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# User-Centered Awareness in Computer-Supported Cooperative Work-Systems:
## Structured Embedding of Findings from Social Sciences

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**Abstract**. An increasing number of Computer-Supported Cooperative Work (CSCW)-software systems try to provide users with awareness information—information about the presence, activities, and availability of members of a community. However, most of these software systems are designed from a feature-oriented rather than a human-oriented point of view. In this paper a structured embedding of findings in social sciences is proposed. It reveals the variety of approaches in technology-driven CSCW developments featuring awareness, as well as the variety of empirical evidence in small group research with respect to awareness. We have been looking from different aspects to awareness: The terminology used in both disciplines, the concepts that have been developed, and the different constructs that evolved from empirical research. Finally, operational instances of awareness have been revisited. From our findings we can conclude that awareness addresses different constellations of group settings, different types of individual behavior, and different contexts of use. These findings can be used by CSCW software-system developers for ex-post evaluation—that is, to identify empirical evidence for awareness features already implemented, as well as to identify those already implemented features still lacking empirical evidence. The findings should also encourage social scientists to investigate the usage of existing and envisioned software features empirically in CSCW settings. Overall, the results should help to achieve a shift from technology-driven development towards human-centered design of collaborative communities, due to the envisioned integration of understandings and concepts.
**Keywords**. User-centered design, Computer-Supported Cooperative Work (CSCW), Groupware, Awareness, Online communities, System development, Social computing, Operational definition of awareness.

# 1 Introduction

Members of workgroups need information about each other, about shared artifacts, and about the group process. This information is often referred to as (group) awareness [Begole *et al.* 1999; Erickson *et al.* 1999], or workspace awareness [Gutwin & Greenberg 1998a]. In face-to-face situations, this information is ready at hand and group members can collect it naturally. In situations with distributed work groups, technological support providing this information is necessary [Dourish & Bellotti 1992]. The technical support for awareness faces several principle challenges such as how to capture, process, and present information about others or context and various dedicated challenges such as privacy issues, and disruption of users by awareness information [Endsley & Jones 2001; Hudson & Smith 1996].

Although (Computer-Supported Cooperative Work) CSCW applications have penetrated society steadily, in the field of CSCW less studies displayed a human-centered perspective on awareness [Gaver *et al.* 1992; Tang & Rua 1994]. They rather focused on features and technology, such as services and protocols for the Web [Palfreyman & Rodden 1996]. Although some developers have already identified problems with a techno-centric perspective on awareness, such as Erickson [2002] with respect to the notion of awareness, only recently cross-disciplinary approaches appeared to overcome some of the difficulties [e.g., Gonzalez *et al.* 2004]. Awareness concepts or constructs stemming from social sciences could form the empirical ground for development decisions and be put to practice by CSCW developers. Vice versa, features enabling mutual awareness of group members should also be empirically tested with respect to their individual utility and group support—a trend that has been observed recently by several authors such as Tang [2001]. Since CSCW systems are socio-technical systems, user performance and user satisfaction should be used as indicators for the usefulness and usability of awareness features. Finally, focusing on the development of technical features ignores the potential influence of distributed information on users (beings part of the socio-technical system) and their behavior. Developers might not receive relevant feedback for their work, spending effort on unreflected improvements.

In order to distinguish between CSCW software systems and CSCW socio-technical systems the following naming convention is introduced: “CSCW system” refers to a socio-technical system involving information and communication technology systems and human as equal and highly interrelated parts, while “CSCW software system” refers to the technology itself.

Our research procedure to tune the mutual findings is composed of several steps:

1. *Review of Awareness (Features) in CSCW Research*: The rationale of providing awareness features is reviewed and an overview of the commonly accepted CSCW terms describing awareness is given. CSCW-software systems are identified that feature awareness and classify them according to different categories of awareness and collaboration support. Finally, the integrity and consistency of the applied concepts is reviewed.
2. *Review of Awareness (Constructs) in Small Group Research*: The understanding and constructs of awareness in social sciences is analyzed. Several categories of awareness and some operational definitions (through measurable human

behavior) can be identified—for further explanation of operational definitions see also below.

3. *Cross-Checking the Results from Step 1 with Step 2*: First, differences between CSCW research and small group research are revealed at the conceptual level: Various concepts of awareness are compared and differences are traced back to different use of terms and understandings. Secondly, the operational—that is, software-functional—level of awareness is addressed. On the one hand enablers of different human behavior in CSCW systems are considered—that is, the technical features implementing a construct; on the other hand, it is checked whether social sciences have provided empirical data with respect to already implemented features of CSCW applications.
4. *Consolidation*: Finally, the results from the previous steps are interpreted. It is analyzed whether an embodiment of findings is facilitated through the short semantic distance between technical enablers of human behavior, concepts and understanding of awareness, or a drifting apart of the addressed fields is likely to occur due to identified differences.

Operational definition is a term stemming from qualitative content analysis. In this context it specifies the concrete instances of human behavior based on empirical evidence. Analytical definitions contain the semantics (meaning) of the constructs, concepts, and terms underlying operational definitions. This paper lays ground for analytic definitions by explaining terms, concepts, and constructs, and providing operational definitions for human-centered CSCW-software development.

# 2 Awareness in CSCW

This section first discusses the motivation of CSCW researchers or developers to introduce awareness features (section 2.1). Then the terminology used in CSCW concerning awareness is analyzed (section 2.2) and various CSCW applications are analyzed and it is checked what types of awareness information they provide (section 2.3). Finally, the CSCW approaches for a common understanding of awareness (section 2.4) are analyzed.

## 2.1 Rationale and Origins

Awareness is crucial to users when interpreting the visibility of objects, services and other users [Dey & Abowd 1999]. Awareness of the factors that define a group of items and users and tasks associated with the group *helps to implement and manage services as well as devices for a group and its members*. It should help to increase the orientation of individuals within a group and task space. Tasks should be accomplished more effectively, by using contextual information and related services (group).

Awareness captures the social and work context of use in CSCW systems: Context is defined by Dey and Abowd [1999, pp. 3-4] as “any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant between the user and the application, including the user and application themselves”. Context-aware CSCW applications have the ability to use context to provide relevant information or services to the user, where relevancy depends on the user’s task.

Sohlenkamp [1999] closely relates awareness to collaboration and communication. Hence, besides the availability of information about others with respect to individual tasks, this information influences the interaction and can be used to increase effectiveness in collaboration. Beaudouin-Lafon and Karsenty [1992, p. 171] address this issue explicitly in the context of awareness ("each user should be aware of what the others are doing"), and promote awareness features "to facilitate coordination". A similar rationale can be found in Dourish and Belotti [1992, p. 107], where the provision of awareness should facilitate the management of collaborative work (in their case: text editing).

Early awareness systems, such as the Session Capture and Replay system by Manohar and Prakash [1995], were motivated to provide insight into the history of interaction, as they proposed to allow to trace communication among group members by saving the content group members have already seen. Sophisticated CSCW systems elaborate awareness in 3D spaces such as Greenhalgh and Benford [1995, p. 167], or take into account the focus of attention of users as proposed Ishii et al. [1994].

Similar to communicating the focus of attention is the idea to synchronously showing availability data from individual group members to others, as proposed by Sohlenkamp and Chwelos [1994, p. 332]. As Loevstrand [1991, p. 266] pointed out, awareness data improves the effectiveness in which information about events is communicated in a group. As such, the availability of awareness data might change the interaction patterns within a group. Fuchs et al. [1995] argued that for dispersing event information in a work group awareness features should include events in the past as well as current events. In addition, events should be coupled to the activities of individuals. If this is not possible, they should be marked as unrelated events to the individual workspace. Borning and Travers [1991] argue for user control for awareness features. Information about users in a (virtual) community and their activities should only be dispersed, if the concerned group members have agreed with the transmission of those data. Otherwise, positive effects, such as spontaneous conversations as described in Dourish and Bly [1992, p. 541] are not likely to occur. However, once users feel comfortable with being transparent to others, a variety of ways to query information of other users might be developed [cf. Gaver *et al.* 1992], and are likely to be used.

Overall, striving for effectiveness in group work through transparency started with providing historical data about tasks and user interactions, and the mutual exchange of those data among members of a work community. The development of features was and is still based on the assumption that the availability of awareness data will not only facilitate coordination and collaboration, but also stimulate spontaneous set up of social and work relationships.

## 2.2 Definitions and Fundamental CSCW Concepts

In the Oxford Dictionary [Fowler *et al.* 1995] *awareness* is defined as the noun of "to be aware"—conscious, not ignorant, having knowledge or being well informed. In the context of CSCW systems a *group* can be seen as a *number of individuals* who interact directly or through shared artifacts and who perceive themselves as a group [Gross & Traunmueller 1995]. *Group awareness*, therefore, can be broadly defined as consciousness and information of various aspects of the group and its members. Figure 1 shows a schematic view of group awareness.

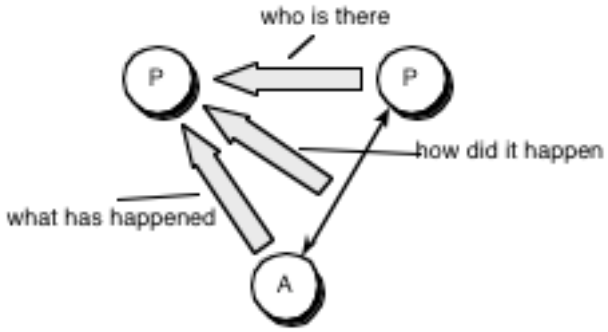


**Figure 1**. Schematic view of group awareness: Group awareness basically comprises information about the actor, the event, the activities, and the reason for the event. P: person; A: artifact. Source: Dix [1996].

Several other definitions of (group) awareness can be found in the literature. For instance, Dourish and Belotti [1992, p. 107] have identified awareness as "an understanding of the activities of others, which provides a context for your own activity". Gutwin and Greenberg offer a more specific definition. They argue that real-time desktop conferencing systems allow geographically dispersed users to collaborate synchronously in a shared virtual space, but that they lack the rich communication and awareness of face-to-face interaction. They define this synchronous group awareness as [Gutwin & Greenberg 1995, p. 88f]:

> "The up-to-the-minute knowledge of other people's activities that is required for an individual to coordinate and complete their part of a group task. Group awareness is maintained by keeping track of information such as other participants' locations in the shared space (where are they working?), their actions (what are they doing?), the interaction history (what have they already done?), and their intentions (what are they going to do next?)".

This definition contains various aspects of awareness and allows distinguishing four different types that are relevant for CSCW applications. Figure 2 shows the four different types of awareness in group work. The four circles should illustrate that the four types of awareness overlap and are interdependent.

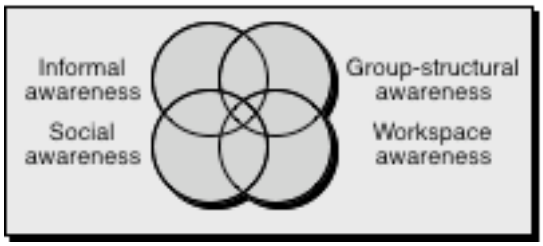


**Figure 2.** Types of awareness in group work. *Source:* Gutwin et al. [1996b].

*Informal* awareness is the pervasive experience of who is around, what these persons are doing, and what they are going to do. Informal awareness is a prerequisite for spontaneous interaction [Gutwin *et al.* 1996a]. *Social* awareness addresses the availability of different kinds of information such as interest and attention, or emotional state of a conversation partner. It is often perceived in a non-verbal way through back-channel feedback and non-verbal cues like eye contact, facial expression, and body language. *Group-structural* awareness comprises information about the group itself and its members like their roles and responsibilities within the group, their status or their positions on certain issues. *Workspace* awareness includes knowledge about the

workspace in general—information about other participants' interactions with the shared space and the artifacts it contains. Awareness of the workspace is composed of several elements. In each situation a combination of elements might be relevant. Table 1 shows sample elements of workspace awareness. This Table is taken from one of the core papers of a whole special issue in the Journal of Collaborative Computing on Awareness, which was published in the year 2002.

**Table 1.** Elements of workspace awareness *Source:* Gutwin and Greenberg [2002].

| Category | Element | Specific questions |
|---|---|---|
| Who | Presence | Is anyone in the workspace? |
| | Identity | Who is participating? Who is that? |
| | Authorship | Who is doing what? |
| What | Action | What are they doing? |
| | Intention | What goal is that action part of? |
| | Artifact | What objects are they working on? |
| Where | Location | Where are they working? |
| | Gaze | Where are they looking? |
| | View | Where can they see? |
| | Reach | Where can they reach? |
| How | Action history | How did that operation happen? |
| | Artifact history | How did this artifact come to be in this state? |
| When | Event history | When did that event happen? |
| Who (past) | Presence history | Who was here, and when? |
| Where (past) | Location history | Where has a person been? |
| What (past) | Action history | What has a person been doing? |

In the field of CSCW a lot of work on awareness has been done in the 1990s. Later, the research on awareness has been continued, but has not been that prominent. Nevertheless, many challenges concerning the support of group awareness information in cooperative applications remain. As Schmidt [2002, p. 3] states: "despite the growing interest in awareness, and the recognition that it is of critical importance to the successful development of systems to support cooperative activity, research remains fragmented and their contribution limited.". In his 'Introductory Remarks' to a special issue on 'Awareness in CSCW' Schmidt [2002, p. 287] continues that "in fact, the term 'awareness' is being used in increasingly contradictory ways.". From this statement it can be concluded that the CSCW community itself is looking for some device to weld the scattered results on awareness into some kind of (conceptual) framework. Before following that path subsequently some CSCW applications that provide group awareness information are presented. They are clustered according to the different types derived from the implemented features to avoid further scattering.

## 2.3 CSCW Applications Providing Awareness Information

In Table 2 an overview of CSCW applications providing various types of awareness is given. For Table 2 classes of CSCW system supporting awareness are identified. For identifying the classes, the following approach was taken: Based on the authors' knowledge and experience in the design and development of CSCW applications as well as a thorough literature research the awareness support in current CSCW applications was discussed. The awareness support was clustered and classes of CSCW applications were

identified. The underlying distinction according to the temporal nature of the support (into asynchronous, synchronous, and semi-synchronous) is the classical and basic way of categorizing CSCW applications that is very widespread in numerous classifications of systems in the CSCW literature. This distinction was extended by some specific classes of CSCW applications.

Please note that in Table 2 the types of awareness listed are termed and explained as introduced by the system developers.

**Table 2**. Feature description of CSCW applications, which focus on awareness.

| **Synch.** | **Classes of apps** | **Example systems** | **Features to provide group awareness information** | **Awareness info. provided** |
|---|---|---|---|---|
| Asynch. | Replay systems | Session Capture & Replay System [Manohar & Prakash 1994] Intelligent Collaborative Transparency [Li & Li 2002] | Capturing users' interactions with any application by storing data into a session object, and logging users actions. The Intelligent Collaborative Transparency (ICT) approach is based on similar technology, but mainly with the aim of sharing applications by capturing user input and distributing it to other computers.<br>Awareness facility:<br>• replay of users' past actions (what-you-see-now-is-what-I-saw-then, WYSNIWIST) | Workspace awareness |
| Synch. | Coll. text and graphic editors (cf. [Dourish & Bellotti 1992] for a dated, yet good overview) | GroupDesign [Beaudouin-Lafon & Karsenty 1992] REDUCE [Shen & Sun 2002]) | Drawing support designed for collaboration among a large number of users creating structured graphics. Various systems have been designed and developed.<br>Awareness facilities of GroupDesign:<br>• manipulated objects are marked with busy icon in selected color by user<br>• graphical and audio notifications about changes (echo)<br>• search other users' positions (localization mode)<br>• objects have color of user who created or last modified object (identification mode)<br>• history mechanism | Workspace awareness, audio and video echo |
| Synch. | Coll. editors with awareness about actors | ClearBoard [Ishii *et al.* 1994] | Shared drawing medium for two remote users drawing synchronously. Key metaphor is "talking through and drawing on a transparent glass window" (p. 93).<br>Awareness facilities:<br>• image of head of drawing partner is overlaid with image of shared artifacts<br>• camera focusing on the head of the participants allows the transmission of facial expressions and gestures (gaze awareness)<br>• simultaneous gesturing and drawing | Workspace awareness / (gaze) awareness |
| Synch. | Coll. virtual env. (cf. [Benford *et al.* 2001] for a good overview) | MASSIVE [Greenhalgh & Benford 1995] | Virtual Reality (VR) conferencing system supporting multimedia communication through audio, video, and text.<br>Awareness facilities:<br>• simultaneous meetings can be held<br>• users are embodied as symbols showing their capabilities (e.g., a simple T-block called textie representing users with text | Informal awareness, social awareness |

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|---|---|---|---|---|
| | | | terminals)<br>• notion of space—distance between users influences media they can use and awareness information they can get from each other and which they emit themselves | |
| Semi-synch. | Virtual office env. | DIVA [Sohlenkamp & Chwelos 1994]<br>Orbit [Mansfield *et al.* 1997] | Integrating the functionality for communication, cooperation, and awareness of various CSCW applications into a single virtual environment.<br>Awareness facilities:<br>• office model integrating people, documents, and desks for collaboration<br>• rooms can be assigned for special purposes | Informal awareness, workspace awareness |
| Semi-synch. | Event notification app. | Khronika [Loevstrand 1991]<br>Elvin [Fitzpatrick *et al.* 2002; Fitzpatrick *et al.* 1999] | Based on sensors, indicators, and infrastructure. Sensors capture information, send it to an event server, and indicators present the information to interested and authorized users.<br>Awareness facilities:<br>• users can subscribe to event types in which they are interested<br>• event demons map a user's personal interests with data in the database and notify them accordingly | Workspace awareness |
| Semi-synch. | Context-aware notification applications | GroupDesk [Fuchs *et al.* 1995]<br>NESSIE [Prinz, 1999 #2349;Gross, to appear #3006],<br>TOWER [Prinz *et al.* 2002] | Similar to above event notification applications. Additionally, they analyze the current work context of the user and provide the user with information relevant to the context.<br>Awareness facilities:<br>• analyze context in which events happen<br>• analyze current work context of user<br>• provide users with adequate information<br>NESSIE and TOWER additionally provide a 3D multi-user world for visualizing awareness information:<br>• shared workspaces and artifacts are represented as cities and buildings in the world<br>• users working in the shared workspace with the artifacts are represented as avatars in the world. The respective users' actions are visualized by automatic positioning of the avatars in the world and by animations of the avatars with symbolic actions<br>• users can either watch the current evolution of the world or replay past changes in the world | Informal awareness, workspace awareness |
| Semi-synch. | Web-based applications | CSCW3 [Gross 1997]<br>UCoB [Aneiros *et al.* 2003] | Populating the Internet—Web pages are considered as rooms, which users enter when they visit a page. Users are provided with awareness information about others visiting the same page and can communicate with them.<br>Awareness facilities in CSCW3:<br>• information about other users who visit the same Web page or who recently left the page<br>• users can meet on Web pages<br>• users can chat with integrated chat tool and exchange information and bookmarks<br>• users can search for colleagues | Informal awareness, workspace awareness |

| | | | | |
|---|---|---|---|---|
| | | | • users can navigate jointly through the Web | |
| Media spaces | Constant awareness | Polyscope [Borning & Travers 1991], Vrooms [Borning & Travers 1991], Portholes [Dourish & Bly 1992]) | Providing permanent information about presence, activities, and availability of others in virtual space; features:<br>• Polyscope displays a window with a 2D matrix of frame-grabbed video images and user names; observers can specify the source they want to monitor and the interval between updates; observees can specify whether they want to be visible<br>• Vrooms is the successor system of Polyscope with some improvements concerning social and interface issues: the metaphor of virtual rooms as places where social interaction and conversation take place was introduced. Users in the same room can see each other's video images and can start a conversation<br>• Portholes support awareness across long distances; digitized video images exchanged between Rank Xerox Research Centre in Cambridge, UK, and Xerox PARC in Palo Alto, California | Informal awareness, social awareness |
| Media spaces | Social browsing (cf. [Churchill *et al.* 2004] for an overview) | RAVE [Gaver *et al.* 1992], Montage [Tang & Rua 1994] | Allowing browsing and searching for users in virtual environment.<br>In RAVE each person is equipped with audio and video devices that connect him or her to other offices and common areas.<br>Awareness facilities:<br>• background: lowest degree of engagement; users can select a section of a public area, which they want to have displayed on their monitor<br>• sweep: short (about one second) one-way connections to a number of specifiable nodes<br>• glance: single three second one-way connection to a specified node<br>• vphone: video phone connection that can be initiated by one conversation partner and has to be accepted by the other<br>• office share: vphone connection that also has to be accepted by the other conversation partner<br>The Montage system uses a hallway model.<br>Awareness Features:<br>• users navigate virtual hallways and glance into others' offices; glances give a good impression if the user is in his/her office and if s/he currently wants to be approached<br>• if the doorway is open, the cruising person can peek in; peeking is reciprocal—that is, a person who is monitored can also see the observer<br>• users can put signs on their door to indicate their availability<br>• meeting users can start desktop video | Informal awareness |

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|---|---|---|---|---|
| | | | conferences | |

This table did not include ambient interface applications. Ambient interfaces use the physical environment of the user to present digital information. They process events similar to event notification systems and their primary goal is to inform users. However, the essential difference to the applications described above is the fact that ambient display applications primarily focus on the subtle presentation of information, and the information *per se* is in general only of a minor concern. Examples of ambient interfaces are the ambientROOM [Wisneski *et al.* 1998], the Abstract Representation Of presence supporting Mutual Awareness (AROMA) system [Pedersen & Sokoler 1997], the information percolator [Heiner *et al.* 1999], and the AwareBots [Gross 2002].

In order to make the different concepts and implementations for the respective type of group awareness information more explicit, the features of CSCW applications are clustered in the following according to the types of awareness introduced above (cf. Table 3).

**Table 3.** Clustering of features of CSCW applications.

| **Awareness information** | **Initiative** | **Features to provide group awareness information** |
|---|---|---|
| Informal | System | • Users are embodied as symbols showing their capabilities (e.g., a simple T-block called textie representing users with text terminals) (synchronous collaborative virtual environments (e.g., MASSIVE)<br>• Notion of space—distance between users influences media they can use and awareness information they can get from each other and they emit themselves (e.g., MASSIVE)<br>• Office model integrates people, documents, and desks for collaboration (e.g., DIVA)<br>• Users can see other users working in the shared workspace with the artifacts as avatars in the 3D multi-user world; the respective users' actions are visualized by automatic positioning of the avatars in the world and by animations of the avatars with symbolic actions (e.g., NESSIE, TOWER); with the replay function past information on other users can be retrieved<br>• Users are provided with information about other users, who visit the same Web page or who recently left the page (e.g., CSCW3)<br>• Users receive audio notifications (e.g., Edison system as part of Portholes) |
| Informal | User | • Users can search for logged on colleagues (e.g., CSCW3)<br>• Users can retrieve images of other offices (e.g., Polyscope, Vrooms, Portholes)<br>• Users can retrieve images of public places (e.g., view-master system as part of Portholes)<br>• Users can establish one-way connections to public and private areas (e.g., background, sweep, and glance features in RAVE)<br>• Users can initiate video phone connections (e.g., vphone feature in RAVE)<br>• Users can navigate virtual hallways and glance into |

| | | |
|---|---|---|
| | | others' offices to get an impression about other users' availability (e.g., Montage)<br>• Users can peek into other users' offices (e.g., Montage)<br>• Users can put signs on their door about their availability (e.g., Montage)<br>• Users can start desktop video conferences (e.g., Montage) |
| Social (incl. gaze awareness) | System | • Users can see an image of the head of drawing partner with an overlaid image of shared artifacts (e.g., ClearBoard)<br>• Users can do simultaneous gesturing and drawing (e.g., ClearBoard)<br>• Users are embodied as symbols showing their capabilities (e.g., a textie representing users with text terminals) (e.g., MASSIVE)<br>• Users receive audio notifications (e.g., Edison system as part of Portholes) |
| Social (inc. gaze awareness) | User | • Users can retrieve images of others (e.g., Polyscope, Vrooms, Portholes)<br>• Users can retrieve images of public places (e.g., view-master system as part of Portholes) |
| Group-structural | System/User | None of the systems provide group-structural information. |
| Workspace (audio and video echo) | System | • Users can see changes in shared editor as busy icon in color of the user manipulating the respective object (e.g., GroupDesign)<br>• Users receive graphical and audio notifications about changes (e.g., GroupDesign)<br>• Users can see color of user who created or last modified an object (e.g., identification mode in GroupDesign)<br>• Users can see overlaid image of head of drawing partner and image of shared artifacts (e.g., ClearBoard)<br>• Users can subscribe to the event types they are interested in; event demons map user's personal interests with the data in the database and notify them accordingly (e.g., Khronika, Elvin)<br>• Users can see evolution of shared workspaces and artifacts as cities and buildings in the 3D multi-user world; information on past changes in the workspaces can be retrieved with the replay function |
| Workspace (audio and video echo) | User | • Users can replay previous actions (e.g., Session Capture & Replay System)<br>• Users can gesture and draw simultaneous (e.g., ClearBoard)<br>• Users, documents, and desks are integrated (e.g., DIVA)<br>• Users may receive awareness information most adequate for their current work context (e.g., GroupDesk, NESSIE, TOWER) |

In Table 3 a rough clustering of the different features of existing CSCW applications concerning the provision of group awareness information was done. So far, the more or less subtle differences in the terminology and meanings of the different authors and designers of the different applications were ignored. Subsequently the awareness terminology explicitly as used and understood by the authors and developers in the field of CSCW is discussed.

## 2.4 Understanding of Awareness by CSCW Application Developers

The terminology of the developers of CSCW applications neither always matches the terminology introduced in section 2.2 nor meets consistency and integrity requirements for software development.

In the following the terms as well as the implicit or/and explicit definitions of the terms as provided by the software developers are examined with the aim of clarifying the motivation for and perspective on awareness by developers of systems of the respective application class. An allocation of the revealed understanding and terms to the clusters of awareness given in section 2.3 (see Table 3) is tried.

The developers of the replay systems from Table 3 tend to focus on technical aspects of cooperation support. Manohar and Prakash [1995] describe an awareness mechanism in their Session Capture and Replay system. They term it WYSNIWIST (What-I-See-Now-Is-What-You-Saw-Then) paradigm, but neither mentions the term *awareness*, nor provides a functional implementation of their paradigm. Li and Li [2002] focus on technical mechanism for coupling single-user applications; they primarily address issues of presenting awareness information in heterogeneous single-user applications. Consequently, their understanding cannot be assigned to one of the categories of awareness in section 2.3.

The developers of collaborative text and graphic editors typically have a clear notion of awareness in mind when publishing their applications. Beaudouin-Lafon and Karsenty [1992, p. 171], in their paper on GroupDesign, explicitly address *awareness* and explain that "by this we mean that each user should be aware of what the others are doing." They focus on the media that are used to convey this awareness information, namely on graphics and audio echo. The paper of Shen and Sun [2002] primarily addresses technical issues of notifications in cooperative applications. Although the authors of both papers use the general notion of awareness, according to the above classification they target *workspace awareness*. Dourish and Belotti [1992, p. 107] studied the use of awareness in collaborative editors. Their objective is to provide group awareness information concerning coordination, since coordination is an important aspect of any collaboration. They define *awareness* as "an understanding of the activities of others, which provides a context for your own activity. This context is used to ensure that individual contributions are relevant to the group's activity as a whole, and to evaluate individual actions with respect to group goals and progress. This information, then, allows groups to manage the process of collaborative working." (p. 107) Their definition of awareness corresponds to the above notion of *workspace awareness*.

The group of Ishii is one of the first and only group to strongly emphasize the need to bridge the gap between social and workspace awareness. Ishii et al. [1994, p. 94] emphasize the notion of *gaze awareness* which they define as "the ability to monitor the direction of a partner's gaze and thus his or her focus of attention." As such, gaze awareness is very similar to *social awareness* mentioned above. Although Ishii et al. focus only on a highly specific aspect of awareness, their system shows a working technical solution for this specific aspect. Furthermore, these authors point to the fringes between different types of awareness and emphasize the importance of bridging these seams.

The developers of collaborative virtual environments often have a very clear notion of spatial awareness in mind, yet it is typically limited to spatial applications. Greenhalgh and Benford [1995, p. 167] use the concept of awareness in the context of collaborative virtual

3D-environments. Although they do not define awareness explicitly, they provide some information on the binding of awareness to objects and media of a universe: "An object may have different awareness of each connected object in each medium. Awareness is quantifiable and may range continuously from full, through peripheral to none. Having a low awareness on another object results in little information being received from it and a high awareness results in more detailed information." (p. 167) This view on awareness can be compared best to *informal awareness*.

The developers typically have a similar point of departure: by introducing virtual office environments, they gain the advantage of a spatial layout and consequently similar strengths as in collaborative virtual environments. However, they are also limited to their metaphor and furthermore their environment often is in competition with file managers integrated in graphical user interfaces. Sohlenkamp and Chwelos [1994, p. 332] distinguish between asynchronous and synchronous awareness. Concerning asynchronous awareness they claim that "users should be able to determine when shared artifacts have been changed by others, determine how those artifacts have changed, and determine when and where others have left messages for them." (p. 332) These types of information refer to *workspace awareness* above. Concerning synchronous awareness they claim that "users should be able to obtain some idea of what co-workers are doing, ascertain a co-worker's availability for contact, control their own level of availability, control the information about themselves which is broadcast to others, know when shared documents are in use by others, know exactly what others are doing during a shared editing session." (p. 332). These types of information refer to workspace as well as *informal awareness* listed above. Although the distinction between asynchronous and synchronous aspects is quite traditional in CSCW, Sohlenkamp and Chwelos (1994) are the only authors who conceptually apply this distinction to an awareness service. Mansfield et al. [1997] have a quite broad notion of awareness; they write: "awareness here refers to the information about any of the entities mentioned above… For example, can you see who is working on a task? What are they doing? What is the current state of an object? With what degree of granularity?". So, it is really about co-workers and artifacts. The locales framework, which constitutes the conceptual grounding of the system, is rather generic and covers informal and workspace awareness.

The developers of event-notification systems often take a pragmatic approach: first, it is checked which types of information can be captured with available sensors or currently conceivable sensors; and secondly, only later with the need of processing and structuring the information, semantic models are introduced. Loevstrand [1991, p. 266] built the Khronika shared event-notification system in order to "increase peoples' awareness of what is going on around them over time by improving the effectiveness in which event information is dispersed in a work community." (p. 266) The events captured and propagated to the users include information from *informal* and from *workspace awareness*. Fitzpatrick et al. [2002, p. 448] emphasize notification, rather than awareness; they point out that "Elvin was primarily designed as middleware for distributed systems". However, they continue, "Elvin supports awareness because it allows us to augment the workaday world and give imperceptible computer-based events a form that can be made publicly available and accessible as an informational resource for perception." (p. 448) So, these authors focus on the technical distribution of information, rather than on theoretical concepts of awareness. Like Orbit, Elvin is based on the locales framework

[Fitzpatrick *et al.* 2002]. Prinz [1999] distinguishes between "task-oriented" and "social" awareness. Task-oriented awareness is "focused on activities performed to achieve a specific shared task"; and social awareness refers to "information about the presence and activities of people in a shared environment" (p. 392). Related to our classification above, task-oriented awareness refers to *workspace awareness*, and social awareness refers to *informal awareness*. Later on, Prinz et al. [2002] focus on technical requirements for an event and notification system and on the presentation of the awareness information. They point out that "it is necessary to develop an open infrastructure that supports the exchange of activity information and awareness across the boundary of different applications." (p. 91). This infrastructure should be able to "visualize activity information using different presentations that can as well be integrated into different applications" (p. 91). In another research strand Gross and Prinz [, to appear #3006] introduced awareness contexts to structure the information. Fuchs et al. [1995] provide a hint to meet these objectives. They define two dimensions of awareness specific for the design of their GroupDesk system: synchronicity and coupling. Awareness includes events in the past as well as current events and events that are related to the own activities and unrelated events.

Web-based applications typically are based on a spatial notion of awareness (cf. collaborative virtual environments above). Gross [1997] does not explicitly define awareness, but provides a concept and an implementation on how to achieve group awareness information for Web users. The author claims that there are several areas where group awareness information is important and that only few of them have been identified so far.

The developers of media spaces primarily focus on information awareness, which is gained by providing users with presence (and sometimes availability) information of other users. The definitions of shared awareness of Borning and Travers [1991] as well as the definition of general awareness of Gaver et al. [1992] refer to *informal awareness*. They emphasize that awareness has to be shared among group members and refer to group awareness as shared awareness, when they write [Borning & Travers 1991, p. 13]:

> We are interested in supporting shared awareness: distribution of general information about the environment, both physical and social. Such information includes who's here, what they are doing (if they want this to be known), whether they are available for interactions and what's happening in the common areas.

In this way, Borning and Travers [1991] raise awareness of the physical *and* the social environment. Dourish and Bly [1992, p. 541] write about general awareness and claim that awareness "involves who is around, what activities are occurring, who is talking with whom; it provides a view of one another in the daily work environments. Awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures…". In that context, Tang and Rua [1994, p. 37] emphasize the notion of tele-proximity and claim that it has several advantages:

> …encourage(s) group work. Team members can easily initiate lightweight communications that allow informal interactions, coordinated further contact, or sometimes transition into more focused communication. They typically share awareness about relevant people, resources, and events—who's in today? who can answer this question? is the group meeting about to start?

Both examples of media spaces constitute valuable prototypes for the provision of *informal awareness* information. Although the authors have targeted for informal

awareness, they did not explicitly indicate what kind of information has to be provided to design or implement support for informal awareness.

Gaver et al. consider general awareness a basic feature of their RAVE system. In defining general awareness they write [Gaver *et al.* 1992, p. 28]

> This simply refers to the pervasive experience of knowing who is around, what sorts of things they are doing, whether they are relatively busy or can be engaged, and so on. Neither planned nor involving a great degree of interaction, this sort of awareness acts as a foundation for closer collaboration.

Gaver et al. rather try to show the advantages of awareness concerning social encounters. They have elaborated a model of different types of querying information about other users. These mechanisms might either be used for *informal* and *workspace* awareness.

The reviewed contributions to develop the notion of awareness and to provide conceptual knowledge about awareness show the following:

- increasing focus on awareness
- wide support of informal and workspace awareness
- different terms addressing similar concepts of awareness
- no intra-disciplinary discussion about a common terminology and widely acknowledged categories of group awareness
- no cross-boundary discussion with other fields

Thus, there is no consolidated body of knowledge with respect to awareness to build on for further developments. Rather, the analysis rather shows the variety of understandings in the CSCW field.

# 3 Awareness in Social Sciences

Since awareness is a widely investigated construct in social sciences, either in sociology with respect to group research, or cognitive and social psychology, there are commonly agreed constructs as well as empirically sound results with respect to different types of human behavior. In section 3.1 the identified constructs are reviewed. In section 3.2 the operational definition of the identified constructs with respect to group awareness is given.

## 3.1 Awareness Constructs

The performed in-depth literature research in applied sociology and psychology (step 2 of our research procedure) comprises possible concepts of awareness as well as a variety of operational definitions, that is, human behaviors reflecting one or more of the identified constructs. In this section first the compilation of constructs is given, and the assignment of human behaviors to the identified categories of awareness follows.

Empirical studies of human behavior in have revealed several understandings of awareness:

*Group Awareness*: It has been defined as ”a specific set of behaviors as characteristics of intimate, primary groups and maintains that these behaviors will occur more often in those groups that have attained an enhanced level of (the group’s) self-awareness” [cf. Barker 1991, p. 82f]. This understanding goes beyond self-awareness addressed below [Mullen *et al.* 2003].

*Social Awareness*: As the ability to take the perspective of another is critical for effective social functioning it is an important component when emphasizing with another. To capture the complexity of social experience, a model has been developed that crosses the three dimensions of *perspective* (that of self or other), *target* (self or other), and *content* (overt appearance or covert appearance) to create eight social awareness forms [cf. Sheldon & Johnson 1993, p. 321]. Social awareness seems to be a crucial performance factor for teams [cf. Salas *et al.* 1999].

*Task-specific Awareness* of the working process can be ”demonstrated by the adequate description of the used strategies (consciously monitoring and regulating these strategies), and by detailed reports on the difficulties in understanding” the task [cf. Etelaepelto 1993, p. 251]. This aspect has been deepened in the domain of education [cf.Arvaja *et al.* 2002].

*Situation Awareness* is defined as ”the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” [cf. Endsley 1994] cited in [Hogg *et al.* 1995, p. 2395f]. The authors propose a generic model of situation awareness (i.e. across many different dynamic task environments) with three levels of situation awareness. Situation awareness is the mental model of the dynamic environment that, when combined with more static system and procedural knowledge, allows decision makers to function [Endsley & Garland 2000].

*Objective Self-awareness* ”refers to the process of taking oneself as the focus of one’s own attention, or becoming aware of oneself” [cf.Mullen & Goethals 1987, p. 125]. It can be situationally induced by the presence of an audience, a mirror or a video camera. Self-awareness ”in conjunction with some salient behavioral standard may lead the individual to begin a matching standard process. That is, if one is sufficiently aware of oneself, one may more readily come to recognize a discrepancy between one’s present behavior and the standard of behavior which is salient in that setting” [Mullen & Goethals 1987, p. 126]. The individual tries to reduce this discrepancy depending on his outcome expectancy [cf. alsoMullen *et al.* 2003].

Given this list of constructs, it becomes evident that the understanding of awareness in social sciences strongly differs from its understanding by CSCW system developers. However, in order to set the features of CSCW applications in relation to constructs from social sciences it might be good to look at operational definitions to each of the identified concepts of awareness in the social sciences. As operational definitions reveal human behavior (patterns) specific for constructs it might bridge the gap between system development and human needs. They might help to compare the expected type of user behavior when interacting with CSCW software (system development perspective) to the actual behavior of users (and being typed according to the set of social science constructs).

## 3.2 Operational Definitions

Empirical evidence to each of the concepts of awareness introduced above (cf. corresponding authors) indicates an influence of awareness on the performance of work tasks. In case of proper enactment and support awareness might significantly reduce human errors and increase the accuracy of work results (cf. authors). In order to take into account this influence throughout system development, detailed knowledge about the constructs has to be made available for developers. Operational definitions enable this

transfer of knowledge. They allow for the collection of reliable data on human behavior for system developers. Table 4 shows the currently available operational definitions.

**Table 4.** Definitions of various kinds of awareness.

| Type of awareness | Operational definitions |
|---|---|
| Group awareness | There are a specific set of behaviors as characteristic of intimate, primary groups according to [Barker 1991, p. 82f]:<br>1. affective behaviors in the form of (verbal and non-verbal expressions of emotions):<br>a) positive sentiments (rewards), b) negative sentiments (punishment), c) general affect (neither rewards nor punishment)<br>2. collective orientations: primary group members experience a sense of interdependence with one another, and a mutual welfare in a joint venture<br>3. particularism: is an act in which a given individual orients him/herself towards another on the basis of other's possessions of properties (i.e., qualities or performances), which bear a distinct relation to the actor's own properties (i.e., traits or statuses)<br>4. diffuseness: behavioral occurrences of diffuseness are typified by an actor's display for broad interest in other properties |
| Social awareness | There are eight social awareness forms according to [Sheldon & Johnson 1993, p. 321]:<br>1. awareness of one's own experience from the self: I'm feeling angry.<br>2. awareness of one's experience from the perspective of another person: She's reacting as if I'm angry—maybe I am.<br>3. awareness of the other's experience from the self perspective: She has no right to be so mad.<br>4. awareness of another's experience from that person's perspective: I'd be furious if I were her, too.<br>5. awareness of one's own appearance from the self perspective: scrutinizing ourselves in a mirror<br>6. awareness of one's own appearance from another's perspective: suddenly noticing someone is observing us.<br>7. awareness of another's appearance from our own perspective: Why doesn't he comb his hair?<br>8. awareness of another's appearance from that person's perspective: we notice that a teenager seems obsessed with her complexion. |
| Task specific awareness | Task specific awareness of the working process can be demonstrated by several documentations, according to [Etelaepelto 1993, p. 251]<br>1. adequate description of the used strategies (consciously monitoring and regulating these strategies);<br>2. by detailed reports on the difficulties in understanding the task. |
| Situation awareness | The three level development of situation awareness, according to [Hogg *et al.* 1995, p. 2395f]:<br>1. Level 1 concerns the operator's ability to perceive elements in the current situation.<br>2. Level 2 situation awareness integrates information concerning the current process state derived at Level 1 into overall comprehension of the current situation.<br>3. Level 3 situation awareness concerns the projection of the current process state into the near future. The importance of this future projection is that the operator must assess now if the anticipated future process state is perceived as disparate with operational goals and plan mitigating actions accordingly. |
| Objective self-awareness | Changes in performance may occur subsequently because of an increased motivation to reduce the intrapersonal discrepancies. The individual's performance can suffer if the individual spends too much energy in the current process of self-attention because he/she does not have enough resources to accomplish his/her task [cf.Mullen & Goethals 1987, p. 125]. |

*Group awareness* is related closely to emotions, the perception of others' properties, and the provision of collective leads. There might be patterns of interaction or group roles giving direction to social developments in the group and/or work space. In the context of CSCW this type of awareness strongly affects the collaboration aspect when work is supported by computers, in terms of how group members perceive each other and handle this information when co-operating via information and communication technology in work tasks [cf. Arvaja *et al.* 2002].

*Social awareness* is a very complex construct, since it involves taking roles of others. It might enhance the mutual understanding of group members, but also direct individuals or the group to follow certain goals or procedures. It also captures the individual and collective feeling of being observed and becoming transparent through activities for others, hence it captures social pressure and socially enforced competition. For CSCW processes this category of awareness is relevant when behavior is monitored and transmitted to others by means of communication technology. Overall, it affects the openness of group members to mutual reflection. Each individual as well as a group becomes an object of discourse in the course of collaboration [cf. Salas *et al.* 1999]. The medium computer might influence the behavior of group member to engage in such kind of social processes, both, when being monitored and reflecting behavior by means of information and communication technology. Novel concepts, such as social translucence for the collective mutual awareness of common resources (e.g., task states, activity contexts, artifacts) explicitly deal with social phenomena like peer pressure, accountability, and competition [cf. Erickson & Kellogg 2000].

*Task-specific awareness* addresses the mutual transparency of understanding the rationale of tasks and their accomplishment in a group. In CSCW, making the understandings of tasks transparent might reveal the different ways to interpret work tasks and the individual capabilities to achieve (group) tasks. Olson and Olson [2000] have found that 'distance' seem to be crucial factors for successful task accomplishment. Computer support might help to document and elicit this knowledge, however, bringing in the risk of misinterpretation without human intervention.

*Situation awareness*, as described in Table 4, adds a dynamic dimension to the structural one. Depending on the situation, users might behave differently [cf. Endsley & Garland 2000; Graham *et al.* 2004]. The computer support might only be perceived as such, in case all three different levels of situation awareness can be handled adequately by software systems. The latter means that for CSCW systems, the history of the (group) work processes as well as the projection of the future ones have to be reflected and processed by software in order to provide context-sensitive support.

*Objective self-awareness* is addressing the individual performance. Computer-support of this type of awareness might help either to stabilize individual performance through moving the focus from self-attention to work or group attention, or to improve performance by providing additional resources for social or work processes, respectively [cf. Mullen *et al.* 2003]. This can be achieved through increased transparency of others at the individual workplace providing insight into others' focus of attention by means of information and communication technology.

Overall, each of the constructs can be interpreted in the context of CSCW, and might influence development activities of CSCW software systems.

# 4 Common Ground and Common Future

In this section, the reviewed terms and constructs, concepts, features and operational definitions specific for CSCW and the social sciences are cross-checked, and possible gaps at the notational, conceptual, and implementation level are revealed and tried to be bridged. In section 4.1, the understandings of awareness by CSCW developers are compared to the empirically identified constructs from social sciences. In section 4.2 we put the intended behavior descriptions (as given by CSCW developers) into the context of operational definitions (as provided by social scientists). This step allows us to propose concrete actions for the embodiment of empirical findings into CSCW developments. We suggest evaluation activities, such as checking existing CSCW applications in how far the technical developments implement social-science constructs. Finally, we come up with a list of cross-disciplinary (research) activities, such as the collaboration of CSCW developers with social scientists in the course of design (section 4.3).

## 4.1 Terminology

The dispersed use of the terms concerning awareness can be documented through the use of identical terms for a variety of meanings of awareness, such as in case of social awareness; and the use of different terms expressing similar meaning of awareness, such as for task-specific awareness (social sciences) and workspace awareness (CSCW).

Subsequently, commonalties and differences in naming and meaning according to the identified constructs of awareness are elaborated. Finding common ground along the categories of social sciences, namely group, social and self-awareness is proposed.

The notion of *group awareness* in CSCW is used as a general term covering the entire spectrum of awareness in computer-supported cooperative settings. The notion of group awareness in the social science literature also captures this spectrum, but is more specific, referring to the behavior of the group members, which emerges out of the interactions among group members. As such, it refers explicitly to the human part of the socio-technical CSCW-system—this explicit reference denotes the subject of study in social sciences, namely humans. From the understanding of CSCW developers it can be concluded that, however, their ultimate subject of study after analysis is the technical part of a CSCW system, namely the software system (see section 2.4). Consequently, it is interesting how the mapping of human needs to technical system features is handled. In fact, this mapping requires an explicit switch between the subject of study or universe of discourse, namely from humans to software. Tuning the understanding of group awareness given these facts means allowing for both subjects of study in the course of developing CSCW systems, however, at different stages of development.

The notion of *social awareness* in CSCW addresses primarily acts of collaboration and the information needed for collaboration such as the interest, attention, and emotional state of the other persons. The notion of social awareness in social sciences not only allows for these factors, but also includes and emphasizes empathic human capabilities to see oneself or the other person from the other person's perspective. These capabilities, when considered for CSCW software system development, require a user-centered approach to software development. Besides asking potential users which system behavior they expect with respect to empathic understanding (in the course of analysis), the

adaptability and adaptation of the software system could play a crucial rule, e.g., in case dynamic behavior changes of the software system are required. As such, social awareness requirements might either lead to functional or non-functional requirements for software development, depending on which features are going to be implemented and how they are used. Finally, it has to be noted that social awareness in the understanding of social sciences matters in any kind of interaction between two and more group members, not only in collaborative settings, as probably assumed by CSCW developers.

The notion of *situation awareness* in social sciences and the notion of *workspace awareness* in CSCW have similar meanings. Workspace awareness in CSCW includes dedicated information about the workspace, such as information about other users of the shared workspace and the artifacts being part of that space. The notion of situation awareness in social sciences is more general, addressing the perception of elements of the environment. In the social science literature the elements are traditionally not distinguished any further—for instance, it is not specified whether the element is an artifact or another person. However, for CSCW software development this type of information needs to be identified and assigned to functional or non-functional software requirements.

The term *task-specific awareness* from social sciences is not explicitly discussed in the CSCW literature. However, the different types of group awareness have been identified, in order to describe parameters to improve the performance of group work. Hence, the task dimension has been considered without mentioning it explicitly [Gutwin & Greenberg 1998b]. *Objective self-awareness,* stemming from social sciences, is not discussed in the CSCW community at all. However, it could be argued that a dedicated CSCW concept might help to design proper computer support. As indicated in section 3.2, awareness features of this type might help to stabilize if not improve individual performance.

*Informal awareness* and *group-structural awareness* from CSCW are not discussed in social sciences at all, although it could be argued that situation awareness (concerning the perception of elements of the environment) in social sciences includes informal awareness (as the pervasive experience of who is around, what these persons are doing, and what they are going to do). Considering it as a functional requirement, awareness features of this kind require the presentation of information about other users in CSCW software systems.

The discussion with respect to terms und fundamental understandings of awareness shows only few corresponding concepts between CSCW and social science. Besides workspace awareness and situation awareness, all other CSCW terms differ from social science constructs and need further analysis or require further conceptual studies.

## 4.2 Operational Implementations

In the following, the operational dimension of constructs and concepts are reflected in two directions: First, those types of awareness that are already adequately supported by CSCW software systems are listed. Adequate support in this context means the accurate implementation of a construct. In section 4.2.1 the results of this crosscheck with respect to the specified types of CSCW applications are given. Secondly, (in section 4.2.2) it is checked whether and which awareness features of the investigated CSCW software systems have been studied empirically. In this way, it is possible to identify features that have been investigated from a user's perspective and features that still lack empirical proof

of concept. Section 4.2.3 summarizes the findings to show how CSCW developments basically match with those from social sciences.

### 4.2.1 Human Behavior and Awareness Features of CSCW Applications

Given the results of the previous sections—both capturing the recent developments in CSCW and the findings of empirical research—the paper proceeds according to the objectives of our study, namely to check in how far existing CSCW applications enable or support different forms of awareness from a human behavior perspective. First, the existing types of CSCW software systems (as identified in section 2.3) are set in relation to the social science constructs of awareness (section 4.2.1.1). Secondly, the applications are discussed briefly, in order to provide concrete data on the existing applications for the respective developers (section 4.2.1.2). Finally, the perspective is switched to the social science constructs to list requirements for adequate human group awareness support (section 4.2.1.3).

#### 4.2.1.1 Enabling Applications

In order to achieve a shift from technology-driven development towards human-centered design of CSCW software systems a scheme, which allows the setting of technology-driven approaches in relation to a behavior-oriented understanding of awareness, was developed. The scheme enables the interpretation of existing technical features as enablers of different types of human behavior in the context of awareness (as to be performed according to step 3 of our research procedure), and the identification of required improvements with respect to empirical tests of existing CSCW applications (according to step 4 of our research procedure). The latter fosters the development of human-oriented socio-technical systems, and allows checking whether the enabled human behavior corresponds to the empirical findings (see section 3.2).

Table 5 shows the relevant instance of the developed scheme for our study. It contains the results of the first cross-check at the operational level: Existing types of CSCW applications featuring awareness (as initially listed in Table 1) have been put into relation to the human behaviors given in Table 3. The various capabilities of the sample applications and their degree of support with respect to the awareness behaviors have been crosschecked. The entries of the table reflect the results at a glance. The capabilities of CSCW software systems that enable or support a particular form of awareness are marked with X in the corresponding cell.

The entries in Table 5 show that none of the different types of CSCW applications supports the entire range of human behaviors that developers might want to support. However, a variety of aspects are enabled by the largest number of applications:

- *Collective orientation*—an aspect of group awareness
- Awareness of another's appearance from our own perspective—an aspect of social awareness
- The operator's ability to perceive elements in the current situation—an aspect of situation awareness
- *Overall comprehension of the current situation*—another aspect of situation awareness

**Table 5**. CSCW application support of human behavior with respect to awareness

| **Classes of CSCW applications as given in Table 2, featuring awareness forms of conscious awareness** | **Async. CSCW apps** | **Sync. coll. editors** | **Sync. coll. e. (soc. aw.)** | **Sync. coll. virtual envs** | **Semi-sync. virt. office** | **Semi-sync. event notif..** | **Context-aw. event notif.** | **Semi-sync Web-based apps** | **Const. aw. spaces** | **Soc. brow-sing spaces** |
|---|---|---|---|---|---|---|---|---|---|---|
| Group awareness | | | | | | | | | | |
| 1. affective behaviors | | | X | X | X | | | X | X | |
| 2. collective orientations | | X | X | | X | | X | X | X | X |
| 3. particularism | | | | | | | | | | |
| 4. diffuseness | | | | X | X | | | X | X | |
| Social Awareness | | | | | | | | | | |
| 1. awareness of one's own experience of the self | | | | | | | | X | | X |
| 2. awareness of one's experience from the perspective of another person | | | X | | | | | | | |
| 3. awareness of the other's experience from the self perspective | | | X | | X | | | | | |
| 4. awareness of another's experience from that person's perspective | | | X | | X | | | | X | X |
| 5. awareness of one's own appearance from the self perspective | | | | | | | | X | | |
| 6. awareness of one's own appearance from another's perspective | | | | | | | | | | |
| 7. awareness of another's appearance from our own perspective | | | X | X | X | | | X | X | X |
| 8. awareness of another's appearance from that persons perspective | | | | | | | | | | |
| Task specific awareness | | | | | | | | | | |
| 1. adequate description of the used strategies | X* | X* | X* | | X* | X* | X* | X* | | |
| 2. detailed reports on the difficulties in understanding the task | X | | X | | X | | X | X | | |
| Situation Awareness | | | | | | | | | | |
| 1. the operator's ability to perceive elements in the current situation | | X | X | X** | X | X | X | X | | |
| 2. overall comprehension of the current situation | X | X | | | X | X | X | X | | |
| 3. projection of the current process state into the near future | | | | | | | X* | | | |
| Objective Self-awareness | | | | | | | | | | |
| | | X | X feasible | | | | | | X*** | X*** |

* not mentioned explicitly by authors
** limited to the actor's environment
*** monitored person

In summary, three types of awareness have been addressed explicitly by most of the CSCW application developers: *group*, *social*, and *situation awareness*.

#### 4.2.1.2 Critiquing at the Application Level

Taking a closer look at the different types of applications reveals that ClearBoard, Diva and CSCW3 address most of the characteristics, namely ten out of eighteen aspects of awareness. They are the *most comprehensive awareness support systems*.

In current software systems there exists a typical way of supporting social awareness, namely the use of *awareness symbols*. Systems such as CSCW3 use symbols to represent social attitudes as well as personal feelings about certain topics or persons. They can be placed anywhere along textual information. However, the investigated CSCW applications also lack some types of awareness:

- One form of task awareness, namely the "*adequate description of the used strategies*" can only be *achieved implicitly*, since the developers did not mentioned this context of use for their systems (e.g., Session Capture and Replay, ClearBoard, GroupDesign, DIVA, NESSIE) explicitly, although providing relevant features.
- *Particularism* has *not* been *supported* so far. It denotes an act in which a given individual orients him/herself towards another person on the basis of the other's (assigned) properties such as qualities or performance. These properties bear a distinct relation to the actor's own traits or statuses.
- Two out of eight forms of *social awareness* and the projection of the current process state into the near future (*situation awareness*) have *not* been *implemented* at the feature level so far. Consequently, no software system exists that provides an explicit set of features to support the entire range of various aspects of social or/and situation awareness.
- The latter holds for all types of awareness. None of the investigated CSCW applications supports all aspects of one kind of awareness.

In order to provide the entire spectrum of a particular kind of awareness, several improvements are required from the respective applications' perspective:

- The *Session Capture and Replay System*, for instance, provides an implicit description of the used strategies, a constituent of *task-specific awareness*. Visualizations like bar charts and flow diagrams could help users to become adequately aware of the used strategies.
- Although the *ClearBoard* system supports *social awareness*, it does not provide users with information about their own appearance (points 5 and 8 in Table 5); nor does it provide information about the effect(s) of the own appearance on other users. Diagrams providing users with an overview of the collaborative setting (including both, actors and their actions) could improve social awareness information support of ClearBoard.
- The *NESSIE* and *TOWER* system support *situation awareness*, but lack explicit projections into the future. Users can see the current changes in the workspaces and the current presence and activities of other users. They are also able to replay past information on workspaces and users. A small tool analyzing the changes in the workspace could extrapolate the development and give valuable hints as far as future behavior is concerned. Furthermore, statistics about past use could provide valuable hints for potential developments. For instance, the system could find out the daily

work rhythm of individual users and provide information on the current availability of users based on these rhythms.

- The *Constant Awareness Media* Spaces, such as Polyscope, provide *group awareness* information, but do not support particularism. In order to support particularism, more information about the activities for task completion should be provided. For instance, cameras capturing activities of single users and transmitting them to other geographically dispersed users could be helpful.

Overall, a variety of possibilities of enhancing existing applications exist, either to complete their set of features or to equip the application with awareness support for a particular aspect or type of awareness.

#### 4.2.1.3 Reflecting the Empirical Evidence through Human-Centered (Non-functional) Requirements for Awareness Support

Accounting for the social science dimension of awareness lays ground for implementing human-centered design specifications. Each of the technical features or enablers has to reflect or incorporate a cognitive or social dimension with respect to the different types of awareness.

- *Group awareness*
  - Since none of the existing CSCW applications support particularism, improvements to that respect are essential. CSCW software systems should support particularism to enable a transactive memory system. According to Wegner [1987], a transactive memory system is a ”set of individual memory systems in combination with the communication that takes place between individuals” and is ”more than its individual component systems”. Furthermore, Wenger argues that,

    ”The individual gains other’s domains of expertise, of course, but also gains access to the knowledge that is created through integration within the transactive memory. … Moreover, a group with a smoothly working transactive memory is likely to be effective in reaching its goals and will thereby satisfy its members.” (p. 197).
- *Social awareness*. Several aspects are involved:
  - Awareness of one’s own appearance from the self that can be interpreted as a part of the theory of *objective self-awareness*. To support this type of awareness, *mirroring video cameras* can be used carefully in order not to stress users. Using this feature, they could benefit through reflecting their behavior in the collaboration setting at hand.
  - Awareness of one’s own experience from another’s perspective. This type of awareness could be supported through *feedback mechanisms*. They have to be *context-sensitive*, and as such, reflect the communication rules between the involved partner. Inputs from the field of cognitive or social ergonomics are useful.
  - Awareness of another’s appearance from that person’s perspective. This type of awareness requires mechanisms for reflection that go beyond supportive introspection. Here again, the particular situation of communication has to be taken into account to convey the intended meaning of the appearance correctly.

- *Situation awareness*:
  - Projection of the current work/social process state into the future. Process states are part of the organization applications in which they are embedded. Process-oriented representations can be found in today's workflow management systems. Hence, information about states can be derived from these applications and utilized for the required projection to support situation awareness.

### 4.2.2 Empirical Data on CSCW Applications

In section 4.2.1 existing CSCW applications were evaluated with respect to their support for different forms of awareness from a human behavior perspective. In this section features of existing CSCW applications are identified that have to be tested empirically, in order to ensure user-centered development. Table 6 lists the features along the CSCW categories as introduced in section 2 and table 2 and 3.

Subsequently, the findings of Table 6 are commented for each type of awareness. Group-structural awareness is not considered due to the lack of features. All the systems under study (cf. table 2) are considered.

*Informal awareness*. The informal awareness features of *MASSIVE,* a virtual reality system with 2D and 3D mode, have been empirically tested with relevant findings for peripheral awareness and presence [Greenhalgh & Benford 1995]:

1. The first observation concerning *peripheral awareness* was that the devices used did not support real-world fields of view. The real-world field of view is about 150 degrees width, whereas the head-mounted displays had a field of view of about 40-50 degrees. This technical limitation had impact on the behavior of the participants. For instance, they had some difficulties in forming a circle at the beginning of the meeting. This shortcoming has been solved with some technical extensions: a zoom-in and zoom-out function has been introduced. Additionally, the in-body view has been extended with a bird's eye view, a front on view, a view of other users and so forth.
2. Another observation was made concerning the lack of *engagement*. There were several instances when conversations stopped and several situations in which the participants did not know whether they were heard. Feedback for both the speaker (concerning the other users' attention) and the audience (concerning the person who is speaking) was not possible. It also happened that users engaged in other activities and were not actively participating in informal events.
3. Finally, relevant findings were made concerning the *presentation of information.* Users provided with a textual presentation of information did not respect the distance of politeness in conversations and often even walked through other users. The users of the 3D applications were provided with proper means of visualization and consequently, respected adequate distances.

These findings can be compared to the findings with respect to social awareness in social sciences. Overall, they show that *awareness support requires a tuned mix of views and perspectives on various targets (objects, persons) in different contexts of use*. Furthermore, these findings suggest that situation awareness is highly determined by the field of view and the adequacy of the presentation of information.

**Table 6.** Features of CSCW applications requiring empirical evidence

| Type of awareness | Features providing awareness information to be tested empirically |
|---|---|
| Informal | • Office model integrates people, documents, and desks for collaboration (semi-synchronous virtual office environments, e.g., DIVA)<br>• Users can see users working in the shared workspace with the artifacts as avatars in the 3D multi-user world (e.g., NESSIE, TOWER)<br>• Users are provided with information about other users who visit the same Web page or who recently left the page (semi-synchronous WWW-based applications, e.g., CSCW3)<br>• Users can meet other users on Web pages and exchange information and bookmarks (semi-synchronous WWW-based applications (e.g., CSCW3)<br>• Users can search for colleagues logged in on the same server (semi-synchronous WWW-based applications, e.g., CSCW3)<br>• Background, sweep, and glance buttons establish one-way connections to public or private areas (e.g., RAVE)<br>• vphone allows users to initiate a video phone connection (e.g., RAVE)<br>• Hallway model allows users to navigate virtual hallways and glance into others' offices; glances give a good impression if the user is in her office and if she currently wants to be approached (media spaces: social browsing applications, e.g., Montage)<br>• If the doorway is open, the cruising person can peek in; peeking is reciprocal—that is, a person who is monitored can also see the observer (media spaces: social browsing applications, e.g., Montage)<br>• Users can put signs on their door saying that they are available, busy, and so forth (media spaces: social browsing systems, e.g., Montage)<br>• From these reciprocal glances, full-featured desktop video conferences can be started immediately (media spaces: social browsing systems (e.g., Montage) |
| Social (gaze awareness) | • Constant awareness systems display images of others (e.g., Polyscope, Vrooms, Portholes)<br>• Edison system additionally plays audio sequences (e.g., Portholes)<br>• View-master system displays images of public places (e.g., Portholes) |
| Group-structural | None |
| Workspace (audio and video echo) | • Replay of users' past actions (what-you-see-now-is-what-I-saw-then, WYSNIWIST) (asynchronous CSCW systems (e.g., Session Capture & Replay System))<br>• Manipulated objects marked with busy icon in color of user (synchronous collaborative text and graphic editors (e.g., GroupDesign))<br>• Graphical and audio notifications about changes (echo) (e.g., GroupDesign)<br>• Objects have color of user who created or last modified object (identification mode) (e.g., GroupDesign)<br>• History mechanism (synchronous collaborative text and graphic editors (e.g., GroupDesign)<br>• Office model integrates people, documents, and desks for collaboration (e.g., DIVA)<br>• Rooms can be assigned special purposes (e.g., DIVA)<br>• Users then can subscribe to the event types they are interested in (the recipients are placed in control); the event demons map a user's personal interests with the data in the database and notify them accordingly (e.g., Khronika, ELVIN, GroupDesk, NESSIE, TOWER)<br>• Depending on access rights to the events, the system provides information about all activities of all users currently logged in and all time and system events (e.g., Khronika, ELVIN, GroupDesk, NESSIE, TOWER)<br>• Users receive awareness information about present as well as past activities and about coupled events, which are events that are related to the current activities of a user, as well as uncoupled events, which are events that are not directly related to the current activities of a user but which are of general interest (e.g., GroupDesk, NESSIE, TOWER)<br>• Users can see the evolution of the shared workspaces and artifacts as cities and buildings in the 3D multi-user world; with the replay function information on past changes in the workspaces can be retrieved (e.g., NESSIE, TOWER)<br>• Users can annotate Web pages for others (semi-synchronous WWW-based applications, e.g., CSCW3) |

The *Polyscope* system was used and studied for two months by a dozen users at EuroPARC. The study showed that users enjoyed features like the facility to see several video sources simultaneously and the symmetry of the awareness—that is, users who are monitored get information about the person who monitors them [Borning & Travers 1991]. However, after the use of the system got to be business-as-usual users hardly utilized the feedback feature (77 percent of the users turned it off). The study presented in [Borning & Travers 1991] does not contain relevant findings about social awareness, task-specific awareness, situation awareness, and objective self-awareness as presented in the social science section. Behaviors related to these types of awareness should, therefore, be studied.

Informal observations of the use of the *Portholes* system in order to connect Xerox PARC in California with EuroPARC in the UK showed that the informal awareness information was very helpful for users. They were well aware of the presence of other persons at the other site. However, several users complained that the system needed too much space on the monitor. Furthermore, the system helped in improving the sense of a community [Dourish & Bly 1992]. However, the authors concluded that, since the "image information is intended to be available without necessary actions from the users, other information is intended to be available in a lightweight … manner", evaluations would be challenging (p. 545). Compared to our findings in the social science literature, these features support *social awareness* and *situation awareness*.

The *DIVA* virtual office environment offers informal awareness. The software system implements clearly distinguished asynchronous and synchronous features of awareness. Since such an explicit distinction is quite unique in the CSCW community, evaluations of the effects of the different types of information about users, documents, and desks could show the effect(s) of synchronous and/or asynchronous provision of awareness. The same holds for NESSIE and TOWER. Both provide innovative types of awareness features. However, no results on user evaluations have been published so far.

The informal awareness features of *CSCW3* have only been studied in non-systematic empirical studies. Informal studies of students using the CSCW3 prototype revealed that users enjoyed informal awareness. They rarely closed the room view since they often glanced at the provided information there. However, the features did not scale—that is, the room list (a list of all users on the same Web page) has been developed for a small number of users rather than for large number of dispersed users. In the latter case the use of the tool has been experienced as confusing.

The functionality of the *RAVE* system and particularly the set of features implementing informal awareness was built on previous development experiences, such as Polyscope and Portholes. However, there are no empirical studies of the RAVE system available. The RAVE system has been developed in a participatory design style—the developers of the system constantly used the system, in order to receive early feedback and to improve its functionality continuously. Although the results of this iterative evaluation essentially influenced the development of the software, no documentation of the experiences gained is available.

The *Montage* system was used for eight months by the development group, and for nine weeks data were collected. The results show mainly that the glance view feature was quite often used and that only 36 percent of the glances were acknowledged. Many glances had only the purpose of peeking into another person's office without the intent to

contact this person. These findings relate to *situation awareness*. It would be interesting to see how the features influence group awareness, social awareness, task-specific awareness, and objective self awareness.

*Social awareness*. The *ClearBoard* system and its functionality with respect to social awareness have been studied intensively. The system was developed iteratively from TeamWorkStation-1 to TeamWorkStation-2, to ClearBoard-1 and ClearBoard-2. Whereas in TeamWorkStation-1 users had two screens, one for the private workspace and one for the public workspace, TeamWorkStation-2 provided an integrated workspace on one screen. Users did not have to switch between screens when their focus of attention has been the social setting of the group. In ClearBoard a half mirror was used on the screen. Therefore, users were able to look at their own screen and have eye contact and so-called gaze awareness at the same time (in the TeamWorkStation systems users had to decide to either look into the camera or on their screen). However, the goal of ClearBoard was only to support social awareness. Therefore, only social awareness was tested. Group awareness, task-specific awareness, situation awareness, and objective self-awareness were not in the scope of this project.

The social awareness features of *MASSIVE* have been empirically tested with findings concerning engagement (See the discussion on informal awareness above). In the studies of *Polyscope* and *Portholes* no findings concerning social awareness are mentioned.

*Workspace awareness*. The *Session Capture & Replay System* has been tested in order to study technical features such as scalability [Ishii *et al.* 1994]. However, no results have been publicly reported about the effect of the provided awareness information. The empirical studies and the iterative design of *ClearBoard* have already been described above. The particular features supporting workspace awareness - overlaid images and simultaneous gesturing and drawing—were a result of this approach [Ishii *et al.* 1994].
No empirical results are reported about the workspace awareness features of *GroupDesign*. The same holds for the informal awareness features of the *DIVA* virtual office environment with respect to the work tasks. There are also no empirical data available for the semi-synchronous event notification systems *Khronika* and *ELVIN* as well as the context-aware notification applications (*GroupDesk*, *NESSIE*, and *TOWER*). Finally, the workspace awareness features of *CSCW3* have only been studied in non-systematic empirical studies without leading to significant results.

In summary, most of the features seem to have undergone user tests. However, few sound empirical results exist. Most of them address informal awareness, and, as such awareness about the social setting of group work.

### 4.2.3 Matching Concepts

This section summarizes the correspondence of the different types of awareness as they have been identified in CSCW and social sciences (see also Table 7):

- Correspondence for *group awareness* exists. In CSCW the entire spectrum of awareness is captured by this term. In social sciences the emergence of behavior of group members when they mutually interact is meant by group awareness. Consequently, the concept of social sciences is oriented towards the human part of the socio-technical CSCW system, whereas the CSCW notion of group awareness implicitly addresses a set of features that support awareness.

- Correspondence for *social awareness* also exists. Similarly to group awareness, there is a strong emphasis in social sciences on the human part of the CSCW system. In this case, social awareness denotes the empathic capabilities of individuals in seeing oneself or the other person from the other person's perspective.
- The concept of *workspace awareness* in CSCW and the concept of *situation awareness* in small group research literature are similar. In both cases the perception of the environment is emphasized. In particular, the perception of roles of artifacts and the objects of a workspace seem to be crucial for CSCW (software) system development.

**Table 7.** Corresponding categories of awareness.

| **CSCW**<br>**Corresponding category of awareness** | **Social Sciences**<br>**Corresponding category of awareness** |
|---|---|
| Group awareness | Group awareness |
| Social awareness | Social awareness |
| Workspace awareness | Situation awareness |

**Table 8.** Non-corresponding categories of awareness.

| **CSCW**<br>**Category of awareness** | **Social Sciences**<br>**Category of awareness** |
|---|---|
| Informal awareness | ? |
| Group structural awareness | ? |
| ? | Task-specific awareness |
| ? | Objective self-awareness |

As indicated in Table 8, equivalents for four types of awareness do not exist: informal and group-structure awareness on the CSCW side, and task-specific and objective self awareness on the social science side. Nevertheless, some relations to other types of awareness exist in each of the fields:

- As was shown in section 4.2.2, at the operational implementation level, several features of *informal awareness* could be part of situation or social awareness (see also table 9 in section 4.3).
- *Task-specific awareness* has been supported implicitly since there are features enabling the awareness about tasks and workspaces (see section 4.1).
- *Objective self-awareness* can be considered a specific aspect of social awareness, as shown in section 4.2.1.3. Consequently, features enabling social awareness can be checked whether they provide awareness of one's own appearance from the self.
- *Group-structural awareness* has been addressed by CSCW developers, but has not been implemented so far. Consequently, no behavior data can be provided. They could provide a frame of reference for design and (empirical) evaluation.

## 4.3 Improving operational implementations

As already indicated in section 4.1. and 4.2 some ideas have been developed to overcome experienced deficiencies or to implement certain features enabling awareness. Table 9

summarizes those suggestions for implementation and improvement. The addressed categories of human behavior, since user-centered system development should be characterized by behavior-related objectives are followed.

**Table 9.** Consolidated suggestions for improvement.

| Type of Awareness | Recommended Means | Expected Benefit |
|---|---|---|
| Group awareness | Provision of information for task completion | Establishment of transactive memory system facilitating collaboration and increasing group satisfaction (particularism) |
| | Provision of simultaneous source of information | Symmetry of awareness |
| Social awareness | Visualization through diagrams or symbols (2D, 3D) | Provision of information about one's own appearance enabling feedback on the effect of the appearance on other group members |
| | Context-sensitive feedback mechanism | Reflection on communication rules through feeding back on one's own or other experience from another group member<br>Establishment of sense for community (informal awareness) |
| | Mutual sensing of presence | Respect of other's spheres or interaction spaces (peripheral awareness) |
| | Motivation for and control of engagement | Each member is heard and can be brought into the group |
| Task-specific awareness | Visualization: bar charts, flow diagrams | Mutual transparency of working process leading to increased understanding of group members |
| Situation awareness | Extrapolation tools | Provision of explicit projections into the future of collaborative activities leading to increased understanding of individual behavior of group members and allowing sound revision of individual expectations |
| | Feedback provision at an informal level | Improving the sense of community |
| | Presentation of group member's location | Improving the spatial feeling of community (location awareness) |
| Objective self-awareness | Mirroring video camera | Increased awareness of oneself leading to accurate support of self reflection |

Apparently, social awareness and situation awareness can be supported in a variety of ways. Context-sensitive feedback mechanisms and accurate presentation of information seem to be highly recommended for most of the proposed means.

# 5 Conclusions

Based on the results of the discussions of awareness with respect to CSCW applications as well as on the awareness of empirical findings on this topic in small group research, this paper lays ground for revisiting the research agenda through structured representation of concepts and the comparison made. Several approaches can be found in literature, where phenomenology is used for deriving conceptual grounding of awareness in CSCW. Examples are the work of Dourish [e.g., Dourish 2001], Robertson [e.g., Robertson 2002], and Chalmers [e.g., Chalmers to appear]. On a whole this paper tries to approach this challenge of awareness support in CSCW systems from a different angle—that is, from a combination of the lessons learned from CSCW literature and findings from social science literature. The multi-step procedure of this paper involved the review of existing technical features as well as the structuring of results in social sciences (studies concerning human behavior). As such, the demand for interdisciplinary research in the field of CSCW has been met, and, finally has led to requirement definitions for artifact development. In addition, this paper provides a rich set of features to be studied empirically.

The comparative analyses in this paper clearly reveal that, firstly existing CSCW applications only partially support user-centered awareness, and secondly, some important kinds of information are not supported at all.

Further investigations are required. They concern methodological issues. First, the designers should be aware of what kind of awareness their applications should support according to the classification of awareness stemming from social sciences. Following the traditional classifications proposed by CSCW researchers will lead to a continuous disregard of empirical results (i.e., the social realities of CSCW application users). In the long run, the resulting methodological and conceptual drifting-apart of social sciences and CSCW will continue—a process that does not facilitate, but rather hinders the integration of previously isolated fields.

Finally, it is necessary to enrich the existing CSCW applications with the missing features to support the corresponding behavior. In this way, holistic support of the type of awareness they aim at becomes feasible. However, the results of these improvements have to undergo critical review. Empirical evaluations of the group performance achieved through the novel mix of features for the different types of awareness are required. Following this procedure, novel behaviors might be recognized that lead in turn to novel features, and so forth. According to this concept, a truly interdisciplinary discourse can be established since it not only lays ground for novel conceptual and methodological inputs for CSCW and the social sciences, but also enables benefits in terms of synergistic effects for group members. The latter has to be considered as a prerequisite towards human-centered system design.

In small group research literature the emphasis is on an individual and his/her environment. Often there is no clear distinction between the overall environment and the individual artifacts contained. Studies that make this distinction could make a great contribution towards human-oriented design of CSCW applications.

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