporal order. To control for effects of acquaintance among participants all names were removed, i.e., contributions were made anonymously.

The group awareness tool provided to the small groups in the treatment condition was embedded into the online discussion environment. It consisted of (1) seven-point Likert rating scale that allowed learners to rate each contribution (except their own) with respect to (a) agreement with a contribution and (b) novelty of a contribution to the discussion, and (2) a visualization of the contributions represented as dots on a two-dimensional graph, where the *x*-axis represented the average agreement rating, and the *y*-axis represented the average novelty rating that a given contribution received. The visualization was personalized in that learners could distinguish their own contributions from other group members' contributions, and by indicating contributions a learner hadn't rated yet (see Fig. 1). By clicking on a particular dot in the visualization learners could read the corresponding contribution.

The test material for assessing the knowledge of the learners consisted of two test sheets that were individually administered before and after group discussion. The first test sheet required participants to state their preference for one of the two controversial viewpoints, and to rate their confidence in this preference. The second test sheet, which was administered after the discussion, asked the learner to state the decision that the group arrived at. Moreover, learners were required to indicate their individual preference for one of the controversial viewpoints and to provide a confidence rating for the individual

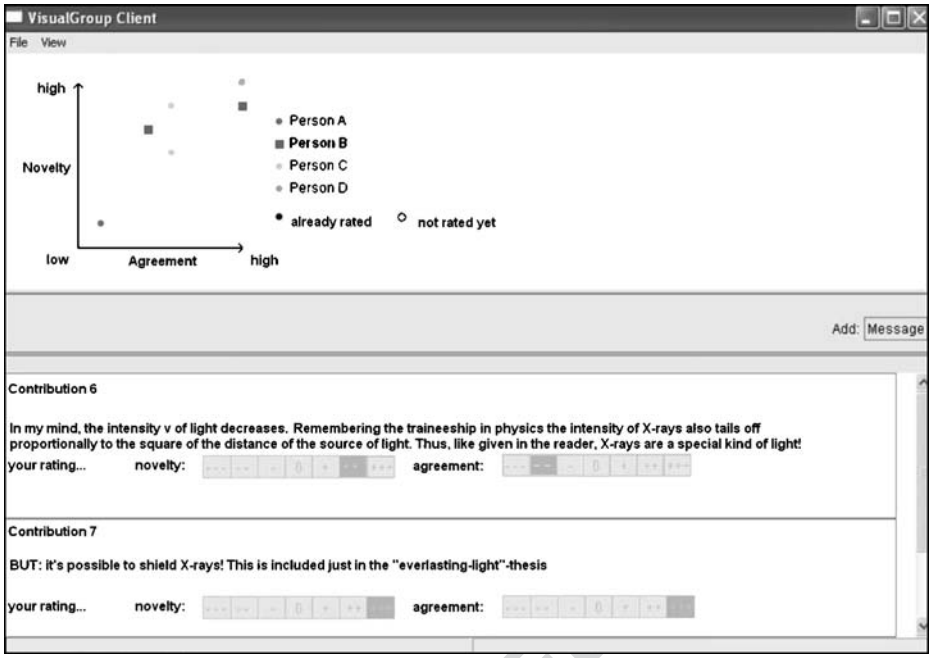

Fig. 1 Screenshot (translated) of the augmented group awareness tool. The *lower window* displays two messages and the rating scales. The *upper window* contains the visualization of contributions according to average novelty and agreement

decision. The second test sheet also contained subjective ratings about the task environment.

Measures

To test the usefulness of the augmented group awareness tools five types of dependent measures were analyzed.

Group decisions (correct vs. incorrect decision) were extracted from the contents of the group discussions. Since subjects were also individually required to explicitly state the group decision after the discussion, these data could be used in cases where the actual group decision was not evident. It was expected that groups in the treatment condition would make better group decisions than groups in the control condition.

Measures of learning were derived from the decisions among the two conflicting viewpoints that both the groups and the individuals made after discussion. In order to gain access to a rough indicator of individual learning, the preferred decision alternative and the confidence ratings were used to calculate a correctness value of the decision ranging from 0% (wrong answer and confidence rate of 100%) to 100% (correct answer and confidence rate of 100%). It was expected that in treatment groups (with the augmented awareness tool), minorities would exert a greater influence on the group decision, thereby yielding higher correctness values across group members.

Discussion parameters were derived as indicators for knowledge building processes. Log files of the discussion contents were used to generate general measures of participation (e.g., number of written contributions). The discussion content was additionally coded by

two independent coders. Single contributions were rated according to three categories (knowledge construction; negotiation of preferences; other). It was expected that groups in the treatment condition would display a lower number and rate of contributions rated as negotiation of preferences because the visualization already contained the corresponding information. As a consequence, it was tentatively hypothesized that this might lead to a higher number and rate of knowledge construction contributions.

On the level of the whole group discussion sessions independent coders additionally categorized the deliberation style of groups. Deliberation style is a concept drawn from research on mock juries. Hastie et al. (1983), for example, have found that some juries have evidence-driven discussions, i.e., they start by exploring the evidence before integrating the evidence into a verdict. Other groups, however, are verdict-driven, i.e., they start by pooling their preferences to reach a verdict as fast as possible, and then start a (biased) search for information in support of this verdict. It was expected that without augmented group awareness tools groups might be tempted to reach a consensus overly quickly, thereby employing a verdict-driven style. Due to the small sample size, deliberation style of groups was only analyzed in descriptive terms.

Ratings data were derived from the treatment group. Of particular interest were the average agreement and novelty ratings that majority and minority contributions received. Moreover, it was analyzed whether the average ratings changed over time. Therefore, discussion time per group was divided into three slots of equal time. These analyses were of an exploratory nature to identify whether discussions followed particular patterns with respect to majority and/or minority influence.

Individual use of the tool was measured by asking subjects in the treatment condition about the subjective frequency of using the visualized graph, about the perceived usefulness of the ratings mechanisms, and about the perceived usefulness of the visualized graph.

Procedure

The experiment consisted of two phases: an individual learning phase, and a group discussion phase. During the entire experiment subjects of a group were seated in separate rooms. In the first phase learners received information about light propagation individually (10min). While the information distribution was identical across conditions, it differed within the small groups according to the informed minority paradigm of Stewart and Stasser (1998), as described above. Subsequent to the individual learning phase, but prior to the group discussion, individual preference and confidence were measured. After the learning phase individual group members were given the opportunity to test the online discussion environment by writing contributions. Group members in the treatment condition were additionally asked to rate test contributions by other participants.

In the second phase groups were instructed to discuss the conflicting viewpoints. All learners were made aware that other group members might have received different pieces of evidence. Groups were asked to make a decision about the conflicting viewpoints within the allotted discussion time (30min). According to the experimental design of the study, the small groups in the control condition were only provided with the online discussion environment, while the small groups in the treatment condition were additionally provided with the group awareness tool.

After the discussion phase individual learners were asked to repeat the group decision, state their individual preference and indicate their confidence in their individual preference. Then subjects received a questionnaire about subjective variables (e.g., usefulness of the tool). Subjects were briefed about the study at the end of the experiment.

Results

Manipulation check

Across both conditions, all minority subjects showed a preference for the correct viewpoint, as indicated by pre-discussion choice. However, seven out of 48 majority subjects also chose the correct viewpoint. The distribution of pre-discussion choices between the two conditions was not different, i.e. out of the seven subjects that did not adhere to the manipulation, three were in the condition without group awareness tool vs. four in the experimental condition, thus yielding no significant differences between conditions—($\chi^2(1, N = 64) = 0.68$, n.s.). Nonetheless, analyses that compared the two types of learners were conducted both with respect to the original, intended member status (minority vs. majority) and with the actual pre-discussion choice (correct vs. incorrect) as an independent variable. Although results using pre-discussion choice as independent variable were slightly more favorable with respect to the hypotheses, the results described in this paper are based on the more conservative variable of member status (majority vs. minority).

Group decisions

Among the eight groups using the augmented group awareness tool, six arrived at the correct group decision vs. two for the incorrect decision. In contrast, groups without group awareness support arrived at the incorrect decision in six cases and at the correct decision in one case, while one group did not arrive at a conclusion during the allotted time. The difference between conditions is significant (χ^2 (2, $N = 16$) = 6.57, $p < 0.05$). This provides evidence that the augmented group awareness tool reversed the bias towards majority opinion.

Individual correctness

Table 1 shows the correctness values for minority and majority subjects within the treatment and control condition. A 2 × 2 analysis of variance (ANOVA) with support and member status as independent variables yielded a significant main effect for member status (see Table 2). The main effect for support and the support x status interaction approached significance ($p = 0.08$ in both cases). However, the data from Table 1 show that majority members in the treatment condition were scoring much higher than majority members in control groups. An additional, one-tailed t-test revealed that this difference was highly

Table 1 Average individual correctness values for learners, depending on member status (majority vs. minority) and experimental condition (treatment vs. control)

Support	Measures	Status		
		Majority	Minority	Overall
Control	*M*	37.17	78.63	47.53
	SD	36.89	32.51	39.76
Treatment	*M*	74.58	78.38	75.53
	SD	36.02	36.18	35.51
Overall	*M*	55.88	78.50	61.53
	SD	40.72	33.23	39.97

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Table 2 Results of 2×2 (support × status) analyses of variance (ANOVA) with respect to the correctness values, and a number of discussion parameters (KC refers to contributions coded as knowledge construction)

Source of variance	Dependent variable	*df*	*F*
Support	Correctness	1, 60	3.20
	Abs. number of contributions	1, 60	21.75**
	Abs. number of KC contributions	1, 60	5.70*
	Rel. number of KC contributions	1, 60	6.49*
Status	Correctness	1, 60	4.74*
	Abs. number of contributions	1, 60	0.88
	Abs. number of KC contributions	1, 60	0.52
	Rel. number of KC contributions	1, 60	0.07
Support × status	Correctness	1, 60	3.29
	Abs. number of contributions	1, 60	0.27
	Abs. number of KC contributions	1, 60	0.03
	Rel. number of KC contributions	1, 60	1.09

*$p<0.05$, **$p<0.01$

significant $t(46) = 3.56$; $p < 0.01$. In other words, there is evidence for the hypothesis that majority members moved from the incorrect to the correct viewpoint if they were using an augmented group awareness tool.

Discussion parameters

Table 3 shows the absolute number of contributions written by majority and minority members across the two conditions, separated by the three coding categories (knowledge construction, negotiation of preferences, other). Results of 2 × 2-analyses of variance (ANOVA) indicate that members from control groups wrote more contributions than group members in the treatment condition. No differences were found for member status or the support × status-interaction (Table 2). A main effect for support could also be found by only taking into account messages that were coded as knowledge construction contributions. However, an analysis of relative amounts of knowledge construction messages reversed this effect. In other words, treatment groups produced a higher relative amount of knowledge construction contributions than control groups ($M = 0.67$, SD = 0.18 vs. $M = 0.51$, SD = 0.17).

The descriptive analyses of the groups' deliberation style indicated that seven out of eight control groups were following a verdict-driven style. Four of the eight treatment

Table 3 Average number of contributions across conditions depending on message type

Support	Measures	Majority			Minority			Overall		
		KC	NP	Other	KC	NP	Other	KC	NP	Other
Control	*M*	9.37	4.67	3.63	10.63	5.13	2.63	9.69	4.78	3.38
	SD	6.11	2.76	2.00	7.33	4.49	1.92	6.33	3.20	2.00
Treatment	*M*	6.21	2.21	0.50	7.00	3.00	1.38	6.41	2.41	0.72
	SD	2.86	1.38	0.66	2.27	1.93	0.92	2.71	1.54	0.81
Overall	*M*	7.79	3.44	2.06	8.81	4.06	2.00	8.05	3.59	2.05
	SD	4.98	2.49	2.16	5.56	3.51	1.59	5.11	2.76	2.02

KC Knowledge construction, *NP* negotiation of preferences

groups were using an evidence-driven style of deliberation (vs. three verdict-driven groups). The remaining two groups in both conditions were not uniformly classified among raters (see Fig. 2). The results suggest that a deliberation style starting with a collection of evidence, followed by coming to a consensus was only found in treatment groups. Additional analyses revealed that all four evidence-driven groups, the two mixed-style groups and just one of the verdict-driven groups arrived at the correct group decision. In contrast, all verdict-driven groups made a decision in favor of the incorrect majority viewpoint.

Ratings data

Table 4 gives an overview of the agreement and novelty ratings that contributions by majority and minority members received over three time frames of equal size. The 2 × 3-analyses of variance (ANOVA) with member status and time frame as independent variables indicated no main effects and no interaction for agreement ratings (see Table 5). In other words, the ratings received by majorities and minorities in terms of agreement did not differ across the entire discussion. With respect to novelty ratings a significant effect of time frame was found, but no effect for member status, and only a marginally significant effect for interaction (see Table 5).

However, given that agreement and novelty were expected to change over time, additional analyses were conducted that compared agreement and novelty ratings during the first time frame only, i.e. at the beginning of group discussion. These analyses indicated that there was no significant difference in agreement between majority (M = 5.07, SD = 1.50) and minority contributions (M = 4.99, SD = 1.44; $t(85)$ = 0.23, p = 0.41). However, minority contributions received novelty ratings during the first time frame that were significantly higher than majority contributions (M = 5.41, SD = 1.29 vs. M = 4.80, SD = 1.43; $t(85)$ = 1.95, $p < 0.05$).

Subjective data

Subjects of the treatment condition were asked to report how useful they found the ratings mechanisms, how useful they found the visualizations, and how often they used the visualization. These data were analyzed in relation to the question of whether the individual post-discussion choice was correct or incorrect. These analyses showed that subjects who

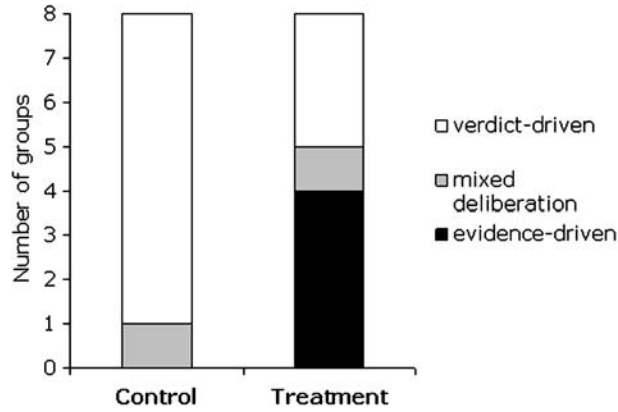

Fig. 2 Number of groups coded as following a verdict-driven vs. evidence-driven style of deliberation

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Table 4 Average agreement and novelty ratings (7-point Likert) for contributions made by majority and minority members across three discussion time slots of equal size

Status	Measures	Agreement				Novelty			
		Time1	Time2	Time3	Overall	Time1	Time2	Time3	Overall
Majority	*M*	5.12	5.11	5.83	5.42	4.85	4.25	4.66	4.58
	SD	1.55	1.36	1.32	1.43	1.39	1.48	1.40	1.43
Minority	*M*	5.17	4.83	5.16	5.07	5.44	4.44	4.39	4.74
	SD	1.46	1.59	2.00	1.72	1.37	1.47	1.39	1.47
Overall	*M*	5.14	5.02	5.64	5.32	5.06	4.31	4.59	4.63
	SD	1.51	1.43	1.56	1.53	1.40	1.47	1.39	1.45

Q1

arrived at the correct decision reported using the visualization more frequently ($M = 5.60$, SD = 0.96) than subjects who made the wrong decision ($M = 4.43$, SD = 1.90; $t(30) = 2.27$, $p < 0.05$). Subjects who arrived at the correct decision also found the visualization slightly more useful ($M = 5.32$, SD = 1.28) than subjects who made an incorrect decision ($M = 4.43$, SD = 0.98; $t(30) = 2.89$, $p = 0.100$). No significant differences between these two subgroups were found with respect to the subjective usefulness of the ratings themselves ($M = 4.20$, SD = 1.80 vs. $M = 4.43$, SD = 1.40; $t(30) = 0.31$, $p = 0.759$).

Discussion

An experimental study showed that groups using an augmented group awareness tool showed higher performance in terms of group decision and individual correctness than unsupported discussion groups.

On a larger scale addressing the entire CSCL community, one of the most interesting findings of the study was the fact that majority influence indeed occurred in the unsupported control groups. It was often mentioned that CSCL tends to look at positive results, thereby neglecting instances where collaborative learning might actually fail. Our studies have shown that in learning scenarios social psychological factors like majority influence are at work, and that they can have detrimental effects. While this might not be surprising to social psychologists, this point is hardly addressed in the CSCL literature. We hope that in the future findings from social psychology will be merged with findings from CSCL, thereby arriving at a clearer picture of collaborative learning.

While it appears that CSCL groups might arrive at suboptimal solutions because of an overpowering majority influence, our experiment indicated that this inherent bias can be

Table 5 Results of a 2×3 (status × time frame) analysis of variance (ANOVA) with respect to agreement and novelty ratings

Source of variance	Dependent variable	*df*	*F*
Member status	Agreement	1, 280	2.28
	Novelty	1, 280	0.86
Time frame	Agreement	2, 280	2.67
	Novelty	2, 280	6.37**
Status × time	Agreement	2, 280	1.21
	Novelty	2, 280	1.91

**$p<0.01$

overcome by technological means. An augmented group awareness tool specifically designed to focus on learner ratings of agreement and perceived novelty significantly increased minority influence, thereby leading to better group and individual learning performances. This was not only reflected in outcome variables like group or individual decisions, but also in process variables like deliberation style. Whereas control groups were frequently focusing on finding an initial verdict, followed by identifying supporting evidence, it appears that the augmented group awareness tool used in the treatment groups led to a much more open, evidence-driven discussion before groups settled on a decision.

Some results of this experiment are more difficult to interpret. For instance, it is not quite clear why treatment groups produced many fewer contributions than control groups. Given that for collaborative tasks the amount of participation is usually correlated with performance (Cohen 1994), this comes as somewhat surprising. The difference in participation might be due to the fact that in the treatment condition learners needed more time to rate contributions and to use the visualization, thereby decreasing the overall number of contributions. Moreover, the lower absolute amount of interaction was partially outweighed by the higher relative rate of contributions that were directly related to knowledge construction.

Another result that cannot easily be interpreted is with respect to the ratings data within the treatment condition. It was expected that minority contributions would receive higher novelty and lower agreement ratings, especially at the beginning of discussion. These hypotheses could be confirmed only partially. While minority contributions received higher novelty ratings at the beginning of the discussion, this advantage vanished during discussion. Moreover, there was no indication that minority contributions were receiving lower agreement ratings during discussion. Nonetheless, a shift in preference occurred in the treatment groups. It could be the case that minority influence was exerted on the basis of very few or even single contributions, so that quantitative measures are inadequate to reveal the patterns of influence. Further studies could shed light on this aspect, e.g., by including qualitative analyses, using quantitative methods, requiring learners to repeatedly rate contributions, or by investigating the order of messages read.

The inconclusive results with respect to the ratings data lead to the general question of what mechanisms might have produced the obtained results. In other words, what parts of the augmented group awareness tools were conducive to strengthened minority influence? The tool consists of two parts (the rating mechanism and the visualization), both of which can have beneficial effects on learning. Our line of reasoning assumes that the main power of augmented group awareness tools lies in the feedback and visualization mechanisms. They should direct attention to salient features in a group, thereby guiding attention and assisting interaction. However, on the basis of the rating data results it could also be the case that the rating mechanism per se explains the patterns of social influence found. Simply requiring learners to rate contributions might lead them to reflect on the content, to serve as a metacognitive prompt, thereby leading to minority influence and better learning outcomes. This potential effect would hold even in the absence of a visualization. Of course, both mechanisms might be additive. We will disentangle these influence factors in a follow-up study that includes a ratings-only condition (with ratings, without visualization).

The current study found effects for a scenario that could be regarded as highly selective. Of course, in natural CSCL discussions it is not always the case that a minority vs. majority situation exists, let alone that the minority advocates a correct (or superior) viewpoint. What would happen if a minority holds an incorrect viewpoint? According to our theoretical conceptualization, the augmented group awareness tool employed in this study rested on principles that should enhance informational influence in general, particularly in its focus

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on contributions instead of persons, and thereby on argument quality instead of normative influence. The only tool feature that was explicitly geared at minorities was the novelty dimension. It can therefore be hypothesized that the same tool would also strengthen the informational influence of a correct majority. However, such an effect would be more difficult to interpret because majorities additionally exert normative influence (which was the exact reason why this study was focusing on minorities). In sum, the augmented group awareness tool presented here favors informational influence and argument quality, and therefore might be useful across many educational scenarios because normative influence (which was at work in control groups) can hardly be justified as beneficial to collaborative learning. Rating the content of collaboration and being informed about what the group as a whole thinks about its products should lead to higher degrees of elaboration, more systematic processing, and better learning results. Therefore we hypothesize that the tool principles derived for this study can be fruitfully applied to "wicked" problems as well (i.e. situations where neither a "correct" answer nor complete agreement among learners is necessary or even desirable).

This is not to say that the general idea of augmented group awareness tools (providing feedback about what a group thinks) is beneficial in all learning situations. We are currently planning a follow-up study where learners mutually rate contributions, but the aggregation and feedback mechanism doesn't focus on the contributions, but on the authors (i.e. learners are represented as dots in a two-dimensional agreement by novelty visualization). We would expect that such a focus on the persons instead of content leads to detrimental effects because it increases normative influence in a group.

Future directions

It is apparent that the augmented group awareness tool used in this study was specifically tailored to the scenario of majority–minority conflict. However, it can be assumed that the general type of rating-based augmented group awareness tools can be adapted to other scenarios as well. For instance, other studies could investigate this tool not for group awareness, but for social navigation in a stricter sense, by requiring learners not to mutually rate their contributions, but to rate external sources like learning materials. For other scenarios it might be suitable to visualize the given instead of the received ratings. Moreover, depending on the research question, learners could rate contributions on different dimensions, e.g. liking, conclusiveness. The tool itself could use different means of aggregation and visualization. Whereas the tool in the current study simply used arithmetic means of agreement and novelty, other tools could visualize standard deviations (an indicator of the degree of conflict), correlations, or even make use of advanced statistical procedures like cluster analysis and factor analysis in real time. Finally, it will be an interesting question to compare direct social navigation (explicit ratings) with indirect social navigation, where learner behavior will be implicitly captured (cf. the study by Janssen et al. 2007). In the social navigation literature, indirect social navigation algorithms are often regarded as superior because they do not burden subjects with the potentially tiresome task of rating contributions. However, our discussion of the explanatory mechanisms for minority influence in this experiment might indicate that this additional burden might be a key factor in producing favorable learning results.

Conclusions

We believe that augmented group awareness tools enrich our repertoire of CSCL tools both for practical use and for scientific inquiry. While some considerations for the scientific

investigation of these tools were addressed in the preceding section, it is evident that practical use of augmented group awareness tools faces additional hurdles. Among the open questions are the following: Are learners willing to rate contributions in practice? Does mutual rating interfere with the mutually supportive nature of collaboration? Is evaluation apprehension an issue to be taken into account? Will the generation of ideas that lies at the heart of knowledge building be hindered because learners withhold their input for fear of negative ratings? How do augmented group awareness tools work for larger group sizes? While we think that each of these problems can be tackled, the practical usefulness of augmented group awareness tools certainly remains to be tested outside of laboratory confines.

In terms of the scientific analysis of augmented group awareness tools, we believe that they are open to investigations based on a range of epistemologies (Suthers 2006). While many processes involved in collaborative learning can be made visible and quantifiable with these tools, thereby lending themselves to an experimentally-oriented epistemology of knowledge communication, it is of course possible to hermeneutically describe and analyse knowledge building processes that take place during group discussions, and examine the ways they unfold under the influence of ratings and/or visualizations.

On a final note, it should be repeated that augmented group awareness tools as described in this study represent a potentially new philosophy of learner guidance. While they are far from being as directive as other methods (e.g. scripted cooperation), they avoid the pitfall of leaving collaborative groups without any guidance. Being well-informed but fully autonomous might be an interesting condition for collaborative learners that is well worth studying in entirely different contexts of CSCL.

References

Asch, S. E. (1956). Studies of independence and conformity: A minority of one against a unanimous majority. *Psychological Monographs*, *70* (whole no. 416).

Baker, M. J. (1994). A model for negotiation in teaching–learning dialogues. *Journal of Artificial Intelligence in Education*, *5*, 199–254.

Bazerman, M. H., Curhan, J. R., Moore, D. A., & Valley, K. L. (2000). Negotiation. *Annual Review of Psychology*, *51*, 279–314.

Brodbeck, F., Kerschreiter, R., Mojzisch, A., Frey, D., & Schulz-Hardt, S. (2002). The dissemination of critical, unshared information in decision-making groups: The effects of pre-discussion dissent. *The European Journal of Social Psychology*, *32*, 35–56.

Carroll, J. M., Neale, D. C., Isenhour, P. L., Rosson, M. B., & McCrickard, D. S. (2003). Notification and awareness: Synchronizing task-oriented collaborative activity. *International Journal of Human–Computer Studies*, *58*(5), 605–632.

Christiansen, N., & Maglaughlin, K. (2003). Crossing from physical workspace to virtual workspace: Be AWARE!. In D. Harris (Ed.) *Proceedings of the 10th International Conference on Human–Computer Interaction* (pp. 1128–1132). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research*, *64*, 1–35.

Deutsch, M., & Gerard, H. B. (1955). A study of normative and informational influence upon individual judgement. *Journal of Abnormal and Social Psychology*, *51*, 629–636.

Dillenbourg, P. (2002). Overscripting CSCL: The risks of blending collaborative learning with instructional design. In P. Kirschner (Ed.) *Three worlds of CSCL: Can we support CSCL?* (pp. 61–91). Heerlen: Open Universiteit.

Doise, W., & Mugny, C. (1984). *The social development of the intellect*. Oxford: Pergamon.

Endsley, M. (1995). Towards a theory of situation awareness in dynamic systems. *Human Factors and Ergonomics Society*, *37*(1), 32–64.

Gross, T., Stary, C., & Totter, A. (2005). User-centered awareness in computer-supported cooperative work-systems: Structured embedding of findings from social sciences. *International Journal of Human–Computer Interaction*, *18*, 323–360.

JrnlID 11412_ArtID 9037_Proof# 1 - 20/02/2008

Gutwin, C., & Greenberg, S. (2002). A descriptive framework of workspace awareness for real-time groupware. *Computer Supported Cooperative Work*, *11*, 411–446.

Heath, C. C., & Luff, P. (1992). Collaboration and control: Crisis management and multimedia technology in London Underground control rooms. *Computer Supported Cooperative Work*, *1*, 69–94.

Hastie, R., Penrod, S. D., & Pennington, N. (1983). *Inside the jury*. Cambridge: Harvard University Press.

Höök, K., Benyon, D., & Munro, A. (Eds.) (2002). *Designing information spaces: The social navigation approach*. London: Springer.

Janssen, J., Erkens, G., & Kanselaar, G. (2007). Visualization of agreement and discussion processes during computer-supported collaborative learning. *Computers in Human Behavior*, *23*, 1105–1125.

Johnson, D. W., & Johnson, R. T. (1979). Conflict in the classroom: Controversy and learning. *Review of Educational Research*, *49*, 51–61.

Kimmerle, J., & Cress, U. (2008). Group awareness and self-presentation in computer-supported information exchange. *International Journal of Computer-Supported Collaborative Learning*, *3*(1), 85–97.

Konstan, J. A., & Riedl, J. (2002). Collaborative filtering: Supporting social navigation in large, crowded infospaces. In K. Höök, D. Benyon, & A. Munro (Eds.) *Designing information spaces: The social navigation approach* (pp. 43–82). London: Springer.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2002). The sociability of computer-supported collaborative learning environments. *Educational Technology & Society*, *5*, 8–22.

Lim, L.-H., & Benbasat, I. (1993). A theoretical perspective on negotiation support systems. *Journal of Management Information Systems*, *9*, 27–44.

Linn, M., & Hsi, S. (2000). *Computers, teachers, and peers: Science learning partners*. Mahwah, NJ: Erlbaum.

Martin, R., Hewstone, M., & Martin, P. Y. (2007). Systematic and heuristic processing of majority- and minority-endorsed messages: The effects of varying outcome relevance and levels of orientation on attitude and message processing. *Personality and Social Psychology Bulletin*, *33*, 43–56.

McLeod, P., Baron, R. S., Marti, M. W., & Yoon, K. (1997). The eyes have it: Minority influence in face to face and computer mediated group discussion. *Journal of Applied Psychology*, *82*, 706–718.

Moscovici, S. (1976). *Social influence and social change*. London: Academic.

Roschelle, J. (1996). Learning by collaborating: Convergent conceptual change. In T. Koschmann (Ed.) *CSCL, Theory and practice of an emergent paradigm* (pp. 209–248). Mahwah, NJ: Erlbaum.

Schmidt, K. (2002). The problem with 'awareness'. *Computer Supported Cooperative Work*, *11*, 285–298.

Soller, A., Martinez, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *International Journal of Artificial Intelligence in Education*, *15*, 261–290.

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology*, *48*, 1467–1478.

Stewart, D. D., & Stasser, G. (1998). The sampling of critical, unshared information in decision-making groups: The role of an informed minority. *European Journal of Social Psychology*, *28*, 95–113.

Suthers, D. D. (2006). Technology affordances for intersubjective meaning making: A research agenda for CSCL. *International Journal of Computer-Supported Collaborative Learning*, *1*, 315–337.

Vinokur, A., & Burnstein, E. (1976). Novel argumentation and attitude change: The case of polarization following group discussion. *European Journal of Social Psychology*, *8*, 335–348.

Wickens, C. D., & Baker, P. (1995). Cognitive issues in virtual reality. In W. Barfield, & F. Furness (Eds.) *Virtual reality and advanced interface design*. Oxford: University Press.

Wood, W., Lundgren, Ouellette, J. A., Busceme, S., & Blackstone, T. (1994). Minority influence: A meta-analytic review of social influence processes. *Psychological Bulletin*, *115*, 323–345.