Chapter 1
An Historical Reflection of Awareness in Collaboration

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Abstract Mutual awareness has been a focus point of research in Human–Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW) since the early 1990s. At its essence, mutual awareness refers to a fundamental quality of collaborative work, the ability of co-workers to perceive each others' activities and expressions and relate them to a joint context. In this chapter, we explore the history of awareness concepts by analysing existing literature in order to identify trends, research questions, research approaches and classification schemes throughout different stages of research into awareness. We have adopted a historical angle in the hope that it will allow us to show how awareness research has progressed over time. We document this development using three different phases: (*1) Early exploration of awareness* (approximately 1990–1994), (*2) Diversification and research prototypes* (approximately 1995–1999) and (*3) Extended models and specialisation* (approximately 2000–now). While these phases are to some extent arbitrary and overlapping, they allow us to highlight differences in research focus at the time and understand research in context.

1.1 Introduction

Awareness and awareness systems for collaboration have been a focus point of research in Human–Computer Interaction (HCI) since the mid-1980s. The early years of research were primarily about discovering that awareness was important for collaboration, mostly through field studies and the growing use of network communication. While in the last few years awareness concepts have grown increasingly complex, knowledge of what awareness in collaboration actually means has not progressed at the same pace. Early dichotomy-based classifications, such as synchronous vs. asynchronous or social vs. task awareness, fail to accurately

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describe the complexity of awareness research in Computer-Supported Cooperative Work (CSCW) today. In this chapter we will initially take a look at the history of awareness in collaboration by analysing existing literature in order to identify research questions, research approaches and classification schemes throughout different stages of research into awareness. We use this review to extract the characteristics and trends of awareness research over the last 20 years, and provide a picture of how CSCW's knowledge of awareness has progressed and changed.

Why another survey? Surprisingly, despite the popularity of awareness research in HCI and CSCW, the existing research has rarely been summarised in a structured manner. Schmidt (2002) delivers an eloquent critique of awareness research, in which he is concerned with the notion and understanding of the phenomenon of awareness in collaboration, and he points out that our knowledge is far from complete. Gross et al. (2005) provide a comprehensive analysis of awareness approaches, but their main focus is on the terminology used to describe concepts in CSCW and social science research fields. We follow a more pragmatic approach by focussing on what researchers have achieved in awareness research and how this knowledge has been used by designers of awareness systems. In particular we want to find out what tools are available to describe, conceptualise, design and implement awareness in collaborative work and how these tools have evolved over time. We believe that this approach will help researchers understand awareness research, and that it will be of value in developing and addressing new research into awareness.

We approach the development of awareness knowledge from an historical angle and show how understanding of awareness, awareness concepts and models and awareness prototypes progressed through different stages, increasing in complexity and differentiation. Section 1.2 covers roughly the years 1986–1994, revisiting the origins of awareness research in HCI and CSCW, including the exploration of the phenomenon of awareness through field studies and early prototypes (e.g. Bowers 1994; Dourish and Bellotti 1992; Dourish and Bly 1992; Heath and Luff 1991). Section 1.3 covers roughly the period 1995–1999, when awareness concepts and models were developed and increasingly differentiated. We analyse a multitude of intersecting terminologies that are used to specify certain types of awareness, for instance the common distinction between task-based, formal activities from informal, social activities (Tollmar et al. 1996; Prinz 1999). In Section 1.4, covering roughly the years from 2000 to 2006 and early 2007, we show how awareness research has developed and diversified (e.g. Simone and Bandini 2002; Boyle and Greenberg 2005), how awareness research expanded into other domains (e.g. Mynatt et al. 2001; Neustaedter and Brush 2006) and in general how it moved out of the distributed office environment.

This chapter concludes in Section 1.5, by taking a look back at all the topics covered in our historical survey and reflecting on the larger trends that have occurred over the last 20 years of collaboration awareness research. We finish this last section with some speculation as to where these trends might go next and the open research that remains.

1.2 Early Exploration of Awareness

In this section, we explore the early concepts of awareness in the field of CSCW. This early work shows how researchers began to realise that there was more to collaboration than simply direct interaction between people and with shared objects. Successful collaboration is a complex social activity with many subtle peripheral and non-verbal cues between people and around artefacts – in short, it depends on awareness.

While there were earlier technologies that, with the benefit of hindsight, could be considered to provide awareness information (for example, e-mail and the UNIX "who" command), we concern ourselves here with work that formed the basis for rich CSCW research streams about supporting awareness in its various forms. We begin by discussing some workspace studies that made clear the complexity of collaboration activities and demonstrated the need for awareness support. We follow by discussing early media space research, that started from a practical basis of connecting people and discovering what happened. We then provide an overview of some concepts that were in their infancy but proved very important to later research – event-based awareness and the COMIC spatial model of awareness.

1.2.1 Workplace Studies

The workplace studies described below provided real-world justification for awareness research. They showed how awareness was a vital part of collaborative activity, whether it was high intensity, real-time collaboration, as in a London underground control room (Heath and Luff 1991) or constant, peripheral awareness that led to collaborative scientific publications (Kraut et al. 1988). The third work that we present below, Harper et al.'s (1989) air traffic control study, provided an early and firm illustration of the real-world complexities of awareness interactions. Each of these bodies of work has continued to be extremely influential in awareness research and are still referenced strongly today.

1.2.1.1 London Underground

Heath and Luff's (1991) study of collaboration and coordination inside a London underground railway control room is one of the primary works in identifying the phenomenon of awareness and its relevance in collaborative work. Even though they never mention awareness explicitly, their ethnomethodologically informed analysis provides a picture of how awareness forms the basis of real world, tightly coupled collaboration.

The original motivation for the study was fairly specialised. Heath and Luff's wanted to perform a workplace study in a technological setting, thus providing greater relevance to the *Computer* part of CSCW. Their original goal was to use the study as the basis for design of a system, and their paper reports success in this

goal. However, the great contributions of their work to future researchers are the direct findings in their workplace observation study.

The study was an ethnographic observation of a London underground railway control room. There were two people working in the control room, the divisional information assistant (DIA), who made public announcements to passengers and communicated with station managers, and the line controller, who coordinated the running of the railway. These two sit at a semi-circular display and "use a range of devices similar to the technologies being developed in CSCW; they use audio and video channels of communication, a shared display, various keypads and monitors" (Heath and Luff 1991). The railway service was also coordinated through the use of a paper timetable. Heath and Luff observed and recorded how these two people coordinated their activities to keep the trains running and passengers informed in the face of minor train delays, absentees, breakdowns and other unexpected disruptions.

Their observations provide insight into how people work together in highly interdependent, real-time situations. They observed how the two actors would surreptitiously monitor the other's activities in order to inform their own actions, modifying what they were doing to incorporate new information from the other, even though there was no explicit communication. Thus, when the controller told someone to hold up a train, the DIA would make a passenger announcement about the delay simply because he overheard the phone call. The actors also deliberately modified their behaviour to assist the other in monitoring, by doing such things as talking themselves through their task so the other could overhear. Also, because they were monitoring both the local environment and their co-worker, they were able to take over each other's tasks when the other was overloaded.

In awareness terms, though Heath and Luff do not use the term "awareness", the controller and DIA maintained awareness of each other and their environment and they intentionally structured their activities to assist the other in being aware of them and the relevant environmental events.

1.2.1.2 Patterns of Scientific Collaboration

In 1988, Kraut et al. (Kraut et al. 1988) published a workplace study clearly demonstrating the importance of physical proximity for collaboration. They showed that the reason for this was that co-located colleagues had more opportunities for frequent, high-quality informal communication. This work is the basis for much research later into informal interaction and the awareness requirements for supporting it.

They studied a group of 93 psychology academics in multiple departments that had written at least two internal reports recently, with at least one of the reports having a co-author. There were 4278 unique collaboration pairings in the group. These were then correlated with the physical proximity of the offices of the collaborators. Their results were that over 80% of collaborations were with people on the same floor and that being on different floors reduced collaboration to the same extent as being in different buildings. Even after correcting for the fact that people in proximal

offices are likely to have similar research interests, there was still a significant effect from proximity.

Kraut et al. concluded from these results, as well as past studies and interviews, that "What appears to be important . . . is the opportunity for unconstrained interaction that proximity provides". Communication that is frequent, high quality, usually unplanned and low cost has a great impact on the likelihood and longevity of collaboration. It is important to note that this type of communication is not just a requirement of sustaining or supporting existing collaboration, but of getting the collaboration going in the first place. People who are around each other and communicate frequently, regardless of work-related content, are more familiar with each other.

In addition, as they spend more time together, they are more likely to discover common points of interest that lead into collaboration. It is in referring to this behaviour that Kraut et al. make their only explicit reference to awareness in this paper. They state that "*increased awareness of the attributes of one's neighbors allows one to choose partners judiciously*".

Despite the paucity of direct mentions of awareness in this paper, it still informed a large body of awareness research. The study motivated support for unplanned casual interactions, which was the basis of media space research (e.g. Buxton and Moran 1990; Mantei et al. 1991; Dourish and Bly 1992; Fish et al. 1992), and also sparked a rich stream of research in informal awareness (see the section on Informal Awareness). The tie to media spaces was encouraged by Kraut et al. (1988) as they explicitly mention media spaces as a possible technical solution to the distance problem. Other early media space work started to investigate awareness as a requirement for informal interaction. More detail about media spaces follows this section.

1.2.1.3 Air Traffic Control

This early field study of air traffic control by Harper et al. (1989) was important for two reasons. First, it documented the complex awareness and interaction practices of a highly integrated group in a high-pressure situation. Second, the study demonstrated clearly the dangers of ignoring these complex practices when introducing technology support.

The study was situated in an air traffic control room. Small teams of controllers were responsible for geographical sectors, through which planes would fly. They would direct the planes to make sure they maintained sensible courses and avoided other planes. At the boundaries of the sectors, controllers would have to hand off planes under their control to other controllers. As there were usually large numbers of planes, the situation was high pressure – there were a large number of tasks to perform with high stakes.

Awareness of the current task for an individual controller was supported by paper flight strips, which described important details about each plane. These were printed by an automated system and delivered to the relevant controller by assistants. As the controllers worked they would annotate the flight strips with important updates and

flag any issues. The annotations and positions of the flight strips allowed any of the team to see the status of the flight zone at a glance. Agreements between sector teams about how to hand off planes between sectors would also be annotated on the flight strips. The flight strips were the central artefacts for mediating awareness and collaboration.

The introduction of technology to this collaboration was initially a failure because it failed to take into account the complex interaction that went on in the team. For example, the deployed system removed the collaborative benefits of the flight strips in providing awareness to the team and supporting the cross-team communication.

The study was an important motivating case for future awareness, and CSCW, research as it showed how the design of a technical system was sensitive to the complex work practices of the group it was supporting.

1.2.1.4 Workplace Studies Summary

The three workplace studies listed here are often referenced as motivation for collaborative awareness research, right up to the present day (e.g. Boyle and Greenberg 2005; Rittenbruch et al. 2007).

Next, we discuss early media spaces and how they started to support and investigate various types of awareness.

1.2.2 Early Media Spaces

Media Spaces use always-on, or at least always-available, video and audio channels to connect distance-separated locations or sites. The sites are usually common areas or individual workspaces, and the media space allows individuals or small groups to communicate from each location. Media spaces enable distance-separated people to feel as if they were all in the same area. After 1988, this motivation became more grounded by the scientific collaboration report by Kraut et al. (1988).

Early research into video media spaces can be seen as exploring and identifying the important elements of spatial proximity and how these could be captured by media spaces. Most of this early media space research concerned just informal interaction, but researchers at the European office of Xerox PARC (EuroPARC) also had the idea that awareness was a fundamental requirement for informal interaction.

1.2.2.1 The First Media Space

The first media space in HCI research[1] was created at Xerox PARC in the mid-1980s (Stults 1986). Stults reports that he was motivated by seeing that some of

[1]The first media space by the definition here was actually a public art installation called “Hole-In-Space”; Galloway and Rabinowitz (1980) Hole-in-Space. Mobile image videotape. Santa Monica,

his colleagues, whose offices opened onto the hallway, were unable to receive the community benefits of having offices adjoining the commons area. The lab also had a lot of audiovisual equipment that was used for videoconferencing and videophone research. The equipment was sitting idle when nobody was in a call, and so they decided to just leave the audiovisual links on all the time and "build an electronic space to serve much of the role that the common area serves" (Stults 1986). The media space allowed participants to communicate informally and be aware of opportunities to interact with others.

The first media space setup used analog video and audio feeds from each of four offices, the common area in Palo Alto and the common area in Portland. Each of these locations had a monitor display and a remote display. All the remote displays were synchronised showing the same thing and the switch was in the Palo Alto common area.

While this report predates the explicit mention of awareness, Stults comments on the value of maintaining "background contact" with others while engaged in individual work, having "discussions that spanned two offices" and the significance of being able to "move fluidly from one use to the other" (Stults 1986). These comments strongly foreshadow the later media space research on awareness, casual interaction and the transition between them.

This system continued to be developed at Xerox PARC in both the Palo Alto and Portland sites and was used to provide facilities for awareness and social interaction between their common areas, as well as means for collaboration and meeting in teams spread over the sites. Bly et al. (1993) provide an excellent review of this media space development and their experiences of using it every day. The article also contains an excellent discussion and reflection on media spaces in general, and is an excellent starting point for reading on media spaces.

1.2.2.2 Second Generation Media Spaces

During the early 1990s, media spaces were a popular topic in CSCW research. A variety of media space implementations and evaluations were published (e.g. Buxton and Moran 1990; Fish et al. 1990; Borning and Travers 1991; Mantei et al. 1991; Dourish and Bly 1992; Fish et al. 1992; Gaver et al. 1992). All of these systems took inspiration from the first media spaces implemented at Xerox PARC (Stults 1986; as well as successors) and were motivated by the Kraut et al. (1988) study on patterns of scientific collaboration. As with the collaboration study, the media space investigations were concerned with informal interactions rather than awareness and in most cases awareness was not mentioned explicitly.

However, one group realised that awareness was an important precursor for informal interaction. In 1991, media space-related publications from EuroPARC started to contain discussions about how awareness of others was necessary to prompt

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Calif., 1980. http://www.ecafe.com/getty/HIS/ but it was not supporting collaboration and did not have much influence on awareness research in CSCW.

casual interactions (Borning and Travers 1991; Gaver 1991; Dourish and Bly 1992; Gaver et al. 1992). These publications used many different terms for the particular type of awareness that prompted casual interactions, such as general awareness, casual awareness, shared awareness, unobtrusive awareness, distributed awareness and passive awareness. Despite the range of descriptive terms, the concept was entirely consistent – to support informal interactions, people need to be aware of others' presence, activities and availability.

Each of these aspects of awareness – presence, activity and availability – are used to motivate features in the EuroPARC systems. Polyscope and Vrooms (Borning and Travers 1991) and Portholes (Dourish and Bly 1992) all offer a grid of always-on video of offices and common rooms. RAVE (Gaver et al. 1992) offers an always-on view of a common area, a *glance* feature to view a selected office node and an *office share* feature to create a persistent audio/video connection to another office node. Portholes is an interesting example as it demonstrates that low-resolution, infrequently updated images still provide enough awareness to support informal interactions and a feeling of connection. Of course other media space implementations provide awareness as well, simply by having always-on video links, though in these cases the motivation is usually that always-on video provides lightweight facilities to engage in informal interaction.

At this point it is worth saying a few words about privacy in these early systems. While we do not want to offer a complete review of privacy research, awareness and privacy are very intertwined topics so we will mention privacy briefly. There is a trade-off and a tension between privacy and awareness – more awareness means more opportunities for privacy violations, yet more privacy means less awareness and missing chances for valuable serendipitous interactions. The developers of media spaces were very aware of the potential privacy problems of having always-on video and audio links and dealt with it in a number of ways. Most media spaces enforced reciprocity or at least symmetry (Alice has the capability to see the same information about Bob as Bob can see about Alice, but she can choose not to use that capability) (Borning and Travers 1991), although hardware limitations restricted how much that could be done, as it is usually possible to be out of view of the camera while still viewing the display. In some cases where the media space connected common areas, such as VideoWindow (Fish et al. 1990), the area was considered public and so explicit controls were not provided there. In media spaces that connected office spaces, there were usually explicit controls to temporarily turn off the "always-on" facilities and to refuse direct connections. Borning and Travers (1991) and Gaver et al. (1992) provide good discussions of privacy in media spaces, breaking it down into elements such as control, knowledge, symmetry, intention and avoiding unnecessary intrusions.

1.2.2.3 Media Spaces Summary

Media spaces in these early days were seen as a direct method of, at least partially, replacing the need for physical proximity. After these early systems, however, the perception seemed to change slightly so that they were seen as a component of

distributed awareness and collaboration. In research after 1994, media spaces are most often seen as part of a system that incorporates video and audio but also with many more channels of communication (e.g. Mansfield et al. 1997b; Greenberg and Rounding 2001; McEwan and Greenberg 2005). Over time the concept of a media space seems to be migrating to cover these new systems.

Next we talk about the initial forays into the world of event-based awareness, which prompted a great deal of research, especially in the late 1990s.

1.2.3 Event-Based Awareness

Event-based awareness is, at its simplest level and as the name suggests, concerned with providing people with awareness of what is going on around them, as expressed by discrete events. The real strength in this early investigation of awareness came in giving more control to the recipient of information.

The first of the event-based awareness systems was the Khronika system (Lövstrand 1991), which notified people of high-level events such as seminars, social outings and weather.

The important idea in Khronika was in decoupling the sender and receiver. In contrast to message-sending models, such as e-mail, where the sender specifies the receiver(s), Khronika allowed the sender of information to simply post information events to the server, without any concern about who should receive it (although there was an option to restrict the possible set of recipients if needed). Receivers of information would specify general rules (which would later be known as subscriptions) about what kind of information they were interested in and how and when they wanted to receive it. As Lövstrand explains:

> Thus, if user A enters a seminar event for 14:00 on Friday and user B has a daemon looking for seminars with a 15 minute warning, B's daemon will trigger and schedule a notification for 13:45 the same day (Lövstrand 1991).

This model removes the need for the sender to know who wants to receive the information they are sending, reducing the risk of missing someone important or sending people irrelevant information. It also gives the receiver more control over what kind of information they receive and allows them to monitor for information they may not have known existed.

Gaver (1991) used Khronika to implement a prototype sound notification system to explore his new notion of general awareness (mentioned earlier in Section 1.2.2.2). Sounds, such as low conversation or of water boiling in a kettle, enabled awareness of meetings or informal gatherings. This awareness led to informal interactions, which in turn lead to collaboration (previously discussed in Section 1.2.1.2).

Event-based awareness, as pioneered by Khronika, is partly an infrastructure mechanism for delivering different types of awareness information. However, the important conceptual contribution is in decoupling the senders from the receivers. This gave power to the recipients that they did not otherwise have in a directed message model. We will see this concept used later in future awareness research.

Later streams of research also look at how to also provide control to the sender of information.

1.2.4 Awareness in a Spatial Metaphor

Many CSCW systems employ a spatial metaphor, leveraging participants' natural knowledge about using physical space to facilitate virtual collaboration. Awareness systems are no exception, and early spatially based awareness models started with the COMIC[2] awareness model.

Benford and Fahlen (1993) created the COMIC awareness model for application to any environment that can be mapped to a spatial metaphor. Their primary application was within an immersive 3D world. The model consists of six components: *medium, aura*, *focus*, *nimbus, awareness* and *adaptors*.

- *Medium* is the collaborative environment. It defines how information is propagated. For example, in the physical world, we can hear people behind other objects and we can see for large distances in uninterrupted lines. In virtual worlds, communication is often text based and a text message may be clear throughout a room but completely invisible outside.
- *Aura* is a boundary around each entity (person or object), defining their possible range of interaction. For example, in the virtual world a person may not be able to interact outside the current room.
- *Focus* is a person's area of attention. They can direct their focus to control what they perceive. For example, a person is only visually aware of what they are looking at – visual focus is directional and blocked by walls.
- *Nimbus* describes the area of effect of the information that an entity provides. For example, a person cannot be seen from outside a room – their visual nimbus only extends to the walls.
- *Awareness* is a function of both focus and nimbus. If a person is within an object's nimbus then they may be partially aware of it, if the object is within their focus then they are fully aware of it and able to interact. The exact relationship of focus, nimbus and awareness is defined by the medium. For example, a person in the same room looking at another would be very aware of them, while when they look away they are only partially aware of them.
- *Adaptors* are modifiers on focus and nimbus. For example, a telescope increases the range of visual focus, and a megaphone increases auditory nimbus.

This model is interesting in its decoupling of the provider of information and the recipient of information, in a similar way to Khronika's event-based awareness. The

[2]The Computer-based Mechanisms of Interaction in Cooperative Work (COMIC) project was a multi-site multidisciplinary European research project investigating the basic principles, techniques and theories to support CSCW systems, and ran from September 1992 to August 1995.

primary conceptual difference here is that there is control given to the provider as well as the recipient – the provider controls their nimbus, or the information they are sending, and the recipient controls their focus, or how they pay attention to information around them. While this idea is based around a spatial model – Benford and Fahlen's main example is in a Virtual Reality System – later refinements generalised it to other settings (discussed later in Section 1.3.2.2).

1.2.5 Early Exploration of Awareness Summary

In this section, we explore the early concepts of awareness in the field of CSCW. This early work shows how researchers began to realise that there was more to collaboration than simply direct interaction between people and with shared objects. Successful collaboration is a complex social activity with many subtle peripheral and non-verbal cues between people and around artefacts – in short, it depends on awareness.

While there were earlier technologies that, with the benefit of hindsight, could be considered to provide awareness information (for example, e-mail and the UNIX "who" command), we concern ourselves here with work that formed the basis for rich CSCW research streams about supporting awareness in its various forms. We begin by discussing some workspace studies that made clear the complexity of collaboration activities and demonstrated the need for awareness support. We follow by discussing early media space research that started from a practical basis of connecting people and discovering what happened. We then provide an overview of some concepts that were in their infancy but proved very important to later research – event-based awareness and the COMIC spatial model of awareness.

1.3 Diversification and Research Prototypes

The time period from about 1995 to 1999 was the most active phase in awareness research, with many research groups dedicating themselves to awareness research and producing a wealth of publications. During this period a whole range of new concepts and terminologies were introduced to awareness research. Rodden (1996) introduced the nimbus–focus model which was based on the COMIC spatial model (Benford and Fahlen 1993). A large number of often highly related notions of awareness were introduced, such as social awareness (Tollmar et al. 1996), workspace awareness (Gutwin and Greenberg 1995b; Gutwin 1997) and contextual awareness (Mark et al. 1997) to name just a few. The appearance of these notions and concepts highlights the need to understand different facets of awareness as well as a trend towards greater specialisation. We will start this section by revisiting the more prominent notions and concepts in their respective research context.

Because this period was so active, we cannot hope to capture all of the research related to awareness. However, there are a smaller number of general trends in

awareness research that characterise the period. In this section we will describe these trends, starting with the theoretical and moving to the concrete, and briefly discuss some representative research examples within each trend. The sections proceed as follows:

- "The Social Context of Awareness" summarises concepts that place awareness in the larger sociological context of interaction.
- "Awareness Frameworks and Models" provides examples which show a strong research trend in creating models and classification schemes for awareness.
- "Collaborative Environments" describes how theoretical principles and infrastructure were used in the creation of collaboration environments.
- "Physical Display of Awareness" looks at applications for presenting awareness information outside of these comprehensive collaboration environments.
- "Infrastructure" describes the important work in building infrastructure to support awareness, primarily through event distribution architectures.

1.3.1 The Social Context of Awareness

In this section we identify an important research stream that sought to place awareness within the larger social activity and context. The fundamental principle is that people do things other than be aware of each other, and awareness fits into that larger context.

The two examples of this type of research differ a lot in their approach. The first group of work is about the possible negative consequences of providing awareness information. When awareness information is provided inappropriately, the providers may have their privacy infringed, and receivers of the information may be interrupted unnecessarily or receive information they are uncomfortable with.

The second approach, the locales framework, places awareness within the larger social structure and interactions of a person or group.

We differentiate this type of research from the models and classifications described later (see Section 1.3.2) as they take an inward view of describing awareness itself, rather than positioning it in a larger context.

1.3.1.1 Awareness, Privacy and Interruption

Privacy and interruption were issues raised in the early explorations of media spaces (see Section 1.2.2) and many of the prototypes had features to maintain privacy and minimise interruption while still providing awareness information. These features centred on methods for establishing connections and ensuring reciprocity. In the late 1990s, research began to appear specifically about the trade-off between awareness and privacy. The techniques for achieving balance in the trade-off focussed on transforming the display of awareness information to hide sensitive details and to make it "quieter" to avoid distracting interruptions.

Hudson and Smith (1996) were the first to clearly state the trade-off between awareness and privacy. They focused on the problem specifically within media spaces. Their proposed solution was to transform the video or audio feed so it removed potentially privacy violating details while still providing enough information for awareness of activity and presence. For example, one of their prototypes subtly displays image differences over a standard background frame so that the viewer, rather than see full video of a person, would see blocky shadows moving across the still image of the room.

The AROMA system (Pedersen and Sokoler 1997) took the transformation idea even further by fully abstracting awareness information. The abstraction allows presentation of the useful components of the information, e.g. presence, without also presenting privacy violating information, e.g. still wearing pyjamas while working at home. While the framework was generic, potentially incorporating a large number of abstract displays using display, sound, mechanical and other types of devices, their prototype made use of a drifting cloud animation, a mechanical toy merry-go-round, a sea shore soundscape, and temperature of a handrest surface. These abstract representations were linked to various indications of activity, such as how many people were around.

This work is strongly related to ambient displays (see Section 1.3.4) and seems to have arisen in parallel from different motivations.

1.3.1.2 The Locales Framework

The locales framework draws upon Anselm Strauss's (2003) Theory of Action to inform the design of CSCW systems. The intention of the framework was to act as a bridge between the rich social and technical streams of research in CSCW by providing a common vocabulary for communication between the theoretical and the technical. However, the most important contribution is in its amalgamation of most of the existing theoretical knowledge in CSCW at the time. We spend some time discussing the various aspects of the locales framework here because it relates awareness to the context of general CSCW theory of the time.

The locales framework was published in many contexts over a period of many years, with a first appearance in 1995 (Fitzpatrick et al. 1995). This first version of the locales framework was closely tied to the WORLDS collaborative environment (discussed in Section 1.3.3.2). We offer a simplified overview of this first version in Fig. 1.1. There are three primary entities of concern: *people*, *sites* and *means*. *Social worlds, locales* and *trajectories* describe the interactions of these primary entities.

People organise themselves into *social worlds*, defined by the framework as a group with a common purpose or primary activity. *Sites* are the places where the social worlds perform their activities. The *means* are artefacts used by people within the sites to support the activities. *Locales* describe the relationship between sites and means in use by social worlds. This means that the locale is different if a different social world uses the same site and means, or if the same social world starts using a different site and means. For example, while social worlds 3 and 4 share the same

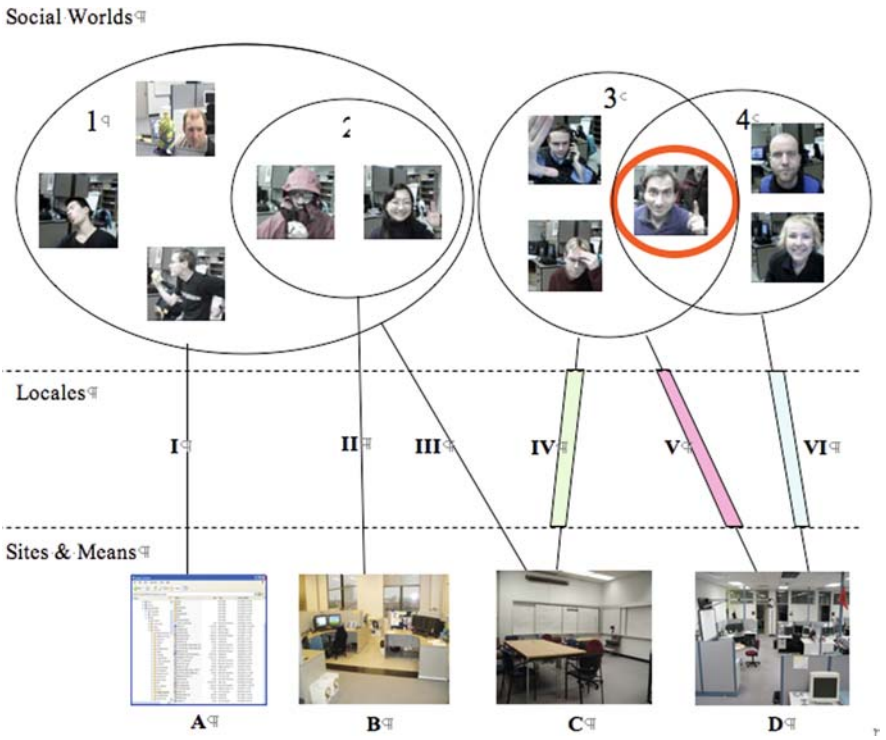

Fig. 1.1 The locales framework – social worlds, sites and means and locales

site and means (seminar room D), the different uses of the room create two distinct locales, labelled V and VI in the figure. *Trajectories* describe how social worlds, sites and means, and locales evolve over time.

For example, Fig. 1.1 shows four social worlds across the top row, labelled 1, 2, 3 and 4. These four social worlds are related to each other through the people that belong to them, i.e. social world 1 is a superset of social world 2. The figure also shows four sites, labelled A, B, C and D. A is a virtual site – a shared filesystem, and B through D are physical – two different work rooms (B and D) and a seminar room (C). Each of these sites also contains many means, e.g. the virtual files in A, and the tables and whiteboards in C.

The next locales framework publication (Fitzpatrick et al. 1996) while still based on the same principles of social worlds, locales, interaction and trajectory changed the structure of the ideas considerably. The framework was now composed of five aspects: locale foundations, mutuality, individual views, interaction trajectories and civic structures.

Locale foundations describe the aspect of social worlds and the locales that they use. Social worlds typically use many different locales when engaging in their activities and this aspect relates to their basic structure.

A major contribution described in Locale foundations is the concept of *centres and peripheries* in contrast to the more usual *boundaries*. Each social world has a centre defined by the collective purpose of the social world. Each person's relationship to the social world is represented as a distance from the centre rather than the binary "on" or "off" which is part of the rooms metaphor used by many groupware systems. For example, at an instant in time a group may be planning an event. Those very close to the centre may be involved in detailed organisation. Another person, who may just attend the event, is somewhat more removed. Yet another may skip this particular event, so they are closer to the periphery of the group, at least for the moment. In real-world situations such as these, boundaries are made only if required; in practice people can fluidly adjust their "membership" from centre to periphery as a consequence of their interests and their actions. Of course, some social worlds have explicit rules, membership lists and duties that define people's roles and what they do, but even these have varying participation levels.

Mutuality incorporates the issues of *presence*, *awareness*, *capability* and *choice*. Presence is the information that an entity makes available about itself, and entities have capabilities for perception of this information. Within those capabilities, the entities can make choices about how much they perceive of others' presence. The combination of the presence information and the perception choices determines awareness between entities. Note how similar these concepts are to focus and nimbus in the spatial model (Benford and Fahlen 1993) introduced in section 1.2.4. The locales framework authors acknowledge this work but note that the framework abstracts from the spatial requirement. It is even closer to the generalised model of awareness (Rodden 1996) that will be introduced shortly (Section 1.3.2.2). Explicit reference to Rodden (1996) does not occur until 1998; however, there appears to be parallel development during this time.

Individual Views. As an individual engages in work, he/she is rarely involved in a single task to the exclusion of all others. There are two important aspects to be considered; a *view* on one social world, and an individual's *viewset* across multiple social worlds. A view is how an individual sees a single social world (the people and the locales), and it is dependent on the level of engagement with the centre of that world. A viewset incorporates the individual's views of all the social worlds with which they are engaged, e.g. when juggling work and family tasks. The viewset will change continually without fully switching out of any of the tasks.

Interaction Trajectories describe how all five aspects of the locales framework change over time. Locales will be set up, used so that the sites and artefacts are modified, and eventually discarded. Individual views and viewsets will constantly change as their focus changes and their relationships to others changes.

Civic Structure describes the relevant outside influences on a social world. No social world operates in isolation. Members are involved in multiple worlds at once. For example, the many social worlds within an organisation (or social group) overlap and influence one another.

The final version of the locales framework (Fitzpatrick et al. 1998a; Fitzpatrick 2003) focused on using the framework as a tool for constructing, understanding and bridging the sociological and the technical. The framework helps to understand the

sociological relations of a context as well as the holistic technical view, and as a list of all the things to consider in analysis and design of a CSCW system.

The locales framework is unique in its coverage. The component aspects were also revolutionary – especially those of locales, centres and individual viewsets. The contribution to awareness is in showing how awareness fits into a larger context.

Unfortunately the locales framework did not make a huge impact on CSCW design. The related work was mostly in the WORLDS and Orbit systems (described in Section 1.3.3) and in some analysis work on the Elvin notification system (described in Section 1.3.5), all of which were within the same group. We believe that this is due firstly to the complexity of the theory's relationship to design, making it hard to use it directly, and secondly to its descriptive rather than prescriptive nature.

1.3.1.3 Social Context Summary

The results of the two social context research areas we have discussed here differed greatly. The work on privacy and interruption left open questions and room for more investigation and models to be developed (see Section 1.4.1.4). The locales framework prompted different uses, as a guide for design of tools such as Orbit and Community Bar (McEwan and Greenberg 2005), and also as a way of describing the social positioning of tools and practices (Fitzpatrick et al. 1999; Fitzpatrick 2003).

In the next section we go on to talk about work, specifically about awareness itself rather than the social interaction framework around it.

1.3.2 Awareness Frameworks and Models

While HCI researchers had realised the importance of awareness in supporting collaboration, the question remained how awareness support could be represented at a conceptual level. Early implementations like media spaces implemented awareness support in a fashion that was very closely modelled on reality. However, if awareness support was to be realised beyond direct audio–video links, researchers needed to understand more details of awareness, such as how people gain mutual aware-

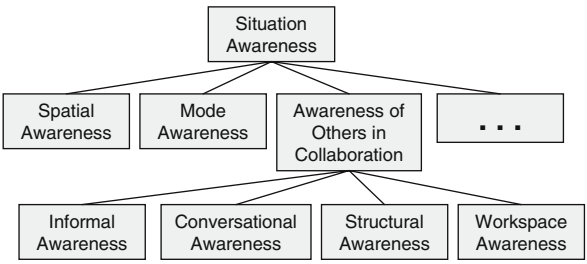

Fig. 1.2 Situation awareness and subtypes (Gutwin 1997, p. 20)

ness of work practices and the types of information that are required to create that awareness.

In this section, we discuss representative samples of awareness models and frameworks. This includes some of the major conceptual awareness models, Gutwin's workspace awareness model (1997), Rodden's model of awareness (1996) and the event pipeline model produced by Fuchs and his colleagues (1996).

1.3.2.1 Workspace Awareness

In 1995 Carl Gutwin and Saul Greenberg published the first version of their influential workspace awareness framework[3]. The framework was targeted at supporting awareness for small distributed teams using real-time synchronous shared workspace groupware (Gutwin and Greenberg 1995b; Gutwin et al. 1995)[4]. They define *workspace awareness* as: "The collection of up-to-the-moment knowledge a person uses to capture another's interaction with the workspace" (Gutwin and Greenberg 1996).

While the original publications in 1995 were not linked to situation awareness, Gutwin extended the model in his PhD dissertation (1997) to include this concept. Gutwin saw workspace awareness as a specialisation of situation awareness. Situation awareness had emerged from psychological concepts and phenomena observed in military aviation (Gilson 1995). Adams et al. defined situation awareness as "the up-to-the minute cognizance required to operate or maintain a system" (Adams et al. 1995). Situation awareness describes single-person activities (perception, comprehension and prediction), and is primarily concerned with interaction with complex technical environments (aircraft, power plants, etc.). Gutwin used situation awareness as a framing concept for awareness and decomposed it hierarchically to position his own workspace awareness work. In doing so he also named and positioned other types of awareness that had appeared in CSCW research.

Spatial and mode awareness are specialisations of situation awareness. Spatial awareness is the ability of a pilot to understand his location in an airspace (Fracker 1989). Mode awareness is "the ability of a supervisor to track and to anticipate the behaviour of [mode-based] automated systems" (Sarter and Woods 1995).

Gutwin contrasted these single-user types of awareness with *awareness of others in collaboration*, which he then breaks down further into four different concepts. *Informal awareness* deals with the presence and availability of people (Who is around?; Are they available for collaboration?, etc.) (e.g. Dourish and Bellotti 1992). Other authors commonly refer to this type of awareness as presence awareness or

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[3] A later summary of the framework was also published in 2002. Gutwin and Greenberg (2002) A Descriptive Framework of Workspace Awareness for Real-Time Groupware. Comput Support Coop Work 11: 411–446, however, it did not extend the basic notions of the concept. It is preferable as a reference and is the definitive version of the work.

[4] An early version of the concept was also published under the term *group awareness*. Gutwin and Greenberg (1995a) Support for Group Awareness in Real Time Desktop Conferences. In: Proceedings of the 2nd New Zealand Computer Science Research Students Conference.

social awareness (e.g. Tollmar et al. 1996; Prinz 1999). *Conversational awareness* comprises awareness of utterances as well as awareness of facial expressions, gestures and other forms of non-verbal communication. *Structural awareness* refersto the structure of the working process including organisational settings like rules of interacting, power and status relationships as well as roles of persons within the working process. While not the main contribution of the dissertation, this collection of terms and partial taxonomy has had its influence on later work, for example, the term "informal awareness" has become semi-standard (e.g. Boyle and Greenberg 2005; Greenberg and Rounding 2001; McEwan and Greenberg 2005).

The workspace awareness framework itself consists of three parts, the type of information that makes up workspace awareness, the mechanisms people use to gather information and the ways people use workspace awareness information in collaboration. With regard to awareness information, Gutwin and Greenberg rely on five questions to describe awareness information: who, what, where, when and how. Based on those categories they define specific questions targeted at analysing awareness in shared workspaces. For instance, in the "who" category the authors specify such questions as: "Is anyone in the workspace?" and "Who was here, and when?".

Gutwin and Greenberg's work stands out from other awareness work at the time as it offers a comprehensive model that addresses awareness from a conceptual rather than a technological angle. The framework allows designers to systematically analyse and describe interactions in shared workspaces.

1.3.2.2 The Focus/Nimbus Model of Awareness

In 1996, Rodden published a generalised version of the spatial COMIC model of awareness (Benford and Fahlen 1993). He generalised the model by reducing the concepts to the generic set of focus, nimbus and awareness. Medium, aura and adaptors are now considered to be part of the specific applications of the general model. He also refined the concepts of focus, nimbus and awareness to be object based rather than space based, thus extending the application of the model to contexts that cannot be easily mapped to a spatial metaphor.

In Rodden's generalised model, focus and nimbus are recast in terms of set theory. In the spatial model they are specified as a volume in the space, and awareness is calculated as a function by the degree of volume overlap. In the new object-based model, focus and nimbus are each sets of objects and awareness is calculated as a function of the set intersection. The benefit of the object-based method is that there no longer has to be a mapping of the application to some concept of volume, allowing the model to be used much more generically to model awareness in any collaborative application. To summarise one of Rodden's examples, in a workflow application a person's nimbus would be the set of tasks already completed, while their focus would, most of the time, be the set of tasks they were just about to do next.

The value of this model is that, like the original spatial model, it makes a distinction between the sender's control of the information they provide and the recipient's

control of their attention to perceiving information. It also provides a framework for modelling how the interactions of sender's information and recipient's attention combine to result in the recipient having awareness of the sender.

Although regarded as influential, the model was not widely adopted beyond the original scale of work on collaborative virtual environments (Sandor et al. 1997) until later. McEwan and Greenberg (2005) implemented an awareness system, Community Bar, that gives user explicit control over the nimbus and focus settings.

1.3.2.3 Event Pipeline Model

The event pipeline model extended the concept introduced by Khronika (Lövstrand 1991) of decoupling senders and receivers of discrete awareness events. The extensions were an important development and captured the fundamental concepts for event-based awareness research in CSCW.

Starting in 1995, Fuchs and his colleagues published a number of studies on a generic event distribution model. The work was first published as part of the GroupDesk model (Fuchs et al. 1995). Building on the notions developed in GroupDesk, Fuchs then developed the PoliAwaC system as part of the PoliTeam project (Fuchs et al. 1996). The model underlying PoliAwaC introduced a number of innovations. As we discussed earlier, Khronika was the first system to introduce the notion of event-based awareness with the decoupling of senders and receivers. The work described here takes the event-based awareness further by adding a number of concepts that give individual users greater control over the event distribution process. The model, here referred to as the event pipeline[5] model, is summarised in Fig. 1.3.

The model is based on the persistent storage of events in a database. User actions, which manipulate system objects, like documents, generate that are recorded and stored in an *event database*. The recorded events are made available for other users through notification mechanisms at the user interface.

Privacy filters let senders select an appropriate level of privacy. All outgoing events that are based on a user's action are matched against individual privacy filter. On the receiver side the model contains interest filters, which let receivers select which notifications they want to receive, and when and how they want to receive them. The filters were introduced with the aim of reducing the large flow of information that event-based systems produce. In addition to these individual filters the model also introduced a global filter that allowed for organisation-wide policies to be reflected in the event distribution model, as well as the notion of conflict resolution between participating parties (Pfeifer and Wulf 1995).

The aim in the 1996 publication (Fuchs et al. 1996) was to apply the model in the context of PoliTeam, a research project that was concerned with supporting the col-

[5]The model was never consistently named. The original paper written in German refers to it as *Ereignissdienst* (event service). Rather than using this generic term we will use the term "event pipeline" which was coined by one of Fuch's co-authors, Volker Wulf. Fuchs himself published the AREA model which has a much broader scope.

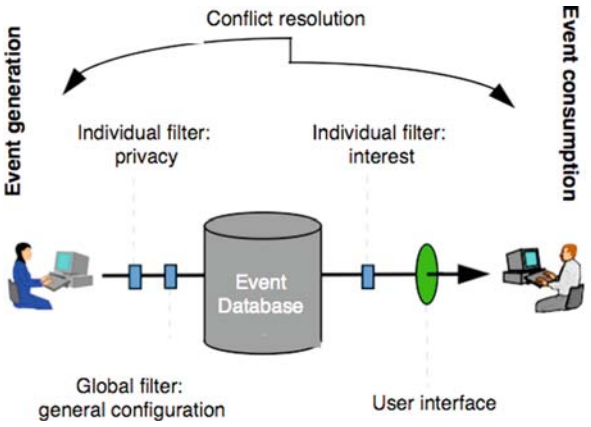

Fig. 1.3 The event pipeline model (Fuchs et al. 1996)[6]

laboration between government departments situated in Bonn and Berlin (Klöckner et al. 1995). The pipeline model itself is described more comprehensively in Fuch's dissertation (Fuchs 1997). Fuch's dissertation is also the foundation for the AREA model described in Section 1.3.5.

1.3.3 Collaborative Environments

So far in this section we have discussed theoretical approaches to awareness to inform design. In this section we discuss collaborative applications.

In the second half of the 1990s, there was a trend to build complete environments that would manage all of the collaborative interactions for a group. These environments would contain access to all of the shared resources for the group and provide awareness of people's presence in the environment and their activities around the shared resources. Rather than being single collaborative applications, they would provide access to a range of applications and group them by task environment.

The common organising metaphor was room based, where users entered a room for a particular context or task, and moved into a different room when working on a different task. An interesting variation on the usual room metaphor was the Orbit system, which was based on the locales framework and supported the concept of individual viewsets containing views of multiple locales simultaneously.

1.3.3.1 DIVA, GroupDesk and PoliAwaC

From about 1995 onwards researchers at GMD[7] explored aspects of awareness through a succession of prototypes, DIVA (Sohlenkamp and Chwelos 1994),

[6]Translated by the authors.

[7]GMD is the *Gesellschaft für Mathematik und Datenverarbeitung* (Society for Mathematics and Information technology), now a part of the Fraunhofer Society.

GroupDesk (Fuchs et al. 1995), PoliAwaC (Fuchs et al. 1996) and BSCW (Bentley et al. 1995; Prinz 1999). Many of those prototypes were applied in the context of the PoliTeam project to support communication between government departments in Germany.

The research undertaken at GMD was characterised by a number of commonalities. First, all prototypes were built on the notion of shared workspaces, and implemented both asynchronous and synchronous aspects of awareness. Second, the design of the system and the underlying awareness concepts were tightly coupled. All prototypes, with the exception of DIVA, utilised an object-oriented notion to describe the system as well as the awareness concept. And third, most of these systems were based on the event pipeline architecture (Fuchs et al. 1996) (see Section 1.3.2.3). We will look at some of these systems and their impact on awareness research in more detail.

These systems were highly relevant for the development of awareness research. They introduced notions that lead to an understanding of asynchronous awareness mechanisms such as notification, event generation, event distribution and notification subscription. Below we discuss each of the prototypes in turn.

DIVA was an early groupware prototype that was based on the virtual office metaphor (Sohlenkamp and Chwelos 1994). The system used a simple abstraction of an office environment consisting of people, rooms, desks and documents. Rooms were shared workspaces that contained representations of people, desks and documents and provided an audio–video link between participants. Rooms allowed participants to control different levels of access and visibility, with the interaction closely tied to imitating real-world interactions. For instance, users could only be present in one room at a time and in order to work closely with another user they would locate themselves around the same desk. DIVA combined a number of groupware services including shared editors (text editors, drawing tools, music editors, etc.) as well as support for synchronous and asynchronous awareness.

The system implemented many innovative awareness features including privacy support and access control. DIVA showed presence and virtual location by placing icons of users in rooms. Rooms had three access settings, providing varying amounts of awareness information to those outside the room. In addition, users could disable the audio–video link temporarily while in a room in order to receive phone calls. Another interesting privacy feature was “private conversations”. Users could initiate private conversations by dragging their icon so that it overlapped with the icon of another user. During a private conversation other members of the room could still overhear the conversation but at a reduced volume.

The literal composition of workspaces allowed users to gain awareness about who was working with whom on which documents. A “catch-up” mechanism was used to replay changes made to shared documents: “DIVA . . . provides a uniform mechanism for catch-up . . . based on the replay of saved history. Changes made by others are replayed with animation so that they may be viewed exactly as if the user had been there watching them being made, except that the replay may be sped up” (Sohlenkamp and Chwelos 1994).

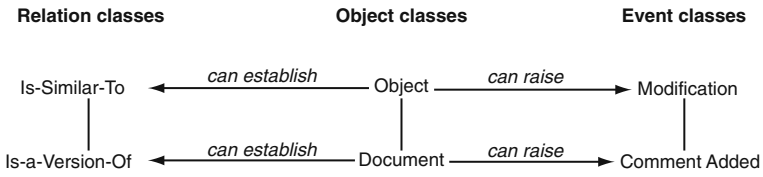

Fig. 1.4 GroupDesk model, class relationships (Fuchs et al. 1995)

After DIVA, in 1995 Fuchs et al. introduced their event distribution model (also referred to as the GroupDesk model, shown in Fig. 1.5). The model becomes the starting point for a series of prototypes, namely, GroupDesk (Fuchs et al. 1995), PoliAwaC (Fuchs et al. 1996; Fuchs 1997), AREA (Fuchs 1999) and had influenced the design of BSCW (Bentley et al. 1995; Prinz 1999) and NESSIE (Prinz 1999).

The GroupDesk model (shown in Fig. 1.4) used an object-oriented approach to model the awareness mechanism. It consisted of two major components, a model of the working environment, which described actors, artefacts, their relationships as well as events, and a model of awareness, which described "work situations", "interest contexts", "event distribution" and "event notification". The object-oriented approach allowed the authors to represent specific kinds of working situations based on a general relationship between objects, events and relations.

The model contained three concepts: objects, relations and events. Objects represented any entity that was modelled by the system (e.g. documents, folders, representations of departments). Objects representing users were referred to separately as actors. Relations linked objects to each other and actors. Events were divided into two types. Modification events represented user-initiated changes of objects within

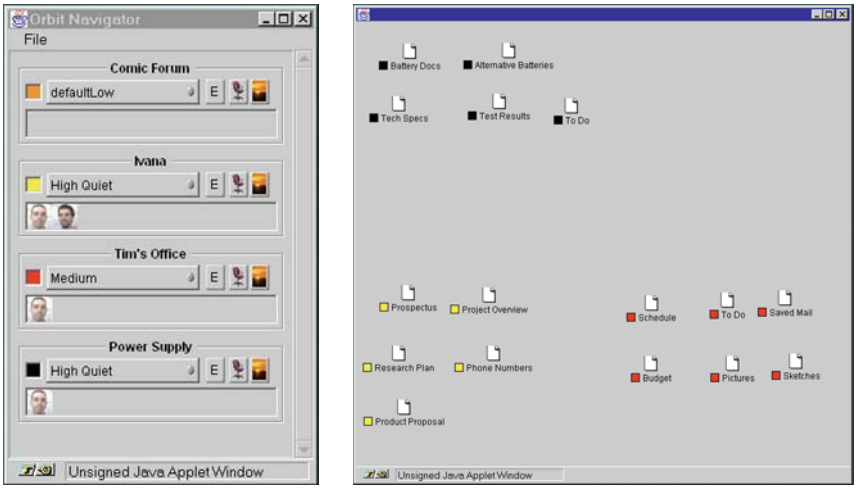

Fig. 1.5 Orbit–Gold interface

the system, e.g. editing of a document. Activity events described synchronous activities, e.g. presence in a workspace.

The main innovation of the GroupDesk model was the level of control it provided for event distribution and notification based on user preferences. Up to that date users had little control over which awareness information they were interested in and how the awareness information was displayed. The GroupDesk model introduced subscription mechanisms that allowed users to define "interest contexts". These subscriptions specified the type of objects, relationships and events. The model also introduced the idea that event notification could occur on different levels of intensity, from urgent and highly disruptive to peripheral and ambient.

The first GroupDesk prototype was just a simple shared workspace system built to evaluate aspects of the event model and lacked an implementation of the event subscription mechanisms described in the model. Later prototypes from the group, such as PoliAwaC (Fuchs et al. 1996; Fuchs 1997), implemented the concepts in the model more completely.

1.3.3.2 WORLDS and Orbit

The WORLDS (Tolone et al. 1995) and Orbit systems (Mansfield et al. 1997a; Mansfield et al. 1997b) are worth discussing here as they are the only systems of this time to explicitly implement the concepts of the locales framework. Both systems were built in conjunction with the development of the locales framework and so reflected the framework principles and helped to refine the theory. WORLDS reflected the early versions of the locales framework, emphasising social worlds and different locales for different tasks, while Orbit incorporated the later concepts of individual views and viewsets.

WORLDS provided a very "room-like" view of locales and the relations between them. The interface showed a single locale at a time, with the tools and artefacts for the locale displayed within it. A number of functions supported moving between locales, including user bookmark lists of favourite locales, "portals" to locales that could be placed in other locales and home locales for users.

Awareness of others was provided through media space components (i.e. audio and video links), to all locale members, opened when entering a locale. Workspace awareness was at the artefact level, where shared documents would be marked with change events, similar to other similar collaborative environments such as DIVA (Sohlenkamp and Chwelos 1994).

In contrast, Orbit provided a view of locales that was much closer to the final version of the locales framework. A user was able to see and interact with all their locales at the same time, and they could dynamically adjust their view on each locale to reflect its pertinence to their current task. This design feature was a marked departure from the collaborative environments of the time and has been seen infrequently since.

The Orbit interface is shown in Fig. 1.5. It consisted of two windows: the navigator (left) and the workspace (right). The navigator listed the locales and showed presence information of other people in those locales. The workspace

showed documents that the user was interested in, selected from all of their locales. Documents were linked to locales through colour, e.g. the "Power Supply" locale is marked black, and all its documents are also marked with a black colour chip (Power Supply documents are all in the top left corner of the workspace). Orbit also provided text chat through integration with the Tickertape tool (Fitzpatrick et al. 1998b), as well as audio and video links with other people.

The importance of these two systems lies in their theoretical foundations and in their concept of awareness that, although only in a very simple manner, contrasted with the prevailing event-based model. The transition from theory to design and implementation is a challenge that continues to face CSCW, and the relationship between the locales framework and WORLDS/Orbit is one of the few examples of such a transition. In regards to the underlying model of awareness, Orbit was more closely aligned with thefocus/ nimbus model of awareness than the event-based models, even though the nimbus was adjusted to equal the focus, enforcing reciprocity.

1.3.3.3 Collaborative Environments Summary

Collaborative environments were usually developed in tandem with theory and the environments that we have discussed here were the implementation side of the theoretical models and frameworks discussed in the previous section. WORLDS and Orbit informed and were informed by the development of the locales framework, while the GMD prototypes were developed along with the event pipeline model. Other systems also explored theoretical concepts, such as the TeamRooms prototype (Roseman and Greenberg 1996) which was an exploration of the "rooms" metaphor and also incorporated early ideas from what would become the workspace awareness framework.

1.3.4 Physical Display of Awareness

An important and influential concept for the presentation of awareness information began to gather research attention. The use of physical devices for interaction with digital artefacts was being driven by the increased interest in ubiquitous computing, and in the late 1990s this trend started to incorporate awareness. We look at two important example publications illustrating ambient display of awareness and conveying awareness of loved ones. Both of these publications were influential and foreshadowed much future research.

Ishii and Ullmer (1997) introduced their seminal work on tangible computing. They describe tangible computing in three concepts: "*interactive surfaces; . . . coupling . . . with graspable physical objects; and ambient media for background awareness*". They present a number of examples of ambient media in the paper as well, such as the ambientROOM, which incorporates ambient light, shadow, sound, airflow and water flow.

Ambient awareness displays provide information in a format that encourages peripheral awareness, which occurs when we are aware of some information without focussing our attention on it. An illustrative example from Ishii and Ullmer is the way people are aware of the weather outside the window without concentrating on it. When there is an interesting change in the information, such as when a storm appears, our attention is drawn to it and we consciously focus on the information. Ishii and Ullmer built an ambient display that projected ripples on the ceiling, and varied the frequency of ripples dependent on weather activity outside.

The principle was also observed in the media spaces work, where the value of peripheral displays of colleagues was noted by Bly et al. (1993). Similar to the peripheral media spaces, ambient displays show awareness information in a non-intrusive manner so that users can concentrate on their main task, but also allow interruption for interesting events.

There are other, earlier implementations of ambient awareness devices in the past, such as Gaver's EAR system (Gaver 1991) and Jerimijenko's Dangling String (Weiser and Brown 1995). However, this earlier work did not seem to capture the imagination of researchers as much as Ishii and Ullmer's, perhaps because of its "packaging" in the larger framework of tangible computing. The important concepts from this work were non-intrusive display of awareness information, capturing attention at interesting events and allowing the user to transition from the peripheral display into a detailed and interactive representation of the information.

Strong and Gaver's (1996) Feather, Scent and Shaker prototypes offer an interesting contrast to the predominantly workplace-oriented awareness research seen up to this point. Their target was to support awareness in intimate, personal relationships where companionship, mood and emotion were the important factors rather than an explicit transfer of information. As such, the prototypes were sensual and abstract. The emphasis on intimate relationships in personal life was an important driver for the later trend in awareness in home environments (see Section 1.4.2.1).

1.3.5 Infrastructure

During this time period it was becoming clear that while research prototypes were providing valuable insight into the design and implementation of awareness systems, there was a distinct lack of awareness infrastructures that would allow groupware designers to build systems quickly. Infrastructure systems were needed to allow for awareness information to be easily shared and so enable designers to concentrate on presentation and interaction. In addition, the focus on collaboration environments proved limiting when it came to collecting awareness events from applications outside the groupware environment.

Awareness infrastructure took the form of event distribution architectures. Systems such as AREA (Fuchs 1999) and NESSIE (Prinz 1999) introduced the notion of a generic infrastructure and cross-application awareness. However, they did not provide a general accessible service that other groupware developers could build

on. During the same time the use of notification services to support awareness was being explored (Ramduny et al. 1998).

In this section we discuss three examples of event distribution infrastructure. AREA supports both synchronous and asynchronous notifications and incorporates the event pipeline model concepts of privacy and interest. NESSIE also implements the event pipeline model but has a greater focus on sources of awareness event information and output modalities for notification. Elvin (Segall and Arnold 1997) is one of the most successful notification services, which is independent of that work and implemented event distribution on a lower level. By providing a generic infrastructure, all of those systems enable awareness events to be shared amongst applications.

1.3.5.1 Area

The emergence of event-based awareness systems posed additional challenges to the design of awareness systems. In general, event-based systems generate a large number of events, making it necessary to allow recipients of awareness information to subscribe to relevant information and influence the types of notification they receive.

The AREA framework (Fuchs 1999) is a result of research on event notification models undertaken by Fuchs and his colleagues over a number of years. While the original ideas for event notification were discussed in the GroupDesk system (Fuchs et al. 1995), Fuchs extended the model as part of his PhD work (Fuchs 1997).

AREA is defined as both a semantic model as well as a groupware infrastructure component. The semantic model is based on the notions of event distribution, user-defined interests and privacy specification. Privacy and interest specifications can be seen as implementations of the privacy and interest filters featured in the event pipeline model (Fuchs et al. 1996).

1.3.5.2 NESSIE

The NESSIE system (Prinz 1999) was one of the first groupware architectures to allow handling of events created by other applications or generated by sensors. The NESSIE model used “sensors” and “indicators” to gather events and distribute event notifications. Sensors could be physical sensors installed in people’s offices as well as macros in programs like Microsoft Word that delivered information about changes in documents. Indicators allowed targeted event notifications. Furthermore, users had access to a configuration interface that allowed them to individually combine the sensors and indicators they wanted to use for a given situation.

NESSIE supported the use of ambient displays for awareness information. For example, the *activity-balloon* ambient device (Fig. 1.6, bottom left), small tower with a balloon on top indicated virtual presence by blowing up the balloon when a remote person was present. In addition NESSIE supported the virtual 3D interfaces “SmallView” and “Theater of Work” (Fig. 1.6, projected display) to provide a virtual world for distributed interactions (Prinz and Gross 2001).

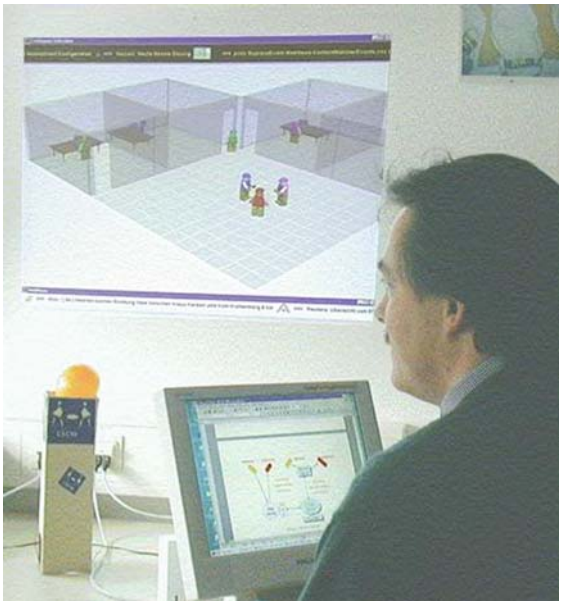

Fig. 1.6 Ambient and 3D interfaces in NESSIE[8]

1.3.5.3 Elvin

Elvin (Segall and Arnold 1997) was not created specifically for awareness events, but rather as generic event infrastructure. Despite not being built for the purpose of awareness, Elvin gained exposure to the collaborative research community through its use in a number of collaborative awareness tools. It was used in the Tickertape application (Parsowith et al. 1998) and it was used to pass awareness events in the Orbit system (see Section 1.3.3.2). It also served as the foundation technology for awareness within an organisational setting, ranging from within small teams to across organisational structures with many event sources and presentation interfaces, as reported by Fitzpatrick et al. (1999).

The strength of Elvin is in its content-based subscription and routing of notifications. Producers of information can send out unstructured information about events, and consumers subscribe by specifying something about the information content they want to receive. For example, if Alice is interested in awareness, she can subscribe to every event that includes the word "awareness" anywhere in its content, so that she can see chat messages discussing awareness, meetings concerning awareness, code changes to awareness prototypes, and anything else about awareness. In practice this means that (a) producers of information do not have to worry about who, if anyone, is interested in the notifications they are sending

[8]From http://www.ercim.org/publication/Ercim_News/enw42/prinz.html.

and (b) consumers can subscribe based on free-form ideas of interesting message content.

The idea of decoupling producers of notifications from the consumers of the information was used earlier in the Khronika system (see earlier Section 1.2.3), but in Khronika there was a specific structure to events and consumers had to subscribe based on the fields in the structure. Elvin does not impose any structure and consumers are free to subscribe to any part of the notification content.

1.3.6 Summary of Diversification and Research Prototypes

This period could be characterised as the golden age of awareness research as it was the period with the most research directed primarily on awareness. During this time the major thrust of research was in developing models and theories to capture how awareness worked and how it was part of collaborative activity. Alongside the theories, comprehensive collaborative environments were developed to test and provide feedback for the theoretical aspects.

In the next section we will see that awareness becomes more of an application component. Development of comprehensive theories starts to dwindle and collaborative environments are replaced by suites of supporting applications that integrate with individual work. To replace these research directions we see an emphasis on extending awareness to other groups of people in different domains.

1.4 Summary of Extended Models and Specialisation

The time period covered in this section is characterised by a number of research trends. Each of these trends is driven by a need to understand awareness in a broader context. First we can see an increasing specialisation of existing awareness models. While the previous time period was concerned with understanding and conceptualising awareness support, the current research period is concerned with addressing issues like support for context information or the relationship between privacy and awareness in more detail (Section 1.4.1.4). Second, awareness research is increasingly penetrating new domains as researchers start to look outside the workplace. Domestic and medical settings are two domains that stand out in this context. Third, we can see a trend where technical developments have opened up new avenues for awareness research. In particular, the increasing popularity of instant messaging has led to the widespread distribution of tools that support awareness of availability and have been extended in various ways to support other types of awareness. Last but not least, we also see the emergence of requirements for new awareness concepts that cover different types of group configurations which go beyond standard distributed settings. The introduction of tabletop devices, for example, has highlighted an increased need for technological support for co-located work on a large shared screen. Notions of proximity and group building in ubiquitous computing and new

types of collaboration, such as mixed presence collaboration, have posed new opportunities and challenges to awareness research.

1.4.1 Models and Diversifying Types of Awareness

While the time period between 1995 and 2000 was undoubtedly the most active when it comes to producing concepts and implementations of awareness, work on awareness concepts and models still continues in the current time period. In many cases this work can be characterised as an extension of existing models. For instance, the event notification infrastructure (ENI) (Gross and Prinz 2003 Prinz and Gross 2004) adds an additional layer of modelling to the existing NESSIE (Prinz 1999; Simone and Bandini 2002) model. By comparison, Simone and Bandini's (2002) reaction–diffusion metaphor takes an existing model from a different domain and applies it to HCI research.

At the same time, many researchers started to fill in the details of particular types of awareness, rather than the issue of how awareness worked in general. Their approach was to look at supporting a particular type of awareness.

In addition, work on the relationship of privacy and awareness continued and started to untangle the confusing mess of concepts involved in the word "privacy".

1.4.1.1 ENI

Event notification infrastructure (ENI) (Gross and Prinz 2003 Prinz and Gross 2004) is conceptually based on prior awareness research undertaken at GMD (Fuchs et al. 1995; Fuchs 1999; Prinz 1999). ENI extends the NESSIE awareness model (Prinz 1999) and integrates the notion of "contexts" into the model. Context information includes locations, artefacts and applications and other information, which is linked to a specific context. ENI adds this information to existing event information in an awareness system.

The model contains three fundamental steps. First, the model tries to determine in which context a user is currently working. The authors suggest a context mapping mechanism that maps events gathered from sensor information against rules saved in a context database. Second, the model identifies the context of the user who is receiving the notification. The authors are less specific about how to achieve this context mapping. In their prototypical implementation (Prinz and Gross 2004), the working context is derived from the selection of shared workspaces. Third, the model checks which notification information that the user wants to receive (user preferences).

The ENI model tries to improve awareness support by gathering additional information and allowing users to receive awareness information in a more context-specific manner. However, the context mapping mechanisms underlying this concept is highly complex. It is unclear who performs this mapping and how inter-individual differences between users can be addressed. The authors refer to this issue as future research.

1.4.1.2 Reaction–Diffusion Model

The reaction–diffusion model of awareness (Simone and Bandini 2002) is a model based on a spatial metaphor. It owes a lot of its origins to the COMIC spatial model (Benford and Fahlén 1993; Rodden 1996; see also earlier Sections 1.2.4 and 1.3.2.2) but extends it with the motivating idea that awareness is a complex phenomenon and so needs a complex metaphor to describe it. They propose the metaphor of reaction and diffusion, common in many other fields such as biology, chemistry and physics.

The common fundamental principle in reaction and diffusion metaphors is that there are many entities in an environment, which move around in the environment and react when they come into contact with each other. For example, in a biological setting there may be zebras on a grassy plain. Each of the entities has a *state*, in our example most of the zebras have a healthy state but there are a few with a virus. The entities move around, or *diffuse*, and come into contact with each other. When they come into contact, they possibly undergo a *reaction*, which changes their state. To take our zebra example again, when an infected zebra comes into contact with a healthy one, there is a possibility of a reaction that changes the healthy zebra to the state of being infected. Contact is defined in terms of each entity having multiple *fields*, roughly equivalent to nimbus, and *sensitivity functions*, roughly equivalent to focus.

There are four types of rules to be determined for applying the metaphor to a particular setting:

1. *Field diffusion rules* define the different possible types of fields along with their area of effect and how they propagate through the environment.
2. *Trigger rules* define how the fields affect sensitive entities.
3. *Transport rules* when entities' positions are changed by fields.
4. *Reaction rules* define how an entity's state is changed by a field.

The reaction–diffusion model of awareness differs from the earlier spatial models mostly in its complexity, which means it can provide more detailed and complex descriptions and explanations of the formal interactions of awareness information. The extra detail helps ease applying the theory to design of a system.

1.4.1.3 Types of Awareness

While not counting as full models of awareness by any stretch, there was work that addressed specific types of awareness and so served to fill the classification space without defining an awareness classification taxonomy. Two example types of awareness are intentionally enriched awareness and informal awareness.

Intentionally enriched awareness (Rittenbruch 2002; Rittenbruch et al. 2007) is based on the observation that many awareness concepts assign a passive role to the person whose actions are being observed. This approach directly contradicts research that shows that people in real-life collaborative situations are often actively involved in providing invaluable information which helps others to understand their

actions in context (Heath et al. 2002; Schmidt 2002). Intentionally enriched awareness acknowledges this fact and provides people with means and mechanisms to enrich awareness information by deliberately adding contextual information. One of the main challenges of this approach is to provide the right balance between additional workload and perceived benefit for the individual. See the chapter on intentionally enriched awareness in this book for a more comprehensive conceptual discussion of this approach. Intentionally enriched awareness is discussed in more detail in Chapter 19.

Informal awareness is the now reasonably stable term for the awareness effects observed primarily through media space research that have been labelled peripheral awareness and general awareness amongst other terms. This is a background awareness of work colleagues, incorporating knowledge of presence, activity and availability. Informal awareness is the foundation for casual interaction, which in turn proves to be vital for supporting ongoing collaboration.

Some research into media spaces continued, such as the deployment of a VideoWindow (Fish et al. 1990) called vKitchen at Microsoft (Jancke et al. 2001). Most research into this phenomenon in recent years has taken the approach of how to design informal applications that support and enhance the informal awareness and casual interaction capabilities of small groups of collaborators. A large part of the motivation for the approach has been studies of Instant Messenger (e.g. Nardi et al. 2000), which show that the simple clients provide a great benefit in informal awareness information and simple transitions to casual interaction. With this motivation, amongst others, prototypes supporting rich multimedia awareness and interaction have been developed, such as the Notification Collage (Greenberg and Rounding 2001) and the Community Bar (McEwan and Greenberg 2005). While these systems provided rich presence and availability information with various multimedia communication channels, activity awareness was minimal. Tee et al. (2006) extended this work to provide extra activity awareness through sharing of screen snapshots.

There are of course many other terms for types of awareness around, but listing them all is beyond the scope of this chapter. Gross et al. (2005) provide an excellent coverage of all the different definitions that have been used.

1.4.1.4 Privacy Continued

Privacy research continued from the work discussed earlier in Section 1.3.1.1. Some research was into trying to ameliorate the privacy invasiveness of media spaces, taking the approach of removing privacy violating details while retaining enough information for awareness (e.g. Junestrand et al. 2001). However, Neustaedter et al. (2006b) showed that at least blur filtration failed to achieve the required balance.

Previous literature on privacy was of a "bottom-up" nature, focussing on the issues arising in technical systems such as media spaces. Palen and Dourish (2003) were the first to address this issue by developing a model of privacy based on the work of social psychologist Irwin Altman (Altman 1975; Altman 1977). The contribution in this important work was to frame privacy as a boundary regulation process. This highlighted the fact that people did not simply want both privacy and awareness

all the time in competition with each other, but instead carefully regulated information flow on a moment by moment basis.

Perhaps the most comprehensive description of privacy to come out of this time period comes from Boyle and Greenberg (2005), who draw both upon a wide variety of fields such as anthropology, architecture, law and sociology, and also upon the technical reports of media space privacy issues. Using both theoretical and technical approaches grounded the principles in real details while at the same time providing a framework to relate issues and gain an overall understanding of privacy regulation.

1.4.1.5 Summary of Models and Diversifying Types

The work in this section has all been a continuation of work in earlier years: ENI is a direct continuation of the GMD event-based awareness research; the reaction–diffusion model is a continuation of other spatial models of awareness; privacy research dates right back to the days of early media space development; and the diversifying types of awareness research are in the tradition of workspace awareness. The main purpose of this section has been to show that these strong streams of awareness research did not suddenly end in the year 2000.

The next section discusses a trend that has a more recent beginning, where awareness research starts to move out of the workplace.

1.4.2 Awareness in Different Domains

In the two earlier time periods we have considered so far, 1986–1994 and 1995–1999, the focus has predominantly been on supporting awareness in an office environment. There has been an assumption that users are in the workplace and using a standard personal computer. In recent years, however, we have seen an increasing amount of research that applies awareness to other domains. These domains are numerous, including home living, healthcare in homes and in hospitals, education, gaming, industrial workplaces, art installations and many others. Fundamental to this research is the concept that new domains mean new awareness behaviour and new requirements for awareness support. Perhaps this is the reason for so much domain-driven research – it is insufficient to simply apply what is known about awareness in the office, so the particular properties of the domain need to be understood before support can be provided.

In this section we use the domestic domain as an illustrative example. While there are many other domains driving awareness research of different types, space does not permit a full discussion. Other domains that are receiving a great deal of awareness research attention include health, both home care (e.g. Pinelle and Gutwin 2002; Palen and Aaløkke 2006) and hospital based (e.g. Bardram et al. 2006; Munkvold et al. 2006), education (e.g. Ganoe et al. 2003) and games (e.g. Dyck et al. 2003; Brown and Bell 2004).

1.4.2.1 Domestic Awareness

While research on applying CSCW to the home environment dates from the late 1990 s (e.g. Hindus 1999; Hughes et al. 1998; Junestrand and Tollmar 1999), this early work focussed either on the home as a site for work or on directed communication mechanisms. It was not until after 2000 that awareness in the home was addressed explicitly.

As noted by Strong and Gaver (1996) (see also Section 1.3.4), awareness in personal relationships has a different character to workplace awareness. In personal and intimate relationships, such as those found in a home environment, the goal is for an emotional connection and feelings of intimacy (Gaver and Martin 2000). The information conveyed is usually of a general form about health, activity, environment, relationships and events, and must show trends and patterns (Mynatt et al. 2001).

The home environment also differs greatly in character from the workplace. The home is often thought of as a sanctuary, where everything is intensely personalised to provide a restful, soothing environment. Home-based awareness devices must be simple and aesthetically compatible with the personal environment (Hindus et al. 2001). Home activities are also different than the workplace, being less task focussed and comprised of more seemingly mundane activities such as coordinating schedules (Edwards and Grinter 2001). Furthermore, people often have strong emotional ties to objects within the home, and purely functional objects are often neglected, requiring an awareness device to have strong meaning attached to it (Tollmar and Persson 2002). Successful prototypes of home awareness devices incorporated the above principles – they were intimate, simple, aesthetically pleasing and emotionally meaningful.

Most early (early in this context means around 2000–2002) prototypes were severely limited in their utility due to technical constraints concerning networking or sensing. The constraints meant that any deployment was very small. Extensive field trials have only started appearing recently, such as the digital family portrait study (Rowan and Mynatt 2005), where the technology was the result of detailed participatory design some years before (Mynatt et al. 2001). The field study was successful in providing a feeling of "peace of mind" amongst distributed family members. Another recent field study, also testing the result of an extensive participatory design (Neustaedter and Brush 2006), was the study of the LINC home calendar system (Neustaedter et al. 2007). LINC was designed to support family activity awareness and the resulting coordination activities.

Recent years have also produced more detailed work on the overall properties of domestic awareness. Neustaedter et al. (2006a) investigated the different groups of people with whom people want to remain in contact and what kinds of information needed to be maintained about members of each group. They found that the relevant groupings of contacts were home inhabitants, intimate socials and extended socials. Elliot et al. (2005) and Crabtree et al. (2003) investigated the contextual properties of location for awareness in the home, showing that where and when devices are deployed is a vital factor for their usefulness and uptake.

1.4.2.2 Summary of Awareness in Different Domains

The example of the domestic domain demonstrates an important lesson. Each domain context is fundamentally different in its requirements. While the emphasis is still on people and so the mechanical aspects of how awareness works are the same (possibly indicating that the general models of awareness are still applicable), people have different expectations and behaviour in the workplace, in the home and at play. Any intervention of awareness-supporting technology needs to reflect that.

1.4.3 Technology Driven Awareness Research

Over the last few years a number of new interaction technologies have led to new opportunities for awareness research. First and foremost the emergence of instant messaging (IM) has led to the widespread distribution of tools that support the awareness of availability. While instant messaging became popular in the late 1990s, HCI research only recently discovered its potential for supporting collaboration and awareness between co-workers (Nardi et al. 2000; Herbsleb et al. 2002; Isaacs et al. 2002; Voida et al. 2002), as well as its use in non-work-related communities (Grinter and Palen 2002).

The majority of instant messaging clients are built around the notion of buddy lists. In the simplest case a user can see whether his "buddies" are available or not available for a chat. In addition to basic availability many instant messaging clients also support more extended status messages either by providing standard status messages (e.g. in ICQ "Available", "Away", "Do not disturb", etc.) or allowing custom messages through free-form text (e.g. iChat). Status messages have become a focus of research as they allow users to relay awareness information which extend the original focus on availability. Smale and Greenberg (Smale and Greenberg 2005) have investigated how the name field in an instant messaging client is used to broadcast personal information to other members of a group. They identified a rich set of communication practices used to communicate different aspects of a person's work or personal context to others. Other research has focussed on the enhancement of existing IM capabilities by adding dedicated awareness functionality (Tran et al. 2005).

Another major technology influence, this time hardware based, has been the proliferation of mobile devices. People are frequently in meetings, moving between locations or on travel away from their usual office (Bellotti and Bly 1996). Awareness is still important in these situations, and research into supplying awareness in a mobile situation was begun early in this latest time period (Tang et al. 2001). In this situation, information about location and "nearness" and the appropriate methods for contacting people become more important.

1.4.4 Group Configuration

The awareness research in earlier time periods that we have reported in this chapter has predominantly focussed on a particular group configuration. This configuration

involves individuals, each with their own single-user computer. While this is a common group setup, in recent years we have seen a variety of other configurations being investigated. These alternative configurations are common situations in work and other contexts.

1.4.4.1 Semi-Public

Semi-public displays are large displays that are placed in the common areas of a workplace, such as the kitchen area or in hallways. The displays are not fully public, as they are not available to the general populace, but they are not completely private either. The role of these displays is to enhance the awareness information that the group already has of each other (Huang and Mynatt 2003).

Semi-public displays have been used for many different purposes since the coining of the term in 2003 (Huang and Mynatt 2003). For example, specialised versions of Instant Messenger (Huang et al. 2004), posting and sharing multimedia information (Churchill et al. 2004) and presence displays (Terrell and McCrickard 2006).

1.4.4.2 Co-Located

Co-located collaboration research is concerned with situations where the group is all together and working on the same task at the same time. Interestingly, many of the early studies that guided distributed awareness research studied co-located participants to see the important factors that needed to be transferred to the distributed case (e.g. see Section 1.2.1, Gutwin 2002). Co-located collaboration research is based on the realisation that, while some awareness issues are simplified by all the collaborators being in the same place at the same time, there are some unique issues in supporting this domain.

From a low-level technical perspective, there is the issue of supporting multiple people interacting with a single display simultaneously. Solutions for this problem are known as single display groupware (SDG) (Tse and Greenberg 2004; Hutterer and Thomas 2007).

One frequent scenario for co-located collaboration involves the group members positioned around a horizontal tabletop display and all interacting simultaneously with equal participation. Such a display has to support the behaviour of people normally using a table surface, including collaboration cues such as orientation (Kruger et al. 2003) and territoriality (Scott et al. 2004). An extension to this domain is looking at the use of upright displays to augment the tabletop display (Wigdor et al. 2006).

There are different common co-located settings that can be imagined. For example, in an educational setting, there are distinct power structure roles of teacher and student. At this time there are even commercial movements into this domain (http://education.smarttech.com). There are also synchronous co-located situations in the hospital domain (e.g. Wilson et al. 2006).

1.4.4.3 Partially Distributed

Partially distributed groups are composed of a co-located core group, consisting of two or more people, and a number of distributed, "satellite" individuals. This configuration is not currently the focus of much work, and the studies that have been conducted seem to be from a single research group (Bos et al. 2006).

The main property of these groups is a bias towards collaborating with co-located collaborators. In competitive trading situations where the resources are with the co-located group, this is a disadvantage to the distributed members. However, if resources are with distributed members then the co-located members' bias can place the advantage with the distributed individuals (Bos et al. 2006).

1.4.4.4 Mixed Presence

Mixed presence groups consist of a mixture of co-located and distributed, with multiple distributed sites and multiple people at each site. This means that all group members have co-located and distributed collaborators.

While there has not been a great deal of work so far concerning mixed presence groups, one primary issue has been identified. Presence disparity (Tang et al. 2005; Tang et al. 2006) is the bias that group members have for interacting with co-located collaborators over the distributed collaborators. The group then effectively dissolves into a bunch of co-located subgroups. However, Tang et al. (2006) and Epps and Close (2007) suggest that the effects can be reduced, or even overcome, by increasing the presence cues for the remote participants.

Sometimes there are other boundaries reinforcing the divisions of location as well. When the connection is between normally self-contained teams at each site, the collaboration difficulties increase (Mark et al. 2003).

1.4.4.5 Summary of Group Configuration

Research of various group configurations can be seen as part of the general diversification of collaboration research. It seems to be of the same trend as the move into different domains. The community has come to a point where awareness knowledge can be applied to domains outside the office and to groups that are not just made up of distributed individuals. The broadening of application contexts is important for much the same reasons as the move to different domains – real collaborating groups are often in these situations. These groups need appropriate awareness support.

1.4.5 Summary of Extended Models and Specification

In this section we have seen two dominant research trends. The first is a continuation of open research from our last rough time period (1995–1999), with some even predating that and extending back to the first time period (1986–1994). This trend includes such things as modelling awareness and investigating the relationship of awareness to privacy. However, even this long-term research has not resulted in

awareness being a "solved problem". One of the most interesting open areas, in our opinion, is the gap between theory and design. There are very few examples of trying to use theory directly for design, and even fewer successful cases.

The second strong trend that we have highlighted is the opening up of awareness research to new contexts. This has been driven by new domains, new group configurations and popular technology use. These newer avenues of research have very few solutions and have asked many new questions, as applying awareness to a new domain is not simply a case of transferring results from the workplace.

1.5 Trends and Conclusions

Awareness is a topic that lies at the very core of CSCW research. Reflecting on more than 20 years of awareness research, we have identified a number of general research trends. These trends do not exist in isolation but are linked to the general development of the research in HCI and CSCW. We believe that our review of awareness has identified the driving research questions in the area and provided an overview of how the body of knowledge has grown and matured.

Unlike Schmidt's (2002) critique of awareness, our main objective was not a critical reflection of shortcomings of existing research but rather to provide an overview that takes into account the contextual research trends during different time periods. We have also attempted to show how different streams of awareness research relate to each other. The benefits that we see in such an approach are twofold. First, this chapter should enable researchers to get familiar with the development of awareness research over time and understand awareness approaches in context. Second, we believe that understanding research trends and thrusts are a valuable resource in determining and addressing new challenges. In each of the rough time periods that we have discussed, 1986–1994, 1995–1999 and 2000–2007, we have identified key characteristics and trends of the research into collaborative awareness.

The first time period (1986–1994) was characterised by the realisation that awareness is a vital factor in collaboration. Inspired by field studies, the original research goal was to understand and describe the concept of awareness and to answer the question of how awareness could be applied to distributed work. Both the realisation of importance and the resulting investigation arose in parallel through field studies, such as Heath and Luff's (1991) London underground study and Kraut et al.'s (1988) scientific collaboration study, and also through practical use of available technology, such as the media space work.

During the second time period (1995–1999), these initial concepts were extended through research undertaken in two major research thrusts. First, the conceptual understanding of awareness matured through theoretical work, such as the nimbus–focus model (Rodden 1996) and frameworks that enabled software designers to integrate awareness as part of their system design. Gutwin's workspace awareness framework (Gutwin 1997) stands out in this context as one of the most comprehensive frameworks on awareness for small teams. Other researches, such as

GroupDesk (Fuchs et al. 1995), AREA (Fuchs 1999) and NESSIE (Prinz 1999) put a stronger emphasis on system design and added important knowledge about implementing event-based awareness. Second, there was a move towards collaboration environments that incorporated awareness features. This was in line with a general trend in CSCW during that time, away from single functionality systems like shared editors, towards environments which were intended to be a single system for collaborating. A large number of these systems were based on the shared workspace metaphor. DIVA, with its very literal implementation of the shared office metaphor, is probably the earliest example (Sohlenkamp and Chwelos 1994). Many other systems that we have covered here are based on the collaborative environments approach including Orbit (Mansfield et al. 1997b), PoliAwAC (Fuchs 1997) and TeamRooms (Roseman and Greenberg 1996).

During the third time period (2000–2007), there was an emergence of a number of additional research trends. Research on awareness models continued to some extent, but became increasingly more specialised. For example, Simone and Bandini's (2002) work on the reaction–diffusion metaphor can be seen as a continuation of theoretical work in the tradition of models like the nimbus–focus model (Rodden 1996). Prinz and Gross's ENI model (Gross and Prinz 2003 Prinz and Gross 2004) addresses questions of integrating additional contextual information and deducting context from sensed information. The concept of intentionally enriched awareness (Rittenbruch et al. 2007) critiques the notion of a "passive actor" and extends event-based awareness mechanisms by integrating information deliberately provided by users. In addition to work on models, we can see the increased application of existing concepts to inform the design of awareness prototypes. The design of the Community Bar system (McEwan and Greenberg 2005) for instance is based on nimbus–focus model as well as the locales framework (Fitzpatrick 2003).

With regard to the design and application of awareness systems, two major trends have emerged. First, groupware designers are moving away from comprehensive virtual environments and are focussing on more targeted solutions. Interoperability between different services is becoming increasingly important. This development is driven by a number of technical trends. Different interfaces such as mobile devices and digital tabletops as well as research fields such as ubiquitous computing have caused a paradigm shift and have required a redefinition of the notions of awareness.

Second, we have observed a shift away from the workplace office as the main domain for awareness research. A number of awareness concepts and systems have recently targeted other domains, most notably health and domestic domains (see Section 1.4.2), and have expanded the notion of the types of groups that can be supported beyond distributed individuals in offices (see Section 1.4.4). This development is congruent with an increased understanding of CSCW as a research field that targets a wide range of domains which include the home, health, education and many other areas, work and non-work related.

Overall, our survey shows that there are a wealth of models, designs and field studies to draw from when considering new research avenues in awareness. Many of the current research trends we discussed during the most recent time period are

portals to new research challenges. The most prominent of these is in applying awareness to domain-specific applications. This area of study is still in its early days and there are many domains offering rich opportunities for research. Another area already discussed, mixed presence collaboration, also has considerable room for future research on awareness.

As this chapter has progressed, an evolution in the way researchers approach awareness has become apparent. In the older research, awareness was treated as an independent concern. This treatment was more apparent in the theoretical work, but even in the systems that had other functionality, there was a sense of "this is the awareness part", "this is the communication part" and so on. This was a natural and effective strategy when awareness was a new area of research. However, more recent work treats awareness as a concept tightly integrated with other concepts such as communication or sharing. The focus is on how to support people in context rather than about awareness specifically.

This approach to awareness has implications for future research. One of these is in the area of evaluation. Each of the systems that we have discussed in this chapter has been evaluated to varying levels of thoroughness. While the systems have been evaluated, there is little in the way of direct measures of awareness itself. One example approach is the ABC-Q measure used in the ASTRA system (Romero et al. 2007) used in the domestic domain.

Awareness in collaboration is far from a solved problem and there will be many open research challenges for a long time still. We are actively engaging in some of the open research discussed above in our own research program and we see other researchers starting to tackle these issues, as well as many others we have not mentioned. We look forward to seeing how research in the field of collaborative awareness develops.

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