SCAN Tools for Collaborative Learning

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Abstract: SCAN tools (Social and Cognitive Awareness and Navigation tools) inform participants about social and/or cognitive variables with respect to a group and its members. This paper describes how SCAN tools facilitate and "institutionalize" the natural processes of becoming aware about social and cognitive variables, thereby leading to adaptive behavior in collaboration. The notion of person-object relations (PORs) is introduced as the basic building block underlying both group awareness and social navigation. Four design principles of SCAN tools (response formatting, juxtaposition, aggregation/transformation, and prediction/recommendation) are discussed, and their application in CSCL scenarios is described. Finally, issues for both practical implications and use-inspired basic research on SCAN mechanisms will be explored.

Introduction

Social settings are characterized by the constant efforts of participants to coordinate their behavior with the behavior of others. In order to achieve coordination, participants of social settings have to carefully monitor the behavior of others, and they have to display markers of their own activity (Schmidt, 2002). Mutual awareness and mutual behavioral coordination were first analyzed by Heath and Luff (1992), and subsequently have become central topics in research on computer-supported cooperative work (CSCW) under labels such as "group awareness" (Gutwin & Greenberg, 1995), "team situation awareness" (Endsley, 1995), "workspace awareness" (Gutwin & Greenberg, 2002), "activity awareness" (Carroll, Neale, Isenhour, Rosson & McCrickard, 2003), or simply "awareness" (Schmidt, 2002). Of particular interest to this community are scenarios where displaying and monitoring of collaborative activities is inhibited, e.g. in net-based scenarios. The tools to provide group awareness in online scenarios are informing team members about the presence, the location, and the activities of their collaborators in virtual space, thereby enhancing mutual coordination. Research on group awareness has flourished within the CSCW community, but has only begun to be addressed in other scientific fields studying collaborative processes.

Simply being aware of others, of course, is only part of successful coordination. It is also necessary that people are influenced by what they perceive in a social setting. This influence often reflects in behavioral variables like navigation, and it does not only manifest itself in inherently social settings of direct communication, but even emerges in the absence of other people. A popular example for the latter phenomenon involves the trampled down paths over a stretch of grass that indicate to a person what might be the shortest way of navigating between places (DiGioia & Dourish, 2005). The influence that other persons' activities have on the subsequent behavior of an individual is generally analyzed under the label of "social navigation" (Höök, Benyon & Munro, 2003). Online environments can make heavy use of this metaphor because digital traces of others can be used to inform the navigational behavior of individuals (e.g. Erickson & Kellogg, 2003).

While the aforementioned examples of group awareness and social navigation refer to the influence that other persons' activities have on an individual, this influence can be extended to social and cognitive factors as well. People perceive what other people think, know, feel, or like ("group awareness"), and they act accordingly ("social navigation"). As an example take a researcher who presents her findings on a conference. When asked by colleagues how the presentation went, a typical answer might be "I think they liked it", or "They didn't get it". This example does not only hint at the pervasiveness of making assumptions about the social and cognitive states of others, but also illustrates the limitations of these assumptions. After all, there is no way of knowing whether the audience of the talk "liked it" because such inferences are drawn from indirect evidence, and they are drawn from only parts of the audience (e.g. someone gravely nodding, or someone else frowning). In other words, awareness about others and social navigation based on others' cognitive and social states often rest on speculation rather than reliable, or comprehensive data.

In standard net-based scenarios (computer-mediated communication, CSCW, CSCL) social and cognitive variables are even more difficult to assess. Since the 1980s the scientific investigation of net-based communication has held that the lack of social cues is one of the main barriers leading to decreased performance of computer-mediated communication (CMC) as opposed to face-to-face interaction (Kiesler, Siegel & McGuire, 1984). However, cues about behavioral, social, and cognitive states can be added to interaction through specifically tailored tools, and by exploiting the power of computers to store and manipulate those cues, we believe that awareness and navigation can be improved towards levels that actually surpass face-to-face
interaction (Buder, 2007). This is the driving force behind the development of what we call SCAN tools. SCAN stands for "Social and Cognitive Awareness and Navigation". SCAN tools are designed to provide persons with systematically accrued information about how groups (or, more generally, collectives) and their members cognitively or socially relate to a given state of affairs. Put simply, SCAN tools answer the question of "How does a group and its members think or feel about something?" While making assumptions about cognitive or social states of others is a pervasive everyday phenomenon, SCAN tools might help to improve the quality of those assumptions by offering reliable data (rather than vague inferences) about groups and their members. An important point about SCAN tools is that they are developed for the participants rather than for scientific observers. In other words, SCAN tools must be designed to be relatively easy to use, easy to understand, and easy to apply in a given situation, preferably in real-time. This distinguishes SCAN tools from rather complex tools that mine for patterns in group data that will be difficult to interpret by novices (e.g. social network analysis visualizations).

SCAN tools are rather prevalent in certain net-based scenarios. For instance, group decision support systems in CSCW contexts provide awareness about social and cognitive variables (Lim & Benbasat, 1993). Similarly, many social software solutions help users navigate towards interesting content on the WWW (e.g. through bookmarking and voting systems like digg). However, SCAN tools have relatively rarely been investigated in CSCL scenarios (for awareness on behavioral rather than social and cognitive variables in CSCL see Amelung, Laffey & Turner, 2007; Bratitsis & Dimitracopoulou, 2007; or Kay, Yacef & Reimann, 2007). This paper seeks to explore the potential of SCAN tools to foster online interaction among collaborative learners.

The next section describes basic mechanisms of SCAN tools. This is followed by the main section describing four design principles that are employed in SCAN tools (response formatting, juxtaposition, aggregation/transformation, and prediction/recommendation). Each principle will be illustrated using examples from CSCL research projects. A conclusion of the design principles section will compare different SCAN solutions on a number of additional variables. Finally, an outlook on practice and research of SCAN tools will be provided.

Basic Mechanisms of SCAN Tools
On an operational level we define group awareness as the perception of and knowledge about what we call person-object relations (PORs). A POR expresses the basic constituents of group awareness by linking a person to an object through a particular type of relation. First, the person constituent of a POR could either be oneself or someone else. If the person is someone else, it could either be a group member that one is interacting with (like in typical group awareness scenarios) or even a member of an anonymous collective (like in many social navigation settings). Second, the object of a POR could be almost anything: it could be a document, a movie, a forum posting, a blog entry, a single word, a TV show, a commercial product, a dancing performance - or even another person. Third, the relation of a POR refers to the type of connection between person and object. In the case of SCAN tools, the relation is of a social or cognitive nature. For instance, it could be a relation of knowledge ("Martha knows the answer"), a relation of understanding ("I have not understood this text passage"), a relation of judgment ("Steve rates this movie 9 out of 10"), a relation of estimation ("Sandra thinks the box contains 200 pellets"), of liking ("Tom likes Anita"), or of agreement ("Samantha disagrees with my latest posting"). Moreover, PORs can vary in complexity. For instance, a movie review can be regarded as a complex POR connecting a movie critic with a film through a relation of liking/evaluating. Once PORs are displayed, participants have the opportunity to achieve group awareness (by perceiving PORs, and potentially by building knowledge on the basis of PORs). If the perception of PORs leads participants to change their courses of action, social navigation is accomplished.

SCAN tools process PORs in three stages: the first stage involves the systematic registering of PORs. In the second, optional stage, PORs can be post-processed or transformed. And in the final stage, POR-based information is fed back to participants in a visual representation. There are several means of how SCAN-relevant information can be registered. Forsberg, Höök, and Svensson (1998) introduced the notion of intentional vs. non-intentional navigation mechanisms. Intentional social navigation means that a person is explicitly and consciously generating the POR (mostly through some kind of rating or voting). In contrast, non-intentional social navigation means that a POR can be implicitly inferred as a by-product from the behavior of a person.

Returning to the example of the researcher giving a talk on a conference, a simple SCAN tool might work as follows: first, audience members assess the quality of the talk by rating it on 5-point scale from highly boring to highly interesting (registering PORs). Second, PORs might be transformed into an aggregate by computing the arithmetic mean of individual ratings. And third, this information is fed back to the researcher as an overall rating. As a consequence, the person giving the talk would get a more adequate impression of whether "they liked it". Alternatively, audience members could be requested to repeatedly rate the talk while it unfolds, thereby giving immediate situational feedback. Many SCAN tools are designed to provide persons with moment-to-moment information, but of course they might also contribute to the establishment of relatively
persistent cognitive structures about what groups think, know, or feel. In the latter case, the perception of PORs can be seen as related to concepts such as common ground (Clark, 1996), teamwork mental models (Cannon-Bowers, Tannenbaum, Salas & Volpe, 1995), or transactive memory systems (Wegner, 1987).

Design Principles for SCAN Tools
This section introduces four design principles that contribute to the efficiency and effectiveness of SCAN tools. Furthermore, it will be discussed which psychological processes are affected by each of these principles. The principles and the psychological processes will be illustrated with examples from research studies that tried to apply SCAN tools to settings of collaborative learning.

Response Formatting
Response formatting is probably the most basic design principle for SCAN tools. It applies both to the first stage (registering PORs) and to the last stage (visual feedback) of SCAN tool processing. A SCAN tool called Agenda Generator (developed by the first author of this paper) provides an example of response formatting (see Figure 1). This tool was used during a workshop where participants were requested to formulate topical statements about CSCL as a research field. Colleagues then read the statements. Rather than requiring participants to provide detailed feedback about a statement (unformatted response), they were asked to rate statements on two pre-defined and pre-formatted dimensions by using a slider bar (formatted response).

Figure 1. Response formatting in the Agenda Generator.

Virtually all SCAN tools make use of response formatting. An obvious advantage of this method is that rating objects requires relatively little effort for the interaction partners, thereby setting a low threshold for participation during the first stage of SCAN processing (registering PORs). Moreover, response formatting provides benefits for the recipients during the feedback stage. They receive a small set of values that can be processed quite easily. Reading lengthy feedback comments can be burdensome. In contrast, gleaning through colleagues’ ratings for several statements is a fast and efficient way of getting an impression, thus reducing working memory load. In this way, response formatting is an efficient way of getting information across. However, it should be mentioned that response formatting might reduce the potential complexity of a POR, thereby taking away some of the richness of full interaction. The main reason why SCAN tools prefer simplified PORs is that response formatting is a necessary condition for all the SCAN design principles described below.

Juxtaposition
Many SCAN tools provide feedback on PORs that mirror the original input, whether this input was gained via intentional social navigation (e.g. explicit ratings), or through non-intentional social navigation (e.g. behavioral data). In such a case, many different PORs will be displayed to a person, and the question of how to juxtapose these PORs comes into play. If similar PORs are represented in spatial proximity, they assist learners in working out relations among these PORs. Juxtapositions make learners aware about patterns in a social setting, and they can help to guide attention towards particular aspects of the state a group is in. If two PORs with different persons, but identical objects and relations are juxtaposed (interpersonal juxtaposition), powerful processes of social comparison are triggered (Festinger, 1954; Suls, Martin & Wheeler, 2000). In addition to comparing oneself with others, interpersonal juxtaposition of PORs enables comparison between two other group members, with both types of comparison bearing the potential to lead towards regulative behavior. In contrast, if PORs with different objects and the same person are juxtaposed (intrapersonal juxtaposition), they provide an indication of a personal preference. For instance, one could see that a reviewer preferred one research paper over another. Finally, SCAN tools could employ tabular juxtapositions of PORs, thereby fostering both social comparison and comparison among objects.
Dehler, Bodemer, and Buder (2007) have introduced the PKA tool (Partner Knowledge Awareness tool) that is based on PORs where the objects are hypertext pages containing learning material, and where the relations are expressing levels of understanding. In the Dehler et al. (2007) experiment, learners individually read hypertext learning material and then rate their subjective degree of understanding for each hypertext page. Ratings are employed in a very simple, dichotomous response format that requires learners to click on a box whenever they believe that they sufficiently understood the corresponding hypertext page. After individual reading and rating, learners are grouped into collaborative dyads instructed to discuss the topic by mutually asking questions or giving explanations. The simple, dichotomous response format has the advantage of being transferable to a very simple, easy-to-grasp visual representation of PORs. In a navigation window (see Figure 2), the domain topics (each referring to one hypertext page) are listed, and the corresponding PORs for oneself (column A) and for the learning partner (column B) are represented by boxes, with colored boxes indicating that a learner has sufficiently understood the content, and white boxes indicating that a learner hasn’t understood it. The vertical alignment of objects and the horizontal alignment of persons represent a tabular juxtaposition of PORs that can be used for both object comparison and social comparison purposes. For instance, across the vertical juxtaposition of boxes learners can get an overall impression of how well they understood the learning material compared to the learning partner. Moreover, since corresponding boxes for both learners are juxtaposed horizontally, learners can use the POR information to guide their interaction, with adjacent white boxes signaling a shared deficit, and adjacent colored boxes indicating shared levels of understanding. The strongest cues for structuring the interaction, however, might be provided by those cases where the color of the boxes differs. Having a white box coupled with a colored partner box is likely to trigger a question, and having a colored box coupled with a white partner box is likely to trigger an explanation. In other words, the SCAN tool is helpful for learners to tailor their contributions to a partner, a process that is termed audience design in the literature on common ground (Clark & Murphy, 1982). The experiment by Dehler et al. (2007) has shown that learners better adapted to their partners if the PKA tool was available.

Bodemer and Scholvien (2008) investigated the Collaborative Integration (CI) tool for dyadic learning based on collaborative manipulation of external representations. This SCAN tool is an extension of earlier work on active integration (Bodemer, Plötzer, Feuerlein & Spada, 2004), an instructional method to foster individual understanding by requiring learners to drag and drop pre-formatted content elements (e.g. variable labels) onto corresponding slots of a graphical representation. In the CI tool, dyadic learners perform the active integration task simultaneously and independently, all the while they are communicating with each other. Each learner sits in front of a computer, and the screen displays a shared image of the external representation. The representation (e.g. a picture) contains several blank slots that have to be filled by dragging and dropping content elements onto them. However, instead of single slots the representation contains juxtaposed pairs of slots, one for each learner. While a learner fills his or her empty slots, the learning partner performs the same task. The juxtaposition of slots works similarly as with the PKA tool, i.e. learners can easily see those parts of the representation that are unaddressed as of now (two blank slots), and they can see if they agree with their partner (two slots with identical content elements dropped onto them). Most importantly, the CI tool makes conflicts visible, viz. if two corresponding slots contain two different content elements. While these mechanisms of the CI tool are similar to the PKA tool, there are notable differences as well. For instance, the Collaborative Integration tool does not require learners to explicitly rate their understanding of particular concepts, i.e. PORs are revealed through the interaction itself. Moreover, collaborative integration provides SCAN-relevant information in real-time as the dyadic interaction unfolds. It was shown in an experimental study that dyadic interaction and communication had a particularly strong focus on the conflicting content assignments that arose during collaborative integration. Seeing these conflicts between solutions provided strong cues for the learners to address the conflict and achieve a shared understanding (Bodemer & Scholvien, 2008).
Juxtaposition as a design principle for SCAN tools works best if the number of persons or the number of objects to be displayed are limited, and if the PORs are relatively simple. But even with very complex PORs SCAN tools can be effective, as was shown by Engelmann and Tergan (2007). Their KIA (Knowledge and Information Awareness) tool juxtaposes complex concept maps that group members have individually created prior to interaction. Although it is somewhat more difficult than with the PKA or CI tool to work out and compare PORs among collaborators, an experimental study has shown that the KIA tool led to better problem-solving performance of groups. All three tools clearly indicate that systematically requesting learners to generate PORs (through rating or through learning activities) is superior to having learners work out and infer PORs from interaction itself (for further discussion on these three Knowledge Awareness tools see Engelmann, Dehler, Bodemer & Buder, submitted).

Aggregation and Transformation

It was already noted that POR processing can involve up to three stages (registering, transforming, and visualizing PORs). The PKA tool, the CI tool, and the KIA tool are examples for SCAN tools where the original input (ratings, actions, concepts) directly map onto the output PORs, i.e. the second stage is missing. In contrast, some SCAN tools aggregate across several PORs, or even transform the feedback based on aggregated data. Through aggregation and transformation SCAN tools can become very powerful because they make information visible that is difficult or almost impossible to achieve in face-to-face or standard CSCL interaction. For example, aggregation can be done for one object over several persons by computing an average value of a group. This opens a window into group cognition, as the SCAN tool now literally displays what a group is thinking about a given state of affairs. Similarly, single PORs can be added for one person over several objects. As a consequence, learners can compare with other learners on an aggregated variable. By these means, SCAN tools can reveal patterns in interaction that provide powerful cues for learners to adapt their behavior.

Buder and Bodemer (2008) have developed a class of SCAN tools (termed augmented group awareness tools) for the support of controversial CSCL discussions. In their scenario, small groups discuss a conflicting issue, and each text-based contribution in their threaded discussion can be rated by the collaborators on dimensions such as agreement or novelty. Augmented group awareness tools consist of a graphical representation that displays the contributions as dots in a Cartesian coordinate system (see Figure 3). The representation is updated in real time when a contribution is rated by a person. Using the rating dimensions of agreement and novelty, learners can see how much the group agrees with a given contribution, or how relevant (and novel) a group considers a given contribution to be. In addition to providing almost instantaneous feedback about one's own contributions, the SCAN tool helps learners to identify crucial contributions in a discussion. In an experimental study involving discussions between a single learner advocating a correct viewpoint and an incorrect majority sub-group it was shown that the SCAN tool strengthened minority influence.

Figure 3. Aggregated and transformed PORs in Augmented Group Awareness tools.
In contrast, the SCAN tools investigated by Kimmerle, Cress, and Hesse (2007) foster social comparison processes among persons by aggregating over several objects. The objects in this case were small pieces of information that could be either shared or withheld, and the SCAN tools compute a level of cooperativeness for single persons based on the aggregation of multiple individual decisions about sharing vs. withholding information. This is an example for non-intentional social navigation since the level of cooperativeness was computed from a set of behavioral data. As a result, the SCAN tool visualizes an individual’s level of cooperativeness in comparison to other group members. In an experimental study it was shown that participants increased their level of cooperativeness over time after receiving bogus feedback about high levels of partner cooperativeness. The study also compared individualized feedback (separate levels of cooperativeness for each partner) with group feedback (instigating comparison between an individual level and the group average level, thus representing a double aggregation over both persons and objects). Interestingly, only individualized feedback increased levels of cooperativeness. This finding is in line with the observation that awareness tools are particularly effective if they instigate mutual accountability and "social translucence" (Erickson & Kellogg, 2003).

Most SCAN tools that employ aggregating mechanisms transform the aggregated PORs into arithmetic means. However, one could think of many other ways of transformation. The Agenda Generator tool introduced in the section on Response Formatting employs an alternative means of transformation, viz. the use of statistical dispersion among data. To recall the scenario, members of a group are requested to formulate statements about a given topic. Other group members rate these statements on dimensions such as agreement and relevance. The Agenda Generator then displays the statements as a list that can be sorted not only by average agreement and average relevance, but also by degree of conflict. Degree of conflict can be computed as the standard deviation of agreement ratings. If a statement receives ratings ranging from high to very low agreement, the standard deviation of agreement ratings will be comparatively large, and the statement will be particularly controversial. The Agenda Generator is designed in a way that the most controversial statements can be listed at the top (or bottom) of the statement list, thereby providing helpful cues for a group about interesting topics to discuss. Along the same lines, different aggregation and transformation mechanisms could be employed for SCAN tools. For instance, correlations of PORs could be used to compute similarity among different objects or different persons. SCAN tools might even perform real-time higher-level analyses on POR data, e.g. cluster analyses, factor analyses, or multidimensional scaling techniques. However, it should be noted that the feedback should be provided in ways that are easy to understand and use for learners.

The tools described thus far use relatively simple, low-tech solutions towards generating SCAN-relevant data. However, a number of SCAN tools have been suggested that rely on much more complex forms of aggregation. E.g., SCAN tools developed in the ARGUNAUT project (De Groot et al., 2007) are designed to identify typical patterns of interaction in graphical e-discussions. The tool analyzes temporal conjunctions ranging over several persons (the group members), several objects (discussion contributions), and several types of relations (pre-defined message types). If crucial patterns are discovered in interaction (identified through machine learning and/or pattern matching algorithms), this information will be fed back to a discussion moderator who can take several courses of action. A second example for complex aggregation and transformation mechanisms can be found in the suite of SCAN tools that Teplovs, Donoahue, Scardamalia, and Philip (2007) have developed as add-ons for the Knowledge Forum. Among these tools is a Semantic Field Visualization that uses very fine-grained PORs (with the objects being single words used by learners) and extracts similarity among texts and/or learners through Latent Semantic Analysis. A third example of complex aggregation can be found by Janssen, Erkens, and Kanselaar (2007). Their Shared Space tool analyzes linguistic markers from chat logs in real time and aggregates these data over the entire group. As a consequence, the tool indicates the collective degree of conflict and feeds back this information to the group as the interaction unfolds.

These examples illustrate that there is an enormous variability among the aggregation and transformation principles used in SCAN tools for CSCL. However, many areas for the application of SCAN tools are still unexplored. For instance, there are currently very few developments geared at capturing the temporal dynamics of SCAN-relevant information. While analysis and feedback on navigational trails is quite a common method to inform groups about behavioral variables (e.g. Börner, Hazlewood & Lin, 2002), the authors are not aware of many similar applications for tracking social and cognitive variables over time (a notable exception being a SCAN tool for the Knowledge Forum indicating vocabulary growth over time; Teplovs et al., 2007).

**Prediction and Recommendation**

A very promising area for the development and research of SCAN tools involves tools that generate new PORs based on existing patterns of interaction. The immediate benefit of predictions and recommendations is that the tool essentially takes the role of a highly informed, additional learner or mentor. In the best case, SCAN tools can assist learners in getting a new perspective on a collaborative setting by explicitly pointing out areas of interest (other persons or other objects), and helping learner to overcome habitual responses. Moreover,
knowing about persons that will be interesting to interact with can help to build and re-structure transactive memory systems and teamwork mental models.

In fields outside of CSCL, tools that explicitly suggest new PORs on the basis of interactional patterns are quite common, e.g. in the case of recommender systems. Recommender systems employ algorithms to determine similarity between persons or between objects in order to predict new PORs. For instance, the recommender system MovieLens (Konstan & Riedl, 2003) predicts movies that a target person will like, but hasn't seen yet. Applying these principles to CSCL scenarios seems to be a very promising approach. However, in our field SCAN tools that predict PORs and recommend courses of action are still in its infancy. For instance, Harrer, Malzahn, Zeini, and Hoppe (2007) used social network analysis (SNA) in order to generate person recommendations (whom to work with) and object recommendations (emerging trends) in a large-scale community. However, social network analysis is limited to showing existing patterns of interaction rather than non-existent, interesting connections. Harrer et al. (2007) tried to overcome this limitation by introducing additional representational schemes (e.g. knowledge maps or ontologies) that are combined with the SNA representations to predict new PORs.

An easier approach towards prediction and recommendation might be to rely on SCAN tools that use intentional social navigation (i.e. explicit ratings by learners) since these can be tailored to the situation at hand. For instance, the Agenda Generator described above is a very simple tool that uses rating patterns to derive recommendations about topics (objects). Likewise, Augmented Group Awareness tools (Buder & Bodemer, 2008) could be adapted to compute similarity ratings among persons, thereby generating recommendations for group compositions (based on maximized similarity or dissimilarity).

Conclusions
This paper attempts to compare various SCAN tools by couching them in the terminology of person-object relations (PORs). It has provided examples from CSCL scenarios that rely on very different persons, different objects, and different types of relations. Firstly, some tools described above provide feedback about individual persons (oneself or other group members), while other tools only provide feedback about aggregated groups. Secondly, SCAN tools differ in the objects they provide feedback on. Some tools use objects that are external to the collaborative group (e.g. pages of learning materials in hypertext formats, Dehler et al., 2007; elements of a graphical representation, Bodemer & Scholvien, 2008; concepts and relations of a domain, Engelmann & Tergan, 2007; small pieces of information, Kimmerle et al., 2007). In contrast, the objects of other SCAN tools are products of the collaboration itself. These can range from macroscopic objects like entire documents (Harrer et al., 2007) over smaller objects like discussion contributions (Buder & Bodemer, 2008; De Groot et al., 2007), up to very small units like words being used (Janssen et al., 2007; Teplovs et al., 2007). Thirdly, there is a whole range of social and cognitive relations revealed through the SCAN tools. Some relations are social in nature (e.g. ratings of agreement), others focus on cognitive variables (e.g. indicating the degree of understanding, or expressing one’s knowledge through collaborative integration). Interestingly, some SCAN tools derive social and cognitive variable from basic behavioral activities. For instance, simple decisions to share or withhold small pieces of information can be aggregated to yield levels of cooperativeness (Kimmerle et al., 2007), or linguistic markers used in chat discussions can be aggregated to yield levels of conflict in a group (Janssen et al., 2007).

In the introduction it was mentioned that successful coordination requires both group awareness and social navigation. The design principles of response formatting, juxtaposition, and aggregation/transformation subserve the group awareness function. Response formatting enables participants to register PORs in fast and efficient ways. Juxtaposition of PORs provides a means to compare persons and/or objects. Aggregation and transformation provide the most comprehensive answers to the question of "How does a group feel and its members think or feel about something?", thereby opening a window into representational and computational aspects of group cognition. SCAN tools make use of the whole range of principles to facilitate group awareness.

With regard to the navigation (or adaptation of behavior) function of SCAN tools there is an even greater variability among tools. Some SCAN tools provide awareness about group states, but present little in the way of affordances to actually adapt one's behavior. For instance, Semantic Field Visualization (Teplovs et al., 2007) shows the similarity among texts and among authors, but this kind of information does not explicitly prompt regulative action. Most SCAN tools described above propose indirect effects of group awareness on navigation. By making aspects of interaction salient and aware, these tools often implicitly suggest potential courses of action to a group without strictly enforcing them. This is very much in line with early conceptualizations in the CSCW literature stating that group awareness denotes "those practices through which cooperative activities are somehow tacitly and unobtrusively aligned and integrated" (Schmidt, 2002, p. 287). However, the design principles of prediction and recommendation show that SCAN tools can be much more directive with respect to the navigation function. The different degrees of directivity among tools were addressed in the distinction between mirroring tools, metacognitive tools, and guiding tools (Soller, Martinez, Jermann & Mühlenbrock, 2005).
The Future of SCAN Tools

Over the course of the last few CSCL conferences an increasing number of studies have employed and investigated SCAN tools. It is not unlikely that this trend is going to continue. New SCAN tools will be developed, and some scholars might apply the SCAN metaphor to entirely new fields involving variables like affect, motivation, or mutual regard (e.g., Murray, 2007). However, for the field to mature some significant advances have to be made. First of all, the field is still lacking demonstrations of how SCAN tools can contribute to actual CSCL classroom practice. For instance, as of now there is no learning environment that makes heavy use of SCAN tools. Such an environment could employ a whole range of SCAN techniques like ratings of learning material, polls on discussion topics, collaborative highlighting methods, mutual peer assessments, and learner expertise maps. Ideally, such an environment would be tested and refined through approaches of design-based research.

In order to improve the practice of SCAN tools, we need more use-inspired basic research as well, both with respect to the group awareness function and the navigation function of SCAN tools. Among the open research questions are the following:

- What kind of group awareness information do learners prefer in collaborative settings? For instance, Yoon (2007) has found that in seeking partners for discussion learners prefer collaborators with opposing rather than congruent viewpoints.
- How does group awareness develop over time? For instance, Sangin, Nova, Molinari, and Dillenbourg (2007) have found that the dynamics of group awareness are quite complex, as learners' use of SCAN-relevant information is partially dependent on the use of the same information by their collaborators.
- What is the relative efficiency of intentional vs. non-intentional metaphors of social navigation? For instance, requiring learners to explicitly rate on a given state of affairs can be tiresome, and might distract from the task at hand. However, through intentional social navigation meta-cognitive and elaborative processes might be prompted, and these could provide an important link between the group awareness and the navigation function. In contrast, non-intentional social navigation mechanisms are elegant and non-distracting, but at least for SCAN tools that involve complex aggregations and transformations they might lead to lower acceptance by group members. Will learners let the computer "tell" them in what state a group is?
- How directive should SCAN tools be? For instance, Miao and Koper (2007) have supported the group awareness function of SCAN tools via a scripting approach that guides learners through sequences of mutual peer assessment. Taking this idea a step further one could think of SCAN tools that even script the navigation function. However, this would massively interfere with the notion of learner autonomy.
- Could SCAN tools inhibit collaboration? There are a number of unexplored, potential side effects of SCAN tools, both on the individual and the group level. For instance, providing feedback about individual learner performance might lead to evaluation apprehension. On a group level, making problematic issues aware might aggravate rather than alleviate these issues. Feedback research in educational psychology (e.g. Shute, 2008) might offer some solutions on how to give feedback that is both informative and supportive.

While this list of questions is far from comprehensive, it might provide some building blocks that can be used for building an agenda on SCAN tool research in CSCL. As of now, SCAN tools look like a promising candidate for enriching our repertoire of tools to foster the practice of CSCL.

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Proceedings of the 7th Computer Supported Collaborative Learning Conference (pp. 87-89). New Brunswick: International Society of the Learning Sciences, Inc.


