Coordinated Computer-Supported Collaborative learning: Awareness and Awareness Tools

Jeroen Janssen

Utrecht University, The Netherlands

Daniel Bodemer

University of Tübingen, Germany

Author Note

Jeroen Janssen, Department of Education, Utrecht University, The Netherlands.

Correspondence should be addressed to Jeroen Janssen, P.O Box 80140, 3508 TC Utrecht. E-mail: j.j.h.m.janssen@uu.nl.

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Abstract

Traditionally, research on awareness during online collaboration focused on topics such as the effects of spatial information about group members' activities on the collaborative process. When the concept of awareness was introduced to computer-supported collaborative learning (CSCL), this focus shifted to cognitive group awareness (e.g., information about group members' knowledge and expertise) and social group awareness (e.g., information about group members' contributions to the group process). In this paper, we show how both cognitive and social group awareness affect coordination of collaborative activities in the *content* (e.g., cognitive learning activities) and *relational* space (e.g., maintaining a positive group climate) of collaboration. Furthermore, we describe how cognitive and social group awareness tools (i.e., tools designed to enhance cognitive or social group awareness) may help learners coordinate their activities in both spaces. We present a conceptual framework that shows how group awareness affects coordination in both dialogical spaces and the effectiveness of collaboration.

Introduction

Computer-supported collaborative learning (CSCL) is regarded as a promising educational approach. A key reason for this is that many studies have demonstrated that combining the use of information and communications technology (ICT) and collaborative learning can be effective, efficient, and enjoyable. Lou, Abrami, and d'Apollonia (2001) have, for example, shown that combining small-group learning with the use of ICT is more effective for learning than combining individual learning with the use of ICT. Furthermore, CSCL seems to increase student motivation (Fjermestad, 2004). In spite of these positive effects of CSCL, many studies have also identified possible pitfalls when using CSCL (Kreijns, Kirschner, & Jochems, 2003). Examples of these problems are escalating conflicts among group members (e.g., Hobman, Bordia, Irmer, & Chang, 2002), free riding behavior and unequal participation (e.g., Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003; Savicki, Kelley, & Ammon, 2002), and discussions that lack depth, high-quality reasoning, and argumentation (e.g., Munneke, Andriessen, Kanselaar, & Kirschner, 2007). Although these pitfalls are not unique to CSCL (they also occur during face-to-face collaboration), some problems that learners may encounter in CSCL environments seem to be enhanced in these environments, for example due a lack of social presence or limited non-verbal cues such as gestures and facial expressions (Daft & Lengel, 1986; Kreijns et al., 2003; Short, Williams, & Christie, 1976).

In this contribution, we focus on coordination, coordination problems, how these problems might be created by a lack of awareness of group members' knowledge and activities, and how group awareness tools (GATs) might help to counter these problems. Because collaboration involves so many different activities that need to be performed by group members (e.g., discussing concepts related to the task, monitoring task progress, keeping a good group atmosphere), the need for *coordination* arises (Erkens, Jaspers, Prangsma, & Kanselaar, 2005). Coordination is an important activity during collaboration, one that “can be viewed as an activity in itself, as a necessary overhead when several parties are performing a task.” (Ellis, Gibbs, & Rein, 1992) This need to coordinate the collaborative process stems from the interdependence between group members during collaboration (cf., Johnson & Johnson, 2009). This means that groups require the mutual input of all group members to be successful. When coordination is absent or problematic, group members are likely to engage in conflicting or repetitive activities, which may disrupt or frustrate the collaborative process (Malone & Crowston, 1992).

Coordinating the Content and Relational Space of Collaboration

The different activities students perform during collaboration reflect group member interaction in two different dialogical spaces, namely the *content space* and the *relational space* of collaboration (Barron, 2003; Cole & Nast-Cole, 1992; Slof, Erkens, Kirschner, Jaspers, & Janssen, 2010). When students work on a group task, they need to exchange ideas and opinions, ask questions, produce arguments and counterarguments, and generally work towards producing a group product (i.e., content space of collaboration). The goal of interaction in the content space is to acquire a deeper understanding of the knowledge domain associated with the collaborative task. Activities in the content space of collaboration include *cognitive* and *meta-cognitive* activities, such as formulating answers, discussing concepts, and discussing the best strategy to solve the task.

On the other hand, collaboration also involves a social-relational aspect. Students have to perform social and communicative activities that establish group well-being and a common frame of reference. Hence, the goal of interaction in the relational space is aimed at aimed at establishing and maintaining shared understanding. Activities in the *relational space* enable students to interact meaningfully in the content space (Beers, Kirschner, Boshuizen, & Gijselaers, 2007; Kreijns et al., 2003). More specifically, interaction in the relational space is aimed at reaching shared understanding about concepts under discussion in the content space. This involves constructing a common frame of reference, helping students to detect, discuss and negotiate conflicting points of view (Barron, 2003). Examples of strategies employed in the relational space are focusing (i.e., maintaining a shared discussion topic) and checking (i.e., establishing whether exchanged information fits within the students' frame of reference, cf. Erkens, Jaspers, Prangsma, & Kanselaar, 2005). Furthermore, activities in the relational space (e.g., exchanging compliments, giving positive feedback) also contribute to the well-being of group members and to group cohesion (Slof et al., 2010).

The collaborative activities in both spaces thus differ considerably. Moreover, group members sometimes divide their tasks, causing coordination problems to arise during collaboration (Janssen, Kirschner, Erkens, Kirschner, & Paas, 2010; Janssen, Erkens, & Kirschner, 2011).

Awareness, Group Awareness, and Group Awareness Tools

One reason why coordination problems may be more prevalent during CSCL than in face-to-face (FTF) collaboration is because CSCL environments offer only a small fraction of the perceptual information that is usually available during FTF collaboration (Buder, 2011; Gutwin & Greenberg, 2002). This means that in CSCL environments it is often difficult to know for example on what tasks group members are working, what group members are contributing to the group process, and which (unique) knowledge and skills group members possess (Engelmann & Hesse, 2010; Janssen, Erkens, Kanselaar, & Jaspers, 2007). Knowledge about group members' behavioral activities (e.g., what are they doing?), their knowledge and skills (e.g., what do they know and what are they able to do?) and social activities (e.g., how is the group functioning?) has been called awareness information (cf., Janssen et al., 2011; Schmidt, 2002). Perceiving and processing awareness information is a prerequisite for the development of awareness (Bodemer & Dehler, 2011). Although this information can be obtained by observing what group members say and do, often this information is difficult to gather or implicit (i.e., students are unaware their teammates possess knowledge or skills that might be useful for the task at hand).

The issue of awareness has received considerable attention in the area of computer-supported cooperative work (CSCW, Dourish & Bellotti, 1992). Much of the research on promoting awareness in CSCW environments has focused on providing participants with information about spatial activities (e.g., seeing who is online, seeing what others are doing and what parts of the screen they are working on). However, when the concept of awareness was introduced to CSCL (see for example Kreijns & Kirschner, 2001), the focus shifted from spatial information to information about cognitive and social aspects of the collaborative process (Buder, 2011). In CSCL research, the term “group awareness” is often used to refer to group members’ knowledge of how the group is functioning (e.g., who is contributing to which task, who are the active participants in the group discussions, etc.) and how expertise is divided among the group (cf., Bodemer & Dehler, 2011; Buder & Bodemer, 2008; Engelmann & Hesse, 2010; Janssen et al., 2011).

When group awareness is a problem of perception and information (Romero-Salcedo et al., 2004), why would this be problematic for CSCL? For example, if students do not know what their group members are doing, they might devote a lot of time and energy to obtaining this information. If they do not obtain this information, they might become frustrated or might accidentally duplicate the activities their group members are performing. Thus, when students perceive and process group awareness information, it can reduce group members' efforts to coordinate their actions, can increase their efficiency, and reduce the chance of errors (Gutwin & Greenberg, 2004). As noted before, CSCL requires students to perform several different activities and the coordination of these activities with the activities of group members. For instance, group members need to coordinate the relational space of collaboration (Barron, 2003). This requires group members to gather awareness information to answer questions, such as: What do my group members think about my contribution to the group? Is the collaboration going well? Are all group members contributing equally to the group task? Likewise, coordinating the content space of collaboration (Slof et al., 2010), requires group members to answer questions such as: Do my group members have information that is also important for me? Do my partners have the same knowledge as I have? When students are able to answer these questions, this may help them to establish shared understanding and common ground (Beers et al., 2007; Clark & Brennan, 1991), or to exchange information that is not known to all group members (Stasser, Vaughan, & Stewart, 2000). This may too facilitate the coordination of the collaboration process (Engelmann, Tergan, & Hesse, 2010; Erkens et al., 2005). Thus, while working in a CSCL environment, group members require awareness information that enables them to coordinate the content space as well as the relational space of collaboration (Dourish & Bellotti, 1992; Gross, Stary, & Totter, 2005).

To assist students in collecting the required information to collaborate effectively in CSCL environments, group awareness tools (GATs) have been developed (Kreijns & Kirschner, 2001). Recently, several researchers have investigated the effects of GATs on group processes in CSCL environments (e.g., Janssen, Erkens, & Kanselaar, 2007; Kimmerle & Cress, 2008; Leinonen & Järvela, 2006). These tools provide group members with information about the content and/or relational space, such as group members' opinions or knowledge regarding a topic (i.e., cognitive group awareness, Bodemer & Buder, 2006; Engelmann & Hesse, 2010) or group members' participation rates (i.e., social group awareness, Jermann & Dillenbourg, 2008; Kimmerle & Cress, 2009).

In the remainder of this article we will explore cognitive and social group awareness further. We will define and explain how cognitive group awareness can facilitate coordination of group activities in the content space, and how social group awareness can enhance the coordination of group activities in the relational space. Moreover, we will discuss how cognitive and social GATs can support learners in establishing group awareness by gathering and providing selective information about their learning partners. The aim of this contribution is to (1) discuss which collaborative mechanisms are supported by GATs, (2) how design features of GATs affect their effectiveness, and (3) the empirical research on the effects of GATs. By doing so, we hope to contribute to a theory of how GATs foster learning in CSCL-environments.

Cognitive Group Awareness: Coordinating the Content Space

Comparable to social group awareness (see below), the notion of cognitive group awareness is a departure from the traditional conceptualization of awareness that can be found in the CSCW literature. We define cognitive group awareness as awareness that results from information about group members' knowledge, the information they possess, or the opinions they hold, all of which can be used to coordinate activities in the content space of collaboration. Thus, cognitive group awareness is different from other forms of awareness which are investigated in the CSCW literature, such as informal awareness (e.g., Who is online for communication?, cf. Gross et al., 2005) or workspace awareness (e.g., What are my group members doing? cf. Gutwin & Greenberg, 2002), because sometimes it cannot be directly observed or inferred from group members' activities in a CSCL environment (Bodemer, 2011). This is the case for example, when group members accidentally do not share information that is relevant for the task.

Cognitive group awareness is considered to be an important prerequisite for successful collaboration. Effective and efficient collaboration depends on how well students know which knowledge and expertise their partners possess (cf., Wegner, 1987). When this is the case, each group member can benefit from the knowledge and expertise of the others. Furthermore, because group members are aware of each other's strengths and weaknesses as a result of the process of discussing and sharing of information, the effort required to coordinate activities in the content space of collaboration is subsequently reduced (Wegner, 1995).

The benefits of cognitive group awareness can also be explained using cognitive load theory (Sweller, Van Merriënboer, & Paas, 1998; Sweller, 2010). On the one hand, the possibility to share the burden of information processing, gives group members an advantage over individual learning situations, because they need to invest less cognitive effort when carrying out their learning task (Kirschner, Paas, & Kirschner, 2009). On the other hand however, the need to coordinate and communicate in collaborative learning situations poses an additional cognitive burden on group members which individual learners do not experience (Dillenbourg & Bétrancourt, 2006). For example, learners have to invest mental effort for grounding processes (e.g., verify whether their understanding of the information matches the other's understanding of the information Clark & Brennan, 1991), for modeling the learning partners' knowledge or beliefs (Dehler, Bodemer, Buder, & Hesse, 2009; Nickerson, 1999).

When the collaboration-based cognitive demands become too high, this may lead to errors and repetitive activities (Ciborra & Olson, 1988). However, in cases in which group members are aware of their teammates' knowledge or opinions, the costs of collaborating may be decreased because group members do not have to devote as much effort to the coordination of activities in the content space of collaboration.

In addition to reducing cognitive load, knowledge about other learners' knowledge or opinions can encourage specific collaborative efforts that are beneficial for learning, such as interacting and discussing with each other in a structured and goal-oriented way (Bromme, Hesse, & Spada, 2005). Thus, referring to the terminology of cognitive load theory, cognitive group awareness can potentially not only reduce extraneous cognitive load but also encourage germane learning processes (cf. Bodemer, 2011). Germane learning processes are activities that foster learning processes; in the case of collaboration these may for example be caused by giving elaborate explanations about one's ideas or solutions (Janssen et al., 2010).

Cognitive group awareness can trigger beneficial learning behavior in different but interacting ways. First, it provides a basis for adapting learners' contributions to their learning partners' knowledge or beliefs. For example, questions and explanations can be formulated that consider the learning partners' expertise regarding a learning topic (Dehler-Zufferey, Bodemer, Buder, & Hesse, 2011). Furthermore, it can initiate processes of information sharing. While providing and discussing unshared information is important for effective collaboration, it has been shown that groups often focus on information they have in common (Stasser et al., 2000). However, knowledge about shared and unshared information can lead to a higher rate of discussing information that only one group member possesses (e.g., Schittekatte & Van Hiel, 1996). Another way of encouraging germane learning behavior is based on comparison processes (e.g., comparing one's own ideas and solutions to those of a group member and noticing one's ideas are incorrect). Cognitive group awareness enables learners to identify gaps and deficiencies in their own knowledge, to avoid illusions of comprehension, and thus to initiate learning activities that aim at gaining missing knowledge (Sangin, Molinari, Nüssli, & Dillenbourg, 2011). Similarly, perceived differences between learners regarding knowledge, assumptions or opinions can trigger collaborative elaboration processes such as thoroughly discussing controversial perspectives (Bodemer, 2011), which can lead to meaningful learning (e.g., Lowry & Johnson, 1981).

Enhancing Cognitive Group Awareness Using Cognitive Group Awareness Tools

Recently, several GATs have been developed in order to provide learners with cognitive information about their collaboration partners. These tools differ with regard to (1) the information gathered from and provided to members of a learning group, (2) how cognitive group awareness information is gathered, and (3) how this information is subsequently provided to the group members (cf. Buder, 2011; Schmidt, 2002). Table 1 gives an overview of the different studies that addressed cognitive group awareness. Additionally, the effects of the different cognitive GATs on the online collaboration process, group performance, and individual achievement are summarized.

Providing Information about Group Members' Knowledge and Information

Cognitive GATs provide learners with information on other learners' knowledge or opinions regarding a topic. Thus, they focus on information that is not directly observable to group members even in face-to face communication. This feature distinguishes cognitive GATs from other types of GATs which provide information that can basically be perceived by group members in face-to-face settings (e.g., the presence of others, their appearance, or their rate of participation, cf. Carroll, Rosson, Farooq, & Xiao, 2009).

Most cognitive GATs focus on providing learners with information about the information and knowledge their partners' possess. A strategy that is used often to gather this information is to ask group members to first individually *construct a concept map* of a learning issue or a problem at hand (Engelmann et al., 2010; Engelmann & Hesse, 2010; Engelmann & Hesse, 2011; Molinari, Sangin, Nüssli, & Dillenbourg, 2008; Schreiber & Engelmann, 2010a). Next, during a collaboration phase, group members have access to their own concept map as well as those of their group members. This allows for *comparisons* between students' own knowledge and the knowledge of their partners. Furthermore, the cognitive group awareness that is available to learners is *very detailed*. The evidence from these studies shows that such an approach can increase learners' awareness of their partners' knowledge and information (Engelmann et al., 2010; Schreiber & Engelmann, 2010a), which may in turn help students to discuss knowledge that is not available to all group members (unshared information, cf., Engelmann & Hesse), and to build on information held by another group member (Engelmann et al.). The research done by Engelmann and colleagues shows that this approach can have positive effects on group performance (i.e., problems may be solved faster and better, group concept maps become more adequate) and individual achievement (i.e., increased performance on a knowledge posttest).

Additionally, the research done by Molinari et al. (2008) shows that the effects of such cognitive GATs may interact with resource interdependence (Buchs & Butera, 2009). In their research, Molinari et al. employed two conditions: (1) a condition in which students received similar information (SI), and (2) a condition in which students received complementary information (CI). In the CI condition, students were interdependent on each other because they had different information resources. The work done by Molinari et al. shows that in the SI condition, objects in the group concept map were more often manipulated by all group members and that individual learning was greater. Molinari et al. hypothesized that this may be due to the fact that learners in the CI condition looked longer at their own concept map and also compared their own concept map more often to the concept map of their partner. This may have drawn students' attention from the task at hand, resulting in less than optimal performance.

Another approach to provide learners with information about group members' knowledge is to use scores on a multiple choice *knowledge pretest*. A cognitive GAT may then provide a visualization of how well one's learning partner performed on this test (Sangin et al., 2011). Although such a tool offers *less detailed* information about the knowledge of one's partner than for example a concept map, Sangin et al. demonstrated that students still use the tool to have more elaborate discussions and to verify and negotiate their information more often, resulting in increased individual learning.

The approach chosen by Gijlers and De Jong (2009) collects information about learners' knowledge by asking them to provide their opinion (true or false) about propositions generated by the learning environment. These opinions are then fed back to the dyad. Gijlers and De Jong were able to demonstrate that providing this information triggered enhanced discussion of (unique) propositions and subsequently increased posttest performance.

Providing Information about Group Members' Opinions or Understanding

To provide group members with cognitive group awareness information, an awareness tool can also collect information about the group members' opinions or their level of understanding. This is mostly done using a form of *self- or peer assessment*. When using self-assessment, several researchers focused on assessment of the students' individual understanding of the learning material. Dehler et al. (2011) and Dehler-Zufferey (2011) for example, asked dyad members to read several pages and then to assess for each paragraph whether they understood the paragraph sufficiently to explain it to their partner. This information was then used by the awareness tool to provide a visualization of whether or not dyad members understood the concerning information. Compared to a control group without awareness support, the tool helped students with knowledge deficiencies to ask relevant questions, to give relevant explanations, and to perform better on a knowledge posttest.

Another way to collect cognitive group awareness information is to *rate other learners' statements or contributions*. The cognitive GAT developed by Buder and Bodemer (2008), for example, requires students to indicate how strongly they agree with discussion contributions made by their group members (as an indication of the learners' opinions), and whether they think a contribution provided new input or a novel perspective to the discussion (as a basis to filter irrelevant and redundant information). The gathered information is provided to the group in a graph which visualizes for each contribution whether group members agreed with it and whether they thought it was novel. This approach, however, was less successful than the approach chosen by Dehler et al. (2011), because Buder and Bodemer found a decrease in the number of discussion contributions when students worked with the cognitive awareness tool, and did not demonstrate an effect of the tool on group performance or achievement.

Conclusions

In sum, the cognitive GATs that have been investigated so far have been relatively successful when considering their impact on the collaborative process, group performance, and individual achievement. Concerning the collaborative process, enhanced group awareness facilitates coordination of the content space, because it allows group members to take actions such as adapting their explanations and questions to the level of comprehension of their partner (Dehler-Zufferey et al., 2011), and to discuss relevant but unshared information more efficiently (Engelmann & Hesse, 2011). This can be attributed to the fact that these cognitive GATs are successful at providing group members with relevant information that allows them to accurately assess the knowledge and opinions of their partners (e.g., Engelmann & Hesse, 2010; Schreiber & Engelmann, 2010b), thus facilitating coordination of the content space. Furthermore, in several studies this facilitation of coordination of the content space also helped group members to perform better as a group (e.g., Engelmann & Hesse, 2011), individually (e.g., Dehler-Zufferey et al., 2011), or both (e.g., Bodemer, 2011).

From Table 1 it becomes clear that the cognitive GATs that have been investigated thus far differ not only with respect to the cognitive awareness information that they visualize, but also in the way they visualize this. Cognitive GATs differ in the amount of *detail* they offer about group members' knowledge and expertise. The GAT of Sangin and colleagues (2011), for example, uses performance on a pretest but feeds this back in a relatively *coarse* way: the awareness tool displays the percentage of correctly answered questions. Tools that gather and provide concept maps (e.g., Engelmann, Dehler, Bodemer, & Buder, 2009) provide very detailed information about the group members' knowledge structures. Both providing coarse group awareness information and providing it in a detailed manner experimentally proved to facilitate the coordination of activities in the content space of collaboration and increased group performance.

Most cognitive GATs are designed to allow for *comparison* between the learner's own information, knowledge, or opinions and the information, knowledge, and opinions held by group members. This allows learners to compare their own cognitive information with that of their group members. The tools differ however with respect to the level of salience of the similarities or differences in cognitive information (cf., Bodemer & Dehler, 2011; Buder, 2011). Tools that gather and provide concept maps (e.g., Engelmann et al., 2009) give detailed information about group members' knowledge structures. However, similarities and differences between the learners' cognitive information may be difficult to extract if the pieces of information to compare – as is the case with elaborate concept maps – are very complex. The tools of Bodemer (2011) and Dehler et al. (2009) are, for instance designed for maximal salience of similarities and differences in order to tacitly guide learners' communication behavior (cf., Buder, 2011). Both tools offer visualizations of small pieces of the learning partners' cognitive information adjacent to each other. Experiments showed that if learners are provided with such kind of knowledge constellations, they adapt their discussion behavior to their awareness of knowledge distributions, such as talking about perceived conflicting perspectives in a more interactive way (e.g., Bodemer, 2011).

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Social Group Awareness: Coordinating the Relational Space

Although several authors refer to social group awareness (or social awareness), they differ in their definitions of the concept. For example, when social group awareness is defined as group members' perception of the activities and online status of others (cf., Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003; Kimmerle & Cress, 2008), it seems to be directly linked to social presence (Kreijns et al., 2003; Short et al., 1976). In other definitions (e.g., Bødker & Christiansen, 2006), social group awareness is defined more broadly to include group members' awareness of the social situation of the rest of the group (Gross et al., 2005, call this group-structural awareness). In this definition, social group awareness refers not only to the perception of the other as a “real” person, but also to awareness about what group members are doing, with who they are communicating, how they are contributing to the common group goal, their roles, and so on. In the former case, social group awareness can be enhanced by simply providing users with information about the online status of group members or with pictures or embodiments (i.e., avatars) of the group members. In the latter case, such information is insufficient to enhance social group awareness. When social group awareness is defined more broadly, it becomes necessary to provide students’ with up-to-date information about what group members are doing, their communicative behavior, and their contribution to the group task. We therefore define social group awareness as awareness generated by information about group members’ collaborative behavior (e.g., equality of participation, number of contributions to online discussion), which can be used to coordinate activities in the relational space. To do so, group members have to plan, monitor, and evaluate the group’s collaborative process (Janssen, Erkens, Kanselaar, & Jaspers, 2007; Yager, Johnson, Johnson, & Snider, 1986). This means, for example, that group members require information about their fellow group members’ participation in the online discussions (e.g., Jermann & Dillenbourg, 2008; Kimmerle & Cress, 2009) and about the communicative style of the group as a whole (e.g., Janssen, Erkens, & Kanselaar, 2007; Leshed et al., 2009).

Enhancing Social Group Awareness using Social Group Awareness Tools

Different social GATs have been developed to enhance social group awareness. These tools differ along several dimensions: (1) the information that is used to enhance social group awareness, (2) whether the system generates the information or whether users are instead required to provide input for the information, and (3) the way the tools provide the users with the information. Table 2 shows the different studies that investigated social group awareness. Furthermore, the effects of the different social GATs on the collaborative process, group performance, and individual achievement are summarized.

Providing Quantitative Information about the Relational Space

GATs may be designed to facilitate coordination of the relational space of collaboration. To do so, they often provide group members with *quantitative* information about collaborative processes that are relevant for coordination of the relational space (Gross et al., 2005).

This is often done by providing students with information about group members' participation during the collaborative process. Participation refers to how actively students are involved in the group process, for example by making contributions to the online discussion or by actively contributing to a group product. Because CSCL environments usually allow students to carry out both task-related activities (e.g., changing parameters in a simulation, choosing a strategy) and communicative activities (e.g., sending chat or forum messages), different sources of information can be used to provide students with awareness information about participation. Awareness information can thus pertain to participation in the content space or in the relational space.

Kimmerle, Cress, and Hesse (2007) and Kimmerle and Cress (2008; 2009) provided students with information about the number of contributions to a shared database made by each group member. This gave group members information about participation in the content space. The research by Kimmerle shows that this can inspire students to participate more actively in the content space. Similar results were obtained by Michinov and Primois (2005). In contrast, although their GAT also focused on participation in the content space, Jongsawat and

Premchaiswadi (2009), did not find increased learner participation in the content space. They did, however, demonstrate that their GAT positively affected group cohesion and commitment as well as group performance.

Another option is to provide users with information about group members' contribution to the process of online dialogue and negotiation of meaning (e.g., relational space). Such an approach was for example taken by Janssen, Erkens, Kanselaar, and Jaspers (2007), because their tool provides students with information about the number of chat messages sent by each group member. Similarly, Leshed et al.'s (2009) social GAT gives feedback about the number of words typed in a chat room by each participant. Providing students with information about participation in the relational space has been effective in increasing students' awareness of activities in the relational space. In turn, this raised awareness has been found to increase students' communicative activity during collaboration (Janssen, Erkens, Kanselaar, & Jaspers; Janssen et al., 2011; Leshed et al.).

Providing Qualitative Information About the Content and Relational Space

Social GATs can also give qualitative information about participation, for example by comparing participation by a certain norm or by interpreting the content of contributions. Janssen, Erkens, and Kanselaar (2007) developed a GAT that analyzed the content of the chat messages sent using discourse markers (Erkens & Janssen, 2008; Schiffrin, 1987). Discourse markers were used to identify instances where group members agreed with each other (consensual discussions) and where group members disagreed (critical discussions). The results were then fed back to students. Leshed et al. (2009) also provided group members with an indication of agreement using linguistic markers. Finally, Jermann and Dillenbourg (2008) described a GAT that visualized the balance between discussing (chatting) and using a simulator.

Their visualization also gave information about whether this balance was acceptable or not (e.g., too much discussion) based on a certain *norm*. The results of these studies show that qualitative GATs can affect the collaborative process. The evidence that these tools affect group performance or individual achievement is limited, however.

In the previous examples, the learning environment collects information about activities in the relational space in order to provide students with qualitative awareness information (e.g., agreement or discussion). With other GATs, the input of students may be required to provide the group with relevant social awareness information, for instance by rating their group members' friendliness. Phielix and colleagues (Phielix, Prins, & Kirschner, 2010; Phielix, Prins, Kirschner, Erkens, & Jaspers, 2011) reported a social GAT that asked students to rate their group members (i.e., peer assessment) and their selves (i.e., self assessment) on several occasions on six variables (influence, friendliness, cooperation, reliability, productivity, and quality of contribution). This information was then fed back to the group in such a way that students could (1) compare their self-assessments to the assessments given about them by their peers, and (2) determine how each student was on average perceived by his/her group members. Phielix et al. showed that using user input to increase social group awareness can stimulate group satisfaction.

Conclusions

Summarizing, the social GATs that have been examined thus far mostly affected the collaborative process (e.g., participation in both content and relational space, equality of participation). In most studies investigating the effects of social GATs the effect of these tools on group performance or individual achievement was not studied (e.g., Kimmerle & Cress, 2009; Leshed et al., 2009) or could not be demonstrated empirically (Janssen, Erkens, Kanselaar, & Jaspers, 2007).

From Table 2 it becomes clear that the social GATs that have been investigated thus far differ in the way they visualize the social awareness information. Similar to cognitive GATs, social GATs often allow students to directly *compare* their own behavior to that of their group members. The tool developed by Janssen, Erkens, Kanselaar, and Jaspers (2007), for example, displays the participation rates of each group member and thus makes each participant identifiable. This creates opportunities for social comparison: when comparing themselves to other group members, students may be motivated to set higher standards for themselves (e.g., Kimmerle & Cress, 2009; Michinov & Primois, 2005). In contrast, when a group instead of a comparison format is used (e.g., the tool provides only information about the behavior of the group as a whole), such comparisons are impossible. Kimmerle and Cress demonstrated in their studies that students more often use a GAT which allows them to make comparisons compared to a GAT that does not allow such comparisons (Kimmerle & Cress, 2009). Furthermore, Kimmerle and Cress (2007; 2008) demonstrated that when comparison of participation rates was possible, this led to increased participation in the content space.

Another important difference between social GATs is whether participation is visualized in a *cumulative* or in an *absolute* format. In an absolute format, the number of contributions is displayed per time unit (e.g., 10 minutes). Kimmerle and Cress (2009) demonstrated that students posted more contributions when using the cumulative format compared to the absolute format. Their explanation for this difference is that although an absolute format may be easier to comprehend, a cumulative format gives a more positive impression of the group (i.e., the total number of contributions always increases, while the number of contributions in a certain time period may be lower than the previous) which may be more motivating.

--- INSERT TABLE 2 ABOUT HERE ---

A Conceptual Framework for Cognitive and Social Group Awareness in CSCL Environments

Figure 1 presents a conceptual framework for cognitive and social group awareness. This framework is based on the concepts discussed previously. As the previous paragraphs have shown, cognitive and social group awareness have been investigated in different lines of research. In both lines, researchers have attempted to increase cognitive or social group awareness by enhancing CSCL environments with either cognitive GATs or social GATs. Figure 1 therefore presents both forms of awareness separately. In the studies conducted thus far, cognitive group awareness has mostly been addressed by providing information about the knowledge, information, understanding, and opinions of one's partner(s). Social group awareness has been addressed by providing quantitative information (e.g., participation in content and relational space) or qualitative information (e.g., quality of group discussion) about the collaborative process.

One might intuitively assume that cognitive GATs facilitate coordination of collaboration in the content space, whereas social GATS facilitate coordination of collaboration in the relational space. Figure 1 however shows that this assumption is not entirely correct. Cognitive GATs have also been found to facilitate coordination of the relational space, for example by stimulating the process of negotiation of meaning and grounding (Sangin et al., 2011) or by fostering a positive group atmosphere (Engelmann & Hesse, 2010). We propose that cognitive group awareness not only facilitates coordination of the content space (e.g., discussing unshared information, elaborating on ideas), but also facilitates coordination of the relational space. Central here is the notion that although the content and relational space have been proposed as distinct dialogical spaces, the two spaces actually overlap and interact. Coordination activities in the relational space might for example strengthen coordination in the content space, as is the case when collaborating partners for example tune their explanations and arguments to the knowledge and level of comprehension of their partner (Erkens et al., 2005) thus facilitating effective sharing of ideas and co-elaboration of knowledge.

Conversely, social group awareness not only facilitates coordination of the relational space, but may also help to coordinate the content space. For example by providing users with social group awareness information about both the amount of discussion in their group and the amount of problem-solving activities Jermann and Dillenbourg (2008) not only found increased coordination of the relational space (i.e., more symmetry in collaborative contributions) but also of the content space (i.e., increased participation in discussion in the content space).

In sum, Figure 1 shows how cognitive and social group awareness may facilitate coordination in both dialogical spaces. Furthermore, the Figure and the studies discussed previously show that by facilitating the coordination of the cognitive and relational space contribute to the effectiveness of collaboration. In other words, when cognitive or social GATs succeed in facilitating coordination in either the content or relational space of collaboration, students may demonstrate higher individual achievement and groups may perform better.

--- INSERT FIGURE 1 ABOUT HERE ---

Group Awareness Research: Trends and Issues

The previous paragraphs outlined the importance of cognitive and social group awareness for CSCL and described how awareness tools may facilitate the coordination of collaboration. To conclude this contribution, we want to look back on research trends in group awareness research and identify issues that need to be addressed in future research.

It is encouraging to note that nearly all of the studies that investigate the effects of GATs employ an experimental design. This allows for a sound comparison between situations in which group members have access to a GAT and situations in which they do not have access to such a tool. This can give insights into how using a GAT affects (1) the coordination of collaboration, and (2) effectiveness and efficiency of collaboration. We agree with Buder (2011), however, that it is necessary to start moving away from making relatively straightforward comparisons (e.g., comparing tool conditions to no tool conditions) to setting up experiments that allow us to test which features of a group awareness tool work under specific circumstances. An example of this is the work carried out by Kimmerle and Cress (2009). They compared a GAT that offered the opportunity to directly compare one's own behavior to the behavior of teammates to a GAT that did not allow such a direct comparison. In the comparison condition, students were more inclined to use the group awareness tool. Such a research approach could have two advantages: on the one hand it might help designers create more effective GATs, while on the other hand it will help advance group awareness research both empirically and theoretically.

A second trend in group awareness research is that researchers tend to focus solely on either cognitive or social group awareness. This somewhat surprising, because both forms of awareness are used to facilitate coordination and collaboration (albeit in different dialogical spaces). One of the issues lying ahead for group awareness research is to investigate how cognitive and social awareness interact. Can one form of awareness be considered more important than another? Or is it the case that social group awareness is more important during the storming and norming phase of collaboration, whereas cognitive group awareness is needed more during the performing phase (Tuckman, 1965)? A related issue concerns the question whether it is possible (and desirable) to combine both cognitive and social awareness information into a single group awareness tool. It could be argued that for effective coordination of collaborative activities, both forms of awareness are required, thus necessitating a group awareness tool that provides users with both types of awareness information.

It is also interesting to note that, although most studies employ an experimental design, researchers also investigate variables that may mediate the effectiveness and efficiency of GATs (e.g., Dehler et al., 2011; Janssen et al., 2011; Sangin et al., 2011). For example, Janssen et al. investigated how the use of a social GAT which gave feedback about group members' participation affected coordination and collaboration. Their study showed that the effect of using this social GAT was partially mediated by social group awareness. The effect of using the GAT on coordination and collaboration was therefore indirect rather than fully direct: using the tool increased social group awareness, which in turn affected how students' coordinated their collaboration. Systematically identifying and investigating variables that mediate the effect of GATs on online collaboration, is another step forward that group awareness research could make in the future.

The use of GATs is often not coerced (e.g., Beers et al., 2007) or scripted (e.g., Weinberger, Ertl, Fischer, & Mandl, 2005). This means that students usually can decide for themselves whether or not they want to use a group awareness tool. This also implies that under such conditions groups will vary in their use of a group awareness tool. Some groups will use their GAT often, while others will use it only occasionally because they for example do not perceive the added value of its use. The effect of GATs on CSCL will therefore depend (at least in part) on group members' ability to make adequate choices about its use for their collaboration

(Clarebout & Elen, 2006; Janssen et al., 2011). This could for example explain why GATs were found to affect group members' participation during online discussions in the studies conducted by Michinov and Primois (2005) and Janssen, Erkens, Kanselaar, and Jaspers (2007), while such an effect was not found by Jermann and Dillenbourg (2008), although in all three studies the social GATs gave information about group member participation. Another direction for group awareness research could therefore be to examine whether scripting or coercing the use of GATs has an additional advantage compared to letting students decide for themselves whether they want to use the tool (Buder, 2011).

Group awareness research in the CSCL community has extended the definition and use of the awareness-concept that was traditionally found in the CSCW literature by incorporating non-observable cognitive and social awareness aspects of collaboration. In doing so, CSCL researchers are able to develop mechanisms to foster the coordination of activities in both the content and relational space of collaboration. Although the issues raised above illustrate that group awareness research still has several empirical and theoretical issues that need to be explored, this need not be considered a failure of group awareness research. Rather, we are convinced that one of the virtues of group awareness research for CSCL is the fact that has been able to spawn new lines of research in the CSCL community. It is therefore our belief that group awareness research will continue to contribute to the field CSCL in the future.

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Figure Captions

Figure 1

Framework of relationships between cognitive and social group awareness, coordination of the content and relational space, and effectiveness of collaboration.

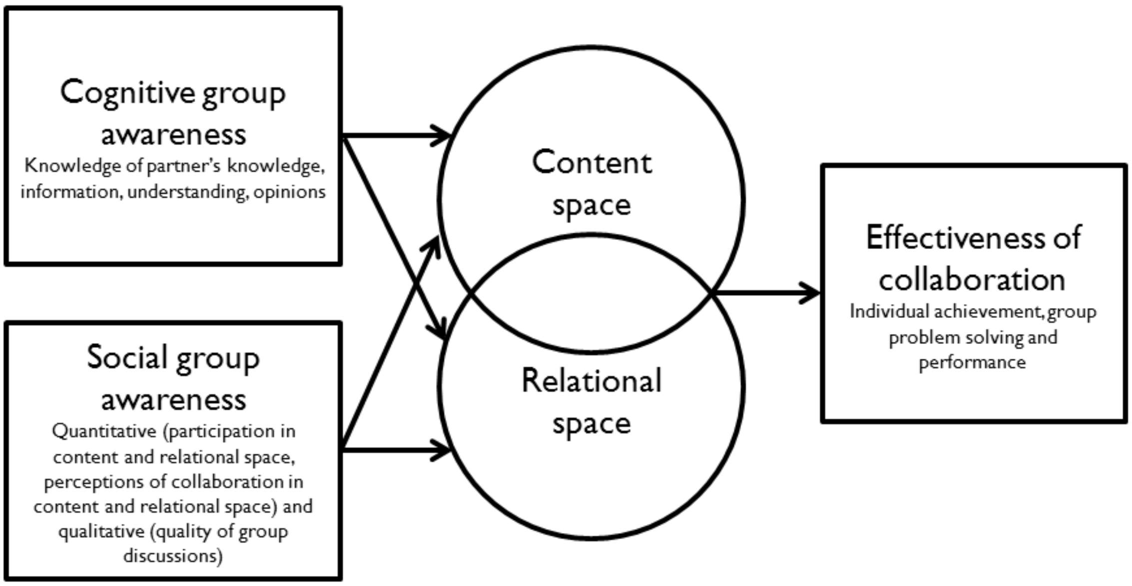

Figure 1

Framework of relationships between cognitive and social group awareness, coordination of the content and relational space, and effectiveness of collaboration.

Table 1

Overview of Studies Investigating Cognitive Group Awareness Tools.

Publication	*Information that is provided*	*How is information gathered?*	*Characteristics of the visualization*	*Effects on collaboration processes*	*Effects on group performance and/or achievement*
Bodemer (2011)	* Partner knowledge * Group knowledge	* By environment	* Comparison possible * Members identifiable * Detailed * Non-normative * Continuous	* Increased discussion of conflicting perspectives	* Increased performance on individual knowledge test * Increased problem solving performance
Buder & Bodemer (2008)	* Agreement with contributions made by group members * Novelty of	* Rating of group member contributions	* Comparison possible * Members identifiable * Detailed * Non-normative	* Decreased # of contributions	* No effect on correctness of contributions

	contributions made by group members		* Continuous		
Dehler et al. (2011)	* Partner's understanding of information	* Ratings of own understanding of information	* Comparison possible * Members identifiable * Coarse * Non-normative * Continuous	* Increased question asking * Increased explaining behavior	* No effect on individual posttest
Dehler-Zufferey et al. (2011)	* Partner's knowledge and information	* Ratings of own understanding of information	* Comparison possible * Members identifiable * Coarse * Non-normative * Continuous	* Explanations and questions adapted to comprehension of partner	* Increased performance on inferential knowledge test
Engelmann & Hesse (2010)	* Partner knowledge and information	* Concept maps constructed by partners	* Comparison possible * Members identifiable * Detailed	* Increased knowledge of partners'	* Problems solved faster * Less correct

			* Non-normative * Continuous	knowledge and information * Increased perception of positive group atmosphere	relations in group concept maps * Increased problem-solving performance
Engelmann & Hesse (2011)	* Partner knowledge and information	* Concept maps constructed by partners	* Comparison possible * Members identifiable * Detailed * Non-normative * Continuous	* Unshared information discussed sooner * Unshared used more in group concept map	* Increased individual problem solving * Increased quality of group concept maps * No increased group performance
Engelmann et al. (2010)	* Partner knowledge and information	* Concept maps constructed by	* Comparison possible * Members identifiable	* Increased knowledge of	* Increased quality of concept maps

		partners	* Detailed * Non-normative * Continuous	partners' knowledge and information * Increased uptake of partner information	* No increased group performance
Gijlers & De Jong (2009)	* Partner opinion (true/false) about system generated propositions	* Group members indicate opinion (true/false) about system generated propositions	* Comparison possible * Members identifiable * Detailed * Non-normative * Continuous	* Increased discussion of (unique) propositions	* Increased posttest performance
Molinari et al. (2008)[1]	* Partner knowledge and information	* Concept map constructed by partner	* Comparison possible * Members identifiable * Detailed	* Increased co-manipulation of objects in SI	* Increased individual learning in SI condition

[1] Study did not employ a control group (i.e., groups without cognitive group awareness tool). Rather, the available information was varied between conditions: same information (SI) versus complementary information (CI).

			* Non-normative * Continuous	condition	
Sangin et al. (2011)	* Partner's performance on knowledge test	* By environment	* Comparison not possible * Members identifiable * Coarse * Non-normative * Discontinuous	* Increased elaborative discussion * Increased knowledge verification and negotiation * Increased use of uncertainty markers	* Increased individual learning
Schreiber & Engelmann (2010)	* Partner knowledge and information	* Concept maps constructed by partners	* Comparison possible * Members identifiable * Detailed * Non-normative * Continuous	* Increased knowledge of partners' knowledge and information	* Problems solved faster * Increased group performance

Table 2

Overview of Studies Investigating Social Group Awareness Tools.

Publication	*Information that is provided*	*How is information gathered?*	*Characteristics of the visualization*	*Effects on collaboration processes*	*Effects on group performance and/or achievement*
Janssen, Erkens, Kanselaar, & Jaspers (2007)	* Quantitative: Participation in relational space	* By environment	* Comparison possible * Members identifiable * Coarse * Cumulative * Non-normative * Continuous	* Increased awareness * Increased participation in relational space * Increased equality of participation in relational space * Increased coordination of relational space	* No effect on group performance

Janssen, Erkens, & Kanselaar (2007)	* Qualitative: amount of discussion and agreement	* By environment	* Comparison not possible * Members identifiable * Coarse * Absolute * Normative * Continuous	* Increased exploratory group-norm perception * Increased perception of positive group behavior and effectiveness of group strategy	* Effect on group performance on one of three subtasks
Janssen et al. (2011)	* Quantitative: Participation in relational space	* By environment	* Comparison possible * Members identifiable * Coarse * Cumulative * Non-normative * Continuous	* Use of AT increased awareness * Use of AT increased participation in relational space * Use of AT increased equality of participation * Use of AT increased participation in content	* No effect on group performance

				space * Use of AT increased coordination of relational space	
Jongsawat & Premchais-wadi	* Quantitative: Participation in content space	* By environment	* Comparison possible * Members identifiable * Coarse * Cumulative * Normative * Continuous	* No increased participation * Increased perceived group cohesion * Increased group commitment	* Increased group performance
Jermann & Dillenbourg (2008)	* Quantitative: Participation content space * Quantitative: Participation relational space	* By environment	* Comparison possible * Members identifiable * Coarse * Cumulative * Normative * Continuous	* Better balance between participation in content and relational space * Increased participation relational	* Not investigated

				space	
Kimmerle et al. (2007)	* Quantitative: Participation content space	* By environment	* Comparison possible * Members identifiable / unidentifiable[2] * Coarse * Cumulative * Non-normative * Discontinuous	* Increased participation in content space in individual feedback condition[2]	* Not investigated
Kimmerle & Cress (2008)	* Quantitative: Participation content space	* By environment	* Comparison possible * Members identifiable / unidentifiable[3] * Coarse * Cumulative * Non-normative	* Increased participation in content space in individual-feedback condition	* Not investigated

[2] Study makes a direct comparison between group-feedback (group members are not identifiable), individual-feedback (group members are identifiable) and no feedback condition.
[3] Study makes a direct comparison between group-feedback (group members are not identifiable) and individual-feedback condition (group members are identifiable).

			* Discontinuous		
Kimmerle & Cress (2009)	* Quantitative: Participation content space	* By environment	* Comparison not possible / comparison possible[3] * Members identifiable / unidentifiable[4] * Coarse * Cumulative / absolute[3] * Non-normative * Discontinuous	* AT used more often in comparison condition * Increased participation in content space in cumulative representation	* Not investigated
Leshed et al. (2009)	* Quantitative: Participation relational space	* By environment	* Comparison possible * Members identifiable * Coarse	* Both conditions increased awareness of language use	* Not investigated

[4] Study manipulated two factors: 1) Allowing comparison and identification vs. not allowing comparison and identification, and 2) A cumulative versus an absolute representation.

	* Qualitative: Agreement		* Cumulative * Non-normative / normative[5] * Continuous	* Increased expressions of agreement * Decreased expressions of disagreement	
Michinov & Primois (2005)	* Quantitative: Participation content space	* By environment	* Comparison possible * Members identifiable * Coarse * Cumulative * Non-normative * Discontinuous	* Increased participation in content space	* Increased group creativity
Phielix et al. (2010)	* Quantitative: Ratings of influence, friendliness,	* Self- and peer assessment	* Comparison possible * Members identifiable * Detailed	* Increased perception of team development * Decreased perception	* No effect on group performance

[5] Study makes direct comparison between non-normative (bar charts) and normative condition (school of fish).

	cooperation, reliability, and productivity		* Non-normative * Discontinuous	of group conflict	
Phielix et al. (2011)	* Quantitative: Ratings of influence, friendliness, cooperation, reliability, and productivity	* Self- and peer assessment	* Comparison possible * Members identifiable * Detailed * Non-normative * Discontinuous	* Increased perception of team development, group satisfaction, and attitude * Decreased perception of group conflict	* No effect on group performance