

Designing for Technology-mediated Collaboration

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Designing for Technology-Mediated Collaboration

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ABSTRACT

This thesis concerns the design of a synchronous shared workspace supporting technology-mediated collaboration. In order to collaborate, participants need to be able to coordinate the activity. And to coordinate an activity, they need be aware of others involved in the collaboration. However, what do we need to be aware of concerning the others? And how do we visualize that? Further, how well does contemporary technology support what we need to visualize? And finally, how do we evaluate this type of system, and how do we communicate the results? Two systems were developed having different support for coordination of activities. The first system was used to gain insight into the impact of minimalist awareness information on a web page, while the second system, a web-based collaboration software was developed based on design guidelines emerging from the first system. Two observation studies and focus group sessions, as well as a literature study, supplemented the set of design guidelines into a first set of design requirements for the collaborative system. Inspired by a design science research approach, the system was developed in a cyclical fashion, alternating between development steps and various forms of evaluation.

The thesis contributes by supplying a set of design patterns made to support coordination in a shared workspace based on a theoretical construct I call “self-awareness”, where users are not only seeing the activity of others, but also their own activity as seen by the others.

Keywords: technology-mediated collaboration, coordination, awareness, CSCW, shared workspace, grounding, social norms, design patterns

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SAMMANFATTNING

Denna avhandling berör design av en synkron arbetsyta för teknikmedierat samarbete. När man samarbetar behöver deltagare kunna koordinera sitt arbete, och för att kunna koordinera sig så behöver man ha en medvetenhet om de andra deltagarna och deras aktivitet. I en situation som gäller samarbete runt ett bord så har vi många sådana verktyg; vi kan till exempel se de andra deltagarna och vi kan föra en diskussion sinsemellan. Vi kan skaffa oss en uppfattning om vad de gör för tillfället, var deras uppmärksamhet är och peka på saker för att leda de andras uppmärksamhet mot något, för att nämna blott några saker som är viktiga för koordination av samarbete. Men när vi inte sitter bredvid varandra, utan samarbetar på distans med hjälp av teknik, hur ersätter vi de mekanismer som då inte längre är tillgängliga? Vilka nya mekanismer bör vi designa, och hur skall dessa se ut? Hur väl stöder dagens teknologi de koordinationsmekanismer som vi behöver visualisera? Sekundärt behandlar avhandlingen även de problem som uppstår i utvärdering av sociala system och frågor som rör kommunikation av resultat. Två system har utvecklats med varierande stöd för koordination. Det första systemet användes för att få en förståelse för effekterna av en minimalistisk typ av visualisering av andra människors närvaro på en webbplats, medan det andra systemet var en synkron, delad arbetsyta vars design var baserad på lärdomar från den första studien tillsammans med nya observationsstudier, fokusgruppsessioner samt litteraturstudier. Systemet utvecklades med inspiration från Design Science Research (DSR), där systemet genomgick ett antal iterationer av utveckling och olika former av utvärdering.

Avhandlingens bidrag är ett antal designmönster avsedda att användas för koordinering av samarbete i en synkron, delad arbetsyta. Dessa är baserade på ett teoretiskt konstrukt jag kallar "self-awareness". Konstruktet innebär att det i ett samarbete inte bara är viktigt att se vad andra gör för stunden, utan också visualisera tillbaks en användarens egna handlingar och dess påverkan till användaren själv. Utan "self-awareness" vet du inte om att det är du som är elefanten i porslinsaffären.

ACKNOWLEDGEMENTS

There are so many individuals to acknowledge and give thanks to after such a long work period. I will surely overlook someone, and for that, I am very sorry.

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Mother, father, sister and brother - you all provided me with a safe and secure childhood, giving me a solid ground to stand on in order to dare to do something like this. I love you all. But dad... I am so very sorry you did not get to see me finish this. I miss you so much.

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1 INTRODUCTION

This thesis concerns the way people collaborate in real-time through the use of technology. The goal of the thesis is to provide design implications for a class of software referred to as “groupware”, built to support collaboration between people who are geographically and/or temporally dispersed. More specifically, I will focus my efforts on a type of groupware that often in research literature is labelled as a “real-time shared workspace”. My approach to attain such design implications is to design, develop and evaluate real-time collaborative systems in a cyclical fashion while at the same time reflect on the theoretical and practical ramifications of the designs as well as on the methodological approach and the communication of research results. This thesis will compile these reflections.

I began this research process with a general interest in a new phenomenon my colleagues and I had just encountered - visual representations of co-present users on a website. In that pre-Facebook/Twitter/Instagram era at the turn of the millennium, traces of people on the web were scarce. Nevertheless, there were a few applications out in the wild, usually in the form of plug-ins to the web browser, that provided functionality that had something to do with creating a sense of co-presence and visualizing the activities of others on the web (see Nilsson et al., 2000). This transformation of the web from being an enormous set of interlinked documents into being a place of social interaction has, in retrospect, had a profound effect on our society, and originated to a significant extent from the curiosity of enthusiasts, fueled by the development of new software frameworks and backed by increasingly powerful hardware and extending network capabilities.

While this transformation was happening on the web, research on people working and learning together using computers had already been around for almost two decades (Grudin, 1994), most notably in the fields of CSCW (Computer Supported Cooperative Work) and its sibling field of CSCL (Computer Supported Collaborative Learning) for about 10 years (Lipponen, Hakkarainen & Paavola, 2004). Until the years preceding the millennium shift, groupware systems coming from research within the CSCW and CSCL fields had been built as proprietary systems where the networks and communication protocols were developed specifically for the needs of collaboration activities (see for example Rodden, 1991; Roseman & Greenberg, 1993), and therefore had a somewhat limited audience (Bentley, Horstmann & Trevor, 1997).

When scholars began exploring the potential of the web as a base for groupware, the knowledge of mediated collaboration converged with the technological developments of the web (see early ground-breaking papers like Bentley et al., 1995; Dix, 1996; Palfreyman & Rodden, 1996), creating the research landscape we see today.

My work over the last 18 or so years has to a great extent been driven by an interest in the potential of new technological developments to support interaction and collaboration on the web. This interest has led my research efforts in different directions, from using sociological theories trying to understand the events in a chat system I developed, to explore the design of real-time visualization of the activities of co-present users on a web page. During this time, one of the main concerns has been the gap between our understanding of what technology should support in a mediated collaboration setting and what technology actually can support; coined the social-technical gap (Ackerman, 2000; Ackerman & Halverson, 2004). We can have a fairly good idea of the processes involved in a collaborative effort that we want to support in a mediated setting, but it is in the transformation of this knowledge into usable, technological artefacts enabling sound collaborative environments for people separated in time and/or space that we encounter challenges. A central notion is that while social life is nuanced and fluid, technology and the use of technology are oftentimes not (Ackerman, 2000).

According to Grudin & Poltrock (2013), technology support for collaboration can be roughly divided into three categories. In a mediated collaboration, we need technological support for *information sharing*, for example workspaces for sharing documents between participants. We also need technology support to be able to *communicate* with each other, such as chat systems and the telephone. Finally, participants in a collaborative effort need technology to be able to *coordinate* the activity, i.e. manage the collaboration. Applying this categorization to my research interest, I will in this thesis place an emphasis on the understanding of *coordination* and *communication* and the design of technologies supporting these activities within a *real-time shared workspace*.

The management of a collaboration has seen a considerable amount of attention in research fields such as CSCW and CSCL, and we see scholars discuss coordination as a crucial activity for successful collaboration (see for example Dourish & Bellotti, 1992; Cummings & Kiesler, 2005; Gross, 2013). But how do we design a real-time shared workspace that facilitates such coordination processes? We know that coordination processes depend on being *aware* of others involved in the activity (Dourish & Bellotti, 1992;

Gross, 2013), and that the design of technologies enabling us to perceive the actions of others are important. However, what type of awareness information is needed in order to coordinate collaboration in a real-time shared workspace? How do we visualize the actions of others?

These challenges that are cornerstones in this thesis, have stirred the interests of designers of collaborative systems for decades, and they still do (see for example Gross, 2013; Greenberg & Gutwin, 2016; Tenenberg, Roth & Socha, 2016). Technology, the people using it, and our understanding of the intricate processes involved in mediated collaboration are ever evolving. We have a constant flow of technological advances allowing designers and developers to address the social-technological gap in new and innovative ways. These technological advances also require us to revisit the mass of literature on collaborative systems (Schmidt, 2009; Bjørn et al., 2014) in order to see if and how a new technology might influence the design and development of groupware systems.

Since the very beginning, my work has explored the potential of new technology in making activities of people on the web visible for each other, and recently, a number of web technologies have been introduced to the public, technologies that together represent a fundamental change in what type of applications we can develop utilizing the common web browser. We now have highly efficient, bi-directional communication protocols to transfer data between the webserver and the web browser as well as a more capable markup standard, HTML5, that together with increasingly efficient JavaScript frameworks present an interesting opportunity to revisit the social-technological gap and learn more of the intricacies of real-time collaboration on the web.

As we design systems and evaluate their use, we learn more about their effectiveness and strengths, but also of their limits and shortcomings, adding our new results to the body of knowledge within the research community. This presents us with a secondary set of challenges in the development of collaborative systems – how do we rigorously and relevantly evaluate the effectiveness of awareness information in supporting coordination and collaboration, and how do we communicate our contributions from the research, placing our research results in the context of previous research as well as allowing other scholars to further evaluate their effectiveness?

1.1 Research aim and question

The aim of this thesis is to develop groupware applications that visualize the presence of others in order to explore coordination processes, and along the way critically reflect on development and evaluation processes and how to report the findings in a clear and cohesive way.

The main research question that guide my work is:

“How should we design real-time shared workspaces to support the coordination of work within small workgroups, and how feasible are the technological frameworks and network infrastructures in providing support for real time awareness?”

Secondary to this, I will also address methodological issues relating to the evaluation of collaborative software and the communication of research results.

1.2 Thesis design

To address the research question, this thesis reports from two studies. The first study was conducted between the years 2000 and 2008, with a licentiate thesis summarizing the research two years later in 2010 (Nilsson, 2010). The study had a socio-technical and abductive approach with the aim to derive design proposals based on the effect awareness information has on human behavior in a computer-mediated setting. The second study started in 2010 and concludes with this thesis. It builds on the results from the first study and has a design science inspired approach with iterative refinements and where the aim is to create guidelines for the design of a real-time, shared workspace.

The results of the studies are of a cumulative nature and are reported in five papers (see *Figure 1. Thesis design*). This cover paper is thus an opportunity for me to be able to present the whole research process in one, coherent publication. It also enables me to revisit and expand the results from the individual papers in the light of new theoretical, methodological, practical and technical developments not known or available to me when the individual papers were written.

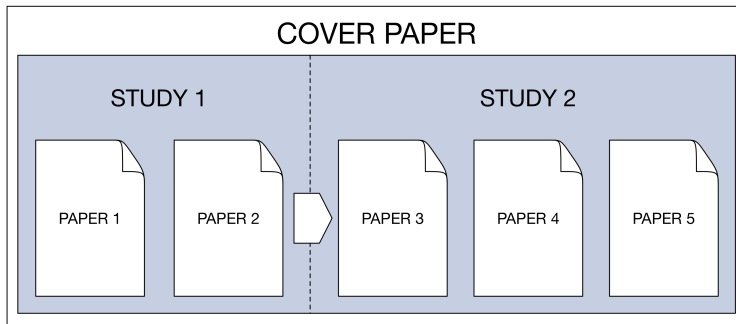


Figure 1. Thesis design

1.3 Paper overview

In order to aid the reader in understanding this cover paper, this section will give a brief overview of the papers and their individual contributions. A more thorough presentation of each paper is featured in chapter 6.

Paper 1: Awareness information and user behavior: A field experiment of an online collective system

This paper set out to investigate the effects synchronous non-verbal awareness information has on users of an online collaborative system. The setup was in an online photo exhibition and a system was developed giving users a minimalist indication of any co-present users. Logs collected from website usage were statistically analyzed and revealed that users who were in the online gallery and were exposed to the notion that there were other visitors there at the same time spent a statistically significant longer time in the gallery as opposed to visitors who were given the information that they were all alone in the gallery. We also saw a difference regarding navigational patterns in the gallery, but the difference was not statistically significant. This spurred us to further analyze the use of awareness information.

Nilsson, S. & Svensson, L. (2005). Awareness information and user behavior: A field experiment of an online collective system. WSEAS Transactions on Information Science and Applications. ISSN 1790-0832. Issue 12, Volume 2, December 2005

Paper 2: Supporting participation in online learning communities with awareness information

In this paper, further analysis of the data collected from the first study was presented. Here, we expanded the scope to also include the verbal communication in the system. The results generated new knowledge as to how people react to visualization of co-present users in a mediated setting, and the implications for design these results created.

The paper contributes to our understanding of awareness information and the fundamental effect it has on co-present users.

Nilsson, S. & Svensson, L. (2012). Supporting participation in online learning communities with awareness information. International Journal of Web Based Communities, Volume 8, No.4 (2012), pp. 537 - 549.

Paper 3: Design Patterns for Visualization of User Activities in a Synchronous Shared Workspace

This paper focused on how real-time collaborative activities can be visualized in a shared workspace. A real-time groupware system was developed to support collaboration and coordination practices in small workgroups, and a subset of five specific features, stemming from a set of design guidelines were presented as design patterns and evaluated by analyzing usage logs as well as by conducting end-user evaluation.

The paper contributes to the CSCW community by introducing design patterns as a way to communicate research results, as well as through analyzing end-user activities and the implications these have on our understanding of collaborative application development.

Nilsson, S. (2015). Design Patterns for Visualization of User Activities in a Synchronous Shared Workspace. International Journal of Advanced Corporate Learning (iJAC), Volume 8, Issue 3 (2015), pp. 42-46.

Paper 4: Visualization of activity in real-time shared workspaces – adapting to nomadic work practices

This paper represents the conclusion of the second study. It explored the use of the real-time collaborative system in real-life settings and its performance in various network conditions. We learn in what way common network issues such as high latency, jitter and packet drops impact the usability of time-

critical awareness mechanisms such as telepointers and this provided us with implications for the design of real-time collaborative systems.

Nilsson, S. & Jobe, W. (2019). Visualization of activity in real-time shared workspaces – adapting to nomadic work practices. Accepted to the Thirteenth International Conference on Design Principles and Practices – Design + Context, 1-3 March 2019, St. Petersburg, Russia.

Paper 5: On Informal Alignment Practices Developing Groupware Systems

The paper reports from the second study. During the development of a groupware system, I encountered issues that could be considered more problematic in web based real-time groupware development as opposed to traditional single user system development. These issues relate to the concept of the social-technical gap and evaluation of social systems. The development of real-time groupware is highly dependent on technological advances in the web development field enabling the design of new innovative artefacts that might circumvent the social-technical gap. At the same time, new knowledge of how people collaborate within a mediated environment is created in the academic community. We argue that this calls for alignment practices to complement more rigorous evaluation practices developing collaborative systems, lean practices focusing on quickly gaining insights about the current state of the field when it comes to technology and research. Another reason concerns the social aspect of groupware, where users as a group must use the system together. Hence, in order to rigorously evaluate a system, we need a functioning group knowledgeable of the system in order to get a usable evaluation result.

The paper contributes to practice as it lays forward reasoning for the specific conditions that apply in evaluating a groupware as well as a methodological approach addressing the issue.

Nilsson, S & Svensson, L. (2018). On Informal Alignment Practices Developing Groupware Systems. This paper has been presented as a working paper ACM Group2018 conference, Sanibel Island, Florida, USA. (Nilsson was the main contributor to the paper)

1.4 Other publications relevant to this thesis

Presented here is a collection of papers, brief papers, short papers and demonstrations authored or co-authored by me and directly or indirectly, through the included papers, referenced in this thesis.

Nilsson, S., Bengtsson, F., Johansson, C., & Svensson, L. (2000). Exploring Awareware. In *Proceedings of IRIS23*, Uddevalla, Sweden

Nilsson, S., (2003a). A Notion of Presence - Exploring the Effects of Minimalistic Awareness Information on a Chat System, In *Proceedings of E-Learn 2003*, Phoenix, USA, 7-10 November, 2003

Nilsson, S., (2003b). Supporting Learning Communities Using Awareness Information, In *Proceedings of international conference on Networked e-learning for European Universities*. Granada, Spain, 23-25 November 2003

Nilsson, S (2006). The Asocial Responselessness of Unfocused Interaction in Computer Mediated Communication. In *Proceedings of IADIS e-Society 2006*, Dublin, Ireland 2006. ISBN 972-8924-16-x

Nilsson, S & Svensson, L. (2007). Interaction and Self-presentation Online: An Analysis of Blogs, Virtual Communities and Places of Serendipitous Interaction. In *Proceedings of E-Learn 2007*, Quebec City, Canada 2007

Nilsson, S. (2010). *Exploring the relationship between awareness information and user activities online*. Licentiate thesis, Goteborg University. Papers in Informatics, Paper 13, April 2010, ISSN 1400-7428

Nilsson, S., Hattinger, M., Bernhardsson, L. & Svensson, L. (2011). Designing the CloudBoard-an ICT tool for online tutoring in higher education. In *Society for Information Technology & Teacher Education International Conference*, pp. 589-592. AACE.

Jobe, W. & Nilsson, S. (2011). Designing the CloudBoard: an innovative tool for collaborative e-learning environments using HTML5. In *24th ICDE World Conference 2011*. Universitas Terbuka.

Nilsson, S. & Svensson, L. (2014). Presenting the Kludd: A Shared Workspace for Collaboration. In *Proceedings of the 18th International Conference on Supporting Group Work*, pp. 295-298. ACM.

Svensson, L. and Nilsson, S. (2014). Re-thinking the LMS–Designing for Engaged Collaboration. In *Society for Information Technology & Teacher Education International Conference*, pp. 1702-1707. AACE.

1.5 Research contribution

The research presented in this cover paper contributes to the research community on three levels. On a *theoretical* level, analyzing users' experiences using collaborative applications as well as conducting technical tests of real-time collaborative systems will generate contributions to the CSCW community regarding how to support coordination practices and how to visualize the activities of others in real-world contexts. On a *practical* level, this cover paper will contribute with an application focused on facilitating a sound environment for mediated collaboration within small workgroups. On a *methodological* level, issues relating to the documentation and communication of a software design process are considered, as well as issues specific to the evaluation of real-time shared workspaces.

In the next section of the thesis I will provide a backdrop and context of my research and present the theoretical underpinnings and concepts from both studies. The sections following will then detail the overall research approach and rationale for the two studies separately and in a chronological fashion. The result section presents the five papers and their contributions. The discussion will then synthesize the individual results from the studies and conclude by addressing the research question.

2 THEORETICAL FRAMING

What I am concerned with in this thesis is fundamentally small groups of people collaborating without sharing a physical space. These types of mediated collaborations can be found both in work contexts as well as in educational contexts, and often occurs in a shared, digital workspace. The focus on small groups can be attributed to the limited screen area available in digital workspaces (Gutwin & Greenberg, 2002), and activities can for example involve the creation, manipulation and organization of digital artefacts (ibid.). A central concern that arise in such settings regards how a group of people know how to act in a coordinated matter, i.e. how do people synchronize their activities to play along with the activities of others, striving towards a common goal?

As the theoretical domain of collaboration is interdisciplinary, this means being subjected to a large number of theories, models, concepts and definitions regarding how people behave in general, and their performance in groups in particular. These must then be defined, understood and problematized before we begin to create software supporting collaboration in order to not just produce “cool tools” that are fundamentally unusable (Ackerman, 2000). Throughout my research process, I have used many different forms of theories, models and concepts from reference fields in order to understand human behavior. Early on in my research I used several theories originating from sociology and social psychology (see for example Nilsson et al., 2000; Nilsson, 2003a; Nilsson, 2003b; Nilsson, 2006; Nilsson & Svensson, 2007), including, for example, self-presentation and impression management (Goffman, 1959), symbolic interactionism (Blumer, 1969) and “asocial responslöshet” from the Swedish sociologist Johan Asplund (1987). While they have had a significant impact on my understanding of social behavior and have certainly had a substantial influence on the work presented in this thesis, I will in this section attempt to focus on theoretical constructs that are positioned closer to the intersection between technology, social behavior and collaboration.

In order to understand “people doing things together” in a mediated setting, I will begin by positioning “collaboration” within relevant research fields. Then I will delve deeper into the particulars of collaboration and the social sub-processes within a collaborative activity such as coordination. In the later parts of the section I will shift focus to look at theories regarding the visualization of activities in a technology-mediated collaboration.

2.1 Positioning mediated collaboration

Sprung from research in human-computer interaction (HCI) that focus on the way we interact with computers, research on the way we interact with each other *through* computers emerged in the 1970's and 1980's as the networked computer was developed. Today, it is in the outlet of the research field of Computer Supported Cooperative Work (CSCW) that much of the work on groups of people collaborating in a coordinated, computer-mediated activity is reported. CSCW is a community of researchers interested in an area where collaboration and technology confluences (Grudin & Poltrock, 2013). The field of CSCW can be described as the study of work practices, with the goal of designing systems that support the way we work together (Schmidt, 2009).

“CSCW addresses how different technologies facilitate, impair, or simply change collaborative activities” (Grudin & Poltrock, 2013)

CSCW research has always been influenced by technological trends and advancements. In the early 1980's, research centered around understanding the use of e-mail and related work practices (Grudin & Poltrock, 2013) as networked computers emerged in the workplace. Later research focused on the use of videoconferencing when computers, webcams and network performance became sufficiently performant (see for example Kies, Williges, & Rosson, 1997; Gemmell et al., 2000). As the mobile phone became a commodity in society, research on how these and other types of mobile devices could be utilized in mediated collaboration became a prominent part of the body of CSCW research (see for example Wiberg, 2001; Kakihara & Sørensen, 2002).

That said, I believe it is important to point out that while the CSCW acronym suggests that the area is concerned with people working together through the use of computers, the field has a broader appeal. It concerns contexts not necessarily work related, and evidently not always through computers (Grudin & Poltrock, 2013; Koch, Schwabe & Briggs, 2015). Today, research on the use of social media, collaborative writing in for example Wikipedia, blogging and online gaming all can have their outlets in the CSCW community.

A way to segment research concerning people acting together in a mediated setting regards group size. While Koch, Schwabe & Briggs (2015) mention that CSCW has a focus on smaller groups of people, up to approximately 10 people, Grudin & Poltrock (2013) argue that CSCW research can be used to address various sizes of groups. They mention group and team level, the

organizational level and the community level. Arguably, they are both right – Grudin & Poltrock (2013) maintain that the organizational level has not been making an impact within the CSCW community, and further, the larger community level is at the time of writing a newcomer in the CSCW field, with the advent of social media, social computing and the social web research finding the CSCW community as an important outlet (Koch, Schwabe & Briggs, 2015). It can thus be argued that CSCW at the time of writing mainly address smaller groups of people acting together in a mediated situation. This is certainly the case when studying the use of groupware systems such as shared workspaces where users are collaborating and are thus in various ways limited by the screen sizes of the devices used (Gutwin & Greenberg, 2002).

Groupware can be seen as the practical outcome of research efforts within the CSCW field. The systems, their functions and features and effectiveness in mediating collaborative work are central. The term “groupware” itself was coined in 1978 (see Grudin, 1994), and has had a number of definitions throughout the years, changing as our understanding of mediated collaboration grew through research on the subject. One early definition is “*computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment*” (Ellis, Gibbs & Rein, 1991, p.40). As with the use of the term in the CSCW acronym, the term “computer” in this definition can be seen as outdated and I would argue that a much wider and at the same time more suitable term would be “technology”, as the computer is but one of many different connected devices that can be used as a platform for groupware applications.

In order to further disseminate the field of CSCW, and primarily the concepts of cooperation and collaboration, I would like to relate it to its sibling field of research - computer supported collaborative learning (CSCL). Although CSCL concerns learning contexts, according to Stahl (2013) they both concern cognitive functions mediated by computers prevalent in teamwork such as learning and generating knowledge in groups as well as problem solving and solving tasks (ibid.). Because of their similarities, cross-pollination between the fields has naturally been extensive between the research traditions (for examples, see Bjørn, 2003; Hernandez-Leo et al., 2006; Stahl, 2013) and efforts to bridge the fields on a conceptual level have been undertaken (Stahl, 2013). While I acknowledge the distinctive features of CSCW and CSCL, such as the intended outcome of the joint efforts (i.e. learning or producing artefacts), I argue that the two fields share many characteristics, especially when it concerns the level of coordination, i.e. the *management of activities* in mediated settings.

In the next section, I will deconstruct the term “collaboration” in light of the two fields of CSCW and CSCL.

2.2 Deconstructing collaboration

While often used synonymously and oftentimes left unproblematized, there are some discussions as to the difference between “collaboration”, used in the CSCL acronym, and “cooperation” used in the CSCW acronym. According to Roschelle & Teasley (1995, p.70), collaboration is “... *a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem*”. While this is but one of several definitions of collaboration found in the field, it incorporates some interesting concepts worthy of further exploration and it is a good starting point of a breakdown of the terms. A key distinction regards synchronicity; while cooperation can consist of asynchronous activities, collaboration is synchronous (Dillenbourg, 1999). Another dimension argued to separate the terms cooperation and collaboration theoretically is in the hierarchical dimension; while cooperation suggests a hierarchy among participants, collaboration is an activity among peers having relative symmetry regarding allowed actions, knowledge and status (ibid.). Symmetry is also a principal ingredient in CSCW research, where symmetry regarding information access, presentation of users and visualization practices are discussed (see for example Dadlani et al., 2011). Dadlani et al. (2011) further argue that asymmetries in mediated communication are difficult to avoid as users’ needs differ regarding opportunities to participate and requirements on how to interact socially in the system (ibid.). Stahl (2016) further dissects the terms, separating them by stating that cooperation rather concerns people working together by division of labor, while collaboration suggests a group that is working together through every step of the work process.

Dillenbourg (1999) adds interactivity as a natural part of collaboration, and that interaction supports negotiation. Negotiation is seen as vital in the creation and maintenance of, for example, a common goal among participants; another key feature of collaboration. Building on the sociocultural tradition, most CSCL research points toward the notion that sound social interaction is vital to collaborative learning (Järvelä et al., 2015). Further, successful collaboration in a mediated setting requires participants to be able to communicate and negotiate with each other (Clark & Brennan, 1991).

Another way of regarding the relationship between cooperation and collaboration is presented by Fuks et al. (2008), where in their “3C” model

collaboration is considered the overarching activity, consisting of cooperation (i.e. the act of producing something), coordination (the management of an activity) and communication.

My interest for this thesis is in activities occurring within a real-time shared workspace, and I will use the term “collaboration” as an umbrella term for people “doing things together” towards a common goal. I recognize cooperation and collaboration closely related in various ways as they are both activities where a set of underlying social processes supporting the “actual work” are important, and where technology to support those processes are needed in a mediated setting.

“...even though words like "cooperation," "collaboration," and "competition" each have their own connotations, an important part of each of them involves managing dependencies between activities.” (Malone & Crowston, 1994, p.90)

Regardless of how we define collaboration and cooperation, one of the key concerns in a joint effort towards a common goal is supporting the management of the activity, i.e. the *coordination* process (see for example Malone & Crowston, 1990; Clark & Brennan, 1991; Cummings & Kiesler, 2005; Fuks et al., 2008; Weinberger, 2011; Janssen & Bodemer, 2013; Gross, 2013).

The next section will discuss coordination further.

2.3 Coordination and common ground

When people collaborate, the activity of coordination between participants is a critical ingredient (see for example Dourish & Bellotti, 1992; Schmidt & Simone, 1996). Coordination can be seen as a meta process that is not directly concerned with the task at hand, but a process that instead deal with the management of the task. Schmidt & Bannon (2013) hold coordination as a central issue in CSCW research, noting that previous studies have suggested that a key factor in the performance of people working together is their ongoing activity of observing the activity of other team members. The study of coordination has a long history in the CSCW field, with notable contributions by for example Heath & Luff (1992) observing work practices in the London underground and Suchman (1997) studying activities in a metropolitan airport. Coordination processes are often conducted as ethnographical studies in workplace settings, where face-to-face situations

are central to informing us of aspects relating to coordination practices (Luff, Hindmarsh & Heath, 2000).

Coordination is an intricate activity, as when it is done well, we do not notice it. It is when coordination fails it becomes obvious (Malone & Crowston, 1990). As a meta process within a collaboration activity, coordination can be seen as a cost. Bjørn (2003) discusses coordination activities in a learning context as an overhead, something that competes with the actual learning activity over time and attention.

“When the effort needed to coordinate decreases, time for learning increases...” (Bjørn, 2003, p.3)

The same idea is presented by Romero, Huttenlocher & Kleinberg (2015) but relates to a work scenario. The basic assumption is that time and effort are limited resources, and the less time and effort we need to spend on coordinating the work being carried out, the more we can focus on actually being productive in a collaborative environment. And while the effort to coordinate work in a non-mediated setting (i.e. face-to-face) can be high, the cost of coordination increases in a mediated setting (Convertino et al., 2011).

Coordination can be divided into “coordination of content” and “coordination of process” (Clark & Brennan, 1991), in a sense *what to do*, and *how to do it*. Coordination of content is argued to require a common ground in a group, that is, a shared understanding of what it is that needs to be done. Coordination of process is the ability to, in real-time, maintain and update that understanding (ibid.). The process of establishing and maintaining a common ground, often referred to as “grounding”, is not only applicable in verbal communication, but according to Clark & Brennan (1991) also to all collective actions. Members of groups collaborating face-to-face can use different social activities, such as pointing at shared documents, nodding affirmative, observe the activities of other members, as well as asking questions and utter statements in order to make sure that the members of a group have an up-to-date common ground.

But the nature of grounding activities changes according to the purpose of the collaborative engagement and the technology used. Further, some of the aforementioned activities such as pointing or nodding are not useful or even applicable when grounding occurs in a mediated setting. Clark & Brennan (1991) list eight constraints affecting the use of communicative techniques in a technology-mediated situation: Copresence, Visibility, Audibility, Cotemporality, Simultaneity, Sequentiality, Reviewability and Revisability.

Copresence and visibility regard being in each other's proximity, and to which extent the participants can see each other's actions. Audibility is the availability of audible communication. Cotemporality, Simultaneity, and Sequentiality are about timing, whether or not a participant can receive communication at the same time as it is sent (Cotemporality), receive and transmit communication at the same time (Simultaneity) and that the communication should not take place out of sequence (Sequentiality). Finally, Reviewability regards the persistence of an utterance in a communication and Revisability is about the ability of a participant to change the communication before it is transmitted to another. Depending on the technology used, only a subset of these constraints is available to groups of collaborators (Clark & Brennan, 1991) and require more or less effort for participants to use. In the same sentiment as with coordination, the grounding activity abides to the "least collaborative effort" principle, and the participants maintaining a common ground wants to put in as little effort as possible to succeed.

To summarize, in order to create a sound collaborative environment, we need technological support for the grounding activity in order to create a common ground, that in turn supports coordination of content and process. Grounding, by both verbal and non-verbal means, requires awareness of the presence and activities of other group members and is framed by a number of constraints guiding how group members can perform in the grounding activity. In a technology-mediated context, we thus need to create such awareness and explore ways to support the grounding activity given the constraints available for that technology.

Mutual awareness of other group members engagement in an activity and the collection, distribution and visualization of data carrying such information has long been a field of interest for researchers of technology-mediated collaboration (see early ground-breaking articles such as Dourish & Bly, 1992 and Ackerman & Starr, 1995). The following section will expand on that research.

2.4 Awareness

Awareness principally concerns mediating a sense of the presence and activities of others in groupware. Wisneski et al. (1998) adds that awareness also regards knowledge of your current environment. The significance of being aware of others in collaborative computing environments has been the attention of scholars for a few decades now (see for example Dourish & Bly, 1992; Dourish, 1997; Erickson & Kellogg, 2000; Ackerman & Starr, 1995;

Gutwin & Greenberg, 1998; Dieberger & Höök, 1999; Farooq, Carroll & Ganoe, 2007). Gaver (1991), aligning with the previous sentiments on coordination and common ground, holds that general awareness is a necessary foundation for collaboration.

Early research on awareness in technology-mediated collaboration contexts support the notion that people will take advantage of visualizations of other people's activities when determining their own actions. Gutwin & Greenberg (1998) presents results suggesting that users of a groupware system with awareness support were both more effective as well as more satisfied than users using a system without awareness support. These early studies also indicate that too much awareness information can result in a form of awareness overload (Gutwin & Greenberg, 1998) as well as information overload (Hiltz & Turoff, 1985), impairing the coordination of an activity.

A theme within the awareness research community is whether designers of groupware should mimic face-to-face situations or strive to explore new and innovative ways to design mediated interaction. Ackerman (2000) argues that to address the social-technical gap, first-order approximations should be created. This idea was introduced to the CSCW community by Hollan & Stornetta (1992) and further discussed by for example Convertino et al. (2011), arguing that imitating face-to-face interaction would only give us something that always will be a second-rate version of the face-to-face interaction. The same sentiment is held by Erickson & Kellogg (2000) arguing that a "realist" approach to the design of groupware contains a number of practical limitations. For example, trouble understanding the direction of gaze depending on the camera setup in a video conferencing situation might generate a mismatch in social cues and be an impediment for the coordination of an activity. One might say that such design directions would to an extent appear like one type of situation, but act in accordance to the communication constraints of another situation.

A good example of first-order approximations is the telephone. With the telephone, aspects of a face-to-face conversation are removed; we no longer see each other's gestures and facial expressions but add the ability to communicate over large distances in real-time. Another example is e-mail, taking advantage of the speed, asynchronicity and connectedness of the Internet enabling persistent forms of communication. We thus not only regard mediation as riddled with issues making interaction insufficient compared to face-to-face situations, being plagued by the lack of certain communicative constraints, but instead investigate the properties of technology to see how

they can be used to develop new, and perhaps to an extent, better ways to communicate (Convertino et al., 2011).

When Gross (2013) in a literature review summarized awareness research, he acknowledges that there is a need to continue to explore awareness and pinpoint the importance of reducing the cognitive load when engaging in the activity of coordinating mediated collaboration. With results similar to that of for example Bjørn (2003) and Convertino et al. (2011) in seeing coordination as a cost, Gross (2013) notes that the effort of interpreting and acting upon awareness information in a mediated context is often high, and conclude with a call to researchers to further explore the nature of awareness and its impact on collaboration, as well as ways to visualize awareness information with the goal of supporting what he calls effortless coordination.

Awareness research is persistently attracting the attention of researchers. An interesting strand of research has recently been the debate around the definition of “we-awareness” (Tenenberg, Roth & Socha, 2016). Whereas awareness research has focused on mediating *activity* and *communication* between collaborators in order to support coordination processes, we-awareness emphasize the importance of mediating the *intentions* of the users (ibid.), and a shared intentionality is seen as essential to support successful collaboration. Not only do I need to know what others are doing, but also why. Greenberg & Gutwin (2016) argue that this is nothing new within awareness research and the CSCW community in general. They illustrate this by raising the sentiment that the notion of common ground has had a noticeable position in CSCW history, and the “coordination of content” (Clark & Brennan, 1991) sentiment is just that, a shared knowledge of the intention of a group. Nevertheless, I find the connotation of “we” intriguing, not only considering awareness as “*me seeing the activities of others*”, but also “*me seeing the activities of us, as a group*”.

2.5 Social translucence and social norms

Building upon awareness research, the socio-technical construct of “social translucence” (Erickson & Kellogg, 2000) bring together the need to make users aware of each other with a dimension of “accountability”. Accountability regards the idea that if you know about the activities of others, they in return would know about your activities. As activities becomes shared knowledge in a group, I can be held accountable for my actions and I can hold others accountable for their activities in return. Erickson & Kellogg (2000) argues that it is not until a sense of accountability is in place that *social norms* becomes effective mechanisms in a collaborative situation.

The idea of the significance of accountability in a mediated collaboration is further supported by for example Cahill (2014) and Wang et al. (2014) who both stress that if a system lacks the functionality to mediate a sense of accountability, there is an increased risk of for example communication breakdowns. Erickson & Kellogg (2000) exemplifies this by the activity log of a system to support conversations in small and medium sized workgroups. By making a shared historic view of past conversations visible and easily accessible, new users got a chance to conform to the customs created by previous users of the system.

“...social translucence is not just about people acting in accordance with social rules. In socially translucent systems we believe it will be easier for users to carry on coherent discussions; to observe and imitate others’ actions; to engage in peer pressure; to create, notice, and conform to social conventions. We see social translucence as a fundamental requirement for supporting all types of communication and collaboration.” (Erickson & Kellogg, 2000, p.62)

McDonald, Gokhman & Zachry (2012) further problematize the concept of social translucence, claiming both that the construct needs to be implemented at the core of the development of a system in order to be functional, and as well as with awareness information, visualizing more activities are not automatically positive (ibid.). This can in a sense be exemplified by a study of Niemantsverdriet et al. (2016) who implemented social translucence in a home automation interface, noting that in order to achieve accountability in a system, users must have an opportunity to sufficiently act upon the knowledge of others and their activity. If a system does not enable users to act in accordance to social norms, social translucence will not be in effect.

Social translucence thus relies on accountability as a property to allow for the emergence of social norms with a group, and those members must also know by what norms they are being held accountable against. Discussion on social norms, rules and conventions has a long tradition in sociology and has been adopted by scholars concerned with mediated collaboration. The study of social norms is a link between scholars of social psychology and mediated collaboration, where both subjects display interests in investigating social sides of people interacting through computers (see for example Guadagno et al., 2013). Social situations are guided by social norms and conventions guiding our behavior, and these norms sets the rules of a situation.

“Social norms are rules and standards that are understood by members of a group, and that guide and/or constrain social behaviour without the force of law.” (Cialdini & Trost, 1998, p.152)

Social norms are something we learn over time, by reading, observing, acting and in other ways experiencing various social situations (Cialdini & Trost, 1998). Further, norms are not static, but organic properties that change over time and tend to not only emerge in interaction, but are also continuously renegotiated, re-established and reaffirmed, much in the same way as “common ground” and the coordination of process. Parallels can be drawn to social theories such as “symbolic interactionism” (Blumer, 1969) in that social norms have both collective properties, and at the same time something that are personal and bound to interpretation. Another use of norms is in the interpretation of the activities in a social situation (Lamerichs & te Molder, 2003), aiding us in our understanding of different social situations.

Meyrowitz (1985) states that when encountering new, unknown social situations, we are inclined to choose a best fitting behavior from a collection of social norms we have gained from past experiences. In other words, we have a bag of norms with us, ever growing throughout life, and when encountering a new situation, we pick a behavior from the bag that we see as a good match for that particular situation. Postmes, Spears & Lea (2000) suggest that norms emerge within the boundaries of the interaction situation itself and is seldom transferred outside of the social system. As Palen (1999) puts it in her work with shared calendars in organizations,

“Over time, pockets of users in the same social network develop their own norms. Some employees do not appear to realize that their groups handle calendars differently than the company-wide norm of open calendars, suggesting that some groups have long-entrenched local norms around calendar use.” (Palen, 1999, p.21)

This can be seen as proposing a challenge for designers of social systems. Users that meet a social system for the first time, such as a real-time shared workspace, probably have different past experiences and therefore bring a heterogenous set of norms and conventions into their encounters with the new system, potentially making the interaction between users inept (Nilsson, 2010). This also suggests that as we are probably not users of one single social system, we operate in an ecosystem of different norm contexts within different systems. Therefore, I argue that it is of importance to understand the context of use when designing collaborative systems and designing systems in a way that lets the users adopt a usage that suits their needs. A designer

should both aim to support the process of the creation and re-negotiation of norms (Ackerman, 2000), as well as take into account norms of surrounding systems and environments.

2.6 Summary and concluding remarks

The picture painted in this chapter is of a complex interrelationship between concepts, theories and models such as collaboration, cooperation, coordination, grounding, social norms, awareness and social translucence, all having an impact on the research presented in this thesis. There are several ways to define their relationship, for example various variants of the “3C” model (Fuks et al., 2008) or the categorization of communication, coordination and shared workspace of Grudin & Poltrock (2013). In order to make sense of the relationship as used in this thesis, the following discussion concerns the way *I see* how they relate, infused with the idea of hardware and software constantly in change.

As previously discussed, *managing an activity* can be seen as competing over users’ time and effort with the *production* of something within a collaboration. See *Figure 2. Model of collaboration*.

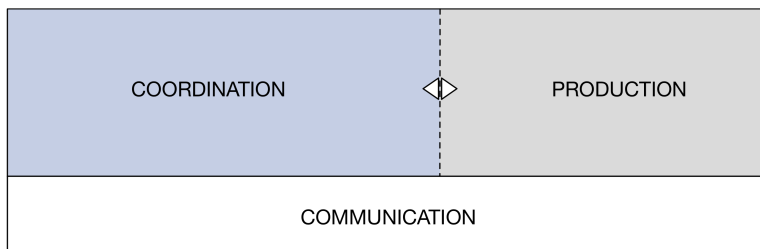


Figure 2. Model of collaboration

Typically, though not always, a group would want as much time and effort spent on the *production* towards a shared goal. *Communication* is here depicted as a separate activity in accordance with the 3C model of Fuks et al. (2008), but I argue that communication also can be viewed as an integral part of coordination. Communication can be both verbal as well as non-verbal, i.e. speech and gestures. It can also have historic properties, as well as occurring in real-time. Thus, the term communication as used here is in many ways analogous to my view of the purpose of *awareness* in mediated collaboration, in the sense that it provides means for participants of a collaboration to coordinate their activities. In a face-to-face collaboration, speech and gestures are used to coordinate an activity, just as in a mediated collaboration

situation. It is just that the way we communicate verbally and non-verbally differs between face-to-face situations and a mediated setting, and act in accordance to different communicative constraints. Although awareness research has had an emphasis on non-verbal cues to mediate a sense of the activities of others, I argue it is of value to, at the same time, consider verbal communication and the monitoring of such in a group as part of the notion of awareness.

In order to reduce the time and effort needed to coordinate activities, processes of creating *common ground* and shared *social norms* must be supported. We also need support for the continuous, real-time reshaping of the common ground and social norms within the activity. These processes can thus be facilitated by implementing awareness information in a shared workspace. Seen this way, awareness information should both directly support the coordination activity such as providing social cues of the presence and activities of others, as well as indirectly by supporting grounding and social norm processes. Finally, the way we can design awareness functionality is dictated by the properties and constraints of software and hardware. See *Figure 3. Overview of the theoretical components of collaboration.*

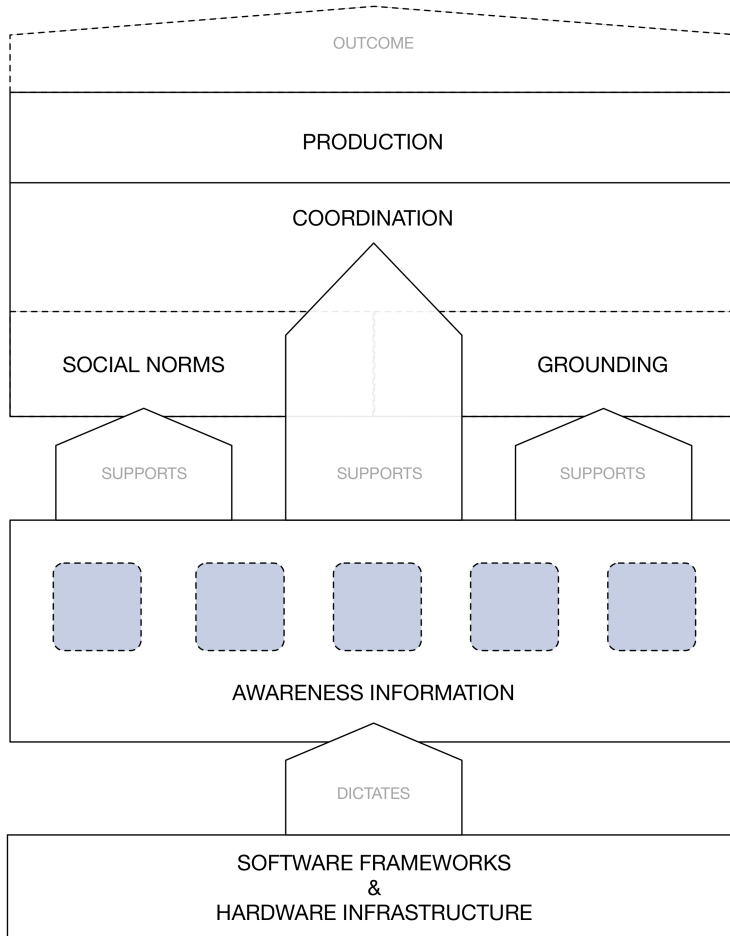


Figure 3. Overview of the theoretical components of collaboration

Being interrelated as discussed here implies that changes on the level of software and hardware gives us a chance to re-examine awareness. Changes of awareness functionality can in turn affect coordination indirectly *through* the support of grounding and social norm processes, as well as coordination directly. This gives us an opportunity to address the social-technological gap and reinvestigate ways to create first-order approximations of social situations.

3 RESEARCH PROCESS

This cover paper summarizes and extends the results from two studies, separated in time by some ten years. This gap in time poses a challenge in presenting the research design in a coherent way. Part of the problem is that research conducted over a long span of time often is not coherent, drifting between research approaches and even moving between different research paradigms. However, I place my research firmly within the socio-technical tradition of research, acknowledging the interplay between the technological artefacts, the users and the social context of use (Mumford, 2006). Users affect the use of technology and technology affects use, within a context.

Within the socio-technical tradition, research can be separated into two not mutually exclusive sub-fields; those who build systems and those who study the use (Bernstein et al., 2011). They hold that there is a strong majority of researchers studying users of social systems as opposed to those who build them. They suggest that there is a great gain to be had to both innovate, design and build social systems as well as studying the use of such systems (ibid.), and the same idea is shared by Erickson & Kellogg (2000) that adds the importance of study the use of the systems we are building in real work contexts. Nunamaker & Briggs (2011) raise much the same sentiment:

“While we continue to track the emergence and use of new technologies, we must expand our vision to inventing new systems that address information needs not covered by current systems. We must not only be observers and historians of technology, we must make technological contributions.”
(Nunamaker & Briggs, 2011, p.2)

Although it is a time-consuming endeavor to both develop and evaluate the use of software as a research approach, I strongly agree with these views. Building systems based on previous research, we get an opportunity to address the social-technological gap as introduced by Ackerman (2000) and Ackerman & Halverson (2004). We get a chance to “play catch-up”, exploring the potential of new technology in order to explore the way we collaborate, mediated by technology. And we get a chance to see and evaluate how they work in real environments. This sentiment bridges my two studies.

The studies in this thesis were conducted in two different eras in the history of the internet where we saw a shift in both the technology used and the way people used the web. The first study was conducted between the years 2000

and 2008 and thus began at a stage in the history of the Internet when we saw a shift of the web from being a static collection of hyperlinked texts and images into being a place of social activity. This transformation, enabled by advances in web technologies, was tantalizing and spurred my curiosity, motivating further investigation. The study was design oriented (Simon, 1996), theory driven and had a strong emphasis on awareness information and the impact of the awareness of others on co-present users in a system characterized as an open, web-based awareness application. The aim was to understand certain aspects of computer-mediated interaction and derive a set of guidelines as how to design software facilitating mediated interaction.

The second study was initiated at a time where the web was transformed by new technological advances enabling real-time systems to be built and used in the web browser. This was late in the year 2010 and the process of building a system supporting collaboration was initiated. The second study was influenced by traditional Scandinavian design traditions involving end-users in the design of the system and was further inspired by the cyclical nature of a design science research (DSR) approach (see for example Hevner, March & Park, 2004; Kuechler & Vaishnavi, 2008; Winter, 2008).

The two studies exist on different levels of understanding; the first study explores basic, fundamental properties of awareness of others and their effect on online behavior, while the second studies the use of a collaborative application made for small groups of people. Both studies consisted of several phases utilizing different methods regarding data collection and analysis, with the general direction going from exploratory through descriptive and explanatory stages of research. The studies involve the creation of IT artefacts, the implementation of them and study their usage to understand their implications and derive new design concepts.

The use of an exploratory approach is motivated in the first study by the emergence of a new phenomenon to be studied, driven by technological advances. In the second study, it was the potential of technological advances to narrow the social-technological gap that was the object of exploration. Exploratory research is an inductive research methodology and is usually used in cases where the problem observed is new (Stebbins, 2001), and the purpose is to generate an initial knowledge into a problem area and provide a fundament for further research. While the exploratory research approach is often seen as a first stage of a research project, or even as a rehearsal of a more rigorous methodological approach, Stebbins (2001) brings forward exploration as an important method to use when conducting studies in the

social sciences, and to report from them accordingly. For a summary of the work presented here, see *Table 1. Overview of the two studies.*

Table 1. Overview of the two studies

	STUDY 1	STUDY 2
CONTEXT	Interaction in open, web based systems	Collaboration within small groups, web based
INTEREST	Understanding fundamental issues relating to awareness	Understanding and designing for collaboration
COLLECTED DATA	6 months worth of usage data in the logs, with 1,408 log-ins in the chat system and a total of 1,846 messages	Notes and recordings from 2 observation studies. Notes from 2 focus groups. Logs from 1 end-user evaluation, 2 end-user self-evaluations, as well as over 50 logs with metrics from network performance tests
METHODS	Literature review, log data analysis	Literature review, observation, focus group, log data analysis, end-user evaluation, technical feasibility evaluation, experiment
ANALYSIS	Qualitative and quantitative	Qualitative and quantitative
CONTRIBUTIONS	Design guidelines & an artefact	Design patterns as well as methodological and theoretical considerations, artefact

In the following sections I will provide an overview of the methodological approach of the two studies individually. For a more detailed description, please refer to the individual papers.

4 EXPLORING AWARENESS

I began my research with a general interest in a new phenomenon I had just encountered; the visualization of co-present users on a website. This study had a clear design focus, where building a system based on theoretical foundations and later implemented and evaluated in a real setting was the method used in order to provide implications for further design. The study stretches over a period of eight years, from the year 2000 throughout 2008, even though the majority of the data was collected during a period in 2001. During the study, 12 papers and short papers were written, peer reviewed and published at various conferences and journals. This study has also been reported on in my Licentiate thesis, published in 2010 (Nilsson, 2010). For this thesis, two papers are selected as representatives of the study. Paper 1 contributes with an insight into the first exploration of awareness information, providing a detailed description of the initial stages of the research and a first set of results. Paper 2 contains a retrospect of the study as a whole, where several of the results of the individual papers from the study as well as the Licentiate thesis are merged. Due to page restrictions though, not all of the material from the study was used in paper 2, nor does it contain a complete and thorough description of the research process. Thus, this section of the cover paper provides me with an opportunity to fill in the blanks and elaborate on the research conducted. Some of the text material of this subsection originates from the previous papers and has been rewritten to fit the format of this thesis.

The study began with a review of existing tools for visualization of co-present users on a website as well as a literature survey on relevant concepts such as “social presence”, “social navigation” and “awareness”. Having gained sufficient knowledge of the problem area, a development process began by designing an awareness application that was made to work as a companion application visualizing co-present users on a web page. The resulting application was then implemented, and data was collected and analyzed from the usage of the system. The papers that emerged from the study used the data as a basis for understanding the properties and effect of awareness information (see *Figure 4. Overview of the first study*). The study then served as a springboard for further application development in the second study.

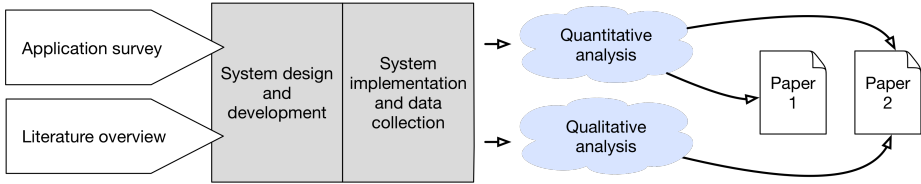


Figure 4. Overview of the first study

4.1 Exploring a new phenomenon

In the years preceding the boom of social media, circa 1999/2000, traces of people on the web were scarce. Nevertheless, there were a few applications out on the web that did provide a social dimension to the web. The applications, ICQSurf, Odigo, Third Voice and Gooye (all now defunct), showed an interesting set of functionalities that all had to do with visualizing user activity on the web. Using the available theory on awareness at the time, we analyzed the individual applications and their functionality in search of different modes of awareness that could help us understand awareness and its implications for design. The purpose was to inform a design process at a later stage. When analyzing the applications in action, we looked at whether the awareness information was explicit or implicit, i.e. if the users were actively doing something to show their presence or if the system rather collected traces of activity itself. Another mode we investigated was if the information was in real-time or if it represented historical data from anytime in the past. The conceptual framework (see *Table 2. Awareness framework*) is presented in paper 1, though some of the wordings has changed since writing.

Table 2. Awareness framework

	SYNCHRONOUS	ASYNCHRONOUS
VERBAL	CHAT	ANNOTATIONS
VISUAL	CO-PRESENCE	FOOTPRINTS

In an effort to try to make sense of the implications and possibilities of visualizing people and their activities on the web, a plan to further explore the effect awareness of others was constructed. I was predominantly

interested in how even the simplest form of awareness visualization affected co-present users. Driven by the literature from awareness research as well as a fair amount of theoretical influences on human behavior and interaction from sociology (for example, I was strongly influenced by the work of Swedish sociologist Johan Asplund (1987) and the works of Ervin Goffman), I set out to design an awareness system providing what I called a *minimalist* representation of co-presence and presented in an *abstract* form (Erickson & Kellogg, 2000).

4.2 Designing an open, minimalist awareness system

One of the key concerns choosing a setting for exploring minimalist, abstract awareness visualization was access to a large user base that could generate a substantial amount of data to be analyzed. A team of researchers and students collaborated with a well-known artist in creating a web version of a real-life art exhibition that had received quite some attention in the media shortly before the millennium shift. The exhibition featured photographs depicting biblical events through a homosexual perspective, therefore also making it quite controversial among certain groups of people.

The web exhibition contained 12 pages that had, for the time, an unusual navigation structure signaling to the user that this was not a conventional website. It was arranged like a tour, where by entering the gallery you would start at page one and eventually end up at page 12, with the option of moving forward or backwards between pages. Each page in the gallery (see *Figure 5. The photo gallery*) consisted of the picture (1, blurred here due to copyright issues), the navigation (2), a short biblical verse (3) and links to comments by the artists (4), and finally the awareness system (5). The awareness feature was placed at the bottom of the screen in the form of a chat system.

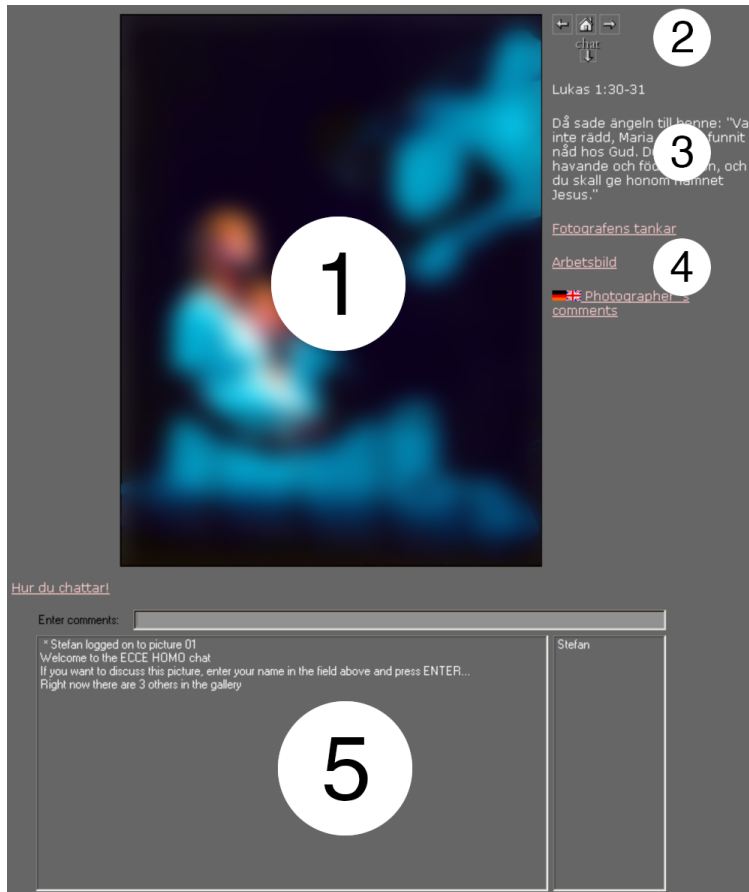


Figure 5. The photo gallery

The system, named “WebAwareness”, was developed as a client/server combination using a server made in Java with a Java applet running in the client browser. In order to expose a minimalist visualization of other co-present users, I chose to just expose the number of people in the gallery at any moment. Further, I gave users the option to chat with others sharing the same page in the gallery.

The chat featured a login field on top, a text field bottom left displaying the ongoing communication and a list of visitors who had logged into the system bottom right. After a user had logged in, the login field was replaced with a text field where the user could write their messages.

The awareness systems visualized in a minimalist fashion how many people there were in the gallery as a whole, but not how many there were at one particular page. If someone logged in to the awareness module at one page, everyone in the gallery would get a message that someone had logged in, and on which page they were. Any conversation that happened was contained to one page and not gallery-wide (see *Figure 6. The WebAwareness system with example data*).

Enter comments <input type="text"/>	
<p>* Laura I. logged on to picture 2 Stefan: Laura - what do you think of the picture above? * Roy logged in to picture 5 Stefan: I think they are nice! Stefan: Bye! Right now there are 4 others in the gallery</p>	<p>Stefan Laura I.</p>

Figure 6. The WebAwareness system with example data

The system described here is by modern measurements quite unsophisticated, but in the year 2000 it was more or less unseen on the web. It provided us with the opportunity to study a new phenomenon in a real and relevant setting. In choosing the setting of the research project, online behavior could be studied in a highly authentic environment with a large body of users constantly changing over time. Furthermore, this resulted in a large amount of data material, but at the same time, access to the users was not possible.

4.3 The technology

In the early 2000's, technology that made co-present users visible to each other on a web page was uncommon. The applications we had evaluated all functioned as plug-ins to the most common web browser then. That meant that to be able to see others, you had to have that exact plug-in enabled in your browser. This did not suit us, as we aimed to make most, if not all of the visitors on the web page visible to each other and enable them to communicate. One technology, called a "Java Applet" (not to be confused with the "javascript" programming language), was released a few years preceding our development process by Sun Microsystems (Hamilton, 1996). A java applet is a program embedded in an ordinary web page, running in a

sandboxed environment alongside the web browser (the Java Runtime Environment, or JRE), providing functionality that the common web browser was unable to do (ibid.). While requiring the JRE to be installed on the client computer to work, the use of Java Applets was widespread on the internet providing different sorts of functionality, resulting in a near-universal availability. Further, the Java Applet is portable, i.e. the same code can be used on all types of computers and operating systems.

Being sandboxed, a Java Applet could not read or write files on the client computer. It could read a few parameters from the webpage on which it resided, but not the whole page. For me, the main feature the Java Applet brought to the table that persuaded me to consider it as a tool for online social interaction between users on a web page was that it enabled bi-directional communication to a server. HTTP (Hypertext Transfer Protocol), the protocol used on the web then, is uni-directional utilizing a request-response sequence. When visiting a webpage, the browser using the HTTP protocol sends a request to a web server, asking for a html document, an image or other type of file. The request also contains header data, consisting of for example the preferred language of the client and information of the browser's capabilities. The server accordingly responds with either the requested document together with header data, or an error message in case the requested document is missing. The header data in the response consists of, for example, the web server version and the type of the requested document.

The uni-directional communication protocol, together with the large amount of overhead in the form of header data makes the HTTP protocol unusable as a base for real-time online interaction. Fortunately, the underlying protocol used by HTTP is TCP (Transmission Control Protocol), and TCP is bi-directional. Developing a bi-directional communication model in a Java Applet using Socket communication, I could send and receive data (or rather push and pull data) simultaneously, without the extra overhead in the form of header data of the HTTP protocol.

I developed a server in Java using `ServerSocket` to manage the communication with the applets running in the client browser. The server kept track of the all concurrent clients, on which page the client was, how many clients were on the same page and all communication between users. Due to the limited bandwidth most users had at the time, the information sent between the client and server was kept at a minimum, enabling up-to-date information on co-present users, their whereabouts and activities.

When a visitor entered the gallery, the browser requested the WebAwareness applet via a HTTP request together with separate requests for each of the other resources on the web page, such as images and html documents. The server responded accordingly to all the requests, and the applet was loaded into the JRE. When loaded, the applet read a parameter from the webpage containing the ID of the page and proceeded to connect to the WebAwareness server via a socket. An initial message was sent to the server signaling that a new user had arrived in the gallery. The string also contained information about which page the user was visiting. The server responded with a short string containing a number representing the number of people in the gallery at the time. This string was sent to all clients in the gallery, thus updating the number of users to reflect the new user. If the user decided to log in to the chat, a message was sent to the server with the user name and the id of the page. The server responded by sending out a message containing the text “A user logged in to picture ##” to all clients except the one where the login occurred.

4.4 Data collection and analysis

The launch of the web gallery was covered significantly in media around the world and the number of visitors grew with each exposure of the site in the press. A prominent exposure came from a mention in the now classical “Wired news” as well as a link in the “Wired” electronic newsletter that within an hour resulted in 3000 impressions on the first page of the gallery. While not an impressive number by today's measurements, back in 1999/2000 that number of visitors was considered huge. Such exposure was mostly positive, but it also meant that the research group had to constantly monitor the experimental awareness system to keep it online.

Online studies differ in numerous ways from studies concerning social behavior conducted in real life, and strategies for studying online activities have been discussed extensively for the last decades (see Paccagnella, 1997; Wittel, 2000). Web activities are often characterized by spatial differences, i.e. users are not at the same place geographically. On one hand, this naturally inhibits access to the research subjects for, for example, focus group sessions, interviews or observations of use from the user's perspective. On the other hand, researchers can observe situations as they occur online (Kozinets, 2002) and collect and analyze data generated by the use of social systems (Sørensen & Fagrell, 2000). The somewhat controversial nature of the system, together with the geographically dispersed users presented us with a limited range of research methods to choose from. Thus, the main data

collection method ultimately chosen was the automatic collection of log data regarding the events in the gallery. Visitors were informed of this procedure at the first page of the website, and we also informed visitors that all data collected was carefully treated and handled confidentially, and they had the option of not partaking in the study by leaving the web gallery.

The system collected two types of usage data contained in different logs. One log recorded all messages, the time and date of the message and from which page in the gallery the message was sent. It also logged the user's IP-address which was only used to be able to distinguish different visitors from each other. The second log was used to collect data on how people navigated inside the gallery and the duration of their stay at each picture. The second log also recorded metadata that could be used to calculate the number of co-present users in the gallery at any given moment. No personal information about the visitors was ever collected apart from the IP-number.

Data was collected for six months in the life of the gallery. During this time period, approximately 200,000 impressions had been recorded by the web server and several megabytes of data in the form of text was written to the logs. Further, 1408 log-ins had been made in the chat system, 583 attempts to initiate interaction in the chat could be found as well as a total of 1846 messages were recorded.

Analyzing the logs were mainly performed by me, with guidance by senior researchers. The data from the logs were examined in several cycles. Initially the logs were imported into a spreadsheet in order to clean up the data. This type of post-processing of logs is intended to be used to remove uninteresting data from the oftentimes large set of data (Helms et al., 2000). I first removed all traces of usage left by the researchers while testing the system. This could be either text messages or logins in the system. Next followed a read through of all the data to get familiar with the dataset and to remove what we referenced as "unintended use" within the logs. For example, we found several occurrences of conversations between people sharing the same IP number. Judging by the conversation taking place, they most probably also shared physical location and used the system as a group chat amongst themselves. Although an interesting phenomenon in itself, interaction in the system between people sharing the same physical location is, in this thesis, not regarded as an example of mediated interaction.

What followed was an analysis of the logs in four cycles. One of the cycles used a quantitative approach, looking at navigational patterns and time of visit as units of analysis using a chi-2 test. The results of this is presented in

paper 1 and 2. The qualitative cycles focused on *conversations*, *opening messages* and “*critical incidents*” (Wright & Monk, 1989) in the chat system respectively. Analysis of breakdowns in communication is common in studies of mediated communication and collaboration (see for example Bjørn & Ngwenyama, 2009; Easterbrook, 1995), as they indicate points where technology often fails at providing a sound environment for interaction. The results from the qualitative analyses are presented in paper 2.

The results of the study informed us of the powerful effects even minimalist awareness information had on users. We could see effects on both the way people used the site and the way they approached, perceived and reacted to conversations with other visitors. We also got a first hint towards the importance of supporting social norms in the use of social software, and that social systems should support the creation, recreation and reinforcement of social norms in order to work as intended.

The first study concludes with a set of design guidelines, utilized in the design of the second system of this thesis.

5 DEVELOPING FOR MEDIATED COLLABORATION

This study began in 2010 with a general interest in computer-mediated collaboration. In my role as a teacher involved in distance education for many years, I was left unimpressed by the technology available for meeting and tutoring students at a distance. Characterizing this setting was the use of collaborative technologies to interact with individuals or small groups of students around a digital artefact, for example an image, a film clip, a piece of programming code or a text. These tutoring sessions were usually associated with an assortment of problems of both a technical as well as a social nature, often resulting in communication breakdowns supported by cumbersome interfaces that oftentimes confused participants at all ends of the communication. My own reflections at the time revolved around the effectiveness of the interaction regarding the amount of time spent on actual tutoring versus the time spent on the set-up, maintenance and management of the collaboration itself. Encouraged by the results from the first study regarding social norms, I set out to explore this problem area.

As details of the conducts of this study are presented in a fragmented manner in papers 3-5, I will here take the opportunity to present the research approach and individual stages of the study in a more complete and cohesive way. Along the way I will attempt to provide the theoretical and methodological underpinnings of the choices made.

In this study, I wanted to apply a traditional Scandinavian approach to the design of IT artefacts by applying general principles from areas such as co-operative design (see for example Bødker et al. 2000), user-centered design (UCD) and participatory design (see for example Kensing, Simonsen & Bødker, 1998). These approaches all involve users as an active participant in the design process with methods ranging from them being a passive informant and evaluator of the design to being actively involved in the process of problem solving, generating design ideas and use the resulting product.

I was likewise intrigued by the Design Science approach that in a sense matured during my development process, with its attention to artefact construction through iterative build-intervene-evaluate stages of development while addressing real-world problems through design and concerns revolving around issues relating to research rigor versus relevance. I was thus standing

with one leg in each of these development paradigms during periods of the development process. This might seem like an odd approach but considering the extended timeframe of the study it is perhaps not that peculiar. While I acknowledge that I did not fully adopt the design science research (DSR) approach from the beginning of the process, much due to the fact that it was relatively new and under-developed at the beginning of this study, in retrospect I saw that I, to a relatively large degree, followed a general DSR approach of cyclical design phases. I would therefore like to give the following section, the rationale for my development process in the second study, a DSR dress.

5.1 Design approach

Hevner, March & Park (2004) argue that there are two main paradigms in IS research; behavioral science and design science. While the aim of the behavioral sciences is to explain human behavior, design sciences focus on the design of artefacts and methods used to develop and evaluate them. Design science can be traced back to Herbert Simon and the book “The Sciences of the Artificial” originally from 1969. Here, a design science is described as a creative activity where solving problems and develop new technologies are central (Simon, 1996).

One of the main arguments for a design science is to make IS research more relevant to practice (Benbasat & Zmud, 1999; Hevner, March & Park, 2004). Design science tends to favor relevance over rigor (Winter, 2008) but this does not mean design science lacks rigor, rather, the process is less well defined (ibid.). DSR can be described as “*learning through the act of building*” (Kuechler & Vaishnavi, 2008), where innovation of technology is central (Järvinen, 2012).

While several perspectives of the DSR process exist in the literature, the research generally dictates a cyclical design model where a problem is identified, a suggestion to the problem is presented, development is initiated, and an evaluation of the design is performed (see *Figure 7. Design Science Research Cycle published in Kuechler & Vaishnavi, 2008*). If deemed successful, the research results are summed up and added to the body of knowledge in the domain. On the other hand, if deemed unsuccessful, the knowledge is added to the body of knowledge and a new cycle is initiated.

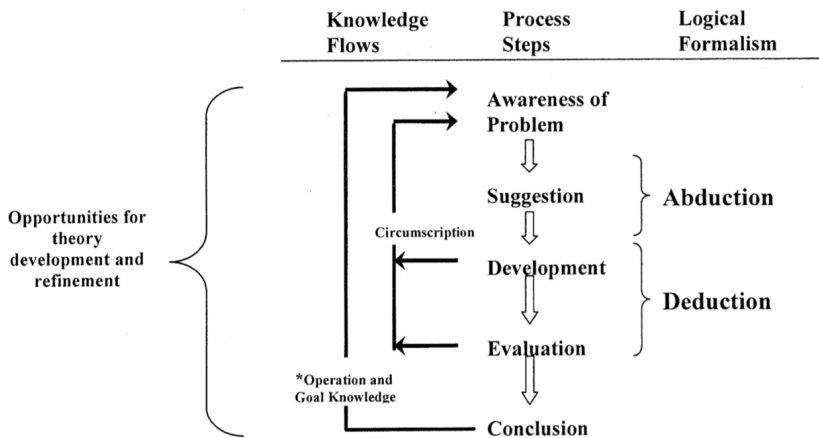


Figure 7. The Design Science Research Cycle published in Kuechler & Vaishnavi (2008)

The development phase is usually informed by *kernel theories*, theories that in some way guide the design on a theoretical and methodological level (Gregor & Jones, 2007).

As my design approach was both influenced by DSR as well as the tradition of user involvement in the design process, I began the cyclical design process with a set of observations of technology-mediated collaboration in use. An observation study has the general purpose of acquiring an initial insight into the problem domain (Nunamaker & Chen, 1990). In choosing the setting of the observation studies, the aim was to find situations that involved small groups of people (from 2 to approximately 6) experienced with the available technology collaborating around some form of media objects. I found such an environment in the engineering department of the university where I worked. Senior students doing their “masters degree project” situated at manufacturing companies off-campus required tutoring sessions with teachers at the engineering department. The observation studies were conducted in the winter of 2010 and involved two separate occasions. Two researchers were involved in the observation studies. In one session, audio of the events was recorded, while in the other, notes were taken. The observations were made at the teachers’ side of the tutoring session, observing the events unravel from the first attempts at setting up the tutoring session until the session finished. The sessions lasted for approximately one hour each.

The results from the observations generally acknowledged the notion that mediated collaboration was ineffective regarding the time and effort spent on both sides of the session setting up and managing the collaboration. The sessions not only validated my initial suspicion, but the analysis also gave me a chance to further narrow down problem areas within mediated collaboration that I later turned into a set of initial design requirements.

5.2 Focus group session

The observations were followed shortly by a focus group session (*Figure 8. The first focus group session*). As one of the aims of focus groups is to gather a set of people skilled in the problem area at hand (Bryman, 2012, p. 503), the participants were teachers and/or researchers within a higher education setting. The group members were selected because they had substantial insight into mediated collaboration and a long experience in experimenting with different types of systems facilitating mediated collaboration.



Figure 8. The first focus group session

Two researchers were present at the session - one led the discussions while the other took notes and supported the discussion leader. The participants were teaching and/or researching in areas such as web design, programming, technology-facilitated pedagogy and 3D-visualization. The purpose was both to further validate the problem area, as well as provide the opportunity to discuss stories from colleagues' experiences in mediated collaboration and to gain insight into how the teachers worked when undertaking a mediated collaboration effort with students, i.e. to tap into their accumulated knowledge regarding the technologies they used. The session was informal in nature, and the participants knew each other well before hand. We

encouraged the participants to think freely, and the session shared several points of resemblance to a brainstorming session (Krueger & Casey, 2002).

5.3 Kernel theory selection and preliminary design requirements

Further informing the initial design of the system, and dictated by the DSR approach, a kernel theory guiding the design of an artefact was chosen. As I had the results from the first study to lean on, this constituted the kernel theory, and was complemented by the notion of “Social translucence” (Erickson & Kellogg, 2000) that influenced my design process from an early onset and made me think in the direction of using awareness information as a tool to achieve accountability. While not touched upon in any length in this thesis, I was to a lesser extent also influenced in early design decisions by the “calm technology” metaphor (Weiser & Brown, 1997), i.e. systems that does not take the focus from the activity at hand, but rather quietly is in the background supporting the activity.

The observations and the focus group sessions as well as the theoretical influences and design guidelines from the first study together resulted in the formulation of a preliminary set of design requirements (see Nilsson et al., 2011). This first set of requirements mandated the system to:

1. be lightweight and not take too much power from the student’s computer
2. be able to switch to a video conferencing mode to enable the student to see his/her tutors
3. function as a life-line beside the screen-sharing application
4. support logging of previous sessions and the results from them
5. enable the sharing of different types of media between the tutor and student
6. support discussion of an object

These requirements, presented in Nilsson et al. (2011) and framed in a learning context were at subsequent stages of the study expanded into 9 requirements (reported in Svensson & Nilsson, 2014), and later refined into 13 requirements (see Nilsson & Svensson, 2014).

5.4 Technology review

To be able to build software in accordance to the design requirements, I examined what types of technology I could use to develop the system. An emergence of new web technologies such as the HTML5-standard and CSS3, as well as server frameworks such as Node.js were becoming popular at the time. While CSS3 enables for example the possibility for advanced animations within the browser, the HTML5 standard provides designers a set of new features that allow for the embedding of, for example, video and a canvas element for drawing in 2D. Further, new attributes to the markup standard make web content editable and draggable within a browser window. Perhaps most importantly though, HTML5 together with Node.js and a package called socket.io enable the use of Websockets that provide the base for high-performance bi-directional communication between a web browser and a server. What this means is that we can provide real-time components into web pages. While not expressed explicitly in the early set of design requirements, real-time components sprung from ideas that was raised in regard to the “*support discussion of an object*” sentiment and from the initial awareness framework from the first study, suggesting that communication has a non-verbal dimension that could have real-time properties.

While supporting the WebSocket layer for bi-directional communication, Node.js did not, at this time, have a stable support for serving dynamic web pages. For this, the combination of a more traditional Apache web server together with PHP was chosen, and data storage was implemented using a MySQL database management system.

The technology review also informed us that the requirement “*be able to switch to a video conferencing mode to enable the student to see his/her tutors*” proved troublesome on two levels. First, the technology did not, at this time, support real-time video conferencing over the TCP protocol. Secondly, it was at the time in stark contrast to the first design requirement “*be lightweight and not take too much power from the student’s computer*” and was therefore not an envisioned component of the first prototype. We rather saw the video conferencing capabilities being provided by external services such as Skype.

Based on the design guidelines and inspired by the affordances of the technology at the time, a first mockup of the system was constructed (see *Figure 9. The first mockup of “CloudBoard”*).



Figure 9. The first mockup of “CloudBoard”

Inspired by the “calm technology” concept, the system (named “Cloudboard”) was designed with a whiteboard metaphor in mind as the main user interface. Based on the first set of design requirements, the mockup depicts features such as real-time visualization of user activities, historic awareness of past activities, drag-and-drop upload of files, collaborative text editing, and movable and resizable media objects. All activities in the system are meant to be distributed to other participants, i.e. when for example an image is moved or resized, everyone else sees the action in real time. A number of functions such as storing data in the form of pictures and videos would be handled by external services. This should make the system lightweight and simpler to maintain as opposed to having all features centralized to one server and one system. A timeline at the bottom of the screen was imagined enabling users to rewind the system, thus visualizing the state of the system at any given time in the past. Objects removed from the system could in the historic view be “revived”, adding them again to the “live” system, thus nothing was ever deleted from the system. All objects in

the system should be able to be associated to text fields, enabling users to comment on everything in the system.

5.5 Validating the initial design

In order to validate the design, a number of overlapping activities took place over a period of time. Iterative evaluation practices are treated as essential ingredients in a DSR effort (Peppers et al., 2012; Pries-Heje, Baskerville & Venable, 2008; Gregor & Hevner, 2013). However, while essential, there are not many descriptions, practical examples or best practices on how to evaluate in a DSR project (Mettler, Eurich & Winter, 2014; Venable, Pries-Heje & Baskerville, 2012). In later years, there has been an increased effort in documenting different approaches to evaluation in the DSR literature (Peppers et al., 2012), but the heterogeneous set of artefacts that can come out of a DSR effort varies greatly making the landscape of evaluation methods difficult to grasp. Recent methodological developments regarding DSR evaluations consider the outcome of evaluation efforts. Venable, Pries-Heje & Baskerville (2012) describe two dimensions: Ex Ante (evaluation prior to the development of an artefact) and Ex Post (evaluation after development). See *Table 3. Evaluation strategy selection framework published in Venable, Pries-Heje & Baskerville (2012)* for the overview.

Table 3. Evaluation strategy selection framework published in Venable, Pries-Heje & Baskerville (2012)

DSR Evaluation Strategy Selection Framework		Ex Ante	Ex Post
			<ul style="list-style-type: none"> •Formative •Lower build cost •Faster •Evaluate design, partial prototype, or full prototype •Less risk to participants (during evaluation) •Higher risk of false positive
Naturalistic	<ul style="list-style-type: none"> •Many diverse stakeholders •Substantial conflict •Socio-technical artifacts •Higher cost •Longer time - slower •Organizational access needed •Artifact effectiveness evaluation •Desired Rigor: "Proof of the Pudding" •Higher risk to participants •Lower risk of false positive – safety critical systems 	<ul style="list-style-type: none"> •Real users, real problem, and somewhat unreal system •Low-medium cost •Medium speed •Low risk to participants •Higher risk of false positive 	<ul style="list-style-type: none"> •Real users, real problem, and real system •Highest Cost •Highest risk to participants •Best evaluation of effectiveness •Identification of side effects •Lowest risk of false positive – safety critical systems
	Artificial	<ul style="list-style-type: none"> •Few similar stakeholders •Little or no conflict •Purely technical artifacts •Lower cost •Less time - faster •Desired Rigor: Control of Variables •Artifact efficacy evaluation •Less risk during evaluation •Higher risk of false positive 	<ul style="list-style-type: none"> •Unreal Users, Problem, and/or System •Lowest Cost •Fastest •Lowest risk to participants •Highest risk of false positive re. effectiveness

The purpose of ex ante evaluation is to examine whether an artefact should be developed at all, choosing suitable technology, testing prototypes and happens before the process of constructing the artefact. Ex post evaluations consider the value of the system in use by real or simulated users. Ex ante and ex post evaluations are ends of a timeline, where ex ante occurs at the beginning of the process and moves on in cycles of design and evaluation towards the finalized product evaluated ex post. According to Sonnenberg & vom Brocke (2012), ex ante evaluations validate “the design of an artefact”, while ex post evaluations validate “artefact instances and artefacts in use”. These can in a sense be compared to Nunamaker & Briggs (2011) and their “proof-of-concept”, “proof-of-value” and “proof-of-use”, where proof-of-concept prototypes are evaluated in an artificial laboratory setting, proof-of-value prototypes are evaluated in a more naturalistic setting where real users test the system, and finally proof-of-use where systems are evaluated in real use.

While the framework of Venable, Pries-Heje & Baskerville (2012) had not yet been published when I did my initial design activities, nor the categorization from Nunamaker & Briggs (2011), they are in several perspectives useful as mirrors of my own considerations at the time. At this stage in the design process I had begun to reflect upon evaluation activities and how to conduct rigorous *end-user evaluations*, something that is considered essential in many design efforts (see for example Nunamaker & Briggs (2011) and their call for “proof-of-use” studies) and something that for example Venable, Pries-Heje & Baskerville (2012) consider the best way to evaluate effectiveness. But as Pinelle & Gutwin (2000) saw in their literature survey, about 33% of systems in research literature were not evaluated in any formal way, and only 25% of the evaluated systems were deployed in real settings. Lopez & Gerrero (2017) finds in their literature survey on awareness research and system design for awareness that only 42% of the systems included in the study specified an evaluation method. While not problematized in any length by Lopez & Gerrero (2017), I would argue that one reason for the lack of rigorous evaluation is because of the complex socio-technical context where these types of systems are positioned. The same sentiment is expressed by for example Gutwin & Greenberg (2000) who in their work are exploring more cost- and time-effective ways of evaluating a shared workspace. But whereas the efforts of Gutwin & Greenberg (2000) are pinpointing whether a system supports the more practical and technological activities of collaboration such as effectively monitoring others’ activities, coordination of activities and communication, my main concerns in this sense are rather on a social level, or what Gutwin & Greenberg (2000) refer to as the “...*social and affective elements that make up group dynamics*” (Gutwin & Greenberg, 2000, p. 99). As processes such as grounding activities and the emergence of social norms might take time and needs to be in place in a system in order for it to work in a social translucent way, my considerations are around what type of results I would get from evaluating the use of a system by a newly formed group of people. Further, if I (and a group of users) had the time and opportunity to perform a more longitudinal evaluation, how would I know that the group had established some form of common ground and social norms within the system?

For the purpose of my first evaluation, which could be considered a naturalistic, ex ante evaluation or proof-of-concept, I gathered the focus group once again, in which I presented the mockup and invited the participants to a discussion around the envisioned features and interface design. Further, I conducted a technological feasibility test which could also be considered an ex ante evaluation. To perform the test, I proceeded to

develop an early pre-prototype of the real-time parts of the system (Node.js and Websockets), as well as the web-based parts using PHP on top of an apache web server and MySQL as data storage. While the techniques proved somewhat cumbersome and time-consuming to combine, I found them to be very performant. This initial conclusion was later confirmed by Gutwin and colleagues (Gutwin, Lippold & Graham, 2011) who in parallel conducted a study to evaluate the performance of the WebSocket technology. The technological test was purely artificial, as no real users or real settings was involved. The third activity was a market survey into products available online with similar approach to mediated collaboration (see Jobe & Nilsson, 2011). These *ex ante* evaluation activities combined with the market survey resulted in a refined set of design requirements that was later used to build a first functional prototype (see *Table 4. Design requirements*).

Table 4. Design requirements

Open and platform independent	Everyone should be able to use the system. As the world of devices capable of running applications becomes more heterogeneous (for example different types of computer systems, operating systems, tablets, smartphones), the system needs to be built on open and universally available technology.
No installation	The system should not require an installation. There is a need for the system to work on public computers, computers crippled in the sense that it is impossible for users to install software. This is often the case in many educational institutions and companies.
Lightweight, or scalable for slower computers	It is supposed to be a support system, and capabilities of computers and other devices can be limited. As a support system for collaboration, the system is supposed to run alongside other systems and should not restrict the use of these systems.
Historic visualization	From the social translucence theory, we derive the need to visualize historic activity in the system. Visualizing who have done what in the system, we strive for a sense of accountability for the users.
Document sharing	Easily sharing documents and files, like PDF documents, images and videos.
Real-time awareness visualization	Visualisation of current activities, also derived from the kernel theory of social translucence, to increase the sense of accountability visibility and awareness of others.
External connections	Educators in the focus group expressed a need to incorporate external material from the web into the system. Resources such as streaming video from YouTube, twitter feeds and other services should be easily included in the system.
Discussion	Users should be able to annotate and discuss objects in the system.
Unobtrusive interface	The interface of the system itself should be peripheral, and the focus for the users should be on the actual content of the system.

Following the aforementioned activities, an intense development process began, incorporating several of the outlined features into the first functional prototype (see *Figure 10. The first functional prototype of “CloudBoard”*).

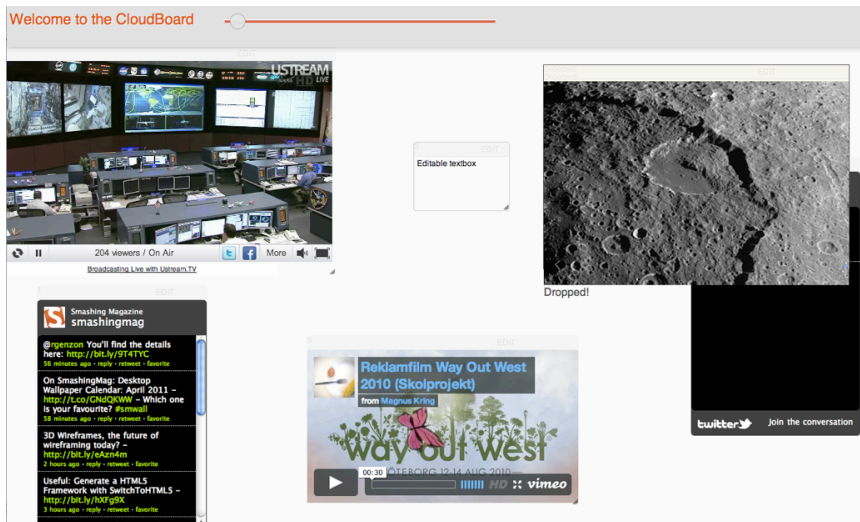


Figure 10. The first functional prototype of “CloudBoard”

This prototype was written about, submitted to and subsequently presented and demonstrated at an academic conference in 2011 (Jobe & Nilsson, 2011). The prototype featured functionality such as the ability to embed external material in the form of twitter feeds, film clips from video sharing sites, as well as streaming sites such as Ustream TV. Drag-and-drop of other media files such as images was supported, as well as the moving and resizing of the objects on the board. The ability to rewind the system using a time slider was in place. This was an effort to enable historic awareness, to be able to pick a date and time in the past to see how the system appeared then. It further had the functionality of reviving deleted objects, i.e. had someone deleted an object in the system, a user could always rewind the system to find the object and revive it, thus making it appear again in the “live” view.

Reflecting on the overall experience of getting feedback, both written in the form of reviewer feedback on the article, as well as questions and comments from scholars and practitioners during and after the presentation made me begin to consider such activities in the light of evaluation. While not rigorous and at times not possible to document properly, I did get input from people well versed in the challenges of mediated collaboration and I thus began to think of such activities as a form of *alignment activities* of a system in

development. The value of alignment activities was further proven as suitable opportunities to demonstrate and discuss the system in for example meetings with local business representatives as well as in meetings with teaching colleagues continuously emerged, with each such activity providing valuable insight into the design of the system.

The experiences from the first international conference presentation, as well as the other alignment practices discussed here, led me to another intense re-design and re-development stage. In parallel, I continued to study developments from the academic community on for example awareness mechanisms, from practice regarding user interface and user experience developments as well as keeping track of developments in technology I could use in my development efforts. This influenced the development of a more evolved prototype, stable enough to be able to be evaluated using real users (see *Figure 11. “CloudBoard” used in the end-user evaluation* for a depiction of the system).

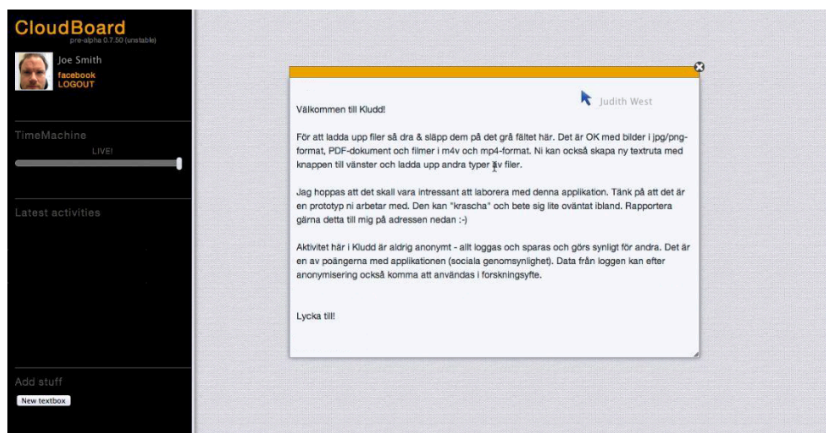


Figure 11. “CloudBoard” used in the end-user evaluation

In this prototype, I added “telepointers”, showing other participants’ pointers in the system. The pointers have their respective names attached, so a user knows which pointer belongs to whom. Obviously, this is only applicable to users utilizing a computer to access the system. Using a phone or tablet with touch input, a pointer is not visible until the user starts to manipulate an object or tap somewhere in the system.

The system now has a “private” area (the dark area to the left in Figure 11) containing the previously described timeline function. Security functionality was also added – in the picture we can see a person logged in using their

Facebook account. We also added an activity log in the private area, where all events in the system are made visible to the user - an attempt to enable “social translucence” in the system, i.e. “I know that you know what I do, thus you can hold me accountable for my actions”. As can be seen in the text area (displaying information to the participants in the end-user evaluation described later), the function had a handlebar at the top that is used to drag the object around the workspace, adhering to how windows are designed in most popular operating systems. We also see the resizing function in the bottom right part of the object.

5.6 End-user evaluation

This version of the system was considered mature and stable enough to be exposed to the first ex post evaluation with end-users of the system. As previously mentioned, I was somewhat concerned about the results of such evaluation since the group was newly formed and had never used the system before.

The setting was within the context of an online university course. A group of geographically dispersed students were given a task requiring them to use the system. The system was in an alpha version, i.e. functioning but containing bugs. The system logged all actions made by the participants in a database, and the students were further required to write a report where they analyzed their own experiences using the system. The students were given a few weeks’ time to finish the task and to write their analysis of the system.

Analyzing the interaction as logged by the system provided me with some interesting data. What I saw was that, most of the time, the students were negotiating how to use the system and how to make sense of the functionality. Little time was spent actually collaborating on the given task. While the results of the evaluation were interesting and would later inspire a major design initiative, the results were also interesting from a methodological standpoint. What we saw could be considered traces of how well the system supported grounding activities and the formation of social norms and not that much regarding how well the awareness mechanisms supported coordination of the task.

However, together with the reports, we derived a set of new design guidelines as well as refined existing guidelines. These were reported on in a poster at ACM Group’14 conference (see Nilsson & Svensson, 2014), and further expanded on in full paper publication in 2015 (referred to as paper 3 in this

thesis), utilizing the design pattern approach. The new design requirements were;

1. Provide visual distance from old interaction models
2. Provide the opportunity to hear and see each other
3. Feedback and confirmation of own actions and what others are seeing in the system
4. Provide a clear, simple awareness visualization

5.7 Reflecting on communicating design

As the functionality of specific parts of the system became increasingly complex at this point in the development process I began to reflect on the issue of documenting and communicating the outcomes of design activities in a clear and concise way. While it is one of the goals of design science is to make research more relevant to practice (Benbasat & Zmud, 1999; Hevner, March & Park, 2004), it is also an area identified in need of more work (Gregor & Hevner, 2013). The interest stemmed in part from my own struggle to understand the outcomes from other design research carried out in the field in order to build upon those results, but primarily it originated from the needs to document my own work. What I saw as essential was to be able to, in a structured manner, acknowledge the work of others in my own designs, describe the problem area and suggested functionality, as well as to identify a use context.

For my research, I have chosen to adopt a “design pattern” approach (Alexander, Ishikawa & Silverstein, 1977). Design patterns as a concept has been featured in many disciplines throughout the years. Originating from architecture literature, it is presented as a way to describe solutions to common, reoccurring problems in design. Design patterns exist on different abstraction levels, from high-level conceptual descriptions of problems and their solutions, down to very specific, concrete design problems. While being applied to different abstraction levels, Chung et al. (2004) stress the value it adds when applied to specific design problems. Design patterns can be seen as a vocabulary shared between members of a development project (Borchers, 2001).

“It must be stressed that Alexandrian patterns are, above all, a didactic medium for human readers, even (and especially) for non-architects. This quality must not be lost in a more formal representation or extension of the idea to other domains.” (Borchers, 2001, p. 370)

Patterns are generative by nature (Chung et al., 2004), i.e. they are able to be built upon each other and to be shared and extended by the research community. A set of interlinked design patterns can, in the end, build up to a pattern language (see for example Chung et al., 2004) or a pattern catalogue (see Gamma et al., 1995) for a specific class of applications.

Design patterns have seen attention in several fields related to CSCW, most notable in software engineering (see for example Ko et al., 2011), but also in such fields as ubiquitous computing (see for example Chung et al., 2004), game design (see for example Bergström, Björk & Lundgren, 2010), HCI in general (see for example Seffah, 2010) and CSCL (see for example Baggetun, Rusman & Poggi, 2004). Concerning the CSCW field, one of the most significant uses of design patterns is arguably by Schümmer & Lukosch (2007), who in their book present a rich collection of design patterns relating to collaborative work.

There is no standardized way of describing design patterns (Breuer et al., 2007; Dearden & Finlay, 2006), and a central concern is the balance between describing a complex pattern in a detailed way yet at the same time keeping it simple enough to be easily understood and communicated. The original design pattern format from Alexander, Ishikawa & Silverstein (1977) includes a name and reference number, a picture as an example of the design pattern, a text to contextualize the pattern and set it in relation to other patterns, and a text outlining the problem the pattern solves. The pattern concludes with a discussion and motivation of the pattern and a proposed solution to the problem, a picture of the solution and a set of related design patterns in a pattern language. Breuer et al. (2007) suggest a format that describes a situation, the problem the pattern should solve, the context and solution, similar to the original idea of Alexander, Ishikawa & Silverstein (1977), but arguably somewhat simpler.

Adapted from Breuer et al. (2007), in my work I chose to describe my design patterns in the following fashion:

1. Name
2. Context
3. Problem
4. Solution
5. Examples of use

“Name” should be a descriptive text of the design pattern. “Context” will outline the problem area where the design pattern can be applied to. The

“problem” should state the design challenge at hand and the “solution” should state a rich description of how the proposed solution functions and pictures of the proposed design. “Examples of use” would indicate, if applicable, the pattern used in previous research and/or examples from practice.

With this setup, I acquired a template that I would argue to be easy to understand for the reader, transferable to other contexts and the influence from and contribution to the design community clearly stated.

5.8 New technological developments

At this point in the project, my focus had to be on other research projects and academic work (primarily teaching) and the activity of developing the groupware was put on hold for a few years. When an opportunity to restart development arose again in late 2013, I began by evaluating the technical developments (i.e. an ex ante evaluation), and found that the cumbersome combination of Node.js and PHP with MySQL as a database could be changed into a full-stack JavaScript approach, substituting the use of PHP with a Node.js package called `express.js`, and moving the storage solution from MySQL to a NoSQL database system called MongoDB. Having all the subsystems (socket communication, web service, clients and storage) implemented in one common programming language as well as using JSON as a data format proved useful and made the development process more effective. The new technological developments together with the results from the end-user evaluations were used to yet again redesign the system. The new prototype is depicted in *Figure 12. The “CloudBoard” redesigned and re-programmed.*

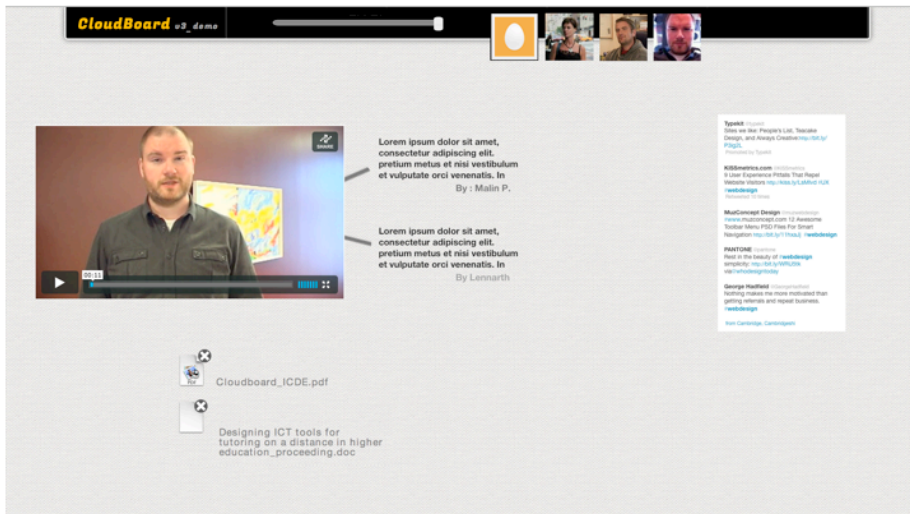


Figure 12. The “CloudBoard” redesigned and re-programmed

This third prototype was reported on in a brief paper to the SITE conference in early 2014 (see Svensson & Nilsson, 2014). This provided us with an opportunity to demonstrate the system yet again and validate its continuing development. Focus was on better visualization of who was in the room and again remove the “private” part of the system. In the image, we also see how files in the system were visualized using icons. These objects were downloaded once clicked on, and could, as all other elements, be moved around inside the system. They could not, though, be resized. The menu bar of an object is displayed once the object is clicked on. When clicked on, the object also locks, making other users unable to interact with it until the locking user unlocks it, or a timer unlocks it when the object has not been used for a set period of time.

5.9 New practical developments

At this time, I got a chance to revisit theory on awareness in particular, as well as web development trends in general. One strong trend was the mobile-first movement at the time. The use of mobile devices had not been in focus for the system up until this point, and the development in the industry made me re-design the system yet again. Specifically, the menu at the top was removed. While mobile use often dictates that the user interface changes to accommodate smaller screens, I wanted to keep the user interface and user experience consistent between devices. This led to the design depicted in *Figure 13. The “Kludd” redesigned for mobile use.* Please note that the system here also changed name to “Kludd”

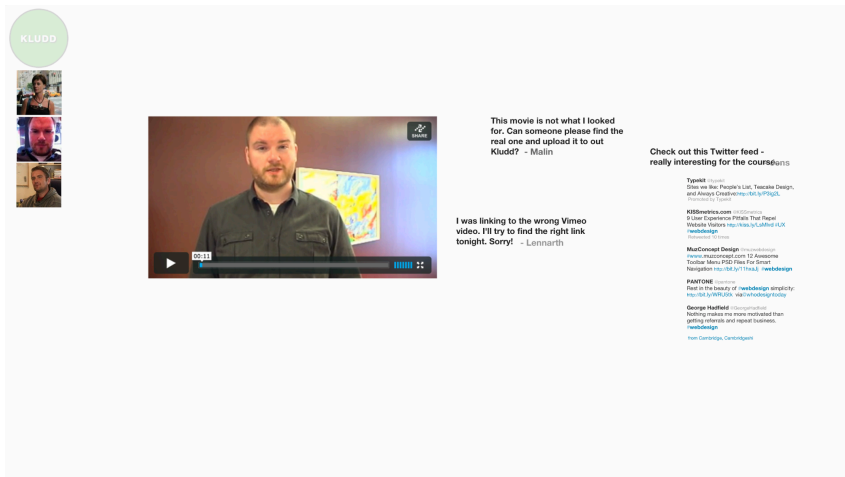


Figure 13. The “Kludd” redesigned for mobile use

All of the user interface is now under the green circle at the top left corner. The list of users underneath the green circle is displayed for 10 seconds as people enter or leave the room, or if hovering or clicking on the dot. The list is otherwise hidden. Clicking on the green circle reveals a modal window with the user interface, the timeline and a function to upload files for users using the system on a mobile device where drag-and-drop functionality is unavailable.

This version of the system was featured in a demo session at the ACM Group’14 conference (see Nilsson & Svensson, 2014), enabling me to discuss the system as well as letting conference participants briefly use the system while I observed their behavior.

5.10 New theoretical developments and technological evaluations

In 2015, the development was put on hold yet again, as focus was on publishing academic papers about the system. 2016 provided me with the opportunity to revisit the theoretical foundations of the system. While having had little attention in the CSCW field during the last few years, awareness research saw renewed interest in the community during 2016. As previously reported on in this thesis, the concept of “we-awareness” was introduced by Tenenberg, Roth & Socha (2016) and this fueled an academic discussion, reigniting the interest in the field. The concept of we-awareness intrigued me and compelled me to revisit the original design requirements once again.

The system underwent a comprehensive technical feasibility evaluation during 2017 (see paper 4), where implications of network conditions on design requirements and general performance of the underlying server and client technology were central. The driving force was now the implications of nomadic work behavior, where users could be perceived moving between different network conditions and different work contexts during a workday.

The system, having been previously deployed on a local server at the university, was now moved to a commercial Amazon EC2 server in western USA. The system was then put through a series of tests in various network conditions on mobile connections from the USA as well as from Sweden. The result from the tests provided further design implications, presented in paper 4. The focus was to account for uncertain network conditions with the design of the real-time awareness functionality supposed to support the coordination activity.

This last iteration concluded the system development. I estimate that a total of 250-300 hours was spent on programming the system and on the design of the graphical interface, an effort performed solely by me.

6 SUMMARY OF PAPERS

This section presents a summary of the included papers and their respective results and contributions. Since the results presented here are of a cumulative nature, where results from paper 1 informed paper 2, paper 2 informed paper 3, and paper 3 informed paper 4, an emphasis in this section will be on the contributions of the latter papers in the series. Paper 5 in this section adds a methodological discussion to the practical and theoretical results from paper 1 through paper 4.

6.1 Paper 1

Title: “Awareness information and user behavior: A field experiment of an online collective system”

This paper set out to investigate the effects synchronous non-verbal awareness information has on users of a collaborative system. The experiment was setup in an online picture exhibition where users were given a minimalist indication of co-present users. The study focused on differences in time spent in the system and navigational patterns between two groups of users; those with notion of co-present users and those who were alone in the system. Logs from the website were analyzed, and while navigational patterns did not show a significant difference between the two groups, the results leaned towards the notion that solitary users tend to navigate from page 1 through to the end of the gallery, while users with co-present users tended to jump back and forth between pictures. More conclusive, while users who were in the online gallery exposed to the notion that there were other visitors there at the same time spent a statistically significant longer time in the gallery as opposed to visitors who were given the information that they were all alone in the gallery. The result of the study indicated the effect even minimalist awareness information has on use of a collective system, and motivated further studies.

“...the implication of these findings should be valuable to designers of web-systems where social interaction, communication or collaboration is a desired outcome” (Nilsson & Svensson, 2005)

The paper also marks the first ventures into problematizing synchronous (real-time) and asynchronous (historical) awareness information, as well as ideas relating to the social dimension of “participation” in a technology-mediated setting.

Reference: Nilsson, S. & Svensson, L. (2005). Awareness information and user behavior: A field experiment of an online collective system. *WSEAS Transactions on Information Science and Applications*. ISSN 1790-0832. Issue 12, Volume 2, December 2005

6.2 Paper 2

Title: “Supporting participation in online learning communities with awareness information”

Utilizing the same system as in paper 1, the purpose of this paper is to explore the potential of awareness to support the concept of participation in a learning community. Extending the results from paper 1, this paper looks at the verbal communication that took place within the chat system. Results indicate that communicative strategies were affected by the awareness of co-present users. From the logs collected by the system we saw that users, upon seeing that others were present often referred to these others in their opening messages. The most common effect of this is that there was no response from the co-present users, which often led to increasingly irritated messages from the initiating user, wondering why no one was responding. We further saw frequent communication breakdowns when a conversation did occur, where users left the interaction without any notice.

This result, analyzed using several theoretical lenses regarding social behavior, led us to consider the importance of supporting the negotiation of social norms within a social system. While awareness of others can trigger social actions from an individual perspective such as trying to initiate conversations, it fails if the system is unable to support negotiations between multiple people on how to act together within the system.

“While the system implemented in this study facilitates visibility and awareness of each other, we see a lack of adherence to social norms in the users of the system by the disintegration of even the most basic rules of communication.” (Nilsson & Svensson, 2012)

The paper concludes with four design guidelines, all concerning social norms within a social system. For clarification, *OLC* below stands for “Online Learning Communities”.

- First, as norms for participation in an OLC tend to evolve over time, it might be a good idea to include a historical

aspect where new participants can observe past actions in the OLC.

- Secondly, social norms also emerge in communication, and designers should provide support for joint negotiations of norms for participation that also are persistent in the system.
- Norms are not only created verbally; non-verbal actions are just as important to norm-building processes, and it might be a good idea to provide social cues as to how participants act and have acted historically in the system.
- Finally, designers of social media for online learning communities would probably better support norm-building processes and subsequently participation by adopting models of online social behaviour familiar to participants.

Although these four design guidelines are presented from an “online learning communities” perspective, we considered them on a level of social behavior that enables them, to a large extent, to be transferable to other settings where group processes are considered.

Reference: Nilsson, S. & Svensson, L. (2012). Supporting participation in online learning communities with awareness information. *International Journal of Web Based Communities*, Volume 8, No.4, pp. 537 - 549.

6.3 Paper 3

Title: “Design Patterns for Visualization of User Activities in a Synchronous Shared Workspace”

This paper reports from an end-user evaluation of the system developed for the second study. The system is built upon the design guidelines from paper 2 and further informed by a series of focus group sessions, observations, market surveys as well as previous research on awareness information. It is constructed as a real-time shared workspace supporting the collaboration of small workgroups and featured awareness mechanisms such as a telepointer, real-time drag-and-drop of media objects and the ability to observe past events. The end-user evaluation was conducted with small groups of students partaking in an online university course. They were given a task to complete within the system, and analyzing the traces of interaction left behind by the users, as well as the analysis of reflections of use written by the students, provided us with insights into how well the awareness functionalities supported the coordination of work.

To document the awareness features that we intended to evaluate, this paper adopted the concept of “design patterns”. Five such design patterns were the focus of the paper, “The Telepointer”, “Drag-and-drop sharing”, “Object locking mechanism”, “Activity log” and the “Time slider”.

Three of the design patterns, the “time slider”, the “locking mechanism” and the “activity log” were of less interest to the study due to the lack of use and or mentions in the material collected. The “time slider”, providing a novel take on historic awareness, was unfortunately in an unstable state providing a less than optimal experience for the users. However, we could still see a potential for this type of design pattern. In the logs, we saw that the students used the time slider, rewinding the workspace to a previous state in time. It seemed to spark curiosity, but the flawed functionality of the beta state of the system made it difficult to draw any conclusions regarding its ability to support effortless coordination. The other mechanism to provide historic awareness, the activity log, was not a focal point of the students’ reports, nor could we see any trace of activity relating to the presence of the log. This could be interpreted in two ways; either it was not seen, or it was functioning in the intended way supporting the coordination activity. This also needs to be explored further. The “object locking mechanism” is a crucial part of a real-time system designed to prevent two or more simultaneous users to interact with the same object. When manipulated by one user, it immediately became locked for others’ use for a period of time.

The telepointer, a time critical awareness function made to visualize where the attention of other users was within the workspace generated more interest from the users. It was reported as confusing, and one user stated in his/her analysis that seeing the pointers moving around the workspace as co-present users were performing various tasks in the system, while at the same time being unable to hear anyone speak or seeing anyone, invoked an “eerie” feeling.

The drag-and-drop design pattern revealed signs of uncertainty when using the system in general, and a widespread disbelief towards the functionality. For example, as users uploaded objects to the system via drag-and-drop as in design pattern number two, it was often followed by a text in a text-box asking if the co-present users were seeing the object. A similar doubt was observed when users manipulated objects in the workspace by dragging or resizing objects or writing text. This inspired the first ideas towards the notion of an awareness feedback loop, aimed to visualize not only the activities of others but also a users’ own impact on the shared workspace.

The paper is an effort to evaluate a number of awareness functions and describe their functionality, use and context using design patterns. It allows the research community to understand the use case where a function was utilized and build upon that knowledge with more design activities.

Reference: Nilsson, S. (2015). Design Patterns for Visualization of User Activities in a Synchronous Shared Workspace. *International Journal of Advanced Corporate Learning* (iJAC), Volume 8, Issue 3, pp. 42-46.

6.4 Paper 4

Title: “Visualization of activity in real-time shared workspaces – adapting to nomadic work practices”

This study contributes by addressing the specific use context of the “modern nomad” being connected to a variety of networks of varying quality during a day, sometimes using touch-based devices. In this paper, we evaluate an updated version of the system depicted in paper 3 by collecting quantitative data about its performance in numerous different network conditions in order to inform the design of time-critical awareness mechanisms.

Conducting the survey on two continents and in different situations, we learn of four critical network issues that should be accounted for in the design of real-time shared workspaces. High latency, jitter, head-of-line blocking and dropped messages (i.e. data loss) all impact the usability of time-critical awareness mechanisms such as telepointers as presented in paper 3. While telepointers have been scrutinized in the light of network issues in awareness research before (see Gutwin et al., 2004), focus has been on addressing latency and jitter issues in simulated contexts. Building on the research of Gutwin and colleagues, we suggest that the telepointer becomes an “action space” (see *Figure 14. The telepointer as an “action space”*), wherein the remote user’s attention probably is. Whereas Gutwin et al. (2004) built their solution on latency data and speed of cursor, our design makes use of data on both latency and jitter as well as cursor speed in order to calculate the size of the action space. As we saw that the action space often became very large under low quality network conditions and high-speed cursor movements, we further suggested adding information about the direction where the remote user is moving their cursor in order to increase the accuracy of the predicted action space.

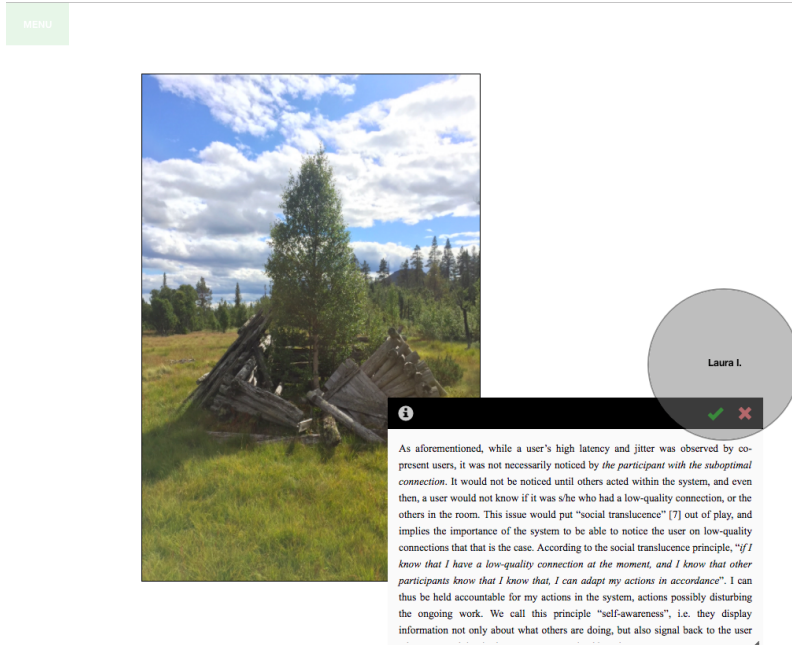


Figure 14. The telepointer as an “action space”

But by applying just a technical solution to the problem of predicting a user's attention area would not provide a suitable solution. In the paper we suggest taking advantage of social transience and infuse a sense of accountability to the system. By making users see their own action space at the moment just as the other users sees it, as well as its relation to their local pointer, users get a notion whether there is any inconsistency between where their local pointer is and the predicted action space. A user can then take action, like moving their mouse cursor slower, in order to appease the action space area. Not doing so can hold the user accountable for hindering coordination in the system.

For users on touch-based devices, the paper suggests visualizing the viewport of the device within the shared workspace, with an action space placed in the middle of the screen, thus informing a user of their network condition and function as a suggestion of where on their screen they are predicted to make any input. When interacting with the screen, the action space would move off-center to depict the actual attention area of the user.

Further infusing information regarding network conditions to the user interface, we suggest that head-of-line blocking should be visualized in the

system as a fading action space, thus indicating whether a user's actions stopped because of inactivity or because of network congestion, aiding coordination activities in the system. Finally, loss of data is crucial to support in the user interface, where the integrity of the system is at risk, and user could end up with different views of the system which would be disastrous from a coordination perspective. We suggest that in the rare cases of data loss, the affected users' interface should completely disable any interaction functionality temporarily and thus minimize the risk of multiple views of the workspace.

Reference: Nilsson, S. & Jobe, W. (2019). Visualization of activity in real-time shared workspaces – adapting to nomadic work practices. Accepted to the *Thirteenth International Conference on Design Principles and Practices – Design + Context*, 1-3 March 2019, St. Petersburg, Russia

6.5 Paper 5

Title: “On Informal Alignment Practices Developing Groupware Systems”

During the development of a collaborative groupware system, we have encountered issues that we argue are unique to, or could be considered more problematic in, groupware development as opposed to traditional single user system development. These issues relate to the concept of the social-technical gap. Constant technological advances in this field enables the development of new innovative artefacts that might circumvent the gap. At the same time, new knowledge of how people collaborate within a mediated environment is created in the academic community.

We argue that this calls for lean alignment practices to complement more rigorous evaluation practices developing collaborative systems with lean practices that focus on continuously gaining insights about the current state of the field when it comes to technology and research, as well as acquiring insights from experts and end-users alike.

Three alignment practices are identified within the development process; “*Technological alignment practices*”, “*Academic alignments*” and “*End-user alignments*”. Technological alignments relate to the rapid development of the underlying technologies that our system relies on, and the importance of keeping up-to-date with these in order to bridge the social-technological gap. The academic alignment practices relate to keeping up-to-date with new knowledge produced within the academia; theoretical as well as methodological innovations. The end-user alignments are here seen as a form

of “quick-and-dirty” evaluation with users keeping the design and development of the system in line with the users’ needs. It does not replace rigorous end-user evaluations, but rather serve as a natural part of the daily development process, inspired by lean development practices.

This paper contributes to practice as it lays forward reasoning for the specific conditions that apply in evaluating a groupware as well as a methodological approach addressing the issue.

Reference: Nilsson, S. (2018). On Informal Alignment Practices Developing Groupware Systems. *Presented as a working paper at Group2018*, Sanibel Island, Florida, USA. (To be re-written and submitted to The Journal of Collaborative Computing and Work Practices)

7 DISCUSSION

This thesis has concerned the design and development of collaborative software. Through two studies and two systems, I have set out to address the following research question:

“How should we design real-time shared workspaces to support the coordination of work within small workgroups, and how feasible are the technological frameworks and network infrastructures in providing support for real time awareness?”

As the two studies are of a cumulative nature and the results of the first study has been incorporated into study two, the discussion will have an emphasis on the later parts of the research process in order to address the research question.

7.1 Designing awareness mechanisms for collaboration

The focus of the first study was to explore minimalist awareness information and the effect it had on people. At the same time as I designed the study, I was developing an interest in human behavior, both face-to-face and in a mediated setting. While face-to-face collaboration should not be seen as a golden example to imitate (Ackerman, 2000), I believe it serves as a good counterpoint in a discussion on mediation of collaboration and frames the understanding of technology-mediated interaction.

One of the main problems observed with the system from the first study was that, although paper 1 reported the powerful effects minimalist awareness information had on use, it did not support the process of norm building. A reason for this can be attributed to the ephemeral nature of conversation in the system. As conversations were not stored, and users came and went freely within the system, there was never any “memory” within the system where past behavior was stored. New users approached the system with a blank slate when it comes to how to behave, and returning users had no way to observe the behavior of others, other than those occurring in real-time. Negotiation of how to use the system were never sustainable. According to Meyrowitz (1985), as people encounter new social situations, they tend to behave in accordance to similar situations they have experienced from the past. As this type of system was somewhat of a novelty at the time, users could not have

any extensive experience from comparable systems. In a rather simplified manner, users could be seen as choosing very different ways to behave from their individual repositories of past experiences as they approached the system, resulting in the communication difficulties we observed. I would argue that if the study was conducted today, we would have seen a different outcome from the events within the gallery as people today are more familiar with web-based systems enabling social interaction in a variety of forms.

When designing the second study, supporting norm-building processes was a central theme and implemented primarily by displaying historic awareness information. Users got an opportunity to not only observe a current state of the system, but also rewind the system to follow the proceedings leading up to that state. The functionality, originally presented as a design pattern called “time slider” in paper 3 should, in retrospect, have been more prominently featured and evaluated as it was not used to any significant extent by the users. This could be explained by the unstable nature of the time slider while testing the system, but also by the relatively short period of time the users spent in the system. There was simply not any considerable amount of history to review, and users started using the system at roughly the same time. Had users joined the group at later stages, the time slider would perhaps have had a more noticeable use.

Building on the ideas of Meyrowitz (1985), the concept of “familiarity” became one of the resulting design guidelines from paper 2. The idea is that if users are already proficient in using a certain type of interaction mechanism, they would more promptly adopt its use in other systems and carry with them some form of social norms from other uses in other systems. With the evaluation of the second system, we observed a drawback to this design guideline. As users were not familiar with the “annotation” feature of the system, they initially adopted it as a chat function and negotiations revolving how to use it use as such quickly formed. This caused some frustration, as users found the functionality of the “chat” to be quite dated according to paper 3. This indicates to us that the use of the concept of familiarity is effective in social systems but should probably be used with care. On the other hand, the way the users proceeded suggests a system that is malleable in nature, adapting to how the user wants to use the system. In a sense, the users adapted the system in accordance to their needs. They needed a way of communicating with each to better coordinate their activities and created a (albeit sub-par) system for it. This goes in line with the assumption from Koch, Schwabe & Briggs (2015), where they suggest that a groupware should allow for the users to design their own processes and ways to work with the system. Of interest is also that, as the users used the annotation

feature to chat with each other, they made arrangements to communicate with each other using Skype instead of using the “chat”, and in a sense they negotiated the need to upgrade the fidelity of communication.

As users tried to make sense of the annotation feature, as a consequence, they also began to show skepticism towards the real-time visualization feature as reported in paper 3. We found repeated attempts in the annotation function where users were asking the other users whether they could see his or her actions. The need to obtain confirmation if other users are seeing the actions in the shared workspace is intriguing and should be considered vital from a coordination point of view. Not only does it seem like there is a need for mutual awareness of activities in a system, i.e. *I see what you do, and you see what I do*, but we should also infuse a system with a sense of how others are perceiving my own actions. I have dubbed this form of awareness “self-awareness”, and the concept is further dissected in the light of the telepointer.

7.2 Self-awareness and the telepointer

The telepointer, introduced as a design pattern in paper 3, was a central awareness function in the system that conveyed a real-time approximation of a users’ attention (see paper 3 and 4) and supported the coordination of activities in the system. Without initially using a secondary channel to communicate by, a user described watching the other users’ telepointers move about in the system produced an “eerie” feeling. Perhaps when used in conjunction with a video conferencing tool or audio communication, as intended, this would be remedied. It suggests to us that some forms of awareness visualization, when used out of context, could provide effects adverse to their purpose.

The design of the telepointer was reconsidered by the time paper 5 was written. We found that while it was supposed to provide crucial coordination benefits to the users, technical issues relating to network latency and jitter made it display misleading information. Relating to the concept of “familiarity”, the telepointer, looking like an ordinary local mouse pointer on a computer, did not function like users were used to due to the network conditions. Rather than indicating where another user’s attention was in the workspace, what it actually showed was an historical view, lagging behind a number of milliseconds in time depending on current network conditions. The lag also differed between users, adding issues relating to the synchronicity of the system, i.e. users of the system got different views of the state of the system, and activities could get out-of-order. Sequentiality, one of the eight constraints in mediated interaction as described by Clark & Brennan

(1991), is here jeopardized. In order to support real-time coordination and collaboration, I argue that it is important to address the uncertainty of available constraints due to users moving between networks and acting in different network conditions. One participant's low-quality network connection affects the whole collaborative process, and as we have shown, this impact is not in any way apparent for the one causing the disturbance.

While utilizing `node.js`, Websocket communication using `socket.io`, web services through `express.js` and data storage using MongoDB proved very performant on high quality networks, mobile networks of lower quality proposed a design challenge. On high quality connections with the server placed in the USA, we got an average, stable latency in Sweden of well under the 300 milliseconds limit that was a target to strive for according to Gutwin (2001). Jitter, i.e. the individual message deviations from a baseline latency was also very low on high quality connections and even on good mobile networks. On lower quality mobile connections, the issues of latency and jitter grew. Other problems involved "head-of-line" blocking, where the "messages", i.e. packets of data, got stuck for a period of time when the mobile network failed to deliver the data. We also saw occurrences of total loss of data when a user moved between using different network types, for example going from a wi-fi network to a mobile connection.

The issues of latency, jitter, head-of-line blocking and loss of data were not isolated to the use of the telepointer. Other design patterns like the object locking mechanism were also affected. If activities in the system occur out of order, the same object could be manipulated by more than one person at the time, proposing a design challenge.

A proposed solution to the issues of network latency, jitter, head-of-line blocking and loss of data is a reimagined telepointer, designed as an "action space" (see paper 4). The action space is a circle indicating the area in the workspace where the attention of a specific user *probably* is. The size of the action space is mandated by the network conditions and the actions of a user and changes over time as network conditions change. Building on the concept of self-awareness, I suggest that a user should see his/her own action space as it is seen by other users in the system, as well as their own local mouse pointer, further building on the self-awareness principle. If a user can see that their own actions makes his/her own local pointer move out of their action space, the user knows that he/she is producing an inaccurate depiction of where their attention is, thus compromising the coordination process. In a sense, this relates to the findings of Niemantsverdriet (2016) in that by visualizing the action space as well as its relation to the local pointer gives

users a tool to act upon the knowledge of the effect of their actions. And in the case where a user sees that their own action space is becoming increasingly large due to a low-quality network connection, the user can for example temporarily leave the system enabling others to continue using the system in a coordinated fashion until the network conditions are resolved.

A further implication of using dynamically resizing action spaces is to alleviate the issue of object locking mechanisms. An object in the system should, as soon as it is overlapped by a user's action space, be temporarily locked for further manipulation by others. This proactive locking mechanism would help in providing a less error-prone system when it comes to objects being manipulated by two users at the same time. While such proactive, or predictive, object locking mechanisms has been discussed in CSCW research (see for example Migge & Kunz, 2012), I would argue that infusing it with a social dimension such as self-awareness and activate social translucence (Erickson & Kellogg, 2000) would balance some of the more techno-centered solutions that is common in the research literature.

This also implies that an action space should not be able to become too large within the shared workspace too quickly, not allowing for users to react to and act upon their network conditions changes. The size of the action space should have a limiter that automatically deactivates a user's interaction with the system at a given size.

Another implication of the use of action spaces is in the way objects in the shared workspace should be depicted. In most graphical user interfaces manipulated by mouse pointers, functionality in the form of buttons to close, minimize and drag the object/window is located next to each other. This is also the case in the shared workspace presented here. But coordination issues might arise as an action space of a user is overlapping more than one button (see *Figure 15. Overlapping functionalities with an action space*). In this situation, co-present users cannot be certain of the intentions of the user "Laura I.". Does she intend to remove the object, move it, or, by clicking the green checkmark, release the locking mechanism?

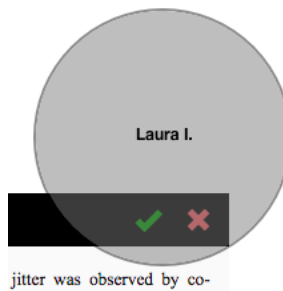


Figure 15. Overlapping functionalities with an action space

Taking into account network performance issues, I propose that buttons that activate different types of manipulation of an object, for example the deletion of the object, dragging an object and resizing an object should be separated as far from each other as possible within the object, possibly at either corner of the object. This would enable co-present users to better understand the intention of the user who is using an object.

Infusing a social system with self-awareness and functionality to enable users to act upon the self-awareness, a sense of accountability could potentially emerge thus creating a socially translucent system (Erickson & Kellogg, 2000). Without self-awareness, you do not know that it is you who are the bull in the china shop.

In the logs from the end-user evaluation I saw the users expressing the need to supplement the system with another system giving them the ability to talk with each other in real-time (paper 3). This was indeed the intended way to use the system, but it was evidently not expressed clearly from my point of view. As a user stated, *“It feels a bit lonely in here without Skype...”*. Here, we believe that either a lifeline in the form of a video conferencing tool should be incorporated in the system itself or point to available external resources providing the service. The HTML5 standard now has, as opposed to when this design requirement appeared in the first prototype, tentative support for video conferencing using video and audio, called webRTC. Further, computing power has increased since the rejection of the design requirement. Incorporating such a feature in the early versions of the system, it would no longer adhere to some of the other proposed design guidelines, as the system would not be based on standards, and would not be lightweight anymore as video conferencing takes a toll on computer performance. Now,

with technological advances on both hardware as well as software frameworks and standards, the design requirement could very well be implemented. Incorporating video in a system where users might be using a smaller screen device such as a smartphone would potentially use too much screen real-estate. An alternative to video conferencing could be to use only audio communication, especially in those circumstances where a small screen device is used, and network performance is of low quality.

Keeping up with technological advances is thus imperative in a development process in order to design first-order approximations, as further described later in this section.

7.3 Presenting design research as design patterns

From early on in my research, I have been struggling with both understanding the practical implications of the work of other researchers, as well as clearly documenting the outcomes from mine. How to describe and communicate design results in the form of artefacts is debated today and was naturally much less evolved at the beginning of my research. In my search for a way to describe and communicate my results, I grew more and more fond of the concept of “design patterns” (See Alexander, Ishikawa & Silverstein, 1977). This is a term that I was familiar with since it is commonly used in the web design community, where design patterns are a commodity, describing, often in detail, various ways to design for example menu systems, overall information architecture and form layouts. Pattern libraries are abundant in the web design industry, where practitioners share design patterns and describe instantiations of these.

As indicated in paper 3, while the general purpose of a design pattern is to describe common ways to solve reoccurring problems by design (Alexander, Ishikawa & Silverstein, 1977), the nature of design is often to innovate; problems and solutions are not always “common” in this context and we would need to arrange for a way to describe design as design patterns “in the making”. Chung et al. (2004) call these pre-patterns, while I have used the term “tentative design patterns” in my work. Despite different names, the idea is the same, to indicate a design pattern that needs to be evaluated further to be relevant. By using tentative design patterns, we get a tool to, in a very practical form, describe our proposed designs, the context of use, images of the instantiation we tested and a way to align them with previous work done in practice or within the academic work.

Early on in my use of design patterns, I used a model to describe design as follows:

1. Name
2. Context
3. Problem
4. Solution
5. Examples of use

While a good format for design patterns, I would suggest an addition when dealing with tentative design patterns in order to address issues of rigor and relevance in a design research effort. The addition would be to trace the origins of an evolving design pattern. In our work, this could for example be applied to the “action space” design pattern that evolved from the telepointer. Such field could also be used to describe the justification for the evolution. In the “action space” justification, we could thus add “to account for low quality network conditions”. I believe that such additions to design patterns and tentative design patterns can have a role in providing more rigor to design science research results.

By tagging the design pattern as “tentative” and trace the origins of a design pattern, we signal to other researchers to further jointly evaluate the design, thus providing means for both rigor and relevance in this type of research. The same type of sentiment has been touched upon in Nunamaker & Briggs (2011), where IS research is proposed to move from “*a single-investigator, social-science-driven model of research*” (Nunamaker & Briggs, 2011, p.2) towards “*multi-investigator, multidisciplinary, even multiuniversity research teams*” (ibid.). Whereas Nunamaker & Briggs (2011) discussion regards the complex nature of organizations, I would argue that the same sentiment is valid for the development of groupware such as a real-time shared workspace.


The following tables will detail the tentative design patterns of crucial parts for coordination of the activities of the real-time system designed in study two. The first tentative design pattern is an overarching pattern that dictates the self-awareness functionality of the workspace. The following are mechanisms of a real-time shared workspace adhering to the self-awareness principle.

Tentative Design pattern – The Self-awareness principle (tDP1)	
Context	Web based real-time shared workspace
Problem	Low quality network conditions may make coordination processes cumbersome. Latency and jitter make the current attention area of any given user uncertain. Head-of-line blocking might hold up the real-time awareness mechanisms, and loss of data might compromise the integrity of the workspace.
Solution	<p>Provide feedback loops in awareness mechanisms that informs a user of their own actions as seen by the others sharing the system, as well as the impact of their actions on the workspace.</p> <p>Provide alternatives for users to act upon their high impact on the coordination of work in the system.</p>
Examples of use	-
Inherited from	-

Tentative Design Pattern – Action space (tDP2)	
Context	Web based real-time shared workspace adhering to tDPI - self-awareness
Problem	In order to coordinate work, users need to see where within the shared workspace other users' attention is. Visualising their pointer in the real-time shared workspace is not enough, as network conditions make the actual pointer location uncertain at any given time, thus obstructing coordination of work.
Solution	<p>The action space is a circle around the pointer. The area dynamically resizes according to an algorithm taking into account the latency, jitter, speed of the cursor and direction.</p> <p>Self-awareness in the action space is considered by making a user see his/her own action space. If the area of the action space is large, the user can adjust his/her pointer speed, or potentially leave the room if network conditions are of such low quality that it makes the action space protrude too much.</p> <p>By visualizing the user's local pointer at the same time as the action space, users can see whether they are acting in a way that are violating the coordination of the system, for example by moving the pointer device at a speed that makes the local pointer to be situated outside the action space.</p>
Examples of use	Gutwin et al. (2004)
Inherited from	Telepointer (see for example Nilsson, 2015)

Tentative Design Pattern – Mobile Action space tDP2b	
Context	Mobile use of a Web based real-time shared workspace adhering to tDP1 - self-awareness
Problem	In order to coordinate work, users need to see where within the shared workspace other users' attention is. On a touch-based device such as a mobile phone or tablet, visualising a pointer in the real-time shared workspace is not possible until the screen is actually touched.
Solution	In order to visualize an action space, the viewport of the devices should be visualized instead of a pointer. When a touch input is detected, it should in the same manner as an action space from tDP2.
Examples of use	-
Inherited from	Action Space (tDP2)

Tentative Design Pattern – Action space constraints tDP3	
Context	Web based real-time shared workspace adhering to tDP1 - self-awareness
Problem	As network conditions change and an action space grows too big, it might take over an entire screen real-estate.
Solution	Set a limiter on the size of the action space. As an action space grows too big, the affected user should not be able to interact within the system until network conditions stabilizes.
Examples of use	-
Inherited from	Action space (tDP2)

Tentative Design Pattern – Object manipulation tDP4	
Context	Web based real-time shared workspace adhering to tDP1 - self-awareness
Problem	<p>Low quality network conditions make the action space in tDP2 grow larger, thus it creates an uncertainty of the intentions of a user, where the action space overlaps one or more functionalities at the same time.</p> 
Solution	It is a good idea to separate functionality of an object in the shared workspace as far from each other as possible. Those functionalities could be the “delete” button, the “drag handle”, the “release” button and the resize functionality.
Examples of use	-
Inherited from	Traditional UI design

Tentative Design Pattern – Object locking (tDP5)	
Context	Web based real-time shared workspace adhering to tDP1 - self-awareness
Problem	Due to uncertainties in network conditions, users might manipulate the same object at the same time, thus creating a shared workspace that is not the same for all users.
Solution	It is a good idea to lock the ability of others to manipulate an object as soon as a user starts to interact with it. Further, to minimize the possibility of latency and jitter in the network to delay the locking of an object long enough to be able to be locked by multiple users at the same time, it should preliminary lock as soon as a user's action space (tDP2) overlaps any object's functionality buttons.
Examples of use	-
Inherited from	See for example Migge & Kunz (2012), Zinnikus et al. (2013)

7.4 Evaluation of groupware

Evaluation of the research effort is central to a development process. While many research endeavors within the CSCW literature do not rigorously nor relevantly evaluate the system developed (Pinelle & Gutwin, 2000; Lopez & Gerrero (2017), paper 5 raises some concerns as to the specific needs in evaluating a system that is collective in nature. I argue that a rigorous and relevant end-user evaluation of social systems in general, and real-time shared workspaces in particular, is *extremely* difficult to achieve, with a substantial danger of rejecting awareness functionality on false grounds. In order to evaluate how well groupware applications supports collaboration, social norms must be in place in the group of users (see paper 1 & paper 2). Social norms and common ground take time to emerge, and a system also need to support the maintenance and reformation of these. I argue that researchers of social systems risk throwing the baby out with the bathwater due to the group assigned to use the system does not have enough time nor means within the system to facilitate grounding processes and the emergence of social norms. I would therefore suggest that we should be careful

analyzing use in real settings with real users (ex post evaluations, or proof-of-value and proof-of-use) and not abandon innovative ideas too quickly in the development process. Early end-user evaluations should rather examine what Gutwin and Greenberg (2000) call “*the social and affective elements that make up group dynamics*” (Gutwin & Greenberg, 2000, p.99), i.e. the ability of a system to support grounding processes and social norms in accordance to the social translucence construct, rather than examining the function of the “*...mechanics of collaboration*” (Gutwin & Greenberg, 2000, p.99).

My argument is that proper, effective use of the “*mechanics of collaboration*” in a group requires “*the social and affective elements that make up group dynamics*” to be used, over time, to create a shared understanding of common ground and social norms. What we observed in the end-user evaluation was that users communicated extensively with each other trying to create a shared understanding of how the system worked. They also had the means to negotiate the change of communication channels when they discovered that the written “chat” was not effective. Such undertakings could in my opinion be considered the beginnings of grounding activities in order for the group to reach a common ground. In a sense, they used the “*social and affective elements that make up group dynamics*” of Gutwin & Greenberg (2000, p.99) in order to negotiate the use of the “*mechanics of collaboration*” (ibid.). But the time and effort spent on trying to understand the system at the beginning of the use was considerable compared to actually doing something meaningful. Given time, as the group would have become more familiar with the system, continuing the grounding activities and building social norms regarding the use of the system, we would perhaps get another result regarding the balance between coordination of activity and actual work.

In order to address the complex situation of end-user-evaluation, Paper 5 presents an approach for informal ex ante and ex post evaluations of collaborative systems taking advantage of the knowledge of experts in the field. Such alignment activities proved invaluable to my own design process, where the features of the system were guided to a large extent by informal encounters with users, developers and researchers of collaborative technologies. Such exposure to users enabled me to align the development process regarding technological developments (i.e. other similar systems as well as new frameworks that could be used) as well as theoretical developments from for example the CSCW field. It oftentimes also enabled me to observe use of the system by experts.

My work has, in line with many others doing design research, tended to lean more towards relevance than rigor. As argued in this thesis, it is difficult to reach a high degree of rigor due to the complex, social nature of groupware. It is both time consuming and costly to evaluate each study and based on the rapid progress of new technological developments oftentimes not relevant. Paper 5 thus emphasizes continuous alignment activities also to be conducted in regard to new, innovative technologies.

Summarizing my experiences, I would suggest the use of informal evaluation such as the alignment activities described here in order to get a sense of the validity of the system, together with user evaluations in order to see how well the system supports the beginnings of grounding and the emergence of social norms. In order to gain rigor in the research, I would suggest using the “design pattern” approach to communicate results to the design research community in order for researchers to contribute to the understanding of a particular design pattern by implementing and evaluate them in new design endeavors.

8 CONCLUSION

During the work on this thesis I have been in a more or less constant state of amazement at the complexities of designing for technology-mediated interaction and collaboration. Doing research in a field stretching from understanding human behavior in social situations and the intricacies of collaborative activities to the design, development, implementation and evaluation of technical artefacts of a social nature, based on ever evolving hardware and software platforms is challenging.

This thesis was guided by the following research question:

“How should we design real-time shared workspaces to support the coordination of work within small workgroups, and how feasible are the technological frameworks and network infrastructures in providing support for real time awareness?”

The first part of the question is answered on one hand formulated as a set of design requirements, later on becoming design patterns, which have been developed, reaffirmed, rejected and reformed throughout the research process beginning with paper 1 and 2 and finalized in paper 3 and 4.

The second part of the research question is addressed in paper 4 where the Node.js, socket.io, express.js and MongoDB combination was deemed very performant. Performance problems were rather originating from sub-optimal network conditions, where latency and jitter became problematic in relation to being able to work together harmoniously. These issues were the basis of several of the resulting design requirements and design patterns previously presented. Network issues also gave birth to the central theoretical contribution of this thesis, the notion of “self-awareness” in real-time shared workspaces, where users are made aware of their own situation, and becomes confronted with how their actions affect the coordination of the collaboration.

Secondary to the main research question, I have also addressed issues relating to the evaluation of groupware, and how to present these in a clear and coherent way. Due to the complexity of performing rigorous end-user evaluations of systems of that nature, as well as the possibility of these resulting in the rejection of usable designs, we suggest that the development process is complemented by continuously evaluating by using informal “alignment” activities.

Regarding communication of research results, I am in this thesis using “design patterns” to describe the functionality of parts of the system. I argue that design patterns, as a way of communicating design research results, further possess the ability to address the less rigorous alignment practices in that it can provide an inter-study rigor.

By addressing the research question, this thesis fills a gap in research on technology-mediated collaboration. Approaching the area with both a technological as well as a social perspective, spanning from issues relating to network performance through development tools to understanding people in social situations, has given me the opportunity to thoroughly explore not only what we should visualize about the activity of others, but also how to visualize it and the feasibility and constraints of technology.

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