

# Handbook of Research on Socio-Technical Design and Social Networking Systems

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# Chapter XLII

## Situational Awareness in Collaborative Work Environments

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### ABSTRACT

*This chapter addresses awareness support to enhance teamwork in co-located collaborative environments. In particular, the authors focus on the concept of situational awareness which is essential for successful team collaboration. Mutual situational awareness leads to informal social interactions, development of shared working cultures which are essential aspects of maintaining working relationships. First, an overview of the studies on team coordination and situational awareness support is presented. Second, a collaborative working environment is described for scientific teams in a molecular biology omics experimentation domain. Then, the results of practical case studies are discussed, as well as situational awareness support for scientific teams in collaborative environments. Finally, the authors discuss practical challenges in design and evaluation of group support systems for collaborative working environments and our multi-level analysis approach. The chapter gives new insights into how shared displays support group awareness, and how to design and evaluate interactive systems and visualisations that afford awareness in order to stimulate existing and new forms of collaboration in advanced working environments.*

*Discovery is seeing what everyone has seen, and thinking what nobody else has thought*

—Albert Szent-Gyorgy

## INTRODUCTION

The diversity of multiple disciplines in teams positively impacts collaborative problem solving (Coughlan and Johnson, 2006; Shalley and Gilson, 2004). It is essential to analyse how such collaboration takes place in daily work practices. Team collaboration can be supported by providing an appropriate environment and a certain context (Coughlan and Johnson, 2006). However, introducing a new environment and new technologies, like multiple visualisations on a large display, may increase the cognitive load of team members and influence the way they collaborate (Varakin et al., 2004). Awareness information in such shared workspace environment is always required to coordinate team activities (Dourish and Bellotti, 1992).

The overwhelming amount of visual information on multiple displays, and the multitude of personal and shared interaction devices in new collaborative environments lead to a lack of awareness of team members on ongoing activities, a lack of understanding of shared visualisations, and a lack of awareness on who is in control of shared artefacts. The focus of our research is on the awareness support of co-located teams working on long-term scientific projects in collaborative working environments. Understanding who you are working with, what is being worked on, and how your actions affect others, is essential for effective team collaboration (Dourish and Bellotti, 1992). Such shared awareness helps getting jobs done that cannot be done by a single expert, or by experts that only have a limited range of disciplines covered. Moreover, shared awareness also leads to informal social interactions and development of shared working cultures which are essential aspects of maintaining good working relationships in a team.

## Situational Awareness

Situational awareness (SA) concerns “knowing what is (and has been) going on”, basically being aware of what is happening around you in the environment and having a shared understanding of the information. Before giving the extensive definition, we will first explain the importance of SA for team collaboration.

Situational awareness is expected to be an important determinant of team performance (Bolstad et al., 2005; Endsley, 1995). Especially in multidisciplinary settings situational awareness information is affected by abilities of individual members, their interaction with other team members, and the environment in which they collaborate (Bolstad et al., 2005). Various factors affect individual situational awareness formation: context (physical location, display arrangement and size, system capabilities etc.) and group aspects (communication, use of collaboration tools, team processes etc.). In order to assess SA during evaluation of collaborative interfaces or awareness displays, specific factors need to be identified relevant to a particular domain.

Situational awareness is critical in such complex multi-display environments that change rapidly and that provide a lot of information to keep up with. Recent studies (Borchers, 2006; Brad et al., 2002; Huang, 2006; Rogers and Lindley, 2004) clearly point out that people are less aware of their visual surroundings than they think they are. Data overload, fatigue and other stressors can undermine the development and maintenance of situational awareness (Bolstad, 2006). The phenomenon of change blindness shows that even if people have an accurate representation, they may still fail to notice changes (Martens, 2007; Varakin et al., 2004). Actively capturing attention at the location of the change by means of spatial cues improves the detection of the information and detection of

changes. Therefore, it is of a great importance to design systems that support situational awareness and sharing of SA between team members in order to ensure that a collaborative environment supports efficient and effective team coordination and decision making.

Endsley's (1993, 1995) theory of situational awareness suggests that SA can be achieved by linking an objective state of the world to its mental analogue on three main levels: perception, comprehension and projection. Level 1 of SA—is perception of relevant elements in the environment. It is an active process whereby individuals extract salient cues from the environment. Level 2- embraces comprehension of the meaning of these cues. It involves integration of information in working memory (Salas et al., 1995) to understand how the information will impact upon the individual's goals and objectives. In this way an individual develops a comprehensive picture of the world in this way, or of that part of the world of concern to the individual. Level 3, projection, consists of extrapolating this information forward in time to determine how it will affect future states of the operating environment (Endsley, 1993). The third level of SA combines what the individual knows about the current situation with his or her mental model of similar events from previous experience, to be prepared for what might happen next.

In our research, we define SA as based on the three main aspects:

1. a person's previous knowledge and understanding of the situation, which contributes to identifying the source and nature of issues and problems;
2. detection and comprehension of the relevant perceptual cues and information from the environment, which supports comprehending multiple visualisations in their context;
3. interpretation of these and reconfiguration of understanding and knowledge in a continuous process during the group collaboration effort. This allows awareness of changes in the environment, knowing what team members

do and have done regarding current events in the environment, and keeping track of work progress.

Henceforward we refer to *shared situational awareness* as to the amount of communality of the individual SA of team members on the three aspects defined above. Our research investigates the following questions: What does situational awareness mean in team collaboration? How can we support situational awareness in collaborative working environments? How can shared displays support shared situational awareness in practice? How can we design and evaluate interactive systems and visualisations that afford situational awareness in order to stimulate existing and new forms of collaboration?

## **Team Coordination**

There have been a series of studies investigating group processes in real world situations. However, the tasks used in these studies did not address scientific teams. Still, one can be just as creative in science as in design (Johnson and Carruthers, 2006). A recent empirical study by Johnson and Carruthers provides a good overview of the relevant theories on creative group processes. Results of this work are requirements for software tools to support specific creative tasks (Johnson and Carruthers, 2006).

Other empirical studies, although conducted in real work environments, focus only on team coordination in extreme collaboration scenarios (Blandford and Wong, 2004; Manser, 2006; Wilson 2006). *Extreme collaboration* refers to collaboration within *warroom* environments where teams work together synchronously in all phases using a variety of computer technologies to maximize communication and information flow. For instance, Manser et al. (2006) investigate coordination needs of cardiac anaesthesia teams in an operating room environment. The result of their study is a conceptual framework for the analysis of multidisciplinary team collaboration in complex work environments. A qualitative study by Wilson et al. (2006) reports

the impact of a shared display on small group work in a medical setting.

Applying a human-centered approach, we need to analyse the actual context in which the collaborative system will be deployed (Carroll et al. 2006; Varakin et al., 2004). An understanding of the work context will help us to design technology that supports team members in their primary task at hand, and thus leads them to communicate and interact in a collaborative environment with prolonged involvement and, hopefully, better results. It will also help us to find out how new computing technology in collaborative environments, such as large shared displays, influence scientists' work and team coordination (Hallnass and Redstrom, 2002).

### **AFFORDING SITUATIONAL AWARENESS IN SCIENTIFIC COLLABORATION**

In contrast to domains such as aircraft or plant operation control, emergency dispatch or crisis management (Mark, 2002; Sharma et al., 2003), scientific teams are not working in life-threatening situations and are not under constant strong time pressure. However, long-term scientific projects involve high costs and therefore it is hard to recover from any errors. Shared visualisations on large displays have proven to be helpful to support group discussions because the support situational awareness (Borchers, 2006; Huang, 2006; Rogers and Lindley, 2004). Other examples of teams using a large display to enhance awareness of their activities are programming and design teams (Biehl et al., 2007).

Evolving technologies in molecular biology produce vast amounts of data. Scientists in this domain are confronted with the problem of applying methods from different disciplines when analyzing and interpreting their data, such as statistical, mathematical and machine learning techniques. Moreover, integration of the results from heterogeneous information sources is a difficult but essential part of the analysis of experimental results. Current omics experimentation in molecular biology, for

example in drug discovery and cancer research, is a complex, highly dynamic and multidisciplinary task that requires teamwork (Rauwerda et al., 2006; van der Vet et al., 2007). It is essential for life scientists to design the experiment precisely and accurately to ensure the statistical validity of the data. Timely spotting outliers and abnormal patterns in a huge amount of data is crucial for experimentation (see Figure 1). Recent studies showed that there is a strong need for visualising the omics datasets on a shared display for comparing and discussion among multidisciplinary scientists (Kulyk et al., 2007; Li et al., 2005).

Presenting visualisations on a shared display in a collaborative working environment can support group discussions (Borchers, 2006; Huang, 2006; Rogers and Lindley, 2004). Looking at the statistical representations of the same data on a shared large display enables scientists to assess the quality of the entire omics experiment at a glance (Kulyk et al., 2007). The visualisations on the various parts of the display are implicitly related, in the sense that they refer to the same experiment, but currently it is not always evident what this precise relation is. To prevent team members from getting lost and to support situational awareness, the relations between various statistical representations have to be explicitly visualised. In order to afford detection of changes in visualisations and to avoid change blindness, it is important to draw team members' attention to current changes without distracting them from the discussion.

Multiple visualisations can be closely related, and therefore a change in a visualisation on one display will have to be related to visualisations on other displays in a manner pioneered by the Spotfire<sup>1</sup> system. In our case, however, the situation is more complex. Scientists in multidisciplinary teams use discipline-related visualisations. For example, in microarray experimentation, spotting the outliers and abnormal patterns in the large data set can be done only by an expert in both statistics and in molecular biology, by analysing a combination of various statistical representations and microarray scans. Another example is when, at the microarray

Figure 1. Scientists interacting with multiple visualisations in e-BioLab, MAD/IBU, University of Amsterdam



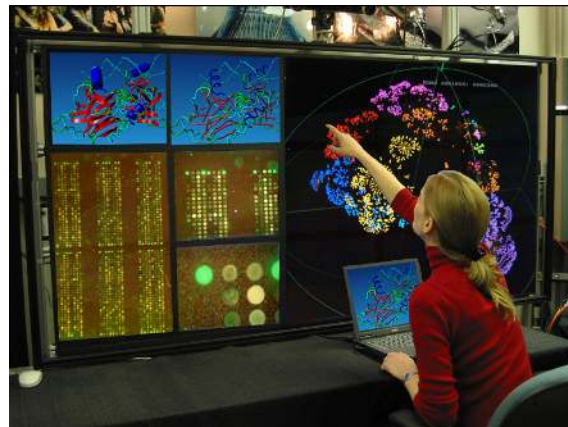
experiment design stage, a statistician needs to establish confidence intervals and statistical power of an analysis. However, only molecular biologists and microarray experts can assess whether it is experimentally possible in the wet-lab to increase statistical power or to avoid confounding by choosing a different experimental setup.

Molecular biology in general is a highly visual discipline (Campbell and Heyer, 2006). Visualisations play a large role in the analysis and interpretation of *omics* experiments (van der Vet et al., 2007), Figure 2. In the next section, the issue of collaborative working environments is addressed. We discuss how visualisations can support group discussions in such environments. We will also report our own experience on situation awareness support of scientific teamwork in a molecular biology context (Kulyk et al., 2007). We argue that situational awareness can be supported in such environments by bringing relations between various visualisations in the focus of attention at any particular moment.

## VISUALISATIONS AND SITUATIONAL AWARENESS IN COLLABORATIVE ENVIRONMENTS

Until recently, most of the studies in scientific visualisations mainly address the design of integrated software visualisation tools, with “single

Figure 2. A scenario in which a life scientist is interacting with multiple visualisations



user—single visualisation” interaction. However, as a study on collaborative scientific visualisations illustrates (Li et al., 2005), the picture becomes more complex in situations in which groups of users will be interacting with multiple visualisations and communicating with each other at the same time. In genomics research, there is a strong need for visualising the large genomics datasets during multidisciplinary collaborative discussions for comparing and sharing data among scientists (Li et al., 2005). Designing visualisations for multiple use to enhance exploration of heterogeneous information is a new challenge in cooperative work.

Much of the work on situational awareness cited before is relevant but has to be adapted to the spe-

cific needs of the multidisciplinary teams in omics experimentation: molecular biologists, microarray experts, bioinformaticians, and statisticians. The practitioners of the various disciplines involved in our research bring with them rich and often implicit background knowledge, as was found for scientists in general by Dunbar (1995).

The *e-BioLab* is a collaborative environment that aims to facilitate multidisciplinary teams during project meetings on molecular biology omics experimentation, with an initial focus on *microarray experiments* (Rauwerda et al., 2006). The goal of a microarray experiment is to simultaneously examine the expression level of all genes of a specific organism, in a cell type in a specific growth or stress condition. Microarray technology is currently one of the most important methods in genomics and is usually applied to unravel complex cellular mechanisms or discover transcriptomics biomarkers: genes whose expression profile can be used for diagnostic purposes or to monitor and predict cellular processes (Stekel, 2003).

In interpreting a microarray experiment in the *e-BioLab*, both the results of the experiment itself and those of statistical data analysis can be displayed in the form of visualisations on the large display, as in the example in Figure 2. In this way, team members can assess an entire microarray experiment. Moreover, in a multidisciplinary setup a large high-resolution display connected to online genomics resources can be used to construct models of biological mechanisms, thus enhancing omics experimentation and collaborative interpretation of the results. The largest tiled display is split into a number of displays, Figure 1 and 2. Visualisation of various statistical representations of the data on the tiled display enables scientists to assess the quality of the entire experiment at once. The visualisations on the various parts of the display are obviously related in the sense that they refer to the same experiment, but currently it is not always evident what the precise relation is. To prevent users from getting lost and to support situational awareness, the relations between various statistical representations have to be explicitly visualised. In order to enable

detection of changes in visualisations and to avoid change blindness, current changes have to be put in focus of attention.

The complexity of multiple displays showing often complex visualisations can, as mentioned earlier, be reduced by employing attentive and proactive interfaces, also called notification services (Crowley, 2006). Such interfaces have to anticipate the context and provide an appropriate feedback without distracting the users from their main task. An example of such an interface for awareness and collaboration support is the persuasive displays environment designed by Mitsubishi Research Lab (Dietz et al., 2004). Such an environment can also include a *peripheral awareness display*: an information system or a graphical representation that resides in the user's environment and provides information within the periphery of user's attention (Plaue et al., 2004). Monitoring the peripheral display should cause minimal shift from the user's current focus of attention, allowing users to garner information without being distracted from their primary task. Most current peripheral display approaches use visual, auditory and tactile modalities for conveying the information. Our primary focus for this chapter is on the visual modality, since this is the main source of information in state of the art *E-BioLabs*. The information can be generated on the basis of multimodal cues sensed by the sensors embedded in the environment (Iqbal et al., 2005). The evaluation of such an awareness display is mainly focused on effectiveness and unobtrusiveness: the ability of the visual representation to communicate information at a glance without overloading the user (Plaue et al., 2004; Kulyk et al., 2006).

The next section gives an overview of various practical case studies on team coordination support in collaborative working environments. Our own case studies in different subdomains of bioinformatics are presented as examples (Kulyk and Wassink, 2006). We also introduce the assessment model of team situational awareness in collaborative working environments that can be used for human-centered design and evaluation during practical case studies. Finally, we discuss practical challenges in the



design and evaluation of group support systems for collaborative working environments and our multi-level approach for the analysis of technology-mediated interaction. We end with a conclusion and discussion.

## **SITUATIONAL AWARENESS IN OMICS EXPERIMENTATION**

The support of multidisciplinary scientific teams in collaborative environments is centrally addressed within our BioRange project. As in any user-centred approach, user studies and task analysis are a core activity in our research (Bartlett and Toms, 2005; Javahery et al., 2004; van Welie and van der Veer, 2003). Contextual observations and interviews are conducted to find out how such collaboration takes place in daily work practice between biologists, bioinformaticians, and biomedical researchers and how we can support them (Kulyk and Wassink, 2006). The results of our studies underline that multidisciplinary collaboration is essential in molecular biology and bioinformatics. Visualisations of experimental and biological data are used for discussing the experimental results and for assessing the progress of an experiment. Scientists expect they will profit from multiple visualisations in a collaborative environment. At the same time, they point out the danger of overwhelming the viewer with too much information. They strongly prefer to collaborate face-to-face. This is also confirmed in studies for other user groups (McCowan et al., 2003; Nijholt et al., 2006; Rienks et al., 2006) and for scientific teams (Dunbar, 1995). The results of our exploratory study have been translated into requirements for the support of collaboration and multidisciplinary teamwork in bioinformatics, as well as into profile descriptions of novices, experts and scientific teams (Kulyk and Wassink, 2006).

In order to identify the key aspects and user requirements for collaboration support in the context of a scientific collaborative environment, we also perform an extensive task analysis of the current microarray experimentation practice, based on

contextual interviews and observations (van Welie and van der Veer, 2003). Use case scenarios for empirical studies in microarray experiments are provided by our project partners (Rauwerda et al., 2006). Scientists from various disciplines: molecular biologists, microarray experts, bioinformaticians and statisticians, closely collaborate during such experiments. In particular, we aim to build a detailed task model of microarray experiments. A task model of the current work situation describing phases of a microarray experiment is currently being validated with domain experts.

As the literature confirms, creative problem solving in scientific collaboration can be supported by providing an appropriate environment and a context (Coughlan and Johnson, 2006). However, introducing a new environment and new technologies, as for example presenting multiple visualisations on a large display (see Figure 1,2), may increase scientist's cognitive load and influence the way project team members collaborate (Varakin et al., 2004). Awareness information in such shared workspace environment is always required to coordinate team activities (Dourish and Bellotti, 1992). We believe that situational awareness is a very important aspect of co-located team collaboration in complex environments, as other research confirms (Manser et al., 2006) (see section 2). Especially in the multidisciplinary settings, situational awareness information is affected by individual team members' abilities, their interaction with other team members, and the environments in which they collaborate (Bolstad et al., 2005). It is essential to provide situational awareness support in collaborative environments in order to support team's coordination needs and creative problem solving.

On the basis of our current findings from conceptual studies and requirements analysis, we are performing a series of practical case studies. We are conducting a series of real-life observations during the project discussions of multidisciplinary scientific teams in the e-BioLab (Rauwerda

et al., 2006; van der Vet et al., 2007). Our aim is to get insight into how shared displays affect teamwork, and to contribute to the development

of novel concepts to support co-located situational awareness in a scientific collaborative environment. In particular, we are investigating the effect of the large display visualizations on both individual and team situational awareness. We are also evaluating new designs to enhance the awareness by making relations and changes between different visualizations more explicit. For instance, during project meetings relevant visualizations on a tiled display will be highlighted and other ones will become faded. In this way, a presenter can draw the attention of other team members to visualizations relevant to the expertise of particular scientists, Figure 2. In addition, a notification of the annotations made on visualizations is essential to make all team members aware of the changes.

### **Concepts for SA Support in Scientific Collaboration**

We are currently exploring various alternative solutions for SA support in collaborative environment for scientific teams (van der Vet et al., 2007).

For instance, a *Highlighting on Demand* interface enables the team member who is currently controlling the tiled display to draw attention of the team by highlighting a certain visualisation using a slider on a personal interaction device (for instance, TabletPC or a WiiMote controller).

Another concept is a *Memory Board* interface, which automatically stores and visualises the history of changes on a shared display, allowing team members to go back in time and retrieve a certain annotation made on previous slides or visualisations. This board serves as a peripheral display, affording memorability. It supports level 2 of situational awareness, comprehension.

We expect a supporting effect of visualisation of status information about who is in control of a display or another shared artefact on a personal interaction device. This would make every member of a team aware of who is making the changes and what changes are made. We also intend to visualise the *control interface* on a shared touch display, as well as displaying it on a personal interaction device

(e.g. tabletPC). Such an interactive interface enforces sharing and thus supports coordination mechanisms and group awareness on who is currently manipulating and annotating the visualisations. It also partially resolves the potential control negotiation conflict about the annotation of visualisations and about manipulation of the shared display.

### **ASSESSING SA SUPPORT IN COLLABORATIVE ENVIRONMENTS**

The complexity of communication processes in the co-located team and the use of a collaborative environment require the combination of a methodological approach to support situational awareness for team collaboration and a practical method to capture and analyse the dynamics of technology-mediated interactions in context. The nature of the interfaces as well as physical characteristics and affordances of the environment influence the way in which interactions occur (Fruchter and Cavallin, 2006). Therefore our approach for data analysis includes a combination of behaviour, interaction and environment analysis.

We will assess shared situational awareness of team members when we provide supportive visualizations on a shared large display. We aim at reducing disturbing factors that are considered distraction from the primary task. We intend to establish an indication of the relations between Situational Awareness, team satisfaction, group processes like decision making, and the perceived task performance. In our case multiple data collection techniques are used: direct observations to assess user behaviour based on a validated coding scheme (Biehl et al., 2007), screen capturing, video recordings, a validated post-questionnaire (Kulyk et al., 2006; Olaniran, 1996; Paul et. al., 2004), and a post-interview. Video recordings from several viewpoints combined with screen capturing of multiple displays, enables us to analyse several simultaneously ongoing interactions. In addition to the observations, post-interviews and questionnaires are carried out to obtain subjective judgements of the

team members, e.g., on group satisfaction, awareness and distraction from primary tasks (Cadiz et al., 2002; Kulyk et al., 2006; Olaniran, 1996; Paul et al., 2004). Group satisfaction will be assessed by a combined validated post-questionnaire featuring the group process and decision making (Olaniran, 1996; Paul et al., 2004). We apply these questions to assess the perceived usefulness and impact of new *Highlighting on Demand* and *Memory Board* concepts on shared situational awareness of team members, on distraction from the primary task, and on team satisfaction with the group process and decision making process.

The three aspects of situational awareness described earlier, as well as recent related studies (Biehl et al., 2007; Blandford and Wong, 2004) are used to identify relevant factors of SA to design our questionnaire. We are adapting a computational model of shared situation awareness (Bolstad et al., 2005) to the context of our case studies. This model uses the Situation Awareness Global Assessment Technique (SAGAT)—an objective measure of situation awareness mainly based on work of Endsley (1995).

Our current observations and video analysis show that scientists tend to walk to the tiled display to inspect a specific detail of a visualisation, which indicates that they are treating the display different from a movie screen or a static projection. This points to the dynamic nature of interactions as reported in other studies (Tan et al., 2006). High resolution of the displays allows them to zoom on fine details. This indicates a high immersion, though possibly partially due to the novelty of the large displays.

Applying user study techniques and a multi-level method for data analysis will allow us to identify interaction patterns: natural ways in which team members interact with each other (behaviour patterns) and with the shared displays in the environment. Thus we may iteratively improve the design of SA support and construct a framework for the evaluation of how shared displays influence scientists' work and team collaboration.

## **FUTURE WORK**

We will perform controlled comparative case studies on the impact of the *Highlighting on Demand* and *Memory Board* SA concepts. Our target groups for the first study are small multidisciplinary teams (3-5 members) working on joint projects and scientific omics experiments in life science domain. We will assess shared situational awareness of team members, providing supportive visualizations on a shared large display. We aim at reducing the distraction from the primary task, and establishing relations with team satisfaction, group process, decision making process, and with the perceived task performance. Analysis of user behaviour allows us to define interaction patterns.

In the second case study we aim at assessing the long-term influence of large shared displays on team shared SA in other domain(s) and different collaborative environment(s). We will apply the adjusted measurements of shared SA from the first study. Cross-culture and cross-organizational differences might show different effects compared to the first study. The first target group for the second study are software engineering teams.

## **CHALLENGES IN MERGING COLLABORATIVE WORKSPACES**

Although our primarily focus is on co-located collaboration in which situational awareness plays a crucial role, we also consider remote collaboration scenarios for future case studies in which *social awareness* (Röcker and Magerkurth, 2007) and *presence* (Bystrom, 1999) concepts are also of great importance. The study of Röcker and Magerkurth (2007) on the Hello.Wall display shows that people are apparently not always willing to publicly display their presence in the collaborative environment and prefer to set their own activity status. In our vision, this can be easily resolved by the abstract representation of the general current level of activity in the collaborative environment based on the level of activities of present members. Such an activity

representation can provide awareness for the remote project members, and may raise curiosity and encourage them to join the team discussion remotely or even to walk to the building and take a look what is going on in the lab.

One of the future extensions on the e-BioLab environment is real-time teleconferencing in order to collaborate with other e-BioScience labs across the Netherlands. New challenges arise when we attempt to merge physical and virtual workspaces in collaborative environments. Figure 3 shows how 3D teleconferencing and natural documents sharing concepts<sup>2</sup> that were once presented for the future office vision, have been partially realised during the official opening of the e-BioLab.

We have to explore the transfer of information between different types of displays, between the virtual workspace and the real one. Control of the shared display remains a potential problem to tackle. Our expectation is that, just as in the physical environment, team members will develop their own coordination mechanisms, negotiating about the control over the central largest shared display. The shared visualisation of the control interface on a plasma touch display currently remains the optimal solution. Sharing enforcement is shown to positively impact coordination strategies, and therefore should work for the team better than several personal controllers. Furthermore, refined evalua-

tion techniques and measures are needed in order to adequately address these aspects of collaborative work in such hybrid workspaces.

## CONCLUSION AND DISCUSSION

A new wave of advanced collaboration environments, such as collaborative interactive environments (Borchers, 2006), multiple display environments (Huang, 2006; Rogers and Lindley, 2004) and our collaborative working environment (van der Vet et al., 2007) requires new methods for design and evaluation in order to adequately address all aspects of collaborative work. This chapter presents the research on group awareness support to enhance team collaboration in the co-located working environments in the context of molecular biology omics experimentation.

This chapter aims to provide new insights into how to design and evaluate systems that afford awareness in order to stimulate existing and new forms of collaboration in advanced working environments, as well as insights into how team members of various levels of expertise and backgrounds interact with new technologies in collaborative working environments. We present an overview of the state-of-the-art studies on team coordination and situational awareness support.

*Figure 3. 3D teleconferencing and natural documents sharing concepts<sup>2</sup> affording presence (left); official opening of the e-BioLab at the University of Amsterdam by Dr Jason Leigh from the University of Chicago (right)*



Furthermore, we discuss how visualisations can support group discussions and describe the collaborative environment for scientific teams in a molecular biology context. As a result we show that situational awareness is of a crucial importance in co-located team collaboration. We argue that SA can be supported in such environments by bringing changes and relations between multiple visualisations more in the focus of attention. We also report our results of an empirical case study and domain analysis translated into user requirements for the support of multidisciplinary collaboration of scientific teams. Finally, we discuss practical challenges in the design and evaluation of group support systems for collaborative working environments and hybrid workspaces, and present our multi-level approach for the analysis of technology-mediated interaction.

Practical case studies bring new insights into how new technology, in particular large shared displays, affects teamwork and contributes to the development of novel concepts for group awareness support. The main contribution of this chapter is the conceptual framework for studying situational awareness of multidisciplinary teams in collaborative working environments, as well as requirements and guidelines for new collaborative technologies to support situational awareness of teams based on the practical case studies. This work aims to inform the theory and practice of human computer interaction and design for collaboration support.

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## KEY TERMS

**Awareness** is the ongoing interpretation of representations of human activity and of artefacts (Chalmers, 2002).

**Collaborative working environment** is a co-located shared workspace that facilitates groups

during meetings. The workspace is enhanced with multiple collaborative systems and media, such as private and shared displays, tabletops, touch screens, cameras and other devices.

**Extreme collaboration** refers to working within *warroom* environments where teams work together synchronously in all phases using a variety of computer technologies to maximize communication and information flow.

**Group awareness** is the understanding of who you are working with, what is being worked on, and how your actions affect others, is essential to effective collaboration (Dourish and Bellotti, 1992).

**Microarray experiment** examines simultaneously the expression level of all genes of a specific organism, in a cell type in a specific growth or stress condition. Microarray technology is currently one of the most important methods in genomics and is usually applied to unravel complex cellular mechanisms or discover transcriptomics *biomarkers*: genes whose expression profile can be used for diagnostic purposes or to monitor and predict cellular processes (Stekel, 2003).

**Omics experimentation** is a research area in molecular biology that deals with *omes*: large or complete arrays of cell components, such as the genome (all genes) and the proteome (all proteins). For example, studies that encompass the whole genome are in general referred to as *genomics* studies, and studies that examine the expression level of all mRNAs (messenger RNA, which directs the synthesis of proteins) in a given cell population are called *transcriptomics*.

**Peripheral awareness display** is an information system or a graphical representation that resides in the user's environment and provides information or visual feedback in the periphery of the user's attention. Monitoring the peripheral display causes minimal shift from the user's current focus of attention, allowing users to garner information without being distracted from their primary task (Plaue et al., 2004).



**Situational awareness** is the perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future, and the prediction of how various actions will affect the fulfilment of one's goals (Endsley, 1995, p.36).

**Shared situational awareness** is a reflection of how similar team members view a given current environmental situation. Thus, if a team has a high degree of shared situational awareness, we can assume they are perceiving, comprehending, and interpreting the situation's information requirements in a similar manner (Bolstad et al., 2005, p.1).

**Task analysis** is a domain-specific analysis of the current work situation, which combines such classical HCI techniques as contextual interviews, field observations, ethnography and interaction analysis (Jordan, 1996; van Welie and van der Veer, 2003).

## ENDNOTE

- <sup>1</sup> <http://www.spotfire.com>, last visited July 2008
- <sup>2</sup> Amin, A., Kulyk, O., Metin, B., Schneider, J. (2004) Pervasive Office, Videoprototype presented at the Océ Design Competition, *European Symposium on Ambient Intelligence (EUSAI)*, Eindhoven, the Netherlands.