Towards a Collaborative Meeting Environment in a Virtual World

DIPLOMA THESIS

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ABBREVIATIONS

AC	Audio communication
CC	Communication coordination
CMC	Computer-mediated communication
CSCL	Computer supported collaborative learning
CSCW	Computer supported cooperative work
CT	Communication technology
CVE	Collaborative virtual environment
DC	Design communication
FTF	Face-to-face (interaction)
GSS	Group support systems
HCI	Human-computer interaction
LSL	Linden Labs scripting language
MMORPG	Massively multiplayer online role-playing game
SC	Social communication
TC	Task coordination
VC	Video-conferencing
VLE	Virtual learning environment

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DECLARATION

The declaration is written in German (official language of home institution).

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Adelaide, Australien, 05.05.2008

(Oliver Stanek)

ABSTRACT

This thesis addresses the research objective to build an observable collaboration environment within the virtual world Second Life. By understanding the behavior of humans, the aim is to ultimately provide real-time support for virtual teams. Therefore, the central requirement for the environment is support for distributed team meetings, while providing mechanisms for data collection of those meetings at the same time. The work is based on certain theoretical foundations, as well as empirical findings, from collaborative work and virtual environments. In particular, the notions of media naturalness theory are assessed in Second Life.

In order to test the suitability of the created virtual meeting environment for collaboration, a usability evaluation cycle frames the investigation. Several group trial experiments are conducted to elicit requirements for future applications of the environment. The observations inform the design of the environment for the next cycle. The collectable data from the trials comprises chat communication, avatar coordinates, screen-capture video and post-hoc interviews. The chat communication is coded and analyzed. The findings help us support or put into perspective observations made during the trial experiments. An outlook regarding the implications for practice, as well as potential research opportunities in virtual worlds conclude the work.

1 INTRODUCTION

Much working time is spent in traditional meetings [Reidsma et al., 2007]. *"We need software that makes it possible to hold a meeting with distributed participants, a meeting with interactivity and feeling, such that, in the future, people will prefer being telepresent"* [Gates, 1999]. State-of-the art video-conferencing technologies like HP Halo [HP] are not affordable for smaller companies trying to connect individuals who are remote or working as part of a distributed team. Nevertheless, these companies would like to benefit from the advantages of meetings with distributed members (see textbox below [Wainfan & Davis, 2004]). At the same time, we must be cautious not to force enabling tools to replicate face-to-face behavior, but instead to exploit the technology for its potential to make new interactions possible [Stahl et al., 2006]. Indeed, a more cost-efficient solution for distributed collaboration than current video-conferencing tools enables meetings that would not be held at all otherwise (or would be facilitated using less rich communication forms such as email, telephone). Therefore, the means and the practical approach taken by the thesis project are not to replicate the real world, as is done with video-conferencing, but to find, build and evaluate a "small budget" collaboration environment for team meetings.

Benefits of virtual meetings

- **Adaptation to market:** Global competition and mass customization require geographically dispersed teams with optimal members (e.g. specialists, people with local knowledge, or people with different perspectives on a problem).
- **Travel savings:** Time, journey cost, and security/logistics savings (increasing terrorism).
- **Meeting responsiveness and adaptiveness:** Quicker gathering of meeting participants (e.g. no room booking). Additional, demand-driven meetings may be possible because of new, enabling technology. Participants can also be added in response to demand during the meeting itself.

As will be shown in this thesis, collaborative interaction based on computer-mediated communication still suffers from various issues. Only if the behavior of collaborating participants is understood well, can they be supported effectively with IT. Thus, to get a complete picture of human behavior, data should be collected from various environments where people collaborate nowadays, including virtual worlds. *"An uninhabited virtual world resembles a house without people, but it is people that make a house a home"* ([Jakala & Pekkola, 2007, p. 13] quoting [Harrison & Dourish, 1996]). Reflecting on this, and assessing the current state of virtual worlds, the architecture of the house has already been studied well, but the home and its residents offer a suitable research direction [Jakala & Pekkola, 2007]. Thus, we observe the behavior of meeting participants in trial experiments. Second Life, the most famous example in this domain, can be viewed as a tabula rasa – a world whose evolution can be witnessed from its very beginning [Junglas et al., 2007]. Indeed, researchers should be aware not to take the virtual world medium for granted and assume its present form is final (rather than a passage to things to come) [Feenberg & Bakardjieva, 2004]. Second Life may suggest many weaknesses of virtual worlds, but these are generally application specific. Virtual worlds hold a much greater potential than can be grasped at the moment.

The following discovery illustrates the above statement. In the 1990's, neurobiologists first detected *mirror neurons*, which are fired when a primate observes the actions of another primate [Bray & Konsynski, 2007]. Thus they mirror the remote subject's neural activity. Regardless of whether an investigated primate or another primate in the same environment performed the action of grabbing a banana, a similar pattern of neurons fired. The visual cues help to identify and recreate cognitively the action in the environment and to predict intentions or actions of others. Hence, it seems important for humans to see the body and awareness cues of others. Virtual worlds appear to relate to the fundamental structures of primate brains. Namely, virtual worlds challenge the disembodied paradigm of two dimensional online environments like the internet, and introduce avatars with body movements and gestures. This may sound revolutionary or counterproductive in a meeting environment. However, we have naturally adapted to various real world metaphors in the past, even to unnatural ones, such as the two dimensional desktop on our computer. Why not extend the metaphor, and collaborate in a three dimensional meeting environment?

2 RESEARCH CONTEXT

This section is not a literature review in the traditional sense. Besides theoretically grounding the topics addressed in the following practical part, it tries to frame the project with input from related fields. The reason for this is the relatively new domain of research in virtual world collaboration. Gaining a holistic view of virtual worlds remains the challenge [Jakala & Pekkola, 2007]. Research in these environments is still exploring various paths without a common foundation. Some authors recommend to commence research on virtual worlds by studying literature not only for a specific field, but related areas as well for a time period from 2007-2015 [Bray & Konsynski, 2007].

The following research context will also be selective rather than exhaustive, and is intended mainly to illustrate the variety of findings in the field. The reader may find the spectrum broad in comparison to the practical work in the next chapter on the thesis project, but this serves a purpose. By showing which theories, concepts or methods can be applied to collaborative work in virtual worlds, future research will be able to make use of the ideas found in this chapter. Thus, the name *research context* is used to highlight that the scope goes beyond the following *thesis project*. Regarding format, a note on *referencing* is made in the appendix (see 6.1). *Textboxes* illustrate insights or findings from related fields.

Firstly, collaborative work is reviewed. The foundation is laid by an overview of *media choice theories*. Then empirical findings from *CSCW (computer-supported cooperative work)* research are presented, with a special interest in the assisting technologies. At the end of the first part, v*irtual collaboration* is introduced. In the second part of the research context, *virtual environments* are discussed. Two-dimensional environments are contrasted from three-dimensional ones, highlighting that this thesis addresses the latter case. A distinction is drawn between *CVEs* (*collaborative virtual environments)* and *virtual worlds*, the latter often being inhabited by *virtual communities*.

Regarding the extensive literature review presented in this thesis, one could argue that this contradicts with the *grounded theory* approach guiding the data analysis in the later part of the thesis project (see 3.1.2). The following textbox addresses the issue. We follow the recommendations by grounded theory co-founder Strauss rather than Glaser (see textbox).

A grounded theory perspective on the literature review

The literature review might constraint, inhibit or contaminate the study [McGhee et al., 2007]. More likely, it will force the researcher into testing hypotheses, rather than directly observing [Suddaby, 2006]. This could lead to the unfavorable outcome that the researcher overlooks emergent categories and sticks to preconceived notions of what is likely to be observed [Suddaby, 2006]. Glaser mentions cases of near misses of theory discovery: Although theory begins to emerge, literature of close relevance is consulted and its impact diverts the emerging theory from its true path [Heath & Cowley, 2004].

However, it is unlikely that a researcher enters the field in an "atheoretical" state; it is simply not possible to disregard one's prior knowledge ([McGhee et al., 2007] and [Suddaby, 2006]). Indeed, Strauss advocated reviewing the literature early in the study [McGhee et al., 2007]:

- It provides justification for the study
- It allows to discover the extent of previous knowledge and assess whether grounded theory is an appropriate method
- It stimulates questions
- It avoids the researcher to trap in conceptual and methodological pitfalls
- It provides a secondary source of data
- It stimulates theoretical sensitivity
- It provides supplementary validity

2.1 Collaborative work

Collaboration means that partners actually do an activity together, in contrast to cooperation, during which subtasks are solved individually and results assembled [Stahl et al., 2006]. The potential outcomes are performance and satisfaction increases during human interaction. A favorable side-effect from collaboration, compared to simple cooperation, is that articulating designs, arguments etc. encourages the kind of reflection that leads to learning ([DeFranco-Tommarello & Deek, 2002] quoting [Guzdial et al., 1996]).

The field of reviewed theories in collaborative work is narrowed down to media choice theories, because they have proven to be most helpful when explaining the concerns regarding virtual worlds (see 4.2). Other theories highlighting the social interaction during collaboration are mentioned throughout the thesis.

The need for theory

"*There is nothing so practical as a good theory*" ([Barley et al., 2004, p. 122] quoting [Lewin, 1951]. As embedded computational devices are on the rise, the interface is becoming ubiquitous. A tremendous growth in HCI (human-computer interaction, see 2.2.1) can be predicted resulting in the need for appropriate theories guiding the development. Already so far, a survey showed [Rogers, 2004] that practitioners in corporations used concepts of affordance (75%), awareness (65 percent), situatedness (55%) and cognitive offloading (45%). These concepts are products of theory. One must bear in mind that the value of a theory is not measured by providing an objective representation of reality, but rather to enable and form the study of an object drawing attention to important issues [Halverson, 2002]. Theories provide us with a common vocabulary to describe the world we observe. Regarding groups, *"theory helps describe the characteristics that tell us how…groups are the same, as well as how they are distinct"* [Halverson, 2002, p. 262]. According to Halverson, there are four main attributes of theories: Descriptive power, rhetorical power, application power and inferential power (inference meaning a theory should help to make predictions, e.g. consequences of introducing changes in a specific state). Theory must be viewed in stark contrast to practical guidelines, which have no underlying assumptions, and thus suffer from fragmentation, incoherence and context sensitivity [Kuutti, 1996].

However, until recently, theory had a small influence on HCI and CSCW. Assessing the state of HCI in 1996, *"it is generally accepted that the lack of an adequate theory…is one of the most important reasons that progress…is relatively modest, compared with the rate of technological development"*

[Kaptelinin, 1996, p. 53].

The following points could be an explanation for the absence of theory:

- First of all, cognition that happens in human-computer interaction involves many interdependent processes for any activity and a unifying theory explaining the behavior proves to be very difficult. People tend to multi-task, dealing with interruptions and talking to others, so tasks are not carried out sequentially.
- Some research results are used wrongly and inappropriate regardless of context or task when translated into practical guidelines, e.g. "the magical number seven plus or minus two" [Rogers, 2004].
- The time it takes to train for different analytical methods can be a hindrance. While heuristic evaluation, e.g. checklists (1 week training), or cognitive walkthrough (3 months) can be understood rather quickly, cognitive complexity theory (1 year) or GOMS (1 year) consume too much time in enterprise context [Rogers, 2004]. Rogers also mentions that a problem with integrating a variety of theories is that *"only the researchers who have developed the grand theories are able to use them"* [Rogers, 2004, p. 121]. Practitioners already have many methods available to them (prototyping, scenario-based design etc.) and hence theory-informed approaches must be put in perspective to current techniques [Rogers, 2004].
- Another reason for the failure of theory can be found in the success of ethnographers and their methods in the field: Prototypes are mainly evaluated empirically and not theoretically [Barley et al., 2004].

2.1.1 Media choice theories

Old media types tend to stay around, before replacing technologies dominate (e.g. e-learning does not completely replace books in education). Thus with an increasing number of media types, media choice becomes more important [Schwabe et al., 2004]. Media choice importance was demonstrated profoundly when the faulty decision to de-orbit the space shuttle Columbia was made using a combination of e-mail and audio communication: Engineers were feeling that they were not fully understood without meeting the decision-makers face-to-face [Wainfan & Davis, 2004]. The disintegration of the shuttle resulted in the loss of the lives of seven people.

A good estimate regarding media choice in the context of collaborative work is given by *social presence theory*, which predicts that people will use a medium that will allow them the social information necessary for doing a specific task ([Verhulsdonck, 2007] quoting [Short et al., 1976]) Social presence makes a communication interaction warm and personal ([Suh & Shin, 2007] quoting [Hiltz & Johnson, 1990]). Thus for a complex negotiation high social presence (e.g. face-to-face interaction) is required, while for a routine task lower social presence (e.g. chat) is sufficient.

Media stickiness theory [Huysman et al., 2003] suggests that individuals have a tendency to keep on working with a “known media”: The process of structuring media use patterns during the outset constrains later flexibility in terms of media usage. The initial patterns become established and team members find it difficult to switch to another media type [Geer & Barnes, 2007], thus “media stickiness” occurs. To conclude, it seems that people prefer using familiar tools, which are also used by their collaborating partners [Noël & Robert, 2004].

A more low-level approach to media choice is *media naturalness theory*, which is influenced by earlier media choice theories such as media richness and media synchronicity, thus the latter two theories are introduced here to understand the context of former.

2.1.1.1 Media richness

Media or information richness theory [Daft & Lengel, 1984] argues that media which can clarify ambiguous and uncertain issues to promote understanding in a timely manner are considered richer and hence more personal. Media richness is raised by the following attributes:

- Medium's capacity for immediate feedback
- Number of cues and channels available

- Language variety
- The degree to which intent is focused on the recipient

Decreasing richness applies to the following media: Face-to-face, video or audio conferencing, voice mail, email, letter. The higher the equivocality of the task, the more richness a media should provide [Schwabe et al., 2004]. Thus, when plotting media richness on one axis and equivocality on the other, there is an area of effective communication [Reichwald, 2000], which neither overcomplicates (providing too much information) nor oversimplifies (too little information leading to an impersonal feeling). The right media choice (decreasing richness of) is thus aligned with the uncertainty and ambiguity of the task. Smoke signals, although a lean medium, can enable rich enough communication, if the signals allow the communicating partners to exchange the message they want to exchange [Rasters et al., 2002]. The media richness of a workspace can not only by raised by media of higher richness, but also by using a variety of media [Suh & Shin, 2007].

2.1.1.2 Media synchronicity

Media synchronicity theory [Dennis & Valacich, 1999] builds on media richness theory, but changes the perspective for media choice from task to process. Media synchronicity is a dynamic approach, reflecting that communication, group, task-requirements change over time and thus media choice is temporally dependent [Verhulsdonck, 2007].

Two kinds of *processes* are identified:

- **Convergent processes**: Useful for reduction of equivocality (e.g. problem analysis, idea selection) and integration of media with high synchronicity
- **Divergent processes**: Useful for reduction of uncertainty and integration of media with low synchronicity

Media supporting these processes are assessed by five synchronicity *factors*, of which feedback and symbol variety are known from media richness theory; feedback and parallelism have the biggest influence on synchronicity [Schwabe et al., 2004]:

- **Speed of feedback**: How fast is return transmission is possible
- **Symbol variety**: How many ways are available for transmission of one communication thread (e.g. intonation, loudness etc. in a face-to-face conversation)
- **Parallelism**: How many channels are available for transmission of different communication threads at the same time
- **Rehearsability**: The degree to which an information preview is provided and in which way can the information be changed before transmission
- **Reprocessability**: How well can the receiver reuse the information

Synchronicity refers to the extent to which individuals work together at the same time. Fast feedback together with low parallelism leads to high synchronicity, and vice versa [Schwabe et al., 2004]. Depending on the group phase and process involved, media with high or low synchronicity are preferable (see Figure 1). The more group cohesion is formed and common ground established, the less is the need for synchronicity [Schwabe et al., 2004].

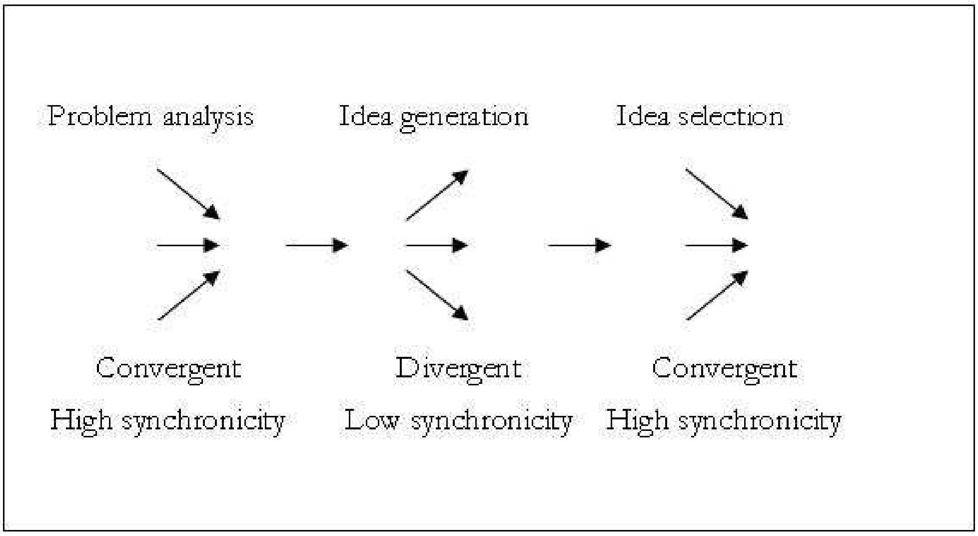


Figure 1: Convergent and divergent processes during problem analysis, idea generation and idea selection (adapted from [Schwabe et al., 2004])

2.1.1.3 Media naturalness

Human-behavior is multi-modal in nature [Poppe & Rienks, 2007]. This leads to a reduction of signal ambiguity during communication, provided that context is known [Poppe & Rienks, 2007]. Context is based around the questions: Who, what, where, when and why. *"In face-to-face exchange, humans employ communication paths simultaneously and in combination, using one to complement and enhance the other"* [Lew et al., 2007, p. 1833]. The question arises, how do current communication media support this fact?

2.1.1.3.1 Foundation

Media naturalness theory [Kock, 2002] can be considered a radical shift, or have profound consequences for technology assessment methods in both HCI and CSCW. It questions media choice theories, not so much because of their followed process or results, but because of their underlying assumptions or their lack thereof. The main contrast of media naturalness towards earlier theories (e.g. such as media richness) is thus its foundation: Media naturalness is based on biological principles, dating back to Charles Darwin. It tries to explain why humans feel comfortable with certain media types and why those technologies lead to more successful outcomes.

In line with media richness, media naturalness theory argues that communication media which suppress face-to-face communication elements are less suitable for human interaction. Media richness theory calls these media less rich, or lean. Kock notes: *"The problem with this notion is that its focus on the communication medium leaves out the communicators, which themselves may possess characteristics that make communication through different media more or less difficult"* [Kock et al., 2007, p. 335]. The focus on media choice cannot explain such phenomena as students choosing an online delivery format to avoid certain problems like long commute times [Kock et al., 2007]. In fact, media richness theory largely ignores the social environment and context in which communication takes place. Furthermore, as Kock observed, *"no underlying explanation was ever presented by media richness theorists for our predisposition toward rich media"* [Kock, 2005, p.117]. Thus, media naturalness includes the missing element of modern organizational theories, namely "human nature". Kock mentions that *"Darwinian evolution endowed modern humans with a brain that is ill adapted to CMC"* [Kock, 2004, p. 341]. In the light of the incompatibility of rational choice theories and social theories without radical changes ([Kock, 2004] quoting [Ngwenyama & Lee, 1997]), it seems very advantageous that media naturalness is compatible with social theories of electronic communication behavior. Thus it has the potential to fill a gap.

2.1.1.3.2 Human evolution

Evolutionary synthesis

Darwin formulated his theory of evolution, now known as the evolutionary synthesis, in 1859. It built on three laws, namely:

- Inheritance (i.e. characteristics are passed on through genes)
- Mutation (i.e. natural changes occur that lead to different characteristics)
- Natural selection (i.e. the offspring with the best characteristics survive and mate, leading to inheritance)

Several evolutionary *principles* have been observed, which are relevant for communication:

- The principle of *brain-body coevolution* explains *"the gradual evolution of certain characteristics of our body…accompanied by the evolution of specialized brain functions that process stimuli sensed by those organs and control their operation"* [Kock, 2004, p. 331]. Over time, humans have developed a complex web of facial muscles, which allow for over 6000 communicative expressions [Kock, 2002].
- The principle of *evolutionary cost* states that adaptations that present a higher cost, are more vital for the designed process than others [Kock, 2004]. The qualities of conveying and listening to speech in the expressive-perceptive dimension (facial expressions, body language, speech) are likely to be more relevant for the designed process, namely communication, than the other qualities in that dimension. This can be illustrated by looking at the higher cost of speech for humans. The larynx (i.e. the voicebox organ in the lower part in the neck) and an enlarged vocal tract allow modern

humans to generate the variety of sounds required to speak most languages, at the cost of having an increased risk of choking when eating ([Kock, 2005] quoting [Laitman, 1984] and quoting [Lieberman, 1998]). Another indicator of humans' physical adaption to communication behavior is the favorable morphology of the ear to decode speech ([Kock, 2002] quoting [Lieberman, 1998] and [Pinker, 1994]).

- The principle of *repeated use* suggests the correlation between the degree of evolutionary optimization of a set of organs and the number of generations in which those organs are repeatedly used for that purpose [Kock, 2004].

Evolution is generally a slow process that takes time to catch up with change, resulting in the suboptimal outcome that humans are adapted not to the current environment, but to previous surroundings of which they are a product. Kock mentions two examples (of which the second one directly relates to our discussion):

- Humans' strong desire for fat, which made sense in earlier times, but now provokes clogged arteries and heart attacks [Kock, 2005].
- Writing was first used by the Sumerians only 5000 years ago, which is an irrelevant time frame compared to the period of face-to-face communication. ([Kock, 2007] quoting [Martin, 1995]). Additionally, writing served the purpose of record-keeping rather than as a tool for communicating information [Kock, 2007]. In fact, during more than 99 percent of our species existence, we communicated in a synchronous and collocated way [Kock, 2002].

Resulting from the above mentioned principles and discussion, it seems obvious that our communication apparatus has evolved for rich face-to-face interaction including gestures and body-language. Therefore, media naturalness theory suggests that any other form of communication, e.g. messaging through email, is unnatural to us.

2.1.1.3.3 Compensatory adaptation

What can explain the success of virtual teams using lean media? According to Kock's *compensatory adaptation model,* there are lean technologies to which humans adapt in a way that does not just compensate the negative characteristics, but overcompensate them [Ned Kock et al., 2006]. Overcompensating can be a result of overestimating and compensating for the perceived additional effort ([DeLuca et al., 2006] quoting [Pinker, 1997]). In a study using asynchronous electronic communication media, participants processed their messages before sending to make them more focused, clear, precise, neutral, concrete, persuasive and complete [DeLuca et al., 2006]. The process of becoming familiar with a communication medium or adaptation in general happens often involuntarily. The outcome may be a positive effect on task outcome quality compared to the situation without obstacles. For instance, users of lean media generally make more elaborate, higher-quality verbal participation than the same subjects would in face-to-face meetings [Kock, 1998]. Kock mentions email as another example. Email is lower in media naturalness than face-to-face communication due to the lack of collocation, the absence of facial expressions, body language and speech. Nevertheless, it is higher in naturalness than paper-based mail because of the increased synchronicity. Furthermore, due to its widespread application in both personal and organizational contexts and its cost benefit, email still improves efficiency [Kock, 2002]. This also explains the success of chat tools in certain business situations, as the synchronicity compared to email is again increased significantly [Kock, 2005].

In summary, the compensatory adaptation theory argues that the indirect positive effect of adaptation (e.g. procedural structuring such as process coordination or reviewing) is stronger than the direct negative effect of electronic communication on team effectiveness. In the case of procedural structuring, "stronger" has been measured by Kock et al. to equal a 41% performance plus [Ned Kock et al., 2006]. In the same line, Fraser et. al. mention that in the case of collaborative virtual environments, individuals will become increasingly familiar with a limited system, in such a way that they develop practices to address those limitations [Fraser et al., 2000]. Hence, changing the appearance of a system might be interpreted disruptive by the users [Fraser et al., 2000].

2.1.1.3.4 Naturalness

According to media naturalness theory, there are certain attributes of *face-to-face communication*, which lead to natural communication:

- A high degree of collocation
- A high degree of synchronicity
- Ability to convey and observe facial expressions
- Ability to convey and observe body language
- Ability to convey and listen to speech

Precisely, interacting in a different manner than face-to-face leads to the following three *consequences*:

- **Increased cognitive effort**. Not all of our brain circuits are hardwired, but learned over time. Learned circuits require increased neural activity, which leads to more mental effort. Such an increased effort is temporally measurable for different media. *Communication fluency*, which is the number of words conveyed per minute through a communication medium, has been shown to be significantly lower for electronic communication than for face-to-face interaction [Kock, 1998]. This is because humans adapt their behavior in a compensatory form (see 2.1.1.3.3). An illustrative example is the composition of precise contributions to an electronic discussion forum, which takes up more time than to converse face-to-face [Kock, 2007]. Thus, the mediums naturalness comes at a communicative cost that can be overcome with added cognitive load [Verhulsdonck, 2007].
- **Increased communication ambiguity.** Due to the lean characteristics of electronic communication, conversation is not clear without ambiguity. Humans try to substitute missing information ("fill in the gaps") with existing knowledge bases, e.g. learned information processing schemas (see 2.1.1.3.3) [Kock, 2007]. This reaction is also called *compensatory decoding* [Kock, 2007]. A result might be interpretive errors like understanding constructive criticism as a personal attack [Kock, 2007]. The opposite equivalent at the sender is *compensatory encoding*, i.e. to enhance and extend information

in such a way to make up for the absence of communicative stimuli. Encoding was observed in telephone communication, where a higher presence of verbal expressions of agreement and disagreement than in face-to-face communication was observed ([Kock, 2007] quoting [Short et al., 1976]. Also, individuals from different cultural backgrounds exchange more personal information in electronic than in natural communication ([Kock, 2007] quoting [Walther, 1997]). Resulting from encoding and decoding, electronic communication is generally more ambiguous than face-to-face communication. A new finding is that the burden of compensating mainly falls on the sender and not on the receiver [Kock, 2007]. Comparing perceived compensatory coding effort between a face-to-face interaction and a web-based communication medium, the increase for senders (encoding) was 26%, while for receivers (decoding) it was statistically insignificant [Kock, 2007]. Consequently, electronic communication tools or human-computer interfaces in general should be designed to facilitate compensatory adaptation by encoders [Kock, 2007]. Especially in the case of a high number of complex ideas to be conveyed, more natural encoding mechanisms may prove helpful for the sender. An example would be video or audio attachments to emails [Kock, 2007]. Low naturalness has been empirically shown to have a stronger effect on communication ambiguity than on cognitive effort or physiological arousal [Kock et al., 2007]. In an experiment of online learning (which is low in naturalness), the communication ambiguity factor increased most, i.e. by 18% at the middle of a semester, in relation to a traditional course. At the end of the semester, online learning did not have relevant effects, which in turn can be explained by compensatory adaptation [Kock et al., 2007].

- **Decreased physiological arousal**. Many organs assume environmental circumstances which were present during most of the time in our past. Dawkins mentions the example that the eye is dependent on proper light stimulation during the first years of life, otherwise eyesight problems or even blindness might arise ([Kock, 2002] quoting [Dawkins, 1988]). Consequently, if certain elements of face-to-face communication are suppressed, this results in a corresponding suppression of physiological arousal and thus, less excitement in the communication interaction. This effect could explain the partial commercial success of virtual news anchors, as humans seem to prefer to listen to news than the less exciting alternative of reading information ([Kock, 2005] quoting [Cracknell, 2000] and quoting [Gilbert, 1999]). However, only if the immediacy of other's people presence within the same space is monitored our physiological senses are aroused to full extent [Verhulsdonck, 2007].

2.1.1.3.5 Consequences

The practical implications of Kock's ideas are described in several studies in literature. For example, a study by Reinig et al. showed that the use of group decision support systems makes meetings less exciting ([Kock, 2005] quoting [Reinig et al., 1995]), i.e. a lower physical arousal is provoked in terms of media naturalness. The quality of the ideas is usually lower, but the contrary is true for the quantity ([Kock, 2005] quoting [Dennis et al., 1996]). Unfortunately, the additional generated information cannot be turned into better task outcomes, as the information processing capability of humans is lower than the information exchange rate [Kock, 2005]. In media naturalness terminology, the cognitive effort is raised substantially when using electronic communication.

Media naturalness theory's contribution mainly lies in explaining why certain media types are less suitable and to improve understanding how humans adapt to this situation (e.g. overcompensation). It is important to know that media naturalness does not suggest that face-to-face communication is the most suitable communication style for any situation, or even for particular situations like e.g. a business meeting. In this regard, it has been shown that media leanness is an unstable predictor of success or failure for specific tasks. The following factors point to the social factors determining media choice ([DeLuca et al., 2006] quoting [Gasson, 2005]):

- Sponsorship by influential stakeholders
- Using a familiar technology (see media stickiness, 2.1.1)
- Choosing a media which causes the smallest disruption to daily business
- Choosing a media with no written record for political aspects

The absence of nonverbal cues can also have a positive influence on multi-cultural virtual teams, whose members may interpret nonverbal cues differently [DeLuca et al., 2006].

Another example where the suppression of face-to-face attributes can prove favorable in a business context is counterproductive gossiping. Kock mentions in this context the *Machiavellian intelligence hypothesis* ([Kock, 2004] quoting [Byrne, 1995]), i.e. humans in a group act in a specific manner so to ensure favorable reactions toward them in the future. This strategy serves both the individual purpose and does not disrupt the social group cohesion at the same time. Gossiping, in this view, has thus come up mainly to serve social grooming. Electronic communication weakens the "gossip instinct" and makes communication more focused and objective [Kock, 2004].

2.1.2 *Empirical findings*

Technologies like Microsoft Surface show the broad applicability of emerging collaborative tools: Surface is a multi-touch product which enables the manipulation of digital content by the use of natural motions, hand gestures and physical objects [Microsoft (b)]. The empirical findings from computer-mediated group work, which helped to enable such tools, date at least twenty years back.

2.1.2.1 Computer supported cooperative work (CSCW)

The field of CSCW emerged from a workshop in 1984, focusing on the role of the computer in group work [Crabtree et al., 2005]. The term *groupware* was coined already before and is now used to describe specific technology in CSCW [Penichet et al., 2007]. Groupware must support both task- and teamwork [Nicolopoulou et al., 2006]. The most basic classification of groupware is according to Johansen's time-space matrix in Figure 2 [Johansen, 1988]. The more complex systems became, the harder it became to classify them in one of the four categories according to the matrix [Penichet et al., 2007]. Potential "anytime/anyplace" infrastructure and systems integrate all four categories, but largely remain in theory [Anson & Munkvold, 2004].

Place / Time	**Same time**	**Different time**
Same place	Synchronous, face-to-face interaction (e.g. meeting)	Asynchronous, non-real time local interaction
Different place	Synchronous, distributed interaction (e.g. chat)	Asynchronous, non-real time distributed interaction (e.g. email)

Figure 2: Interaction according to the Johansen time-space matrix [Johansen, 1988]

Tasks in real-world scenarios are usually not well-defined [Clement, 1990]. Over time, CSCW started to understand the socially organized nature of work to successfully embed tools in the workplace, thus a situated approach became salient (see textbox) [Crabtree et al., 2005]. Computing in general is a far-reaching intervention into a social system [Clement, 1990]. Human activity is based on experience, flexible and contextualized; this must be reflected by computational entities (e.g. such as roles and policies) [Ackerman, 2000]. The contextualized nature of human behavior is inherent in language: Speech is evaluated not so much in terms of its semantics (meaning), but by its felicity (appropriateness to context) ([Carasik & Grantham, 1988] quoting [Austin, 1962]). Overall, for CSCW tools to be intelligent, "emotional skills" are necessary [Lew et al., 2007].

Situatedness

Situated action researches the relationship between actions, by studying how people make use of circumstances to achieve intelligent action, rather than attempting to abstract action away from its circumstances ([Rogers, 2004] quoting [Suchman, 1987]). The focus lies on the user's particular situation. The contribution for CSCW *"has been descriptive, providing accounts of working practices, and on the other, it has provided a backdrop from which to talk about high-level concepts, like context"* [Rogers, 2004, p. 117]. Situated action implies a *situated cognition*.

Situated cognition stresses the distributed nature of cognition between a person and his or her tools [Dieterle & Clarke, 2006], which may be relevant in the context of learning or teaching. For example, the cognition of a person who reads a book resides neither solely in the head, nor in the book, but is dependent on both [Dieterle & Clarke, 2006]. Looking at the social distribution of cognition: *"A process is not cognitive simply because it happens in a brain, nor is a process noncognitive simply because it happens in the interactions among many brains"* ([Dieterle & Clarke, 2006] quoting [Hollan et al., 2000]). For instance, apprenticeship incorporates learning within a social context: The apprentice observes the master until skillful at the task, then the master's presence fades away to provide just-in-time support when needed [Dieterle & Clarke, 2006]. Situated cognition also implies that a situated action is dependent not just on the circumstances, but also on the actor. The mood, feelings, boredom or the mental state in general of the actor thus have a profound influence on situated action [Ciborra, 2002].

2.1.2.1.1 Computer-mediated communication (CMC)

In line with Wainfan & Davis, CMC spans both asynchronous and synchronous textual media (e.g. email, forums, chat), but is separated from audio and video communication [Wainfan & Davis, 2004]. Choosing which form of input and output media for a groupware application is a crucial task (see textbox).

Communication characteristics

Regarding voice and text, the following statements can be made [Grudin, 1988]:

- **Input (speaker):** Speech is much faster than even the fastest typing, and it is easier to convey emotions.
- **Output (listener):** Reading is faster than listening. However, words with different, or even opposite meanings depending on the context (e.g. anxious: "Excited" vs. "filled with anxiety") are particularly sensitive to CMC [Wainfan & Davis, 2004]. On the other hand, voice messages cannot be reviewed and manipulated as easily as written messages.

Recent research suggests that face-to-face groups show high levels of consensus and perceived quality, communicate often and are more efficient than computer-mediated groups [Fjermestad, 2004]. However, CMC groups are sometimes the only viable option. CMC groups have a difficulty with the lack of social presence, especially if prior activity in the group or with the tool is missing ([Fjermestad, 2004] quoting [Berdahl & Craig, 1995]). In fact, compared to face-to-face interaction, CMC groups show the following general characteristics [Wainfan & Davis, 2004]:

- Have a difficulty reaching consensus
- Have greater equality of participation
- Take longer to reach a decision
- Exhibit lower inhibition
- Are more likely to be polarized

Difficulty reaching consensus might be an unexpected result of equality of participation. Although equality of participation exists, this does not necessarily democratize a group: Lurking, the non-participation of certain group members is prevalent in CMC [Wainfan & Davis, 2004]. Being more polarized leads to more extreme thinking (e.g. expression against out-groups, such as participants further away or in different companies, were found to be more likely with CMC than in face-to-face interaction) [Wainfan & Davis, 2004]. The slow pace of typing and the effort needed can further lead to messages perceived as less polite than in face-to-face interaction [Wainfan & Davis, 2004]. It is believed that CMC participants make more explicit proposals, because non-verbal cues are eliminated entirely [Wainfan & Davis, 2004]. Another influence for this can be that behavior in CMC is characterized by a reduction of concerns for self-presentation and judgment [Wainfan & Davis, 2004]. CMC experiments show that such groups not only make more extreme, but also riskier decisions [Matarazzo & Sellen, 2000]. To conclude, face-to-face meetings are most useful for ambiguous tasks such as managing conflicts or setting the strategic direction, while CMC suits for structured, routine tasks ([Powell et al., 2004] quoting [Majchrzak et al., 2000]).

Chat

Chat is a popular example of CMC. First, it is better for documentation and later analysis than audio or face-to-face conversations [Wainfan & Davis, 2004]. Second, it scales up better to an increase in group size than audio communication.

The following empirical findings from Löber illustrate the latter statement [Löber et al., 2007]: Chat groups thrive when increasing the group size from four to seven members, while audio groups in comparable size show a stagnating performance, i.e. the additional members are a waste of resources. Satisfaction is high for big chat groups and small audio groups, thus the prediction of media richness theory that audio groups are generally more suitable for task of equivocalty is only true for smaller groups. However, media synchronicity theory can explain the positive result of larger chat groups, because of the integration of the parallelism factor: Parallelism is high for chat, because humans can read faster than they converse. The slow information production in chat becomes irrelevant because of the many synchronous threads, and the fast information reception dominates. For smaller groups audio showed performance advantages by the improved feedback and multiplicity of clues. Regarding satisfaction in audio, the requirement to passively listen without any chance of input upset the participants. It must be noted here that the privacy and control advantage of instant messaging (a special chat form) may explain the success of the chat medium in some cases, too. Users can control what information they want to broadcast to others, and the signal itself is much less informative about what exactly the individual is doing [G. M. Olson & Olson, 2003]. This can explain the success of anonymous CMC in brainstorming [Wainfan & Davis, 2004].

2.1.2.1.2 Group Support Systems (GSS)

GSS, like groupware (see 2.1.2.1), commonly describe the group technologies to realize CSCW. Overall, an increasing rate of successful adoption of GSS can be observed over time. A reason for this can be the organizational conditions, which in the 1990s (e.g. peer pressure or reward schemes) were more favorable than in the 1980s ([G. M. Olson &

Olson, 2003] quoting [Palen & Grudin, 2002]). Looking at 15 years in the field, meetings can be successfully supported with GSS and large groups seem to benefit more from GSS than smaller ones [De Vreede et al., 2003]. Studies at IBM and Boeing demonstrated the successful introduction of GSS. However, it is generally difficult to elicit such findings: Organizations are seldom interested in spending time filling out questionnaires or present data in public [De Vreede et al., 2003].

In a meta-analysis of 61 studies ([Wainfan & Davis, 2004] quoting [Dennis, 2002]) *comparing GSS with face-to-face interaction*:

- For distributed GSS, decision quality was lower.
- For same-place, synchronous GSS, decision quality and quantity (number of generated ideas) was higher, but it took longer and the process satisfaction was lower. In detail, satisfaction was higher for GSS idea generation (divergent process) than for GSS decision-making (convergent process).

The special field of *GDSS (group decision support systems)* embodies various brainstorming and voting procedures [G. M. Olson & Olson, 2003]. Decision making is potentially assisted by providing templates; flagging potential issues for evaluation; providing descriptive statistics; suggesting action; taking preprogrammed action to mitigate detected issues [Wainfan & Davis, 2004].

Group research

GSS builds on insights from related, non-technical fields. McGrath formulated a theory called TIP (time, interaction, performance) focusing on "how groups do what they do" [McGrath, 1991], and stressing the insight of contextual influence. A group has multiple *functions*: Production function, member-support function and group well-being function [McGrath, 1991]. Each function can be active in one of four alternative non-sequenced *modes*: Inception (goal choice), problem solving (means choice), conflict resolution (policy choice) and execution (goal attainment) [McGrath, 1991].

2.1.2.1.3 Difficulties

A *social-technical gap* is identified in CSCW, which divides what we know must support socially, and what we can support technically [Ackerman, 2000]. CSCW has come up with a set of first-order approximations, i.e. they partially solve a problem with known trade-offs [Ackerman, 2000]. Thus, determining guiding research principles is difficult when a science is still seeking approximations to its problem [Ackerman, 2000]. Furthermore, a cultural gap concerning CSCW publications is mentioned by Grudin: *"Philosophically oriented European submissions often strike empirically oriented American reviewers as lacking in content: American contributions strike European reviewers as unmotivated or shallow"* [Grudin, 1994, p. 23].

Instead of saying what makes groupware successful, it is easier to state what complicates the design process or why CSCW applications can ultimately fail:

- **Principal-agent relationship**: Employees lower in the hierarchy must do extra work when using an automatic meeting scheduler, but they do not benefit from it, in contrast to managers [Grudin, 1988]. *"The application fails because it requires that some people do additional work, while those people are not the ones who perceive a direct benefit from the use of the application"* [Grudin, 1988, p. 86]. Managers, like other individuals, share the intuition that what will be useful to people similar to ourselves is generally good [Grudin, 1988]. Thus to counteract this misleading thinking, it should be the aim in an organizational context that every user benefits by employing the application [Grudin, 1988]. It should be noted that discrepancies between "who gets the benefit and who has to do the extra work" can lead to a failure of groupware, but it is not a necessary condition (e.g. extra work might be regarded as a good job) [Bowers, 1994].
- **Individuality**: People act towards technology on the basis of their understanding of it: Individuals are used to personal computing environments and cooperative applications are difficult to grasp [Orlikowski, 1996]. For example, writing is usually a solitary task and thus it is unrealistic to expect people to abandon their favorite word processor for a new, collaborative tool (see media stickiness, 2.1.1) [Noël & Robert, 2004]. Thus it is required to change people's technological frames to accommodate a new technology, e.g. by giving concrete demonstrations [Orlikowski, 1996]. Individuals have different backgrounds and different IT literacy. Different learning stages in the adoption of

groupware also mean that the user interface should be personalized to suit the individual's needs, thus avoiding information overload for a novice, but offering adaptive features for a professional user.

- **Organizational incentives**: Users need to feel in control of the system in order to accept it [Carasik & Grantham, 1988]. This not only requires "user empowerment", but extensive training and support, which may imply substantial changes in an organization [Carasik & Grantham, 1988]. If organizational structures like incentives, reward systems and work norms are missing, groupware is unlikely to engender collaboration [Orlikowski, 1996]. Orlikowski mentions that in corporations a specific, client-related task is needed to internalize the use of a technology, otherwise the pressure of daily production tasks and deadlines will tend to dominate individual's decisions around how they allocate time [Orlikowski, 1996]. Assimilation patterns of conferencing and groupware technologies were also found to vary across geographical regions [Bajwa et al., 2007], reflecting the different cultural background and organizational patterns.
- **Privacy**: Being a tool also implies that the user should have the discretion if one wants to use it [Clement, 1990]. People have a very nuanced behavior concerning which information they want to share (e.g. the tendency to resist articulating hidden or conflicting goals), nonetheless systems often assume a shared understanding of information ([Ackerman, 2000] quoting [Goffman, 1971] and quoting [Suchman, 1987]). The technology may provide information without knowledge of the user: *"In one example of unintended consequence of technology, when US team members downloaded work only minutes before planned real-time meetings, the Dutch participants interpreted their timing as a lack of preparation, harming group relations"* [Steinfield, 2002, p. 105]. Furthermore regarding privacy, some groupware records information that participants would prefer not to leave the meeting room [Grudin, 1988]. The WYSIWIS approach (what you see is what I see) is too constraining because users wish for a certain independence [Elmarzouqi et al., 2007]. A study by Orlikowski showed that Lotus Notes was mainly used as an individual productivity tool in an organizational context (rather than as a collaboration tool) [Orlikowski, 1996]. Managers feared that if they share ideas they may loose status, control, promotion opportunities and prestige [Orlikowski, 1996].

- **Heterogeneous groups**: CSCW tools must, but often fail to enable the tacit knowledge transfer in a group [Convertino et al., 2005]. The following insight demonstrates the need for knowledge transfer in heterogeneous groups.. As technology evolves, so too does the generation developing with it [Simon, 2006]. Overall population is aging at a fast rate, this calls for research oriented toward capitalizing on the knowledge and skills (e.g. domain expertise, highly refined social skills) that older workers possess [Convertino et al., 2005].

- **Group norms**: People inhabit states that are only partially determined and seldom made explicit [Ackerman, 2000]. Group norms are usually not explicit, either, but should be included in the groupware software to trigger a natural reaction [Carasik & Grantham, 1988].

- **Process rigidity**: Group dynamics, interpersonal relationships and individual user's satisfaction make it hard to capture work into clearly defined tasks [Nicolopoulou et al., 2006]. Process rigidity imposed by tools does not reflect real-world processes [Convertino et al., 2007]. Users do not always have prefixed goals when entering a system. This brings into question that a linear sequence of correct actions leads to a goal [Nicolopoulou et al., 2006]. An example is the rigidity of knowledge management systems, which impose structure prematurely on information, while workers are still in the midst of forming their own categories [Convertino et al., 2007].

- **Local configurations**: Groups who want to benefit from the collaborative features must use compatible software versions and system infrastructure across sites, which was found to be seldom the case ([Noël & Robert, 2004] quoting [Cohen et al., 1999]). Additionally, people not only adapt to their systems, they adapt their systems to their needs ([Ackerman, 2000] quoting [Orlikowski, 1992]).

- **Costs & Economies of Scale**: Introduction of groupware in a company triggers resistance, often because it is simply considered too expensive by management to buy, install and maintain [Lewis et al., 2007]. Due to the innate design of groupware, a critical mass of users is necessary for success, otherwise the costs are greater than the benefits.

2.1.2.2 Virtual collaboration

Collaborative work is especially useful for complex, unfamiliar problems which require expertise from several fields [Vinsonhaler et al., 1998]. Thus, such work is often dispersed, including participants with multidisciplinary background. This phenomenon is reflected in today's organizational context of globalization. "*Global competition, reengineered product life cycles, mass customization, and the increased need to respond quickly to customers' needs are just some…trends currently driving organizational change. Increasingly, successful organizations are those organized in a dynamic network form that, using Information Technology (IT) as a primary enabler, can more quickly adapt to ever-changing competitive landscapes and customer requirements. One of the building blocks of these successful organizations is the virtual team*" ([Powell et al., 2004, p. 6] quoting [Grenier & Metes, 1995] and quoting [Davidow & Malone, 1992]).

The term *virtual collaboration* is introduced here, to stress the partially or fully distributed nature across time and space of such teams [Beise et al., 2003]. Teams, in contrast to groups, necessarily display high levels of interdependency and integration among members [Powell et al., 2004]. Distributed teams that are brought together by information and telecommunication technologies to accomplish organizational tasks (often in response to specific needs) are called *virtual teams* [Powell et al., 2004]. Virtual teams participate in distributed, *virtual meetings*. Increasing terrorism leads to rethinking face-to-face gatherings, especially meetings with high-profile members. Besides giving mental freedom, virtual teams offer great travel cost and security savings. Traditional distributed teams cope with the cost and stress of frequent travel and have to deal with repeated delays ([Hinds & Bailey, 2003] quoting [Armstrong & Cole, 2002]). Nowadays, virtual teams may, at times, be the only viable option for achieving organizational goals [Hinds & Bailey, 2003]. Virtual teams can adapt to the technology and overcome the limitations by developing a shared language after a certain time ([Powell et al., 2004] quoting [Hollingshead et al., 1993]). Additionally, task performance in a virtual team is significantly influenced by relational development [Suh & Shin, 2007]. In the case that meeting participants know each other, they form a community [Nijholt et al., 2004]. They share knowledge, culture, ideas, feelings and goals. Having shared goals allows self-disclosure during breaks, lunches etc. and smoothens exchanges during follow-up meetings [Nijholt et al., 2004]. Periodic face-to-face meetings, team-building exercises, formulating a media strategy, and a clear team structure are further seen as necessary to successful team development [Powell et al., 2004]. The importance of informal communications (e.g. "getting acquainted" activities) among team members has been noted, which in turn fosters the sharing of work-related information [Redfern & Naughton, 2002]. However, virtual teams are mostly short-lived and disbanded after project completion, with members often re-structuring in different, newly formed teams [Powell et al., 2004].

"The virtual environment presents considerable challenges to effective communication including time delays in sending feedback, lack of a common frame of reference for all members, differences in salience and interpretation of written text, and assurance of participation from remote team members. Moreover, nonverbal communication, an important component of team communication, is usually missing in virtual teams" [Powell et al., 2004, p. 11]. Distribution can have negative effects such as that remote partners are blamed for one's own performance ([Pena et al., 2007] quoting [Walther & Bazarova, 2007]). The combination of a lack of awareness and little social relations can weaken trust among remote participants [Steinfield, 2002]. Conveying contextual information on purpose is a way to deal with ill effects of distance [Hinds & Bailey, 2003].

Media choice

Building on media choices theories (see 2.1.1), one strategy among many for selecting the best medium for virtual collaboration is presented in Figure 3 (VC=video-conferencing, AC=audio-communication, FTF=face-to-face).

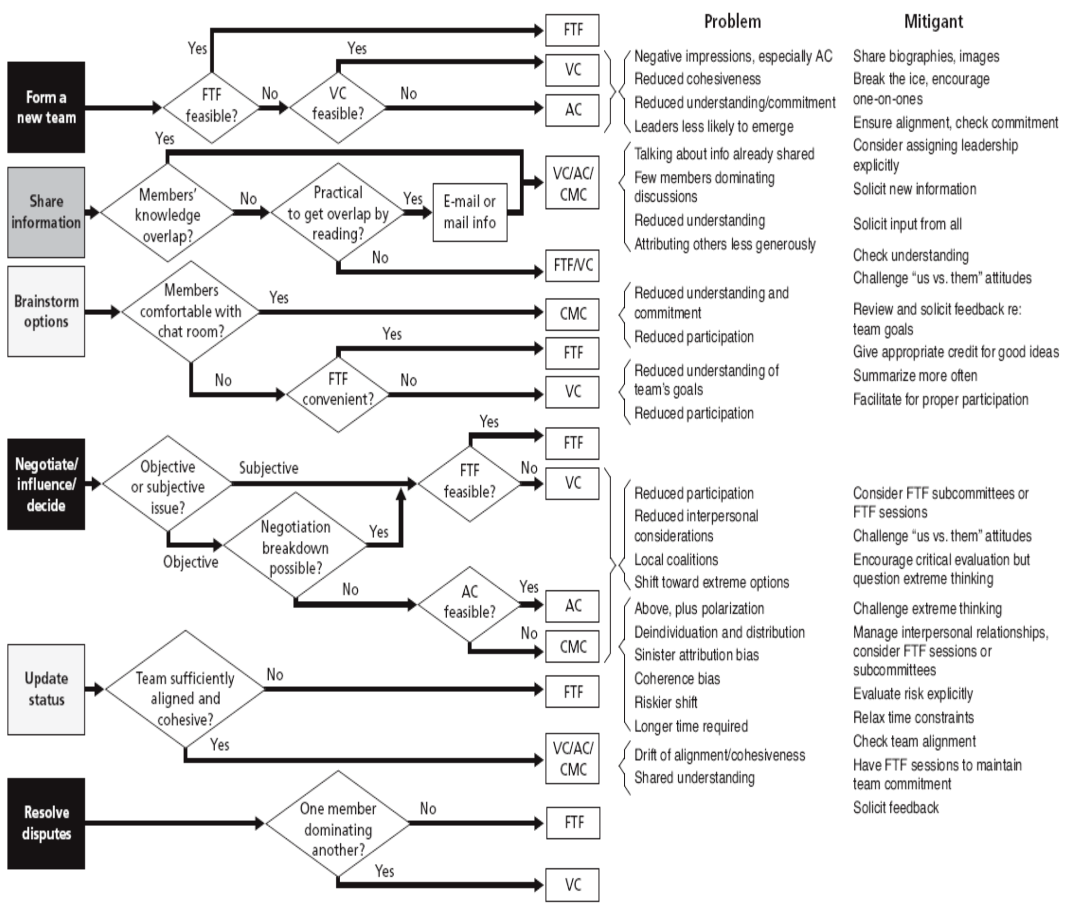


Figure 3: Strategy for selecting the best medium for virtual collaboration [Wainfan & Davis, 2004]

No unifying theory of virtual teams exists [Powell et al., 2004], but some authors have come up with empirically proven success rules for virtual teams, such as [Walther & Bunz, 2005]:

- communicate frequently and be explicit about what you are thinking and doing
- making sure that all members are included on all messages
- acknowledge that you read one another's messages
- set deadlines and stick to them
- multitask getting organized and doing substantive work simultaneously

Future research should on one hand address more closely the personal characteristics of members in high performing virtual teams; and research needs to focus on the context, namely when virtual teams are appropriate, beyond simply comparing them with traditional teams [Powell et al., 2004]. Because of the very nature of distributed teams, observational studies will require teams of like-wise distributed researchers [Hinds & Bailey, 2003].

2.2 3D-Virtual Environments

The concept of 3D-virtual environments, also know as augmented or *virtual reality*, dates back to the work by Ivan Sutherland in the 1960s [Myers, 1998]. Sutherland already noted in 1965: *"The screen is a window through which one sees a virtual world. The challenge is to make that world look real, act real, sound real, feel real"* ([Fraser et al., 2000, p. 27] quoting [Sutherland, 1965]).

Hardware technology like 3D-graphics systems and high bandwidth networks enabled virtual reality to enter a new domain in the early 1990s: CVEs (Collaborative Virtual Environments) [Shao-Qing et al., 2004]. CVEs now coexist with *virtual worlds*, but the term became popular around five years earlier than our current understanding of virtual worlds (Redfern & Naughton, 2002). The distinction between the two terms still makes sense, as not every virtual world is a collaborative environment in the true sense (i.e. if the world does not include mechanisms for collaboration). CVEs were mainly developed out of research interest, while virtual worlds are commonly backed by commercial companies. Virtual worlds are targeted at a large number of users represented as avatars (see 2.2.3.1), resulting in the formation of virtual communities (see 2.2.3.2)

Before reviewing CVEs and virtual worlds, a chapter on *environment design* follows. Virtual places are still often created by programmers rather than designed as places like traditional buildings. A well-designed virtual place is becoming increasingly important in order to cope with the growing complexity in virtual worlds [M. L. Maher et al., 2000].

2.2.1 *Environment design*

Regarding the user experience in 3D-environments, it makes sense to differentiate between *sensation* (what our organs sense) and *perception* (what we actually perceive). Perception is a cyclic process during which we continually try to make sense of the stimuli input. This process is based on our knowledge of the world and thus guided by what we expect to perceive ([Fabri et al., 1999] quoting [Neisser, 1976]).

It is argued that we are able to adapt our perception to the clues given by the interface of a CVE or virtual world (e.g. through internalizing the consistent visual feedback) [Fabri et al., 1999]. Consequently, the virtual environment does not have to be an exact simulation of the "real world" [Fabri et al., 1999], which is also a much more realistic goal. Indeed, virtual environments do not necessarily need to reflect real environments, or provide a sense of realism, to accomplish particular forms of interaction and potentially collaboration [Fraser et al., 2000]. Moreover, it is important to maintain a balance between behavioral fidelity and increasing levels of realism [Vinayagamoorthy et al., 2005]. Otherwise there is a danger of trying *"to create an illusion of place without considering the fact that place is formed by people and their activities"* [Pekkola, 2002, p. 136], which was the case with the wide-screen immersive display CAVE [Park et al., 2000]. We are located in *space*, but act in *place*. Only the latter includes understandings of behavioral appropriateness and cultural expectations [Harrison & Dourish, 1996].

Influencing field: HCI

HCI (Human computer interaction) has lately attempted to tackle design in 3D-virtual environments. Such design encourages social interaction among users and is termed *sociability design:* For example, some locations can be constructed in such a way that people have to wait and socialize there [Ang et al., 2007].

The interest in HCI started with the boom of personal computers in the early 1980s and looked mainly at the underlying cognitive processes [G. M. Olson & Olson, 2003]. Evaluation was concerned with single-user, task-oriented scenarios, which were defined by the projected use and user [Poppe & Rienks, 2007]. The abundance of theories relating to the field of HCI makes it difficult to pin down the relevant ones for a specific task. Therefore, to structure the problem, Shneiderman has identified five main types of theories in HCI: Descriptive, explanatory, predictive, prescriptive and generative ([Rogers, 2004] quoting [Shneiderman, 2002]).

Good HCI design is evolutionary rather than revolutionary, thus multiple generations can learn how to use an interface and do not have to worry about loosing those skills at a later stage [Canny, 2006]. Four principles for ideal interaction design are: Controls are visually obvious; intuitive; provide proper feedback; and a natural mapping between input and output is achieved ([Poppe & Rienks, 2007] quoting [Norman, 1998]). In this line, a variety of usability methods have been developed that make use of psychological principles, and ideally include the social and organizational context relevant for the task [G. M. Olson & Olson, 2003].

Emerging HCI systems are multi-modal and embedded [Poppe & Rienks, 2007]. The future of human-computer interaction lies in perceptual interfaces (e.g. for business card identification through optical character recognition) combined with context awareness (e.g. for targeted marketing) [Canny, 2006].

2.2.1.1 Spaces and Rooms

The notion of rooms needs to be considered in a virtual environment. Because of the absence of physical needs and constraints, the geometric description of spaces does not have the same significance as in a physical building. However, this does not mean it does not have any significance [M. L. Maher et al., 2000]. Indeed, the functional aspects of physical architecture can influence the design of virtual worlds [M. L. Maher et al., 2000]. Moreover in virtual worlds, *"without a provision for functionality, the space is not useful, whereas neglecting the geometric description of the room does not affect its functions although it may result in a less user-friendly environment due to the lack of sense of place and presence"* [M. L. Maher et al., 2000, p. 2].

Navigation in a virtual room ideally comes in the form of moving from one functional area to another, and not from one physical location to another [M. L. Maher et al., 2000]. Physical rooms are persistent and serve several functions: Solid walls provide stability, security, visual privacy and a barrier for sound transmission [M. L. Maher et al., 2000]. However, in a virtual world, for example the security of a room can be achieved in other forms: Regardless of the geometry, a person without permission can be denied access and is thus not able to go through the wall [M. L. Maher et al., 2000]. In fact, the geometry of a room does not even need to be fixed like in real-world. For example the size of the room can be programmed to change in response to the number of people in the room [M. L. Maher et al., 2000].

Nevertheless, rooms in the real-world and the virtual world have prospective similarities [Pfister et al., 1997]:

- Rooms are a means to *structure collaboration*. People meet at a specific place, can communicate and collaborate on objects. The borders limit who one sees and what they can see or manipulate.
- Rooms are a means to *structure information*. People place objects at a specific location in the rooms in order to organize them (e.g. drawers etc.).
- Rooms enable specific *work types*. An auditorium is designed for one one-to many information transmission, while a group room enables collaboration more easily.
- Rooms *control access*. Rooms can represent group structure by assigning different rooms to different persons.

2.2.1.2 Objects

An adequate balance between resemblance and simplification must be found when designing virtual objects. Evaluation of CVEs has shown that making objects visually realistic, endows them with affordances that cannot always be satisfied. Thus, it can get complicated to use objects with realistic appearance and different virtual behaviour [Frécon & Nöu, 1998]. *"Objects in a virtual environment should have a function, otherwise it is better to* *leave them out"* [Kuijpers & Jacobs, 1997, p. 171]. For example, chairs are basically irrelevant in a virtual environment in which avatars do not suffer from physical exhaustion. In fact, chairs pose an obstacle when navigating in space and limit visibility. Nevertheless, chairs in a virtual office still serve a function, namely to indicate the meeting participants where to best take place to see each other. Additionally, sitting down tells that a user wants to participate in a meeting. Indeed, usability in a virtual environment can be achieved through natural metaphors [Frécon & Nöu, 1998]. Providing metaphors also constrains the amount of learning and supports the construction of mental models [Pfister et al., 1997]: As users navigate through various rooms, they structure or chunk information in a meaningful way which promotes acquisition of knowledge.

2.2.1.3 Creativity

The generation of ideas is a cultural demand, vital to business, to science, and to the progress of society [Pissarra & Jesuino, 2005, p. 275]. Creative solutions to complex problems create and sustain a firm's competitive advantage [Ocker, 2005].

It is definitely possible to foster an environment which enhances the chance of creative results, and these conditions are not domain specific [Hewett, 2005]. For example, the environment in which groups operate should be tailorable by the individuals [Hewett, 2005]. *"Being intrinsically motivated to do the necessary work for the sake of personal achievement rather than extrinsic reward appears to be important, as does having a willingness to take risks, to exercise curiosity and to engage in domain exploration"* [Hewett, 2005, p. 386]. Creativity is influenced by the individual's characteristics (e.g. personality), group characteristics (e.g. composition, atmosphere, leadership style) and social influences (e.g. minority and majority influence). A flash of recognition of a new relationship or a new organization of knowledge [Hewett, 2005] is interwoven with creativity: *Insight* leads to creativity and vice-versa. It is often hard to find out what triggers insight, because the solution seems to appear suddenly (e.g. as a side-effect of a process) [Hewett, 2005].

Further *factors contributing* to creativity:

- **Tools**: Tools are helpful to foster creativity. Architects use drawing as a tool to externalize and test their thinking by communication with others ([Hewett, 2005] quoting [Robbins, 1994]). Also newer studies show that the tool does matter when it comes to idea generation [DeRosa et al., 2007]. Because human time is more expensive than computer time, it seems reasonable that electronic tools bear the burden of support for human memory to reduce cognitive load [Hewett, 2005].

- **Domain expertise:** Besides motivation, a certain domain expertise is required to be creative ([Hewett, 2005] quoting [Gardiner, 1993]). Creative research groups include members with overlapping but non-identical backgrounds and are ideally cross-generational [Convertino et al., 2005].

- **Anonymity:** Anonymity reduces the fear of disagreeing and thus leads to higher creativity [Pissarra & Jesuino, 2005]. In a GSS context, over 85 per cent of tasks involving anonymity were found the be about idea generation ([Pissarra & Jesuino, 2005] quoting [Fjermestad & Hiltz, 1998]).

- **Coordination:** Effective task allocation and coordination contribute towards creativity ([Ocker, 2005] quoting [Brophy, 1998]).

- **Minority influence:** An active minority influence causes a group to think in more divergent ways: A minority of opinion holders exert influence on the majority, thus counteracting convergent thought that neglects alternative solutions [Ocker, 2005]. Minority influence is fostered by an independent, confident behavioral style and the willingness to actively confront the status quo [Ocker, 2005].

On the other hand, certain *factors hamper* creativity. *Analogical thinking* is seen as a "two-edged-sword", which can lead to creative designs, but more often guide people off course [Hewett, 2005]. *Groupthink* is a risk especially for highly cohesive groups [Ocker, 2005]. Groupthink occurs when excessive concurrence-seeking overrides motivation to realistically assess alternatives [Wainfan & Davis, 2004]. According to Brown et al, people tend to adjust productivity to the least productive member of the group ([Pissarra & Jesuino, 2005] quoting [V. Brown et al., 1998]). In distributed teams, dominance, downward norm setting, lack of shared understanding, time pressure and technical difficulties are seen inhibitors to creativity [Ocker, 2005].

2.2.2 *Collaborative Virtual Environments (CVE)*

"Email and telephone have given us the means to collaborate with colleagues anywhere on earth, in a near-instantaneous way. Yet both of them have severe limitations, compared to face-to-face meetings. In neither medium can you simply point to a graph as an illustration of a point you want to make, nor can you use a blackboard to scribble some equations or sketch a diagram." [Hut, 2008, p. 3]. CVEs challenge this task. It should be noted that this section focuses solely on 3D-collaborative environments, although the term is sometimes also used in literature to refer to 2D groupware (e.g. asynchronous tools like Microsoft Groove, or synchronous tools like Microsoft Netmeeting).

2.2.2.1 Examples

The field of CVE applications is more heterogeneous than the one of virtual worlds. Each environment supports a specific kind of collaboration leading to interesting research findings. Therefore follows a brief, exemplary overview of a few collaborative virtual environments:

- **MPK20** [Sun] is Sun Microsystems collaborative virtual environment, established after realizing that on any given day over 50% of the companies workforce is remote. Employees, represented by avatars, can thus accomplish their real work, share documents and meet with colleagues using natural voice communication (realized by immersive, high-fidelity stereo audio). Moreover, such a virtual workplace allows for "chance encounters", which employees experience when they work in a traditional workplace (e.g. bumping into somebody in the coffee room and starting a chat). However, such chance encounters happen rarely for a remote workforce and thus they miss this social part of work. MPK20 further enables the concept of mixed reality: integrating and enhancing virtual reality with real-world technology, e.g. such as webcasts [Kadavasal et al., 2007]. This can be useful in the context of remote employees as part of a virtual team, who want to project their work environment to other members. Applications do not need to be shared in an external tool, but can be accessed live in-world, making it possible to discuss issues with other employees and edit documents collaboratively.

- **Croquet** [Smith et al.] is a peer-to-peer collaboration system architecture situated in a 3D-environment, so that ideas can be expressed, explored and transferred. The intention behind its construction was the question: *"If we were to create a new operating system and user interface knowing what we know today, how far could we go?"* [Smith et al., , p. 1]. There is no separate development and user environment, change occurs even while other users are operating in the world. 3D-in-world portals are a main feature, which are a spatial connection between spaces. 3D-sound is recognized to be a crucial part in an immersive environment.

- **Unicron** is an example for integrating a collaborative programming environment into an immersive 3D-environment [Jeffery et al., 2005]. It is thus referred to augmented virtuality: 2D tools are integrated in the 3D-environment where a user would naturally turn to a specific device, such as a whiteboard [Jeffery et al., 2005]. The 3D-environment on the other hand enables a closer reality, such that the voice chat mode can be set to local proximity [Jeffery et al., 2005]. This also supports the principle of information hiding.

Discontinued CVE projects from major institutions include:

- **NetICE**, a former multi-user 3D-environment from Carnegie Mellon university, enabled immersive communication including directional sound, lip synchronization, eye contact, facial expression and hand gestures [Leung & Chen, 2003]. Using eye contact for example, it was able to overcome the obstacles in video-conferencing, such as separate communication windows for each participant (making it difficult to find out who is talking to whom) [Leung & Chen, 2003].

- **Microsoft Task Gallery** [Microsoft (a)], was a research project that investigated the use of multiple desktops in a 3D-environment (started in 1999, but has now been stopped).

- **Adobe Atmoshpere** [Adobe] is another discontinued 3D-environment from a big application developer. It focused on virtual multi-user spaces which could be embedded in websites or .pdf documents.

2.2.2.2 Technical difficulties

Technical limitations plague 3D-virtual environments. To illustrate the idea, Fraser points out *field-of-view, haptic feedback* and *network delays* as hampering in progress [Fraser et al., 2000]. Although these findings are rather old in a fast-developing field, they still apply to newer environments [R. J. Moore, Ducheneaut et al., 2007]. Fraser's concluding thoughts are that a shift in design thinking should abandon the principle of information hiding, i.e. the trend of generally hiding properties and characteristics of a system [Fraser et al., 2000]. This move from content over style will enable sound collaboration.

2.2.2.2.1 Field-of-view

Field-of-view is heavily reduced using a desktop display and is still an issue with more advanced technologies. Cost and limitations of head-mounted displays (HMDs) present another obstacle [Fraser et al., 2000] and thus make them still unsuitable for CVEs. Fraser et al. thus recommend to explicitly model a user's actual field-of-view by showing their view frustum as a graphical object in-world (like in the case of network delay), e.g. a shaded cuboid (see Figure 4). The screens used to access virtual worlds also suffers from the field-of-view problem: They are not wide and curved enough to support peripheral vision [R. J. Moore, Ducheneaut et al., 2007].

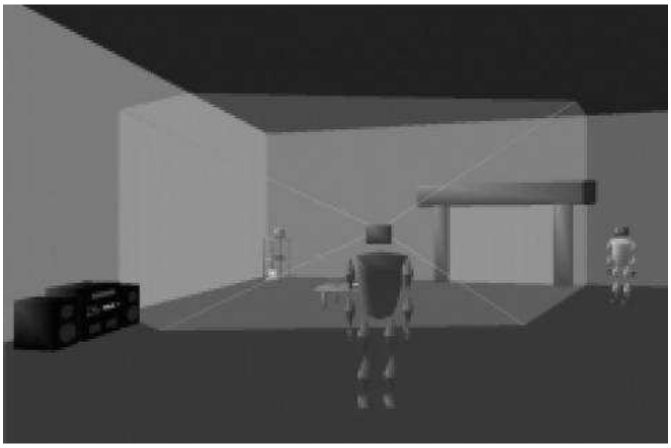


Figure 4: Field-of-view made transparent [Fraser et al., 2000]

2.2.2.2.2 *Haptic Feedback*

The success of the Nintendo Wii controller taught us that interface devices which are more natural than mice or keyboards support satisfaction of interactivity [Kock, 2008]. Haptic feedback and tactile interfaces are still considered in their infancy, e.g. certain textures such as the fuzzy feel of a peach are hard to reproduce in computer simulations and hardware [Fraser et al., 2000]. Thus haptic feedback is nearly absent in CVEs. Instead, audio might be used to convey the effects of forces being applied. A loss of somesthetic capabilities (sensory data derived from skin, muscles, body organs, in contrast to that derived from the common five senses) has been shown to have the following effects relevant to virtual environments [Robles-De-La-Torre, 2006]: Major impairment in skilled performance, even with full vision and hearing; major difficulty performing tasks that combine cognitive loads and fine motor skills such as writing minutes during a meeting; major difficulty learning new motor tasks and relearning lost ones; loss of the unconscious ability to communicate through body language.

2.2.2.2.3 *Network delay*

Network delays not only result in user frustration, *"but can disrupt the very practices upon which face-to-face interaction rests"* [Fraser et al., 2000, p. 33]. For example, turn-taking is disrupted in a talk ([Fraser et al., 2000] quoting [Ruhleder & Jordan, 1999]). Especially professional collaborative virtual environments require a high quality of service to enable complex manipulative tasks, which require short latency [Park & Kenyon, 1999] and should have immediate effect. An example would be the training use of CVEs to repair the Hubble space telescope ([Park & Kenyon, 1999] quoting [Loftin, 1997]). In case of multiple participants the displays must be synchronous so that dynamical events can be discussed as they occur [Watson, 2001]. To give performance guarantees regarding throughput and latency, CVEs are mostly run on LANs over Ethernet [Park & Kenyon, 1999] and thus cannot be compared to virtual worlds accessed through http servers over the internet. The existence of multiple event streams further adds a performance issue to virtual environments: A TCP chat connection and a UDP connection for most environments updates [Jeffery et al., 2005]. However, updates in general only need to be sent to those clients who are in proximity or need to be aware of the information [Jeffery et al., 2005]. Coordination performance, in particular accuracy, is most influenced by *jitter* (variability in delay), when latency is high and the task is difficult [Park & Kenyon, 1999]. Interestingly, long latency without large jitter showed a much smaller effect on performance and performance improved with time similar to a learning curve [Park & Kenyon, 1999]. An explanation for the dominant negative jitter effect could be the reduced ability of individuals to use prediction in performing the task [Park & Kenyon, 1999]. Delays will always be an issue, as the speed of light itself causes a delay of at least tens of milliseconds between two persons on the opposite side of the planet. Due to hardware limits and congestion, those delays will be much higher and make interaction extremely difficult. Interacting on an object may not seem consistent anymore. Concurrent object manipulation is hard to achieve [Kuijpers & Jacobs, 1997]. Approaches for shared workspaces deal differently with the situation: *"Either the system only shows the state of the object when different users' updates have been resolved…or it shows each user the effects of their local interaction as it happens, with the risk that they perceive different (virtual) realities."* [Fraser et al., 2000, p. 30]. In the first case, users have to wait several seconds to synchronize their views [Park &

Kenyon, 1999] and a sudden jump in the user's view might result. Even if there is no conflict, the users may see events in different order, causing a potentially risky different sense of local causality [Fraser et al., 2000]. This effect can be lessened by "delayed commit", meaning that the order of writes is considered temporary until writes are older than the longest network latency between computers [Nijholt et al., 2005]. Thus it is helpful to explicitly make users graphically aware of such effects in-world. Fraser et al. implemented such an approach in the MASSIVE-2 system: A transparent volume around the avatar shows the potential uncertainty in their spatial position, and an indicator above the avatar shows the network delay of the user (see Figure 5) [Fraser et al., 2000]. Another awareness supporting function could be a visual trace of an object that has been snatched away [Fraser et al., 2000].

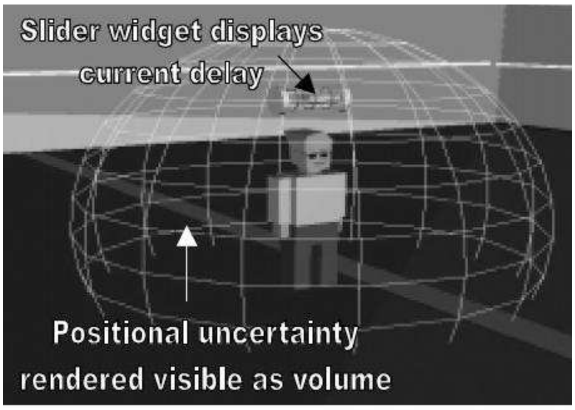


Figure 5: Positional uncertainty [Fraser et al., 2000]

2.2.2.3 Meeting modelling

The research topic meeting modeling is included here because it connects virtual 3D-environments and meetings, which are both central to our empirical investigation in the thesis project.

To have a virtual model of meetings has the following implications (see Figure 6 and Figure 7):

- **Distribution*.*** A virtual meeting room allows access and participation from remote locations [Nijholt et al., 2005]. This representation can be obtained from recordings of behaviors in real meetings [Nijholt et al., 2006]. A virtual meeting room exercise was conducted, in which embodied agents played the role of participants, i.e. mapping their behavior (see Figure 7). Electromagnetic sensors on the head of real-world participants tracked their head movements; body position was captured by simple webcams and image recognition technology [Nijholt et al., 2005]. It was noted that head orientation and gaze direction do not necessarily fall together, but the differences are small and can be neglected, thus gaze is measured in terms of head orientations [Nijholt et al., 2005]. Moreover, the focus was on representing body poses (indicator of involvement) and gestures, rather than facial expressions [Nijholt et al., 2005].

- **Meeting assistance*.*** Ultimately, to have a virtual model of a meeting allows to give real-time support to meeting participants, e.g. addition of meta-data like previous meeting notes, and selective turn taking or interrupting ([Nijholt, 2008] and [Rienks et al., 2005]). To respond appropriately, we must know what caused the behavior [Rienks et al., 2005]. However, true machine perception without context scales poorly: An increase in speech vocabulary or images decreases accuracy ([Canny, 2006] and [Poppe & Rienks, 2007]. Indeed, *"the use of more natural interaction forms poses problems when the input is ambiguous, the communication lexicon is potentially large, and when interpreting signals from multiple communication channels, ambiguities might arise. Identifying the context of use is important because interpretation of input is often dependent on the context. Evaluation of context aware systems is consequently difficult"* [Poppe & Rienks, 2007, p. 6].

- **Re-visualization.** Virtual models permit to structure and present meeting information in such a way that it can be more easily accessed after a meeting, e.g. for analyzing and improving performance [Nijholt, 2008]. This replay can be based on annotations obtained both manually and automatically (e.g. through machine learning). When the virtual environment has the intelligence to interpret the events, it can present them in other useful ways (e.g. a summary) [Nijholt et al., 2005]. For example, some nonverbal behaviors tend to distract interactants, which can now be filtered using algorithms. *"3D virtual replay of meetings allows us to have…restructured and coherent summarization of a topic, even when it was discussed in a disjointed and fragmentary manner"* [Reidsma et al., 2007, p.

135]. The replay can show either the direct observed behavior, or an interpretation of what happened in the meeting [Reidsma et al., 2007]. Storytelling is seen as a vital interpretive part of successful organizational memory systems [Lutters, 2002]. Furthermore, by using argumentation extraction, we can decide who to best send to which meeting in the future [Rienks et al., 2005].

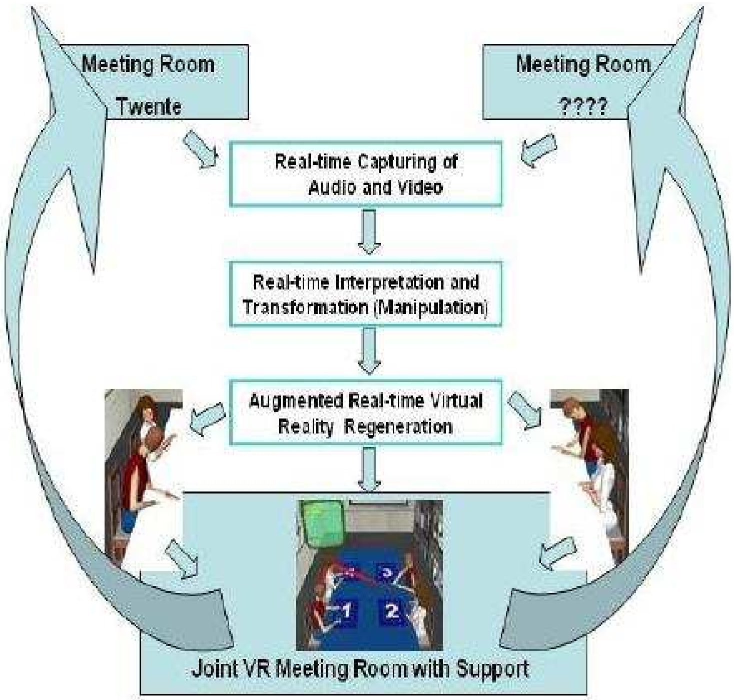


Figure 6: Capturing, manipulation and re-visualization of activities in remote locations leading to a virtual meeting room pictured in the next figure [Nijholt, 2008]

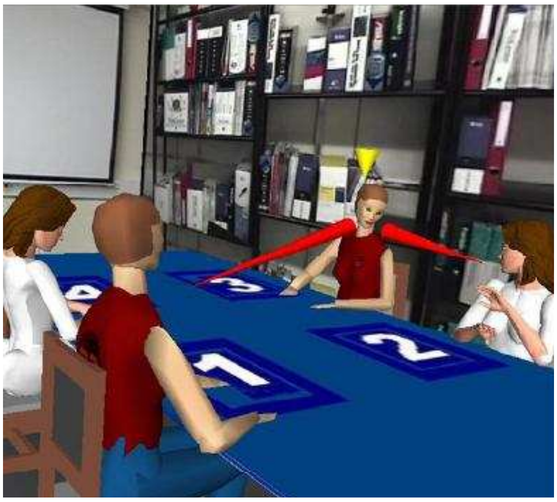


Figure 7: Re-generated virtual meeting room [Nijholt, 2008]

Transformed social interaction

Meeting modeling allows the integration of transformed social interaction, which refers to "reverse engineering" social interaction by decoupling rendered behavior from the actual one [Bailenson et al., 2004]. This certainly raises ethical issues. Spatial or temporal situations can be changed. For example, interactant A may take the viewpoint of interactant B, and perceive oneself performing gestures during the interaction. A consistent representation across interactants is not needed, because the CVE operator can render different avatars to each member. That is, a member of a group can be simultaneously represented in another way to each other member, incorporating features or behavioral characteristics of each respective member. For example, an investigator can be rendered to look at participant A, while in reality the leader follows member's B every move. Another illustrative example showing the potential is that a CVE is not bound by the fact that an interactant A cannot maintain eye contact with interactant B for more than 70% of time if he maintains eye contact with interactant C for 30% of time. This could be capitalized on in an educational CVE, where an instructor may want to direct the nonverbal behavior in a desired fashion. One can also appear completely invisible in the CVE except to one member, reflecting a "virtual ghost", which serves assisting purposes.

2.2.3 *Virtual Worlds*

The term "virtual", and many of the constructs related with it, *"bids fair to become one of the most over-used concepts of the decade"* ([Hindmarsh et al., 2006, p. 796] quoting [Hughes et al., 2001]). However, in the sense of 3D *virtual worlds*, the use is justified. Namely, the objective of virtual worlds is to achieve a feeling of tele-presence, immersion and participation from a distance, enabled through an artificial environment inspired by human imagination [Jakala & Pekkola, 2007].

When reading the literature on virtual worlds, one could easily get the idea that current virtual worlds are already sophisticated collaboration tools. Articles in the research field juggle with "big words" like awareness support, collaboration, learning outcomes and likewise. More realistically, many arguments pro and contra virtual worlds are heavily discussed in literature [Hindmarsh et al., 2006]. The following overview tries to follow the latter perspective.

2.2.3.1 Avatars

Avatars are the graphical representation of users in a virtual world. Avatars allow for expression of personality to a different extent than in real-life because of the absence of physical characteristics and constraints. The anonymity in virtual worlds provides ample room to explore new parts of identity, which may not be possible in real life ([Junglas et al., 2007] quoting [Turkle, 1995]). It could be argued that the virtual identity does not match the real life identity at all, but it would require a lot of psychological effort to keep up such an artificial identity [Junglas et al., 2007]. A newer study showed that a high number of users adapt their avatars to reflect their own appearance; and if the avatar reflect one's own appearance, this leads to a heightened self-awareness, which pervades social interaction [Vasalou et al., 2007]. On the downside, if one avatar outlives its usefulness it can be simply discarded, which disrupts social cohesion in a virtual community [Junglas et al., 2007]. Furthermore, avatars which visually attract attention can be a distraction to serious work.

It has been shown that even crude block-like forms of avatars can be useful for communicating non-verbal social cues ([Redfern & Naughton, 2002] quoting [Snowdon & Tromp, 1997]). Avatar representations of emotions can also be understood by the majority of people with autism [D. Moore et al., 2005]. It could be argued that a causal link may exist in the opposite direction, thus suggesting social isolation or autism as a result of "online life". However, it is a fact that virtual interaction encompasses and strengthens relations among "offline friends" [Nardi & Harris, 2006]. This can be particularly helpful for people who may not have the ability to meet face-to-face, such as hospitalized [Nardi & Harris, 2006] or disabled persons.

Gestures are an exemplary feature of avatars, although still lacking refinement. They help to establish common ground and raise the social presence of the user [Verhulsdonck, 2007]. Cognitive load poses a problem in virtual worlds especially for new users [Ang et al., 2007]. Gestures reduce cognitive load and free up the memory by carrying a large semantic content ([Verhulsdonck, 2007] quoting [Goldin-Meadow, 2003]). In high-context cultures like Japan the use of gestures (which provide context) may be valued higher than in low-context cultures such as the United States, where "content is king" [Verhulsdonck, 2007]. Avatar gestures may be able to capitalize on nonverbal communication phenomena (see textbox below).

Nonverbal communication

Listeners derive only seven per cent of a message by a speaker's verbal content ([Verhulsdonck, 2007] quoting [Mehrabian, 1972]).

Besides the *dialectic* (what is told), the *rhetoric* (how something is told) has a major influence on the perception of a message ([Rienks et al., 2005] quoting Aristotle), namely:

- **Ethos** - how the character of a person influences the audience to consider him to be believable
- **Pathos** - how emotions affect the message
- **Logos** - how the use of the language affects the message

Four *nonverbal communicative actions* have been observed in face-to-face collaboration [Gutwin & Greenberg, 2002]:

- **Deictic reference:** Pointing or gesturing to indicate a noun, i.e. an object in the workspace ([Gutwin & Greenberg, 2002] quoting [Segal, 1995]).
- **Demonstrations:** Gestures to demonstrate actions or the behavior of artifacts.
- **Manifesting actions:** Actions replacing verbal communication entirely (e.g. placing the groceries on the counter tells the clerk "I wish to purchase these items", without having to say so).
- **Visual evidence:** Providing visual feedback that the message has been understood. The receiver needs to have an idea of the visual workspace context, otherwise the meaning may be ambiguous.

Avatars display much less information about the current state than real bodies do [R. J. Moore, Ducheneaut et al., 2007]. Indeed, avatar representation still lacks basic concepts, such as the separation of head and body movements. Thus glancing at others is only possible by changing the whole body movement. However, gaze is an important part of initiating, maintaining and ending a conversation, particularly for providing non-verbal turn-taking cues [Redfern & Naughton, 2002]. At the same time avatars carry along meanings and impressions which the person is willing to reveal [Pekkola, 2002]. Thus, a person's first impression of another's avatar might be contradicting with the observed, limited body language. It is very likely that avatars will never be able to emit rich information like human bodies do. However, *awareness cues* can go a long way to enhance interaction, and especially avoid coordination slippages between users [R. J. Moore, Gathman et al., 2007]. Ethnographic studies showed that *"people tacitly and unobtrusively align and integrate their activities in a seamless and highly sophisticated manner without interrupting each other"* ([R. J. Moore, Ducheneaut et al., 2007, p. 273] quoting [Schmidt, 2002, p. 292]). *"Concealing what players are typing, what menus they are accessing and where they are looking from fellow players leads to delays and slippages in coordination"* [R. J. Moore, Ducheneaut et al., 2007, p. 301]. Thus, the *real-time unfolding* of gestures is crucial to achieve tight coordination in interaction [R. J. Moore, Ducheneaut et al., 2007].

2.2.3.2 Communities

A characteristic of virtual worlds are communities. Social communities in general are based on certain preconditions: Identity persistence of the members, social conventions, a common interest, a collective rationality and being rooted in the same place [Redfern & Naughton, 2002]. Regarding social conventions, it was noted that people report being uncomfortable by their lack of knowledge thereof [Becker & Mark, 1998]. *Virtual communities*, are specifically based on a computer-mediated environment, which enables communication, interaction and relationship-building among participants [Lee et al., 2002]. Such communities facilitate the circulation of knowledge in groups and organizations [Nabeth et al., 2005] and thus, can be especially rewarding for novices or users looking for expert advice in a specific field. Virtual communities are best sustained by allowing participants to be involved in their development [Redfern & Naughton, 2002].

On the other had, under-contribution and lurking are a problem in virtual communities ([Mao et al., 2007] quoting [Nonneeke & Preeee, 2000]). The value of a virtual communities thus lies in the activity of its members, and much research has been done to identify motivational factors for this activity: Direct rewards, increased reputation, altruism, efficacy, and anticipated reciprocity contribute towards participation ([Nabeth et al., 2005] quoting [Hall, 2001]). Reciprocity can be partly explained by *Adams equity theory*, saying that an individual's perception of fairness is determined by checking if the input-output-ratio for oneself is equal with that of others ([Chiu et al., 2006] quoting [Adams, 1965]). However in another study, professional experience and self-efficacy had a much greater influence on knowledge contribution than individual motivational factors such as reputation and reciprocity [Wang & Lai, 2006]. The authors explained that they observed an anonymous community, where different rules seem to apply, i.e. users focus less on vanity. Self-efficacy in this context means the judgment of the ability to organize and execute, however excluding outcome expectations. Outcome expectations can contribute to knowledge sharing, but social factors such as interaction ties, trust, and shared vision have a more dominant influence in another study [Chiu et al., 2006]. It was found that shared language and vision only contributed to more quality, but not quantity [Chiu et al., 2006]. Trust plays an equal important role for quality [Chiu et al., 2006]. Trust in a social system like a virtual world further helps reducing complexity [Junglas et al., 2007].

An alternative framework to understand behavior in virtual communities is *"that individuals are driven to action by desires, these desires lead to plans that need to be consonant with their existing plans as well as their goals, values and beliefs, and how they carry out an action will depend on their interpretation of their environment"* [Bishop, 2007, p. 1890]. This view has been partly supported by empirical studies using positron emission tomography (PET), which showed a neurological relationship between an individuals intentions and the awareness of affordances in the environment ([Bishop, 2007] quoting [Grèzes & Decety, 2002]). It was shown that new users who conversed with regulars soon after joining a virtual community exhibit more social activity and stay involved in the long run, probably because of their favorable environment perception [Medynskiy & Bruckman, 2007].

2.2.3.3 Education

CSCL (computer-supported collaborative learning) is a special field that supports two fundamental processes in both an academical and organizational context, namely that of transmitting skills, i.e. teaching and that of acquiring skills, i.e. learning. Regarding teaching in a business context, IBM estimated in 1999 that it saves half a million US dollars for every 1000 hours of training held outside the traditional classroom [Davis, 2000].

Virtual worlds have a great potential for CSCL, especially when viewed from the socio-constructivist perspective, in which learning is a social activity, rather than an individual process [Dickey, 2005]. In the constructivist paradigm, learning is considered a process of constructing and making sense of our experiences [Murphy et al., 1998], rather than a transmission information [Dickey, 2005].

Distance education often failed because of the lack of social interaction [Redfern & Naughton, 2002]. Newer *VLE (virtual learning environments)* such as Centra [Saba] challenge this situation. Virtual learning environments have also been extended to 3D. For example, Sloodle [Kemp & Livingstone, 2006] merges the learning and course management system

Moodle [Dougiamas] with the virtual reality environment of Second Life. It is an open-source project which aims to develop useful tools to support teaching (e.g. saving chatlogs from Second Life on the Moodle server). In fact, distance education increasingly becomes the preferred method of learning, also because of attraction to innovative technology-mediated environments or the flexible course delivery schedules [Dabbagh, 2007]. This is reflected in a more diverse, less homogenous profile of online learners [Dabbagh, 2007].

Small groups can act as "comfort zones", because students have a tendency to refrain asking questions within larger groups ([Redfern & Naughton, 2002] quoting [Stacey, 1999]). Students will not have to engage in eye contact when asking questions. Virtual environments can also reduce the fear of embarrassment [Jeffery et al., 2005]. Thus, virtual environments are more suitable to ask "stupid questions" and shy people may contribute more than in real-life [Prasolova-Førland & Divitini, 2003]. 90% of students stated in a recent study that they support the 3D-metaphor of virtual classroom e-learning, especially for small groups using audio communication [Bouras et al., 2006].

Agents

Virtual worlds enable the concept of embodied helper agents. Such agents may be helpful, because visitors to an online environment can enter such a place from many different points and thus do not posses enough information about another's cultural background [Isbister et al., 2000]. Social interface agents provide *"ongoing, in-context help in forming social connections and building common ground between visitors"* [Isbister et al., 2000, p. 57]. This help is achieved by monitoring the conversations from participants and actively asking them questions. The agent may suggest a new topic to talk about. However, cultural issues must be considered, as an experiment showed: Agent behavior that was seen nice and competent by Japanese, was perceived rude by Americans [Isbister et al., 2000]. One article mentions the importance of the humans behavioral style towards the acceptance of intervention [Nabeth et al., 2005]: Innovators, compared to a late-adopters, may appreciate an intervention that emphasizes novelty. For the late-adopter, the intervention will have most effect if it stresses the social conformance ("everybody does it that way"). Thus, it is recommended that artificial agents are aware of social cognition theories of participation, so they can construct a behavioral profile of each member [Nabeth et al., 2005].

2.2.3.4 MMORPGs vs. Virtual Worlds

CSCW now encompasses research in activities that primarily provide entertainment ([Nardi & Harris, 2006] and [Ang et al., 2007]). In fact, *MMORPGs (massively multiplayer online role-playing games)* have provided the "killer application" for virtual worlds, mirroring the effect of spreadsheet applications for the personal computer in the early days [Macedonia, 2007]. A major part in the literature of collaboration in virtual worlds is devoted to MMORPGs such as World of Warcraft ([Nardi & Harris, 2006] and [Chen & Duh, 2007]). However, these games include guilds and other social organizational structures that are not found in virtual worlds like Second Life, which makes comparisons difficult.

Moreover, it is important to remember that virtual worlds are not just online games, as they are missing many typical attributes such as ([Fetscherin & Lattemann, 2007] and [Kozlov & Reinhold, 2007]):

- Plot
- Task to accomplish
- Levels
- High scores
- "Game over"

Generally speaking, virtual worlds try to replicate elements of the real world with practical applications in mind, while MMORPGs intend to make the user forget about the real world [Kock, 2008]. However, a common characteristic of MMORPGs and virtual worlds is that online activities are often experimental and experiential, so individuals enjoy both the process of being there as well as the outcome [Kozlov & Reinhold, 2007]. Indeed "*playfulness*" enables humans to discover and learn new practices [Kozlov & Reinhold, 2007]. Humans are seen as playful creatures who love, wonder, worship and waste time

([Crabtree et al., 2005] quoting [Huizinga, 1949]). Individual traits of playfulness are important determinants of *cognitive absorption* [Agarwal & Karahanna, 2000]. Absorption refers to the state where an individual's attentional resources are totally consumed by the object of attention [Agarwal & Karahanna, 2000]. Cognitive absorption leads to *flow*, as described by Csikszentmihalyi. Flow captures an individual's subjective enjoyment and uninterrupted interaction with technology [Agarwal & Karahanna, 2000]. Flow describes *"the state in which people are so involved in an activity that nothing else seems to matter"* ([Agarwal & Karahanna, 2000, p. 668] quoting [Csikszentmihalyi, 1990, p. 4]). Flow comprises the aspects of intense concentration, a sense of being in control, a loss of self-consciousness and a transformation of time perception [Agarwal & Karahanna, 2000]. Cognitive absorption and thus flow are likely to be experienced with technologies that are appealing and visually rich. *"As technology developments continue to focus on richer and more appealing interfaces, the importance of experiences that are intrinsically motivating, i.e. pleasurable and enjoyable in and of themselves, might dominate as predictors of usage intentions"* [Agarwal & Karahanna, 2000, p. 688]. Thus, a *hedonic framework* has been suggested for the study of user acceptance in virtual worlds instead of conventional technology acceptance models [Holsapple & Wu, 2007]: Emotional responses (emotional involvement, arousal, enjoyment) and imaginal responses (role projection, fantasy, escapism) are the drivers leading to consumption and hence acceptance.

Maybe due to the above fact, *"the media still tend to portray these virtual worlds as various forms of escapism, as places of childish, infantile activities, distracting people from more appropriate, "serious" business"* [Kozlov & Reinhold, 2007, p. 2]. This accusation could also have the motive in a natural defense which is shown by pessimists, i.e. *"that people do not want to lose their self-confidence and successful patterns gained in one cultural environment when they enter a new one. In a way, they do not want to become newbies, inexperienced novices"* [Kozlov & Reinhold, 2007, p. 11].

2.2.3.5 Video-conferencing vs. Virtual Worlds

The value of the following discussion might not reside in picking sides but exists in the discourse itself. Indeed, older research the field of video-conferencing must be evaluated critically, because technology has advanced markedly [Wainfan & Davis, 2004]. However, some factors are still plaguing the technique and are likely to stay: E.g. local coalitions form, so participants agree more with those in the same room than those who are remote [Wainfan & Davis, 2004]. The medium also has an influence on dominance perception (see textbox) below): In video-conferencing, camera angles make people look tall or short and volume can be loud or soft, making people sound assertive or submissive [Huang et al., 2002]. In an experiment, artificially tall people had more influence in the group decision than artificially short people [Huang et al., 2002]. Due to the technical setup, it is difficult to maintain eye contact and interpret body language, especially when the number of participants is high [Wainfan & Davis, 2004].

Dominance perception

Dominance perceptions are especially sensitive to a mediated environment. Dominance may stem from individual predispositions or social interaction, however the results are the same: The dominant person attempts to argue, persuade and lead in the group decision-making process ([Pena et al., 2007] quoting [Bales et al., 1979]). High status members have more influence on decisions in both face-to-face and computer mediated groups [Pena et al., 2007]. Situational factors are more critical to the operation of dominance perception than media-specific factors: E.g. anticipated future interaction overrides media choices in several dimensions ([Pena et al., 2007] quoting [Walther, 1994]). Because members of distributed groups are less likely to anticipate future interaction, they care less about self-presentation [Pena et al., 2007]; hence they do not pursue a calm group atmosphere. In turn, they are more likely to exhibit both more dominant and submissive behavior [Pena et al., 2007]. In a field experiment, dominance perceptions were in fact less extreme in co-located groups than in distributed groups [Pena et al., 2007]. Co-located groups also had more symmetrical dominance perceptions: Self and partner dominance perception converged [Pena et al., 2007].

Delay in video-conferencing is still an issue, especially if the audio stream is sent together with the video data, the lag is in the order of a second, which disrupts normal communication [G. M. Olson & Olson, 2003]. These factors make it challenging to manage turn-taking, in some cases leading to participants turning off the audio and choosing a phone call [Wainfan & Davis, 2004]. In virtual worlds, the required bandwidth is reduced significantly compared to video-conferencing, because of the sole transmission of skeleton data (i.e. if video is not integrated in the virtual environment). Worsening the situation for video-conferencing, the *fundamental attribution error* often applies to it [Wainfan & Davis, 2004]: One assumes that a person's actions are based his or her disposition (e.g. intelligence) instead of the environmental situation. Ultimately regarding satisfaction, audio quality and responsiveness are more important than video quality. In fact, video-conferencing with degraded quality produced higher process satisfaction than lower quality video in a study [Matarazzo & Sellen, 2000]: *"It's harder to lose face when faces aren't visible"* [Wainfan & Davis, 2004, p. 38].

Awareness support is more evident in a virtual world than in video-conferencing, which does not provide body language or other spatial cues. Video-conferencing does not create a feeling of co-location (missing gaze direction, peripheral awareness), so one cannot tell what another person is looking at [Redfern & Naughton, 2002]. Furthermore, video-conferencing lacks a non-verbal communication "side-channel" for non-talking groups [Bailenson et al., 2004]. By contrast, gaze in a dynamic 3D-environment not only provides signal feedback and directs conversation flow, it also directs attention to peripheral movements [Gu & Badler, 2006]. *"You can see where everybody is located, people can move around and gather in front of a blackboard or poster or powerpoint presentation, and you can even hear where people are, through the stereo nature of the sound communication"* [Hut, 2008, p. 8]. The affordances of the virtual world medium are even higher if it is possible to associate artifacts to people and leave traces of user actions on them, which will lead to long-term awareness (see 2.2.4.1).

In contrast to videoconferencing, virtual worlds make it possible to break out of a formal meeting with a certain participant and have a chat in a private area. Through the movement of avatars in virtual space, this action becomes similar to an interaction in a real-world collaboration environment.

2.2.3.6 Second Life

Second Life from developer Linden Labs is a virtual world among many: There [Makena Technologies], Active Worlds [Active Worlds] and Kaneva [Kaneva] are just a few competitors in the market (see 6.8).

Second Life – Web 2.0?

Second Life is often mentioned as an exemplary Web 2.0 application. It reflects the main characteristic of the Web 2.0, i.e. "user participation". Most of the Web 2.0 applications are based on the fact that most content is created by the users of the application. Basically everybody has the same rights to create and edit content. Indeed, the distinction between editor and user of the website vanishes. The end user often contributes content free of charge, while the application provider can concentrate on the development of technology and new functionality. As a result of this, many Web 2.0 applications remain in a constant beta status, relieving the application provider of the need to provide a fully functional and stable version, while the user benefits from state-of-the-art technology. Second Life definitely falls into this category of application. Only user contributions are responsible for "what-meets-the eye" in-world, spanning created content and services. Gradually, Linden Labs offers new functionality, on which users can build additional content and services.

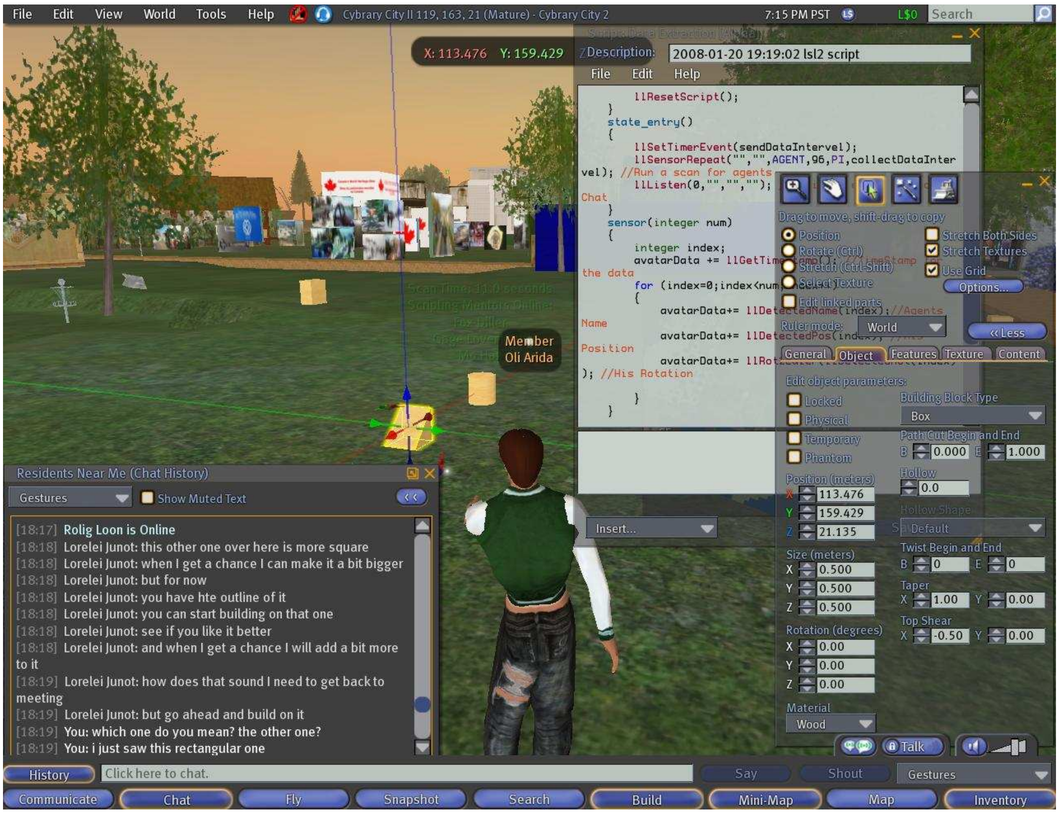


Figure 8: User interface of the Second Life client, showing an avatar editing an object.

2.2.3.6.1 *Technical background*

The virtual world Second Life is simulated on an array of servers called "The Grid", which can be accessed by a client software (see Figure 8). The world is divided into regions, and most regions run a unique server (although some regions just run as a separate instance on physical server) [Wagner, 2007]. Each server provides a physics engine, which handles the interaction of objects [Linden Labs (e)]. All objects are identified by a unique identifier and stored on a separate server farm [Linden Labs (d)]. The only current exception to the above situation is IBM, which has a special relationship with Linden Labs to run its own Second Life servers [D. Clark, 2008]. The reason for this is evident, as commercial interest in virtual worlds *"seems to be morphing, not diminishing. Rather than selling goods and services to users...companies are turning to virtual offices and landscapes as tools for employees and business partners to* *collaborate and learn. Where companies may be happy to hold the equivalent of parties or trade shows in public virtual spaces, for example, conducting confidential business over a network of servers that another company controls can be worrisome"* [D. Clark, 2008].

Second Life shows the common characteristics of a virtual world: It includes customizable avatars, objects and textures. Avatars can move around (fly, walk, teleport), communicate verbally (chat, voice) and nonverbally (gestures). Avatars have a profile and can join groups of interest. Various awareness tools support the avatars, like animations (e.g. that a user is typing) or online status lists of other avatars. Social interaction is adequately supported with the various communication tools and the immersive environment. Objects consist of basic building blocks, i.e. so-called "prims" (which stands for primitives). Textures can be attached to objects. Objects carry the name of the creator and owner, as well as a timestamp of acquisition. Object manipulation is achieved by writing scripts. In-world objects can send data to web-based systems outside Second Life using the hyper-text transfer protocol.

2.2.3.6.2 Acceptance

With a new technology always comes the question of acceptance. IBM expects to see more than a billion users of 3D web by 2012 [Kozlov & Reinhold, 2007]. According to an estimate by market researcher Gartner Group, four out of five active internet users will have an experience in at least one virtual world by the end of 2011 [Bray & Konsynski, 2007]. Already by 2010, the same number should be true for a virtual world presence of Fortune 500 global companies [Macedonia, 2007]. These experiences may be negative or positive, and hence only in the latter case lead to a continuous use of the world. Patterns of usage and system acceptance are deeply depending on personal preferences [Prasolova-Førland & Divitini, 2003].

The mentioned common virtual world characteristics (see 2.2.3.6.1) are unlikely to have contributed to the high attention Second Life was given in the media. Second Life is one of the few virtual worlds which attracted numerous companies to have a virtual presence. For example, the renowned news provider Reuters opened a presence in Second Life, broadcasting stories both to the virtual and real world [Bray & Konsynski, 2007]. The main activities of corporate firms are (ranked by frequency high to low): Communication and PR, marketing, sales, innovation, product development, meetings, training and recruiting, client acquisition and consumer research [Kozlov & Reinhold, 2007]. However, as most users in Second Life are online over the weekend and otherwise during 5pm and 5am [Fetscherin & Lattemann, 2007], it seems obvious that the active use of Second Life is more in a private than in a business context. This is reflected in two surveys. Namely, the motives for users to join Second Life are: Have fun (100%), do things I cannot do in real life (76%), find friends (74%), learn (60%) and simply pass time (55%) [De Nood & Attema, 2006]. Another study mentions the most popular activities: Visiting virtual places (92%), learning (86%), meeting people (66%) and changing identity (37%) [Fetscherin & Lattemann, 2007]. Interestingly, the above order between learning and socializing (meeting people, finding friends) changes from the pre-active motive phase (investigated by De Nood & Attema) to the moment when users are active in the world (investigated by Fetscherin & Lattemann): Learning becomes more important over time. Looking at the gap between residents and corporations goals in terms of what they want to achieve in Second Life, there is an obvious mismatch: Residents come for social, explorative and entertainment purposes into a virtual world, while companies envision marketing and selling products their core activities. In fact, large corporate islands often fail to attract residents, who see the majority of business activities as entirely irrelevant to their own valued experiences in Second Life [Kozlov & Reinhold, 2007]. This often results in company places looking empty without user presence, giving a sense of "abandoned factories" in the real world.

The two following figures highlight current issues of Second Life and do not try to give an exhaustive overview of the economic situation in Second Life. Figure 9 (created by visualizing officially available numbers [Linden Labs (a)]) and Figure 10 illustrate a potential lack of income for Linden Labs. While overall user numbers are still rising, lucrative user numbers (i.e. premium users who pay regular fees) are stagnating (see Figure 9). Figure 10 shows that a large amount of user to user transactions were made up of money transfers for gambling purposes, which are now banned. However, user spending is rising slowly again. This situation does not directly affect Linden Labs, but could limit the overall economic potential of Second Life.

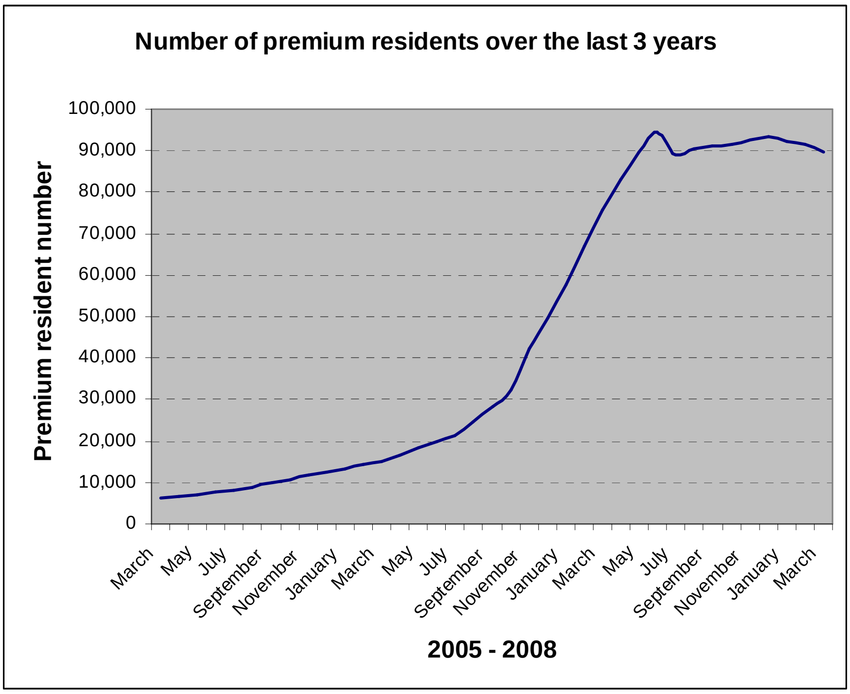


Figure 9: Number of paying users over the last 3 years [Linden Labs (a)]

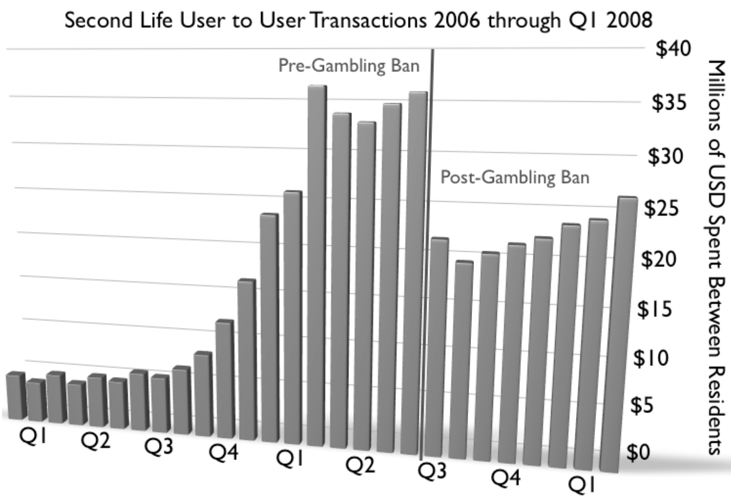


Figure 10: Effect of gambling ban on user spending [Linden Labs (b)]

2.2.3.6.3 Social interaction

An environment that conveys a high level of *social presence* (see 2.1.1) will result in people applying social behaviors that they use in face-to-face interaction [Becker & Mark, 1999]. A quite influential discovery was made recently using Second Life, namely the persistence of nonverbal social norms in online virtual environments [Nick Yee et al., 2007]. The findings are that interpersonal distance and eye gaze "rules" transfer into virtual environments, i.e. the same social norms apply as in the physical world: Male dyads keep larger interpersonal distance and maintain less eye contact than female dyads; decreases in interpersonal distance are compensated with gaze avoidance as predicted by the *Equilibrium Theory* ([Nick Yee et al., 2007] quoting [Argyle, 1988]). This theory states that *"if we get too close to a person with whom we do not want to share high amounts of intimacy, we can avert our gaze to reduce that undesired intimacy and return to an equilibrium state"* [Nick Yee et al., 2007, p. 6].

"People given extrinsic rewards to do something they already enjoy doing are more likely to view the behavior as less intrinsically appealing because this is what an impartial observer would have concluded as well" [N. Yee & Bailenson, 2007, p. 273]. The *proteus effect* applies to avatars in Second Life [N. Yee & Bailenson, 2007]: Individual's behavior conforms to the digital self-representation, i.e. the avatars act how they think they are thought of. For example, users given avatars in a black robe expressed a higher desire to commit antisocial behavior than users given a white robe ([N. Yee & Bailenson, 2007] quoting [Merola et al., 2006]). In another study, more participants assigned more attractive avatars were more intimate with co-avatars in a self-disclosure task than users assigned to less attractive avatars [N. Yee & Bailenson, 2007]. Taller avatars acted more confidently in negotiations [N. Yee & Bailenson, 2007].

As a result of the largely similar behavior in the real and virtual world, it becomes possible to test behavioral science theories at the micro level (e.g. social interaction) and macro level (e.g. economics, legal issues) [Nick Yee et al., 2007]. This view is addressed and contrasted by another study: It suggests that spatial social behavior in Second Life does not exactly mirror real life, but a transformation exists [Friedman et al., 2007]. For instance, the distance between avatars is generally larger than between humans, because Second Life mainly relies on text chat, which is independent of proximity [Friedman et al., 2007]. It was already promised in 1999, that when changing communication partners is as easy as typing in a new name, then it is not worth to navigate to a new location for interaction [Becker & Mark, 1999]. A study in a CVE found this behavior, as well as people talking with their back to each other, to be unnatural [Prasolova-Førland & Divitini, 2003]. The authors of the transformation hypothesis thus propose another field of research, namely that of natural-language interaction, because unlike in simple chat environments, the conversation in a virtual world is situated (see 2.1.2.1) [Friedman et al., 2007].

2.2.4 *Strengths and weaknesses*

In addition to the arguments presented in previous two chapters on CVEs and virtual worlds, an overview of benefits and shortcomings of 3D-virtual environments follows.

2.2.4.1 Strengths

There are several factors justifying the choice of the virtual world medium for collaboration. 3D-environments provide a *shared sense* and understanding of the following points ([Pekkola, 2002] quoting [Singhal & Zyda, 1999]):

- Space and its objects
- Presence of other users
- Time
- Social situation

Such environments encompass for the first time data representations and users ([Redfern & Naughton, 2002] quoting [Churchill et al., 2002]). The space structure is advantageous to remember where a particular document is stored [Prasolova-Førland & Divitini, 2003]. Currently, the dominant model for virtual spaces such as the World Wide Web is *"a bunch of loose-leaved pages, which are connected through a tree of pointers, allowing the user to travel in an abstract way through the information structure. As a result, it is often difficult to retrace your steps, to remember where you've been, or to take in the whole layout of a site. In contrast to the abstract nature of the two-dimensional web, virtual worlds offer a very concrete three-dimensional information structure, modeled* *after the real world. Virtual worlds call upon our abilities of perception and locomotion in the same way as the real world does. This means that we do not need a manual to interpret a three-dimensional information structure modeled on the world around us: Our whole nervous system has evolved precisely to interact with such a three-dimensional environment. Remembering where you have seen something, storing information in a particular location, getting an overview of a situation, all those functions are far more natural in a 3D environment than in an abstract 2D tree of web pages."* [Hut, 2008, p. 2]

A general advantage of multiple users participating in a 3D-space is that users are aware of the actions performed by other users [Kuijpers & Jacobs, 1997]. This is achieved through the constant embodiment of avatars and their activities (see textbox below). Thus, virtual worlds afford ongoing background awareness of others [Pekkola, 2002]. As a result, actions are accountable, i.e. we can observe what our co-participants are doing through verbal or nonverbal cues and thus guide our own actions [R. J. Moore, Gathman et al., 2007].

Awareness in "There" vs. Second Life

Looking at *support for awareness*, the virtual world "There" [Makena Technologies] currently has a few advantages over Second Life [R. J. Moore, Ducheneaut et al., 2007]:

- Different avatar *animations* are played when the user opened an external browser window or an instant messaging window.
- Users can join a "*conversation group*": The system rearranges the avatars in a semi-circular formation, so other users know that a conversation is going on. As a result, the chat bubbles do not overlap on the user's screen. A negative side-effect is that this situation totally prohibits natural arrangement and movements of avatars. By positioning avatars face-to-face the configuration does however provide the necessary social presence for deep interaction [Becker & Mark, 1999].
- To improve turn-taking in the case of composing chat messages, word-by-word

posting is implemented. *Character-by-character posting* could still improve awareness further. At the same time, it would reduce the rehearsability factor according to media synchronicity theory (see 2.1.1.2).

The main positive aspect of a spatial environment lies in the capability of jointly looking at and manipulating objects [Schroeder et al., 2006]. Indeed, the *continuous workspace awareness* by physically remote participants is a major advantage (see textbox below) [Schroeder et al., 2006]. Furthermore, virtual worlds are seen as especially useful for so-called *long-term awareness*, compared to short-term awareness which can also be provided by simpler environments like 2D tools [Prasolova-Førland & Divitini, 2003]. Long-term awareness builds on the persistence of objects in the 3D space and the community in virtual worlds (see 2.2.3.2). Indeed, "*in a place full of toys, it was the place itself, not the collection of toys, that formed a magnet. Presence in a persistent space, a watering hole that quickly became a familiar meeting ground, this is what was felt to be the single most important aspect of the whole enterprise. Everything else was clearly secondary. It goes back to the difference between the abstract nature of the two-dimensional world wide web, versus the concrete sense of 'being there' that we get when we enter a virtual world. Hundreds of millions of years of evolution of our nervous system, in all its perceptive, motor, and processing aspects, have prepared us for being at home in a three-dimensional life-like spatial environment.*" [Hut, 2008, p. 8].

Workspace awareness

People shift back and forth from working alone to working together in a loosely coupled manner on a shared task [Gutwin & Greenberg, 2002]. They do this by keeping track of other people's activities, otherwise they will miss opportunities to collaborate and interrupt the other person inappropriately [Gutwin & Greenberg, 2002]. Thus follows the need for workspace awareness. Workspace awareness explains where others are working on what and how it came that situation, i.e. an up-to-the moment understanding of another person's interaction in the situational workspace, as well as what they may or are going to do next (see Figure 11 & Figure 12) [Gutwin & Greenberg, 2002]. Three general workspace awareness levels exist ([Gutwin & Greenberg, 2002] quoting [Endsley, 1995]):

- Perception of relevant elements of the environment

- Comprehension of those elements
- Prediction of the states of those elements in the near future

Category	Element	Specific questions
How	Action history	How did that operation happen?
	Artifact history	How did this artifact come to be in this state?
When	Event history	When did that event happen?
Who (past)	Presence history	Who was here, and when?
Where (past)	Location history	Where has a person been?
What (past)	Action history	What has a person been doing?

Figure 11: Workspace awareness relating to the past [Gutwin & Greenberg, 2002]

Category	Element	Specific questions
Who	Presence	Is anyone in the workspace?
	Identity	Who is participating? Who is that?
	Authorship	Who is doing that?
What	Action	What are they doing?
	Intention	What goal is that action part of?
	Artifact	What object are they working on?
Where	Location	Where are they working?
	Gaze	Where are they looking?
	View	Where can they see?
	Reach	Where can they reach?

Figure 12: Workspace awareness relating to the present [Gutwin & Greenberg, 2002]

2.2.4.2 Weaknesses

In 1998, experiences from an office project showed the disinterest of industry sponsors in virtual worlds [Pekkola et al., 2000]. They concluded that:

- Virtual reality is not suited for the tasks and unnecessary (employees already know the people they are working with)

- The computers they use do not deliver the performance needed
- Users are not familiar with 3D-interfaces

However, in the light of technology progress and with sufficient training, only the first mentioned point remains relevant. Nonetheless, Pekkola concludes in 2002 that virtual reality is only suitable in very special settings (e.g. where a 3D-model is required). This does not include meeting environments in the common sense. In fact, object sharing in a 3D-environment makes only sense if those objects are 3D-models, which is rarely the case in group work [Pekkola, 2002].

Here follow other arguments highlighting the weaknesses of virtual worlds:

- **Prototype technology.** The current usability of virtual worlds leads to a considerable cognitive overhead that distracts people from working on the actual task [Tromp et al., 2003]. The user interface is non-standardized and presents a stark contrast to more familiar, 2D environments. For example, there is a lack of general "undo" for virtual worlds [Steed & Tromp, 1998], or at least for the 3D-spatial activities in them.
- **Movement.** An obstacle in 3D environments is the fact that users spend little time performing an action, such as manipulating or collaborating, but much more time is invested in moving to a specific location in space [Park & Kenyon, 1999]. This is also mentioned in a newer article: If "working the avatar" takes up too much time, collaborating with others is hampered, and thus one becomes alienated from the very activities the environment was intended to support [R. J. Moore, Ducheneaut et al., 2007]. For instance, movement in Second Life is difficult, as there are only two speeds to choose from (walking or running). A variable speed of movement would increase the spatial experience.
- **Privacy**. An increase in awareness and transparency supported by the 3D-environemnt leads to a reduction of privacy [Ackerman, 2000]. Users of virtual worlds have become accustomed an odd sense of "public privacy": Moore mentions the example where a player worried about "looking stupid" in front of his group mates because they could see that he was repeatedly consulting his map [R. J. Moore,

Ducheneaut et al., 2007]. People tend to set privacy controls to the maximum, which harms collaboration [Steinfield, 2002].

- **Self-centeredness.** The self-centeredness of virtual worlds poses an obstacle towards group work. Participants need to enter the environment regardless whether they need such an interface. This reflects the general problem of virtual reality that one needs to "go into it" [Pekkola, 2002], thus making an unnatural shift which results in a loss of flow (see 2.2.3.4).
- **Activity.** If there are few users around in the environment, people usually stay only a short time and if a critical mass has not been reached, people leave [Prasolova-Førland & Divitini, 2003].
- **Mobbing.** Communication can be uninhibited and the threshold for what is acceptable is lower than in real life [Prasolova-Førland & Divitini, 2003]. Thus, a moderator is often needed to limit unsocial behavior [Prasolova-Førland & Divitini, 2003].

3 THESIS PROJECT

The practical part of this thesis consisted of the set-up and usability evaluation of a prototype meeting environment in Second Life. A bottom-up approach was chosen for our thesis project. This is helpful because design, implementation and use often show unexpected consequences, such as events that fall outside the initial specification [Ciborra, 2002]. Therefore, prototyping or tinkering [Ciborra, 2002] is commonly used when there is a great deal of uncertainty about the requirements of a system or the environment in which it will be employed [Nuseibeh & Easterbrook, 2000]. A prototype is thus useful when stakeholders are numerous, distributed and their goals may not be explicit or difficult to articulate [Nuseibeh & Easterbrook, 2000]. Hindmarsh suggests to research the use of prototype technologies by novices: *"Rather than being overwhelmed by the complexities of the new technologies, an all too common feature of sociological writings, such studies can remind us of the complexities of mundane social interaction"* [Hindmarsh et al., 2006, p. 814].

3.1 Methodology

The prototype environment was built considering the fact that further development and data analysis will surpass the time frame of this thesis. Thus a sound methodology is needed that allows flexibility in virtual world research. Methodology is more than a plain set of methods. It also comprises the philosophical foundations, assumptions and beliefs which underlie a study. In order to give transparency into our work, the following separation of steps in the process illustrates our approach.

3.1.1 Usability evaluation

Usability is a necessary (but insufficient) condition for technology acceptance [Dillon, 2000], and acceptance, in turn, must be the ultimate goal for any tool. The aim of our usability evaluation is to investigate problems regarding the interface and the design of the prototype environment, ideally revealing additional requirements of end-users for improving the functionality of the environment. Two processes of usability evaluation guide our investigation: *Usability inspection* and *usability testing*.

Usability inspection is often applied in an early project stage, when a prototype cannot yet be tested on end-users. In our case, the usability inspection interweaves with the environment set-up and the trial experiments, thus it covers the whole thesis project. The author continuously assesses the created meeting environment. The process develops as follows (see Figure 13): Start with an initial, temporary design of our environment; conduct a practical test-run; analyze the collected data to reach findings; compare our results with the ones from the research context; and finally inform the design to reach a new, temporary design for a new cycle. As part of our trial experiments (see 3.3), we run four cycles, which leads us to usability testing.

Usability testing evaluates a product on several users to minimize personal bias. Novice users reveal a large number of issues, but they often cannot detect the most critical ones [Faulkner, 2003]. On the other hand, "*expert results may highlight severe or unusual problems but miss problems that are fatal for novice users*" [Faulkner, 2003]. No magic formula exists that tells us X users are needed to find Y percent of problems [Woolrych & Cockton, 2001]. However, Nielsen propagated that five users are sufficient in most cases to reveal 80 percent of usability issues. Adding further users would have a negative effect on the cost/benefit-ratio. In fact, this lead to a movement of "discount usability" in industry (i.e. the embracement of cost-efficient heuristic evaluation methods) [Faulkner, 2003]. However, the idea by Nielsen is not to spend a smaller testing budget, but instead to conduct several usability tests with small groups instead of one large group, and to always improve the object of attention between the tests. Following this recommendation, we conduct our trial experiments with a similar, small number of users (see 3.3.1.1), then change the design of the prototype environment, and test it again with new users.

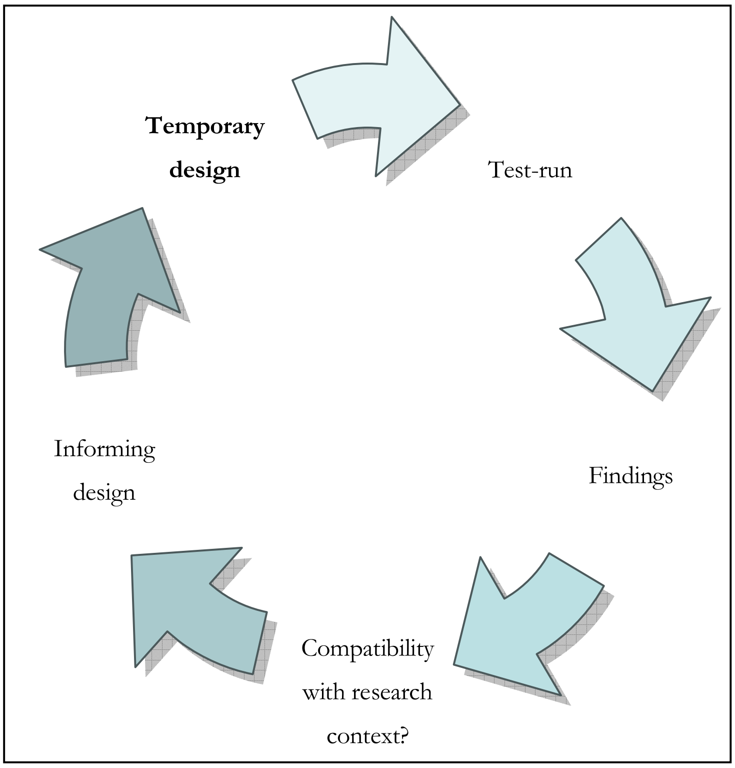


Figure 13: Usability evaluation cycle encompassing inspection and testing

3.1.1.1 Evaluation

"Evaluation is concerned with gathering data about the usability of a design or product by a specific group of users for a particular activity within a specified group of uses or work context" ([Poppe & Rienks, 2007, p. 3] quoting [Jenny, 1994]). Our evaluation builds on *ethnomethodology*, which tries to grasp the behavior of *members* in a *social system* by *observation* [Becker & Mark, 1998]:

- The *members* in our case are represented by the avatars participating in a trial experiment.
- The *social system* is the team working on a particular task (see 3.3.1.1).
- *Observation* is achieved by interaction monitoring and application of various data collection techniques in our environment.

The literature on methods or practical guidelines for the assessment of technologies is vast [Stanton et al., 2005]. If the task in an environment is fixed over a longer period of time, choosing the most suitable evaluation method can become a critical issue. However in our case, the final task for which the environment will be used after the conducted trials is still open. In our prototypical study, the main concern could thus not be the choice of an optimal method. *"The world-out-there is the precondition for our understanding of…models and methods; thus it presupposes them, and is far from being presupposed by them"* [Ciborra, 2002, p. 23]. Indeed, sticking too early in the development process to methods often results in unimaginative, easily imitable outcomes [Ciborra, 2002]. However, unique solutions, often achieved through improvisation, are needed for lasting competitive advantage. Ciborra even sees the concern with methods as one of the key aspects of a crisis in information systems development [Ciborra, 2002].

It is therefore not the aim to focus on a existing evaluation method (such as formative, comparative or heuristic evaluation [Bowman et al., 2002]). The varied investigation is better framed by an overarching direction (see Figure 13), as one single method can never fully handle the insights in a new field for which the method was not developed. In fact, existing design and usability evaluation methods for conventional 2D-GUIs need to be translated for 3D-environments (see 3.1.1.2). Specific constraints, such as the prototypical nature of those applications and the geographic distribution of the subjects, complicate a proper controlled experiment ([Steed & Tromp, 1998] and [Bowman et al., 2002]).

3.1.1.2 Usability

Usability is a very broad term and thus suspect to interpretation, but generally refers to the ease of use of an interface. Many authors developed usability guidelines (see textbox).

Usability Heuristics

The following quotation explains ten principles for interface design [Nielsen]:

- **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
- **Match between system and the real world:** The system should speak the users'

language, with concepts familiar to the user, rather than system-oriented terms.

- **User control and freedom:** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
- **Consistency and standards:** Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
- **Error prevention:** Prevent a problem from occurring in the first place. Eliminate error-prone conditions. Present users with a confirmation option before they commit.
- **Recognition rather than recall:** Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another.
- **Flexibility and efficiency of use:** Speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
- **Aesthetic and minimalist design:** Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
- **Help users recognize, diagnose, and recover from errors:** Error messages should precisely indicate the problem, and constructively suggest a solution.
- **Help and documentation:** If required, such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Extending the notions of Nielsen [Nielsen, 1993], usability comprises both *satisfaction* and *performance* components of a technology or a software. Performance can further be split up in efficiency and effectiveness. Accuracy (how many errors do users make), learnability (how easy to learn is the interface) and memorability (for continuous use, how easy to remember is the interface) are influencing subfactors [van Welie et al., 1999]. In our trial experiments, we do not specifically assess efficiency, effectiveness or any of the subfactors. Our meeting environment would potentially allow such an investigation, but the lack of a large sum of participating subjects or formal experiment conditions do not yet warrant a statistical analysis (see future research: 4.3.2). Generally, we focus on the performance (see textbox below) and satisfaction distinction of usability. An *indicator* towards performance is given by our chatlog coding (see 3.3.2.1). The satisfaction component is mainly covered by the participant interviews after the trials (see 3.3.2.2).

Performance measures

Encompassing quantitative and qualitative data analysis, four classes of performance measures exist ([Poppe & Rienks, 2007] quoting [Rengger, 1991]):

- Goal achievement (accuracy and effectiveness)
- Work rate (productivity and efficiency)
- Operability (function usage)
- Knowledge acquisition (learning rate)

The first two classes could be covered by our observation and data collection of the participant's behavior in the trials. When the solutions are compared to an expert solution (see 6.2), the *goal achievement* is assessed. Because of the fixed time for the task, the *work rate* can be observed. The third class of *operability* is covered by our interviews after the trials. Suggested surveys can be found in the appendix (see 6.7). The *knowledge acquisition* can not be measured in our situation, as the tasks are not suited to asynchronous collaboration.

Because of the dependence on the context (see 3.1.1.1), steps leading to usability are illustrated in the specific case of a 3D-virtual environment in Figure 14. Our investigation into Second Life follows a similar approach like. Starting at the top, the *iterative development* of the CVE application refers to our prototyping approach of the environment design. The *clarification of human needs* was presented in the research context, particularly in the sections on virtual collaboration, environment design, supporting awareness and technical limitations of 3D-virtual environments. This was followed by *observations* through trials in the environment (usability testing, see 3.1.1) and the *consumer evaluation* (interviews). The *clarification of usability guidelines* was conducted continually during the environment development and the trials. Findings are presented in the environment set-up section and in the discussion of the trial experiments. However, further time would be needed to formulate concrete *usability guidelines* for Second Life. The *clarification of HCI evaluation methods* was discussed before (see 3.1.1.1). The *inspection* refers to our usability inspection by the author (see 3.1.1). The *adaptation of existing HCI methods* was out-of-scope for this thesis.

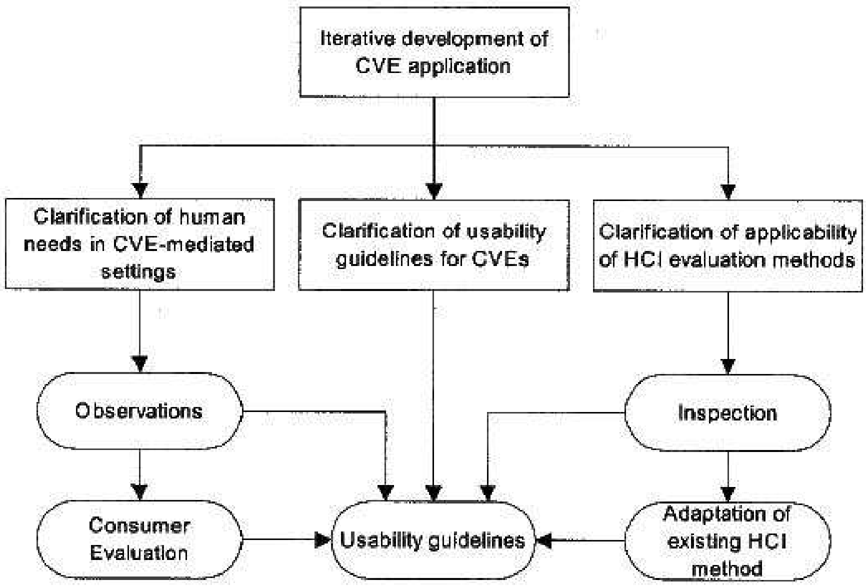


Figure 14: Steps leading to usability guidelines for CVEs [Tromp et al., 2003]

3.1.2 *Data analysis*

In this early stage of our prototype meeting environment, we set the focus on a *qualitative data analysis* (see following textbox). Interaction fragments and interviews are analyzed. Quantitative analysis could be used for a statistical analysis of when searching for patterns in the collected avatar data (coordinates, rotation) from our environment (see 4.3.2). However, as will be shown in this section, the outcomes from the conducted tasks do not yet warrant a quantitative analysis of avatar data.

Quantitative vs. Qualitative

In line with Schroeder [Schroeder et al., 2006], two main *types of data analysis* are identified: Quantitative analysis of sequences and qualitative analysis of interaction fragments.

- **Quantitative:** The researcher will look for patterns by capturing quantitative data and applying statistical analysis, which in turn can reveal frequencies and sequences of events. This procedure can still be subjective, in the sense that behavior is not directly measured, but measured in the observer's category [Schroeder et al., 2006].
- **Qualitative:** Interaction fragments are transcribed and analyzed. The researcher looks for key dynamics or specific patterns of activities [Schroeder et al., 2006]. Qualitative data provides a rich picture of what users find positive and negative about working together [Heldal et al., 2005].

We initially choose a *grounded theory* approach towards the data collection and data analysis of our prototype environment for two reasons:

- Following a similar argumentation like Ciborra (see 3.1), a grounded theory approach (see textbox) supports the notion that methods ought to be chosen in the light of the problem, and not vice-versa ([Bowers et al., 1996] quoting [Anderson et al., 1985]).
- The ideas of grounded theory have been applied before in the field of virtual worlds [R. J. Moore, Gathman et al., 2007] and Second Life in particular [Kozlov & Reinhold, 2007], although the term grounded theory was not used in the latter case.

Indeed, we initially followed the notion of grounded theory, and continuously analyzed the collected data after every step of data collection. The observations from one trial influenced the next trial (see 3.3.3.2). However, while still following the *constant comparison* paradigm (see following textbox), two factors lead us to abandon a pure grounded theory approach:

- **Limited time:** The time-frame of the thesis project did not allow a continuous adaptation of our coding schema after each data analysis. Only this would lead to more fine-grained categorization of the analyzed data (see 4.3.2.2.1) and thus potentially allow us to derive theory (*theoretical saturation*; see following textbox).

- **Prototype technology:** As will be shown, Second Life only supported the divergent collaboration process in our group meetings. We integrated a mash-up tool that supported the convergent process to a certain degree only after the trials experiments started. In addition, we specifically looked at synchronous collaboration because of a lack of tools supporting asynchronous collaboration in Second Life. However, the potential of long-term collaboration in virtual worlds is substantial. Therefore, we could not generate data that would warrant a complete grounded theory analysis (so called *empirical limits* of the data; see following textbox).

Grounded Theory

The aim of grounded theory [Glaser & Strauss, 1967] is not to discover "the" theory, but "a" theory that aids understanding in an area under investigation [Heath & Cowley, 2004]. Indeed, data is systematically gathered to derive theory: Data capture and iterative analysis are interweaved (*constant comparison*), and applied until theoretical saturation is reached [Qureshi et al., 2005]. Constant comparison comprises the first process of coding the data and the second process of inspecting the data for properties of categories and to develop theoretical ideas [Walker & Myrick, 2006]. The constant comparison contradicts with the clean separation between data collection and analysis [Suddaby, 2006]. Caution must be taken towards authors who are unfamiliar with qualitative research and who use grounded theory simply to avoid close description or illumination of their methods [McGhee et al., 2007]. Therefore, when it comes to writing up findings, journal articles and academic publications, the authors ideally follow older positivist origins, which impose discrete and sequential categories of data collection and analysis.

"Only when a science is mature is hypothesis-testing the best approach, and even then it is not the only approach" [Erickson & McDonald, 2008, p. 109]. The essence of the grounded theory approach is an inductive-deductive interplay. Induction is viewed as the key process, while deduction and verification are the servants of emergence [Heath & Cowley, 2004]. Glaser even criticized the deductive method, which leads to asking questions and speculation of

what might be rather than what exists in the real world [Heath & Cowley, 2004]. Therefore not hypotheses form the start of a study, but ideas are derived from the data to form *mini-theories*, which are then assessed by subsequent data ("theoretical sampling") [McGhee et al., 2007]. Thus, decisions about which data should be collected next is determined by ongoing interpretation of data and emerging conceptual categories, and ultimately, the constructed theory ([McGhee et al., 2007] and [Suddaby, 2006]). An obstacle which one faces is to know when *theoretical saturation* is reached. Saturation is a practical outcome of the researcher's assessment of the emerging theoretical model: Empirical limits of the data, the quality or integration of theory and the researchers theoretical sensitivity are major influences [Suddaby, 2006]. In fact, the emergence of theory is based on how well data fits conceptual categories, how well they explain or predict interpretations, and how relevant the categories are to the core issue being observed [Suddaby, 2006]. The researcher's creativity is an integral part in the emergence of categories [McGhee et al., 2007]. However, it is important that these categories are inductively derived from the data and are not based on preconceived notions held by the researcher [McGhee et al., 2007].

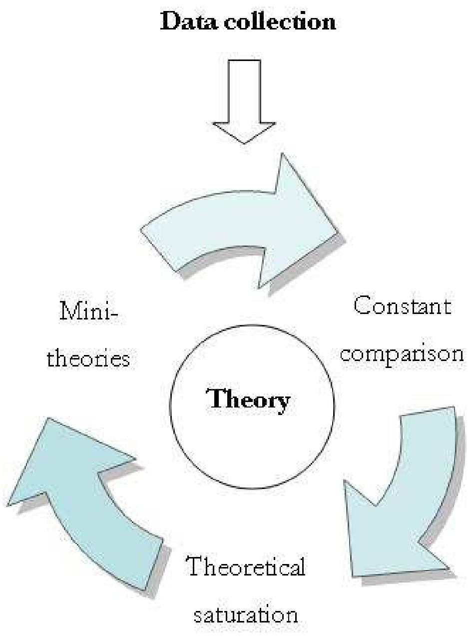


Figure 15: Deriving Grounded Theory (simplified)

3.2 Environment set-up

Requirements for our environment were mainly derived from traditional meetings, which should be *"a gathering of thoughts where the exchange and generation of information leads to an enhanced level of knowledge improving the performance of the individuals as well as the group"* ([Rienks et al., 2005, p. 1] quoting [Moran et al., 1997]). Meetings ideally proceed efficiently and effectively. Thus we have to build an environment that allows us to focus both on the process (i.e. efficiency) and the result (i.e. effectiveness) of the meeting during analysis. Meetings are manageable and accessible afterwards [Rienks et al., 2005]. The automated data collection from the interaction happening in the environment was an essential auxiliary condition of the environment set-up. The focus lay on the monitoring of the artifact development. Further requirements for the environment are listed in the textbox below.

Initial prototype requirements from Diploma thesis plan (see 6.6)

- **Parity:** Every participant should have the same access to the discussion thread(s) – the same chance of being heard, etc. as they would have had in a meeting being held conventionally.
- **Awareness/Presence:** Every participant should have intuition of the availability and "readiness to participate" of other participants – the analogy is to observing colleagues working at their desks or "paying attention" in meetings.
- **Opportunity for network building/socialisation:** A significant benefit of face-to-face meetings is the opportunity for pairs of participants, or larger groups, to break off for a chat, which may or may not be a part of, or even relevant to, the meeting.

3.2.1 Second Life

Firstly, the reasons for our choice of Second Life are discussed. Then the issues faced during the facilitation of Second Life are presented (separated by network, hardware and software). This is followed by the description of the necessary steps to buy land in Second Life, so we could create our meeting environment.

3.2.1.1 Reasons for choice

The virtual world Second Life was chosen based on an expert rating comparing different virtual worlds. Many of discussed supporting arguments in the 3D-virtual environments section of this thesis (see 2.2.4.1) are applicable to Second Life. Finally, the following reasons were deciding:

- **Costs**: Basic user accounts are free and no additional software is needed, resulting in a cost efficient solution.
- **Activity**: Critical mass of users in Second Life, which generates adequate support through forums and in-world help (see also "community of practitioners" [Taylor & Duclos, 2007]).
- **Customizability**: The Linden Labs scripting language (LSL) is provided, which has a smooth learning curve. LSL offers many opportunities to edit and analyze the environment.
- **Open-source**: The client is already open-source, and Linden Labs has the intention to open-source the server code, which is helpful for further development of the prototype.

A more comprehensive overview of the advantages of Second Life is provided by Taylor and Duclos [Taylor & Duclos, 2007]. They compared the virtual worlds Croquet, Second Life, Active Worlds and There according to specific criteria. The resulting table can be found in the appendix (see 6.8.)

3.2.1.2 Facilitation

The facilitation included the management of research lab computers to run the experiments; as well as the installation of Second Life and data collection tools on those machines.

3.2.1.2.1 Network

Before being able to run Second Life, an issue might turn up when the software is used in a network belonging to an organization with strict access rules. We were confronted with this situation when we tried to access the Second Life server from our University network. Access was denied and the IT support centre needed to be contacted, which had to open specific ports for the requested machines. This organizational overhead could be an issue when running several Second Life clients in a company (see also 4.3.1). Furthermore, the ports opened to run Second Life may put the network security of the organization under threat from an external attack.

3.2.1.2.2 Hardware

Getting Second Life to run on older machines can cause problems if they do not meet the system requirements [Linden Labs (c)]. The hardware requirements depend on the operating system (Second Life also runs on Linux and Apple), but generally it can be said that a 1 GHz processor, 1GB RAM and a recommended graphics card are necessary for smooth operation. In our case, the PC's (Windows XP) we used for our trials needed to be refitted with newer graphics cards. Finally, we were using machines equipped with a GeForce 8400 GS graphics card and at least 512MB RAM to fulfill the minimum requirements for running Second Life.

3.2.1.2.3 *Software*

Our environment, like any other on the Second Life grid, is accessed through separate client software. Instead of using the standard Second Life client, which offers an uncommon, hard-to-learn and thus inconvenient user interface (see Figure 16), we chose the *OnRez client* (see Figure 17) [OnRez]. This improved and simplified client software was enabled by the open-source availability of the Second Life client code. User interface improvements include for example the introduction of a "back-button", better readability through higher contrast colors, a more intuitive menu structure and faster response time when navigating the menus. Furthermore, the OnRez client included an in-world internet browser (see Figure 21), which substantially raised the collaboration potential of Second Life (see 3.2.2.4).

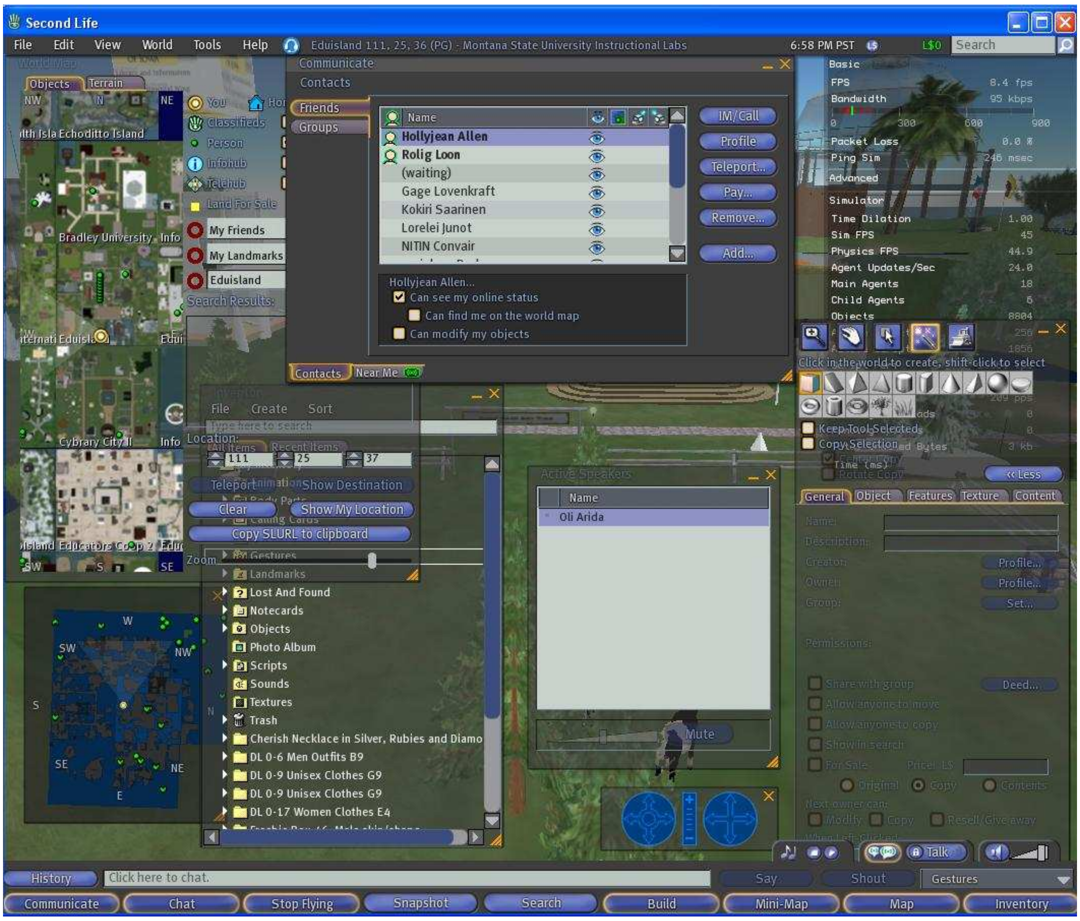


Figure 16: The official Second Life client from Linden Labs, which raised usability issues

3.2.1.3 Buying land

Once the virtual world was chosen, a further decision needed to be reached. In order to be able to build sophisticated constructions in Second Life, the user has to buy *virtual land*. This proved to be a complex and risky situation due to low transparency:

- **Real estate agent.** Land can be bought directly from Linden Labs or from private re-sellers
- **Variation in prices.** Land prices from private sellers and the Lindex currency rate vary greatly
- **Form of purchase.** Land can be rented, leased or bought.
- **Contract restrictions.** Some parcels do not allow high-lag scripting that is used for our data collection. Other parcels have a certain prim allowance (see 2.2.3.6.1). A design principle in Second Life is that objects should be created using the least amount of prims possible [Hayes, 2006], because due to performance issues a certain land allows only a limited number of prims on it. Finally, some parcels charge additional fees for certain services.
- **Image.** Besides educational environments, there are seedy surroundings in Second Life. In fact, a fair amount of user creation is devoted to sexually explicit content, in some cases leading to "gated neighborhoods" reflecting social divisions among residents [Hayes, 2006].

After talking to in-world residents and assessing the various options, the decision was reached to rent a 1024 square meter area on an educational island, for a yearly fee of 200 US dollar (see Figure 17). The space both provides a high amount of prims and an inviting mix of residents and constructions.

Figure 17: The virtual land we bought in Second Life, incl. our constructed meeting environment

3.2.2 *Environment design*

The design of the environment itself is a major part of the environment set-up and reflects on the discussion of environment design in the research context (see 2.2.1).

3.2.2.1 Realization

The practical part of the construction of the virtual meeting environment (implementation) was mainly realized by three students, who were supervised by the author. The process could be generally described as agile, iterative development. Feedback was given in short time intervals and often orally, because the students had co-located workplaces with the author (during part of the project). The students were given guideline criteria by which their work will be judged. Six *criteria* were essential for a successful design:

- **Usability** – how accessible, user-friendly and intuitive are the features and functions of the environment?
- **Creativity** – how novel are the ideas for the architecture and functionality of the environment?
- **Scalability** – is the environment (incl. data collection) capable of handling additional rooms, features and users?
- **Stability** – is the environment free from breakdowns during experiments (incl. data collection)?
- **Structure** – does the environment have an intuitive structure and does the collected data come in a structured form?
- **Maintainability** – does the data collection from the environment require many manual steps in order to capture and process raw data. Is the data stored in a central location, which is easily accessible?

Figure 18: Our created office environment in a final phase

3.2.2.2 Rooms and objects

The meeting environment was designed in a traditional way, with a common room layout which could be found in a real world meeting room (see Figure 18). The reasons for this are explained in the section on environment design (see 2.2.1). A whiteboard and a screen for presenting Powerpoint slides were included in the environment. However, some traditional architectural structures proved cumbersome. For example, ascending or descending stairs quickly requires a certain amount of avatar movement skills. This is reflected in the time it takes to move from one floor to another. Virtual worlds offer other opportunities to master distance: One can not only walk or fly to another location, but also "teleport". Clicking on an object which offers teleport services speeds up the process of moving to another place. Thus we included such teleport stations in our meeting room to allow faster and simpler movement inside the environment (see Figure 19), while still offering the traditional layout with stairs at the same time.

Figure 19: Area for socializing in our building, incl. a teleport object transferring the avatar to the meeting room upstairs

3.2.2.3 Activities

People think of their work as activities ([Convertino et al., 2007] quoting [Moran, 2006]), of which group work in our trial experiments is a special type of activity. Organizing work around activities rather than tools reduces fragmentation of support and thus leads to meaningful integration of tools [Convertino et al., 2007]. Consequently, it was aimed to design the environment so specific activities can be supported (like joint-writing a document), rather than integrating tools and then constructing activities around them. Tools do play a central role in our environment design (see 3.2.2.4), but they are only included as a result of a required activity. *Activity theory* addresses the special role of activities for humans (see textbox).

Activity Theory

Activity theory [Leont'ev, 1978] is based around a set of principles, which focus on the context of human interaction. Kuutti speaks of a "minimal meaningful context" which must be included in the basic unit of analysis [Kuutti, 1996]. The most fundamental idea in Activity theory is that the human mind exists only as part of the interaction with the environment, i.e. the objective reality: Unity of consciousness and activity [Kaptelinin, 1996]. Internal activities (e.g. thinking) emerge out of practical external activity, in fact, *"mental processes are derived from external actions through the course of internalization"* [Kaptelinin, 1996, p. 55]. Personality and consciousness are thus shaped by participation in activities [Kuutti, 1996]. Properties of the environment, not only of physical or chemical nature, but also socially or culturally established, determine the way people act on these entities. There happens to be a reciprocal relationship between subject and object: The subject transforms the object, while the properties of the object transform the subject [Kuutti, 1996]. Activities are often is a collective phenomenon, involving several actors [Korpela & Mursu, 2003]. Hence the *community* exists besides subjects and objects [Kuutti, 1996]. Subjects are situated in communities, which are mediated by rules of participation and by divisions of labor ([Gifford & Enyedy, 1999] quoting [Engeström, 1987]). Human activity is further mediated by a number of *tools* (see 2.2.1.3), both external (e.g. telephone) and internal (e.g. heuristics). The tool is both enabling and limiting, in that *"it empowers the subject in the transformation process with the historically collected experience…but it also restricts the interaction to be from the perspective of that particular tool only"* [Kuutti, 1996].

There is a hierarchical structure in Activity theory, which specifies a certain terminology. *Activities* follow motives, subordinated *actions* are directed at specific conscious goals, and actions are executed through a set of *operations*. Halverson concludes: *"Activity theory is powerful because it names and names well, but this both binds and blinds its practioners to see things in those terms"* [Halverson, 2002, p. 262].

Overall, the situation during a meeting, and during the following trial experiments in particular, relates to activity theory (see textbox): Participants gather in an *environment*, which offers certain *tools*. They hold a meeting, which has a certain objective. The active participation in the meeting is an *activity*, namely the process of solving the task (i.e. co-producing a priority list). Subordinated *actions* could be "discussing priorities" or "writing a list in the online editor". In the latter case, subordinated *operations* would be the use of specific functions in the online editor. The following categorization can summarize different *types* of groups and their specific *activities* (see Figure 20). It further highlights the duality of *goals, organizer* and *knowledge* type.

		Goal		
		Work related	**Socially** motivated	
Knowledge	**Local**, situated	*Operational activities* (short-term, task-oriented)	*Relational activities* (construct networks)	**Activities**
	Global, abstract	*Strategic activities* (long-term, abstraction)	*Integrative activities* (construct organization)	
Organizer	**External**	*Teams, taskforces, crews*	*Social clubs, societies*	**Types**
	Internal	*Ad hoc taskforces*	*Social friendships, clans*	

Figure 20: Taxonomy of groups (adapted from [Sutcliffe, 2005], [Zacklad, 2003], [Arrow et al., 2000])

Reflecting on Figure 20, we will observe groups conducting *operational activities* (because of their task-orientedness) in our trial experiments. This fits well together with the simulated, but potential *work related goal* of the activity (prioritizing items). *Brainstorming* (see textbox) is the main activity of the participants during the trial experiments. Without expert knowledge, the task requires the participants to post several ideas as to why a certain item could be most helpful.

Brainstorming

The most famous creativity technique is brainstorming, based around idea generation in a group exempted of criticism or evaluation. Group members have a positive effect on the others individuals creativity ([Pissarra & Jesuino, 2005] quoting [Osborn, 1957]). According to Osborne, brainstorming groups outperform individuals both in quality and quantity of ideas, but empirical studies have disconfirmed these assumptions for traditional groups [DeRosa et al., 2007]. However, electronic brainstorming can be more efficient, as it combines the advantages of working alone, thus reducing blocking, without suppressing the inputs of other group members (e.g. in chat people can type simultaneously) [Pissarra & Jesuino, 2005]. A newer study shows that this is only true for groups with less than eight members [DeRosa et al., 2007].

3.2.2.4 Enabling collaboration

Andriessen identified five processes leading to collaboration that group work can support: *Communication, cooperation, coordination, knowledge sharing* and *social interaction* [Andriessen, 2002, p. 124]. The contradicting findings regarding *social interaction* were described before (see 2.2.3.6.3) and are extended in the discussion (see 4.2). Regarding *cooperation, coordination and knowledge sharing*, several features are still missing in Second Life, such as sharing non-Second Life artifacts for joint work; storing histories permanently of a conversation session and moreover, inclusion of an internal browser [Olivier & Pinkwart, 2007]. Power point presentations in Second Life require the user to upload each individual slide as a separate image. Also up to now, Second Life is a poor document repository. Reprocessability (according to media synchronicity) is low, as the generated information can only be reused to a certain degree by the receiver. Focusing on the *communication* process mentioned by Andriessen, the poor *asynchronous* tools are a weakness: The available notecards lack structure and formatting by nature, unlike a conversation in a threaded forum (discussion ordered by topic or time). In-world group collaboration is thus hampered. Regarding the *synchronous* communication, the advantages of the virtual environment strengthen the position of Second Life. The user can choose between audio and chat communication.

Creativity was especially relevant for the task in the trials experiments, when participants needed to justify their solutions. Therefore the factors fostering creativity were investigated, so we could design our environment accordingly (see 2.2.1.3). Of those factors, *tools* were especially relevant to our environment design. We tried to capitalize on the advantages of tools (see textbox).

Tools

Tools enable to view alternate representations simultaneously (showing similarities, differences), which increases the chance of creative solutions [Hewett, 2005]. They make it possible to automatically log intermediate results that led to a current state in thinking, which helps recapturing what choices were being made and why they were made at a certain time [Hewett, 2005]. Interim results, without having to make a final commitment, are critical to creative work [Hewett, 2005]. Because individuals do not like interruptions to the flow of their thinking and work, these logs should be captured unobtrusively [Hewett, 2005]. The interim results can assist the individual: Having information brought up without seriously disrupting the flow of work can sometimes be all that is needed to refresh the user's memory ([Hewett, 2005] quoting [Hewett & Adelson, 1998]).

Indeed, Second Life's deficiencies in the support of the collaboration processes mentioned above by Andriessen, lead to a great deal of effort being put into in-world *mash-up tools*. Mash-up tools combine data and/or functionality from more than one source. For our purpose, we tried to integrate the online office solution *Google Docs* [Google] into the OnRez client of Second Life (see 3.2.1.2.3).

Google Docs allows several users to store interim results, contributing to creative solutions (see previous textbox). The software enables authors to co-edit a document stored on a Google repository using a common web browser. By automatically sending updated document versions to a central server in high frequency, conflicts can be held to a minimum. Google Docs is a lightweight application and no configuration on the user's computer is necessary [Dekeyser & Watson, 2007].

Besides offering features helpful for asynchronous work (like being able to access any previous version in the document history), Google Docs allows two forms of *synchronous joint-writing*:

- Individuals can have *synchronous access* to a document. However, if they want to be able to access the document at the same time like somebody else, this does not imply that they write together synchronously [Noël & Robert, 2004].
- On the other hand, users can collaborate, share ideas and edit content *concurrently*.

It was shown, that often the majority prefers the first situation in case of joint writing [Noël & Robert, 2004]. However, exactly the synchronous access functionality is missing in Second Life, and thus it was decided that the integration of Google Docs would substantially raise the collaborative potential of Second Life.

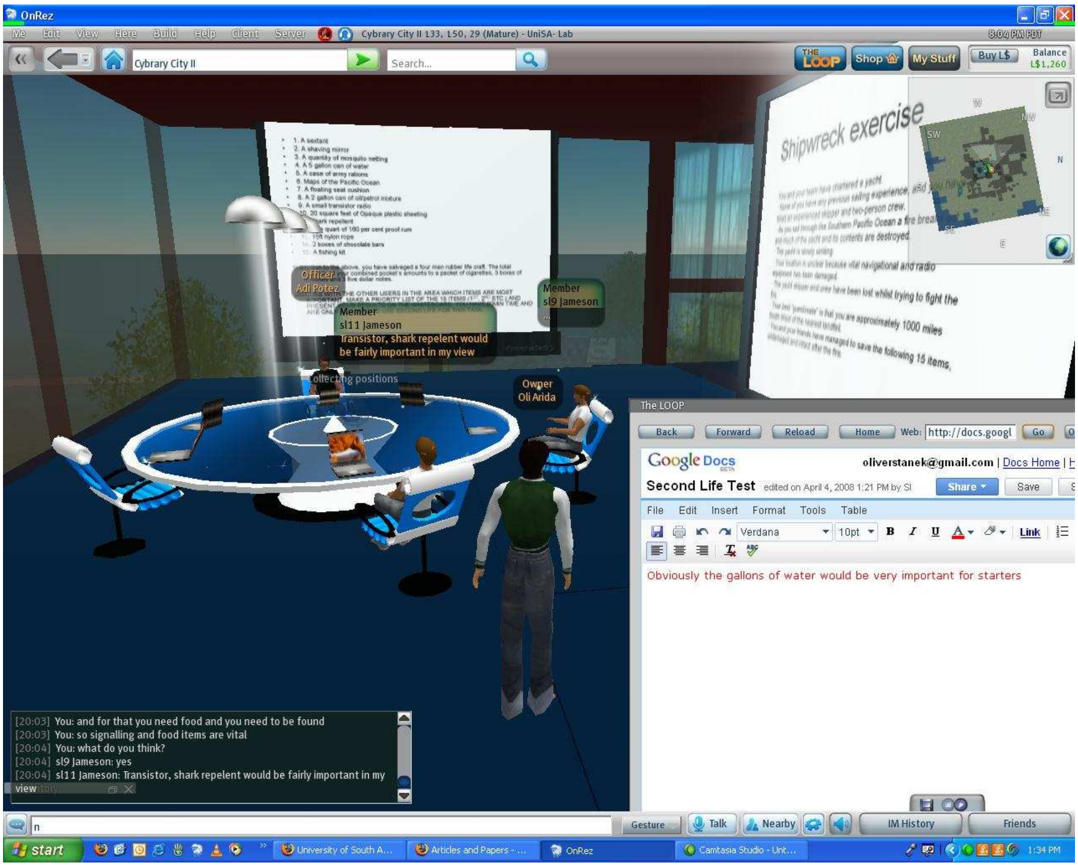


Figure 21: The meeting room during trial 3, showing the integration of Google Docs in the browser of the OnRez client

3.2.3 *Data collection*

The unquestionable value of data collection during virtual collaboration is illustrated in the following quotation: *"If researchers who are geographically remote start writing code together within a virtual space, we can literally capture all that is said and done while writing the code. By keeping the full digital record of a coding session...future users of that code will always have the option to travel back in time to get full disclosure of all that happened during the writing. Many of us, struggling with legacy code that was written decades ago, would be happy to give a minor fortune for the possibility of making such a trip back in time."* [Hut, 2008, p. 10]

The methods for the data collection comprised different approaches, which changed over the time of the project. At first, a script written in Linen Labs scripting language (LSL) collected avatar data and the chatlog. Figure 22 illustrates an example of raw data collected from the LSL script in an early stage. The data was sent to a specially created email account by using the email function of LSL. However, this would have resulted in bad maintainability (see 3.2.2). Therefore, the raw data is now automatically stored on our dedicated webspace using a "httprequest" function in the LSL script. The data is permanently retrievable trough a URL for later analysis. For our trial experiments, the chatlog was collected separately by using Second Life's official log function. Two factors led to this decision. Firstly, we received corrupted data several times when collecting the avatar data with the chatlog together, probably because of a buffer overflow. Secondly, a shift in the data analysis focus occurred in the later stage of the thesis project. The chatlog became the main object of attention, rather than the avatar data or a combination of both. Therefore, an exact synchronization of both sources was not a requirement anymore at this phase of investigation. Nevertheless, we have continued to collect the avatar data throughout our trials for potential analysis beyond the scope of this thesis project.

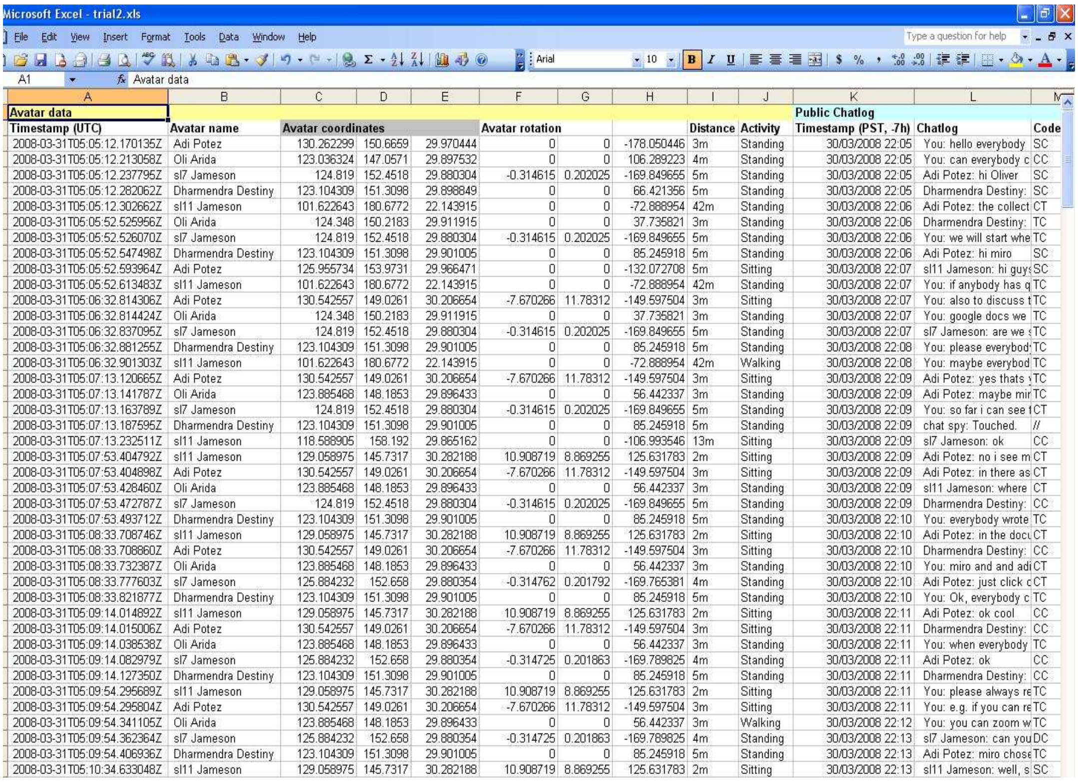
```
Object-Name: The new Box
    Region: Cybrary City II (248064, 244224)
    Local-Position: (103, 162, 22)

    Oli Arida, 2008-02-01T23:13:18.317044Z, <103.111870,
    157.852661, 22.931604>, <0.000000, 0.000000, -
    84.560204>, Adi Potez, 2008-02-01T23:13:18.317096Z,
    <100.644295, 157.037094, 22.557018>, <-10.131050, -
    9.761332, -49.506481>, NITIN Convair, 2008-02-
    01T23:13:18.317145Z, <106.250473, 155.740631,
    22.984556>, <0.000000, 0.000000, 132.197006>,
    Dharmendra Destiny, 2008-02-01T23:13:18.333080Z,
    <106.097160, 153.181992, 22.564913>, <5.917322,
    12.741091, 151.823166>, Oli Arida, 2008-02-
    01T23:13:22.973338Z, <103.111870, 157.852661,
    22.931604>, <0.000000, 0.000000, -84.560204>,

    NITIN Convair[2008-02-01T23:13:18.292500Z] : ok
    Adi Potez[2008-02-01T23:13:18.447598Z] : k anythin to add
    on the ppt?
    Oli Arida[2008-02-01T23:13:20.393270Z] : and see how the
    lag is
    NITIN Convair[2008-02-01T23:13:26.566697Z] : alright
```

Figure 22: Example of raw data collected by the LSL script in an early stage

Before sending the data with the LSL script, it had to be formatted correspondingly so it could be read as a .csv file later on for further processing. The steps during conversion included removal of unnecessary text, storing the data in a comma-separated values file

(.csv) and applying several functions in Excel to receive a sorted, intuitive comprehensible overview of the data. Figure 23 shows the processed data after converting the raw data.

In our final approach for the data collection, the avatar data and the chat log do not have exactly the same timestamp. The avatar data comes with a UTC timestamp, and the official chatlog uses Second Life's own time zone, namely PST (7h difference). Furthermore, the avatar data timestamp has many digits after the comma. A problem with synchronizing the two sources lay in the fact that both data collections were manually started, thus resulting in a slight shift between the start of each.



Avatar data										Public Chatlog		
Timestamp (UTC)	Avatar name	Avatar coordinates			Avatar rotation			Distance	Activity	Timestamp (PST, -7h)	Chatlog	Code
2008-03-31T05:05:12.170135Z	Adi Potez	130.262299	150.6659	29.970444	0	0	-178.050446	3m	Standing	30/03/2008 22:05	You: hello everybody	SC
2008-03-31T05:05:12.213058Z	Oli Arida	123.036324	147.0571	29.897532	0	0	106.289223	4m	Standing	30/03/2008 22:05	You: can everybody c	CC
2008-03-31T05:05:12.237795Z	sl7 Jameson	124.819	152.4518	29.880304	-0.314615	0.202025	-169.849655	5m	Standing	30/03/2008 22:05	Adi Potez: hi Oliver	SC
2008-03-31T05:05:12.282062Z	Dharmendra Destiny	123.104309	151.3098	29.898849	0	0	66.421356	5m	Standing	30/03/2008 22:05	Dharmendra Destiny:	SC
2008-03-31T05:05:12.302662Z	sl11 Jameson	101.622643	180.6772	22.143915	0	0	-72.888954	42m	Standing	30/03/2008 22:06	Adi Potez: the collect	CT
2008-03-31T05:05:52.525956Z	Oli Arida	124.348	150.2183	29.911915	0	0	37.735821	3m	Standing	30/03/2008 22:06	Dharmendra Destiny:	TC
2008-03-31T05:05:52.526070Z	sl7 Jameson	124.819	152.4518	29.880304	-0.314615	0.202025	-169.849655	5m	Standing	30/03/2008 22:06	You: we will start whe	TC
2008-03-31T05:05:52.547498Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:06	Adi Potez: hi miro	SC
2008-03-31T05:05:52.593964Z	Adi Potez	125.955734	153.9731	29.966471	0	0	-132.072708	5m	Sitting	30/03/2008 22:07	sl11 Jameson: hi guy:	SC
2008-03-31T05:05:52.613483Z	sl11 Jameson	101.622643	180.6772	22.143915	0	0	-72.888954	42m	Standing	30/03/2008 22:07	You: if anybody has q	TC
2008-03-31T05:06:32.814306Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:07	You: also to discuss t	TC
2008-03-31T05:06:32.814424Z	Oli Arida	124.348	150.2183	29.911915	0	0	37.735821	3m	Standing	30/03/2008 22:07	You: google docs we	TC
2008-03-31T05:06:32.837095Z	sl7 Jameson	124.819	152.4518	29.880304	-0.314615	0.202025	-169.849655	5m	Standing	30/03/2008 22:07	sl7 Jameson: are we	TC
2008-03-31T05:06:32.881255Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:08	You: please everybod	TC
2008-03-31T05:06:32.901303Z	sl11 Jameson	101.622643	180.6772	22.143915	0	0	-72.888954	42m	Walking	30/03/2008 22:08	You: maybe everybod	TC
2008-03-31T05:07:13.120665Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:09	Adi Potez: yes thats	TC
2008-03-31T05:07:13.141787Z	Oli Arida	123.885468	148.1853	29.896433	0	0	56.442337	3m	Standing	30/03/2008 22:09	Adi Potez: maybe mir	TC
2008-03-31T05:07:13.163789Z	sl7 Jameson	124.819	152.4518	29.880304	-0.314615	0.202025	-169.849655	5m	Standing	30/03/2008 22:09	You: so far i can see	CT
2008-03-31T05:07:13.187595Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:09	chat spy: Touched.	//
2008-03-31T05:07:13.232511Z	sl11 Jameson	118.588905	158.192	29.865162	0	0	-106.993546	13m	Sitting	30/03/2008 22:09	sl7 Jameson: ok	CC
2008-03-31T05:07:53.404792Z	sl11 Jameson	129.058975	145.7317	30.282188	10.908719	8.869255	125.631783	2m	Sitting	30/03/2008 22:09	Adi Potez: no i see m	CT
2008-03-31T05:07:53.404898Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:09	Adi Potez: in there as	CT
2008-03-31T05:07:53.428460Z	Oli Arida	123.885468	148.1853	29.896433	0	0	56.442337	3m	Standing	30/03/2008 22:09	sl11 Jameson: where	CT
2008-03-31T05:07:53.472787Z	sl7 Jameson	124.819	152.4518	29.880304	-0.314615	0.202025	-169.849655	5m	Standing	30/03/2008 22:09	Dharmendra Destiny:	CC
2008-03-31T05:07:53.493712Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:10	You: everybody wrote	TC
2008-03-31T05:08:33.708746Z	sl11 Jameson	129.058975	145.7317	30.282188	10.908719	8.869255	125.631783	2m	Sitting	30/03/2008 22:10	Adi Potez: in the docu	CT
2008-03-31T05:08:33.708860Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:10	Dharmendra Destiny:	CC
2008-03-31T05:08:33.732387Z	Oli Arida	123.885468	148.1853	29.896433	0	0	56.442337	3m	Standing	30/03/2008 22:10	You: miro and and adi	CT
2008-03-31T05:08:33.777603Z	sl7 Jameson	125.884232	152.658	29.880354	-0.314762	0.201792	-169.765381	4m	Standing	30/03/2008 22:10	Adi Potez: just click c	CT
2008-03-31T05:08:33.821877Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:10	You: Ok, everybody c	TC
2008-03-31T05:09:14.014892Z	sl11 Jameson	129.058975	145.7317	30.282188	10.908719	8.869255	125.631783	2m	Sitting	30/03/2008 22:11	Adi Potez: ok cool	CC
2008-03-31T05:09:14.015006Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:11	Dharmendra Destiny:	CC
2008-03-31T05:09:14.038538Z	Oli Arida	123.885468	148.1853	29.896433	0	0	56.442337	3m	Standing	30/03/2008 22:11	You: when everybody	TC
2008-03-31T05:09:14.082979Z	sl7 Jameson	125.884232	152.658	29.880354	-0.314725	0.201863	-169.789825	4m	Standing	30/03/2008 22:11	Adi Potez: ok	CC
2008-03-31T05:09:14.127350Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:11	Dharmendra Destiny:	CC
2008-03-31T05:09:54.295689Z	sl11 Jameson	129.058975	145.7317	30.282188	10.908719	8.869255	125.631783	2m	Sitting	30/03/2008 22:11	You: please always re	TC
2008-03-31T05:09:54.295804Z	Adi Potez	130.542557	149.0261	30.206654	-7.670266	11.78312	-149.597504	3m	Sitting	30/03/2008 22:11	You: e.g. if you can re	TC
2008-03-31T05:09:54.341105Z	Oli Arida	123.885468	148.1853	29.896433	0	0	56.442337	3m	Walking	30/03/2008 22:12	You: you can zoom w	TC
2008-03-31T05:09:54.362364Z	sl7 Jameson	125.884232	152.658	29.880354	-0.314725	0.201863	-169.789825	4m	Standing	30/03/2008 22:13	sl7 Jameson: can you	DC
2008-03-31T05:09:54.406936Z	Dharmendra Destiny	123.104309	151.3098	29.901005	0	0	85.245918	5m	Standing	30/03/2008 22:13	Adi Potez: miro chose	TC
2008-03-31T05:10:34.633048Z	sl11 Jameson	129.058975	145.7317	30.282188	10.908719	8.869255	125.631783	2m	Sitting	30/03/2008 22:13	sl11 Jameson: well, s	SC

Figure 23: Excel sheet showing avatar data columns (timestamp, name, coordinates, rotation, distance, activity) and the chat log columns (timestamp, chatlog, code) from trial number 2

3.2.3.1 Avatar data

Three different kinds of avatar data were collected by our LSL script:

- Avatar coordinates (XYZ location values in the 3D space)
- Avatar orientation (XYZ rotation values around the corresponding axes in the 3D space)
- Animations (e.g. user actions like "walking")

Potentially, a large amount of numerical data can be collected from our environment (avatar coordinates and orientation), which would allow a quantitative analysis. However, there are limitations to this kind investigation (see 2.2.3.6.3). Furthermore, after receiving a tremendous amount of data, the data needs to be cleaned and sorted. Then, transformation functions need to be applied to make sense of the information (e.g. to see the movement of avatars).

3.2.3.2 Chat log

A chat log is an easy method to capture a major part of the conversation interaction happening between avatars in a virtual environment. Unfortunately, the Second Life chat log does have its own, separate timestamp and is thus not synchronized with the avatar data (see 3.2.3). In addition, chat logs fail to capture the temporal dynamic of composing a message, as only the time of posting the entire message to the server is logged [R. J. Moore, Gathman et al., 2007]. Furthermore, such records fail to observe movement through space or user interface actions [R. J. Moore, Gathman et al., 2007].

The chat log in Second Life can be captured in three ways:

- Our avatar data collection script can include the chat log, but because of a buffer limit, the received data can be corrupted (see 3.2.3). This solution seems not bearable, especially in the case of additional data to be collected in the future (see scalability: 3.2.2)
- A second approach is to use the official chat log feature accessible in the Second Life client. It does write the log in a textfile on the local machine. We used this solution for our trial experiments, because it proved to be most stable. However, it was a

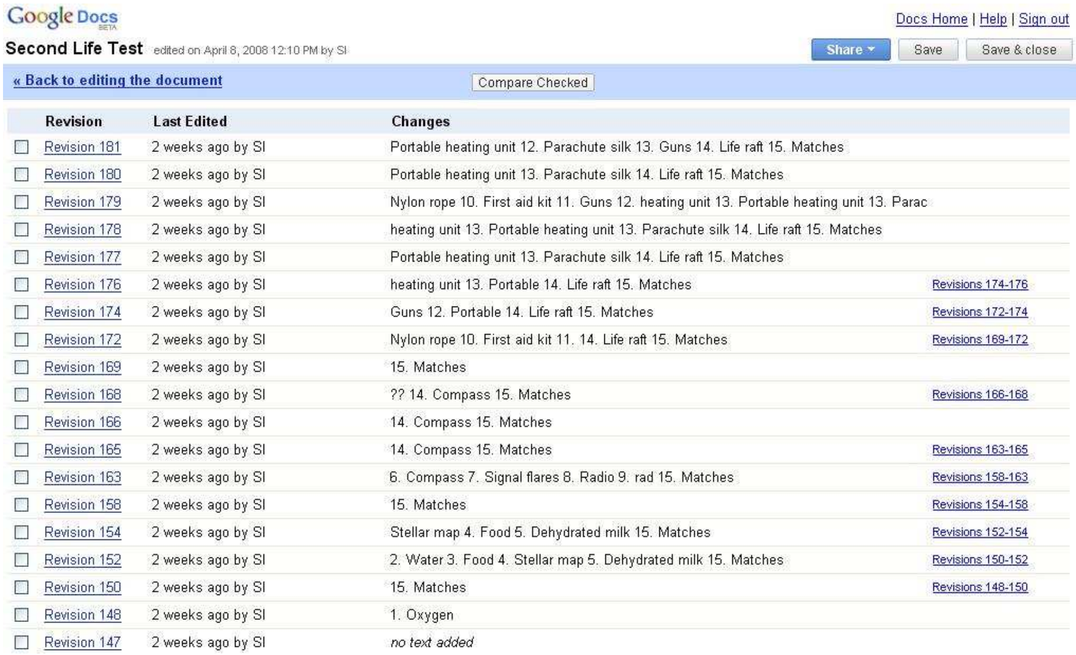
requirement that the chat log could be later accessed in a central location (see maintainability: 3.2.2), which led to a third option.

- The third option is to run a second script separate from the avatar data, which sends the chatlog to a dedicated webspace. This became our final solution after the trial experiments.

3.2.3.3 Artifact

Besides monitoring the process of the discussion *about the artifact*, the development of the *artifact itself* can be monitored in our environment. In the case of the trial experiments, the discussion about the artifact is the task conversation going in the chat of Second Life. The artifact itself is represented by group priority list in the form of a Google Docs document. The artifact develops over time and ends up as the solution of the task. Google Docs allows monitoring the progress by providing a complete overview of revisions made to the document (see Figure 24). The user can also go back to any older version. If required, Google Docs makes a comparison with another version and highlights who made which changes (see Figure 25). The document can be exported in various, common file formats.

Nevertheless, the revision history is not exportable from Google Docs. Thus this situation does not meet our requirements for an automated, centralized data collection of the artifact development. Therefore, the Google Docs revision history is not further analyzed at this stage.



Revision	Last Edited	Changes	
Revision 181	2 weeks ago by SI	Portable heating unit 12. Parachute silk 13. Guns 14. Life raft 15. Matches	
Revision 180	2 weeks ago by SI	Portable heating unit 13. Parachute silk 14. Life raft 15. Matches	
Revision 179	2 weeks ago by SI	Nylon rope 10. First aid kit 11. Guns 12. heating unit 13. Portable heating unit 13. Parac	
Revision 178	2 weeks ago by SI	heating unit 13. Portable heating unit 13. Parachute silk 14. Life raft 15. Matches	
Revision 177	2 weeks ago by SI	Portable heating unit 13. Parachute silk 14. Life raft 15. Matches	
Revision 176	2 weeks ago by SI	heating unit 13. Portable 14. Life raft 15. Matches	Revisions 174-176
Revision 174	2 weeks ago by SI	Guns 12. Portable 14. Life raft 15. Matches	Revisions 172-174
Revision 172	2 weeks ago by SI	Nylon rope 10. First aid kit 11. 14. Life raft 15. Matches	Revisions 169-172
Revision 169	2 weeks ago by SI	15. Matches	
Revision 168	2 weeks ago by SI	?? 14. Compass 15. Matches	Revisions 166-168
Revision 166	2 weeks ago by SI	14. Compass 15. Matches	
Revision 165	2 weeks ago by SI	14. Compass 15. Matches	Revisions 163-165
Revision 163	2 weeks ago by SI	6. Compass 7. Signal flares 8. Radio 9. rad 15. Matches	Revisions 158-163
Revision 158	2 weeks ago by SI	15. Matches	Revisions 154-158
Revision 154	2 weeks ago by SI	Stellar map 4. Food 5. Dehydrated milk 15. Matches	Revisions 152-154
Revision 152	2 weeks ago by SI	2. Water 3. Food 4. Stellar map 5. Dehydrated milk 15. Matches	Revisions 150-152
Revision 150	2 weeks ago by SI	15. Matches	Revisions 148-150
Revision 148	2 weeks ago by SI	1. Oxygen	
Revision 147	2 weeks ago by SI	*no text added*	

Figure 24: Google Docs overview of revisions made to a priority list from the trial experiments

Figure 25: Google Docs functionality to compare document versions

3.2.3.4 Video

An additional form of data collection was achieved by recording a screen capture video. An in-world video of the whole meeting was retrieved in each trial. The video includes the potential voice communication of all participants. As the screen capture feature of Second Life is unstable and not smooth, we used external video recording software. The video shows the interaction going on through the eyes (camera position) of one dedicated "recording avatar". This can be helpful when data is not understandable from the collected chat log or avatar data alone: One can go back to the video and make the required annotations to the textual data. In our study, the video rarely needed to be consulted for clarification and was not further evaluated.

3.3 Trial experiments

Practical trial experiments are one step of our usability evaluation cycle (see Figure 13). In total we run four cycles, thus we conduct four trial experiments. Cognitive biases lead humans to consistently and predictably make errors, thus one should always opt for empirical investigation over intuition [DeFranco-Tommarello & Deek, 2002]. During the environment-set up phase, many usability issues were observed. However, findings from this expert investigation cannot be considered proven unless they show up again in further practical sessions. Thus, we need a group of trial experiments to prove that the observed issues are indeed permanent issues. We capture and record usability issues by various means (see 3.2.3). In order to avoid having limited generalization of our findings, we conduct trials in a common *workplace environment*. These trials should not suffer from the constraints of formal *laboratory experiments*, at least not to the same extent (see textbox). We accept the downside of possible distractions during the trials.

Constraints of laboratory experiments

- A problem of laboratory experiments is that the parameters can be controlled. This is illustrated by HCI systems, which are often only evaluated in laboratory context, where parameters such as lighting and background noise can be adjusted [Poppe & Rienks, 2007]. Consequently, *"the stark differences between a controlled laboratory setting and the messy real world means that many of the theories derived from the former are not applicable to the latter"* [Rogers, 2004, p. 92].

- Ethic considerations forbid putting laboratory experiment participants through stress that may be experienced in many real-world scenarios [Wainfan & Davis, 2004].
- In a laboratory setting where experiment participants know they are being observed, one cannot rule out if user participation is artificially high due to the desire to assist the researchers [Wainfan & Davis, 2004].

Setting up the trial experiments required a considerable amount of time and effort. Organizational issues faced among others were the availability of a certain amount subjects at a specific time at a specific location: Trying to organize people to attend events in a virtual space requires persistent management: "*To get a group of people to adapt to a new medium seems to take a considerable and ongoing amount of prodding"* [Hut, 2008, p. 9].

Furthermore, each machine in the research lab needed be configured before the trials. This included the creation of several avatars, which could only be achieved by creating special emails addresses and then activating the avatar accounts from outside the University network. Before each trial, an avatar was logged in on the machine, so the participants could immediately start to work on the task when the time started. The author was present in the meeting environment during all trials and assisted the participants in case of need.

3.3.1 Resources

The management of resources for the trial experiments comprised the gathering, instruction and supervision of trial participants (see subjects 3.3.1.1), as well as the choice of suitable trial exercises (see tasks 3.3.1.2). The configuration of computers for the trial experiments is discussed in the facilitation section (see 3.2.1.2).

3.3.1.1 Subjects

Our participants are put together in groups and presented with a task when starting the trial experiment.

We are conducting an experiment with a certain number of subjects, so large that the full range of social interactions play out, but not so large that we loose track of what is going on [Stahl et al., 2006]. After several test-runs (see 3.3.3.1) with different group sizes, we decided to conduct the trial experiments with four participants.

Our target group is a research group; however the prototype environment should be flexible enough to support various kinds of groups (e.g. students, task-forces etc.). Our subjects are mostly inexperienced users of the environment. We want to observe what happens if users are presented with a new collaboration environment, thus eliminating the differences in acquired knowledge through learning. The participants were directly chosen from a research group, so we do not face the problem that our subjects are self-selected, which may introduce bias in the answers [Noël & Robert, 2004].

3.3.1.2 Tasks

Our tasks are called "*Lost at sea*" and "*Survival on the moon*" (see 6.2). These tasks are about co-deciding on a priority list of given items and come in many variations. They are often used to assess the teamwork behavior of group interview candidates. Therefore they are helpful to investigate the collaboration in a group. Furthermore, decision-making (e.g. co-deciding on priorities) is a common activity in a meeting. As we are investigating the collaboration potential of virtual worlds for meetings, we decided on these tasks.

Two different tasks were given to participants in separate sessions. The first was used for trial 1 and 3, the latter for trial 2 and 4. The reason for this is simply that the trial participants might have heard about the task from earlier trial participants. However, the tasks are similar in structure, only the solution is different. Thus we can still make comparisons between groups presented different tasks.

The tasks have a suggested ranking, which leads to an ideal solution. Thus these tasks are categorized as *closed-ended* exercises. However, our environment also supports open-ended tasks. An *open-ended* task was initially considered for our trials ("automatic post office") [J. S. Olson et al., 1993]. It can be found in the appendix (see 6.2.3). The automatic post office task was not part of our trials because of the following two reasons:

- Controlled trials are a new research area in Second Life. Many issues come up during the task. Using a close-ended task makes the participant instructions simpler and results in less confusion regarding the expected outcome.
- Second Life lacks the availability of a sophisticated in-world *whiteboard*, which allows free hand drawings. This is a requirement for the "automatic post office" task. Second Life does include a few whiteboard tools (user-generated content), but their operability proved cumbersome to all researchers who tried to use them. The usability was considered so low that people gave up expressing their ideas on the whiteboard. Another hindrance is that one cannot store intermediate results, which are essential for creativity (see 2.2.1.3). This led to the idea to use an external online whiteboard tool inside Second Life (by capitalizing on the in-world web browser of the OnRez client). The free online whiteboard service "Skrbl" [Skrbl] was chosen. However, usability is again limited. Because of the simplified in-world browser, not all types of information are displayed properly. This is not so much an issue with free hand drawings, but text writing/editing fails completely. On the other hand if one uses the Google Docs [Google] service in conjunction with Second Life, text writing/editing works, but free hand drawing is not supported. We decided on the latter solution and used a corresponding task.

3.3.2 Methods for data analysis

The collected data from the trials is analyzed (see 3.1.2) to investigate the usability of the prototype environment (see 3.1.1). Besides coding the chatlog and conducting interviews, real-world and in-world observations were part of the data analysis.

3.3.2.1 Chatlog coding

Our ultimate goal is to find out if virtual worlds in general and Second Life in particular, are potential collaboration tools. Thus it is helpful to investigate the performance component of usability (see 3.1.1.2). However, we realized that measuring the resulting performance of four tasks does not give enough information to make statements about the different trial groups (see 4.3.2.1). In order to assess how much time or effort was spent to master the technology compared to actual communication contributing to the solution of the task, the collected interaction data was coded according to a schema [M. Maher et al., 2001]. The coding schema presented in the next section (see 3.3.2.1.1). It helps us better understand how users behave and solve a task when operating the Second Life technology. The outcomes of the categorization are thus an *indicator of performance*, rather than an actual *performance measure* (see 3.1.1.2).

3.3.2.1.1 Schema

This coding schema has been used before in the case of the evaluation of a virtual environment [M. Maher et al., 2001]. Thus the categories should have a certain maturity and adaptations can be kept to a minimum. The five classifications and their code are:

- **Design communication (DC):** Discussions regarding content, i.e. design and solution ideas of the task (e.g. idea presentation, acceptance, rejection, clarification, development, repetition, evaluation etc.) fall into this category.
- **Communication technology (CT):** Discussions regarding use of the tools and the collaborative environment fall into this category.
- **Social communication (SC):** Discussions regarding social and interpersonal talk fall into this category.
- **Task coordination (TC):** Discussions regarding task instructions, task approach, task process and task scope fall into this category.

- **Communication control (CC):** Discussions regarding maintaining floor, handling control to another person and acknowledging statements or presence fall into this category. Thus communication control is a by-product of communication.

3.3.2.1.2 Measures

Firstly, the basic unit of analysis needed to be defined. Our coding schema works best with *utterances*, as smaller units often do not give enough contextual information in order to be classified. As we are analyzing chat conversation, an utterance was defined to equal one post in the public chat. As a side note, a few, special utterances were not coded at all, because they were exchanged between the facilitators attending the meeting and were not relevant to the trial participants (e.g. "the data collection seems to run smooth").

The coding of the chatlog always started from the point of time when all trial experiment participants were logged in. Therefore, the coding starts before the participants start to work on the actual task. Consequently, the coding does not always span the same time period. This is not an issue, as the differences between the parts of a meeting are still recorded (see below) and visualized in the corresponding pie charts.

Regarding the progress of the trial, three different temporal categories are used in the analysis:

- **Parts:** Firstly, the *entry* and *main part* of the conversation are separated. The entry part constitutes all the communication from the time all participants are logged in the environment, but before the participants start to work on the actual task. The main part forms the remainder. Both parts together are called the *whole conversation.*
- **Phases:** During the analysis of phases, a distinction between the four *quarters* of the meeting is made. The first quarter constitutes one fourth of the total utterance sum, the second quarter the next fourth and so forth.
- **Evolution:** Finally, when looking at the evolution of the meeting, every utterance is analyzed. The term "utterance number" is the sum of utterances up to that point.

To summarize, the entry part/main part distinction is a qualitative separation, while the quarters and the utterance numbers represent a quantitative separation.

3.3.2.1.3 Issues

Sometimes there are cases in which an utterance cannot be clearly classified into one category of the coding schema. An example would be "yes, it should be number 3". "Yes" is communication control, while "it should be number 3" is belonging to design communication. In this situation, design communication overrules the acknowledging statement, thus the utterance is classified correspondingly.

In some cases, a single utterance cannot be classified as such, but needs to be analyzed in the context of the conversation. For example, "yeah, I agree" can follow three utterances after the statement it is actually corresponding to. Thus, and because of syntax errors or informal language, a human content analysis of the conversation is necessary.

3.3.2.2 Interviews

After the trials, participant interviews were conducted to grasp usability issues, which were not traceable in the avatar data or the chat log. For example, the satisfaction component of usability would a prime example. Moreover, the interviews confirmed problems that were observed during the thesis project (usability inspection). Interviews are typical for qualitative research (see 3.3.2). For instance, an interview can go into deeper level of detail than a questionnaire and thus provide more information [Bowman et al., 2002]. This is helpful because collaborating individuals can only articulate their difficulties and frustration of certain activities, e.g. like coordinating activities with their partner (task coordination in our schema), but are unaware or fail in others, such as coordinating speaking (communication control in our schema) [Heldal et al., 2005].

Meeting satisfaction

Meeting satisfaction is described by Reinig's goal–attainment model ([Briggs et al., 2006] quoting [Reinig, 2003]), which is illustrated below (see Figure 26). The perceived goal attainment is defined as the degree to which one perceives that some object either hinders or advances the attainment of one's salient individual goals. Satisfaction is then an emotional judgment that one's requirements have been met. Thus there can be shifts from satisfaction to dissatisfaction during the same meeting as and an individual pursued a different mix of goals.

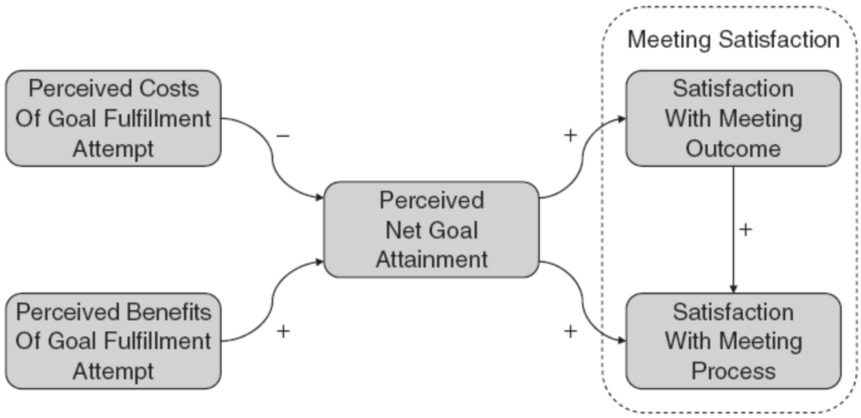


Figure 26: Reinig's goal-attainment model of satisfaction [Reinig, 2003]

Although we investigate meeting satisfaction in our interviews, a meeting model (such as the one in the textbox) is difficult to apply to the tasks that we investigate. First of all, as observed, the participants often do not have prefixed notions of their individual goals. Furthermore, they do not know the prototype technology sufficiently to have expectations regarding the meeting process. Thus our investigation takes a different, more exploratory approach. The participants are interviewed after the trial. Our interviews cannot consist of prefixed questions, but address the issues experienced during the actual task. Thus they are classified as informal interviews.

In the case that a high number of participants contribute in a formal experiment, *surveys* can be a useful instrument to measure the user satisfaction. Two ready-to-use surveys, one which had to be adapted to suit Second Life, can be found in the appendix (see 6.7). One survey assesses the user satisfaction regarding enjoyment and the other regarding technology acceptance.

3.3.3 Results

Results were achieved by applying qualitative data analysis methods (see 3.3.2) to the data collected from practical experiments in our Second Life meeting environment.

3.3.3.1 Test-runs

In order to have a smooth performing environment, several test-runs were conducted before the trials started. Part of our investigation was the use of audio communication in a virtual world. Therefore we needed to supply our machines with headsets (devices combining speakers and microphone). Theses devices allow users to speak in a natural way when communicating with other avatars. One issue came up quickly. The participants complained that they could not understand the other participants well. This was traced back to two factors:

- Participants sitting close to each other heard an echo when speaking. The close physical location of the microphones is the most likely reason for this phenomenon.
- On the other hand, the loudness was generally perceived as too low. A change of the microphone volume level in the Windows sounds and audio device settings solved the matter.

The "Lost at sea" task, which is about discussing a priority list of 15 given items as described in the corresponding section (see 6.2.1), was used for our test-runs. The initial rules were that audio communication had to be used for non-task related topics (e.g. social talk, coordination), and chat for task related topics (which can thus be traced back with a timestamp). Voice communication was not always clear (silent, echo), which led to confusion and participants physically moving to the desks of other participants to check things in real world. It was thus decided to stick solely to chat communication for our trial experiments. *Social presence theory* suggests that chat communication is sufficient for routine tasks (see 2.1.1), such as the common meeting activity of prioritizing items (see 3.3.1.2). Therefore, only textual communication was further analyzed.

3.3.3.2 Trial observations

In order to obtain usability issues, we used different configurations of our prototype environment over the four trials, as illustrated in Figure 27. The results in this section were elicited by directly observing the participants when they solved the task (mainly in-world), and by conducting interviews (see 3.3.2.2) after the trials.

Configuration	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**
Google Docs	No	Yes	Yes	Yes
Chat bubbles	No	No	Yes	Yes
Two screens	No	No	No	Yes

Figure 27: Trial configurations

3.3.3.2.1 First trial

Task: Lost at sea
Date: 11. March 2008
Participants: Experienced users of Second Life
Task duration (main part): 60 min; entry part: 17 min
Configuration: Initial prototype environment

Participants showed a tendency to submit a high number of ideas in the public chat, but often did not respond to what was being posted. This makes it hard to realize which topic (list item) is currently addressed.

The convergent process of structuring a priority list failed. The most obvious explanation was that the tool for supporting the convergent process failed. The participants were supposed to put their solution in the separate "group chat" feature during the first trial. The problem of the group chat feature was that it did not allow the participants to work concurrently on a single solution. *Therefore, a new tool supporting the convergent process was introduced in the second trial.* The participants also voiced the opinion that the time used for the task was too long. Thus, the task duration was cut to 30min in the following trials.

Otherwise, the observations from the first trial are rather limited, because a great deal of attention was given to the stable operation of the environment. A minor technical problem occurred in the first trial. The collection of avatar data failed because of a buffer overflow. Adjusting the sending interval, which led to a higher send rate with smaller packages, quickly solved the problem after the first trial.

3.3.3.2.2 Second trial

Task: Lost on moon
Date: 31st March 2008
Participants: Experienced users of Second Life (2 of them not experienced in our created environment)
Task duration (main part): 30min; entry part: 12min
Additional configuration: Google Docs

The main finding from trial 1 was that a new tool supporting the convergent process of coming up with a group solution was needed. By using the browser of the OnRez client to integrate Google Docs, synchronous document access and synchronous text-editing can be achieved inside Second Life, which was found by several users to enhance collaboration. Especially the convergent process of co-deciding on items in a priority list was simplified during the trials. Although the integration of Google Docs was well accepted by all trial participants, certain issues persist. For example, the cursor is not displayed properly, which leads to workspace awareness problems (see 2.2.4.1). Another issue is that certain "hotkey" functions (known combinations of keyboard buttons) do not work when accessing Google Docs through the OnRez browser.

New users of the environment mentioned that audio conversation would drastically reduce confusion. The speed of chat was too fast for many participants. They could not grasp every idea that was presented in the chat (likely because of information overflow), which could not happen in the same way in an audio conversation. Additionally, participants did not use gestures. Nevertheless, only when discussing "real-world topics" audio conversation is considered essential for virtual meetings (according to one participant).

Another opinion voiced was that the free camera movement options in Second Life contributed towards a feeling of insecurity (i.e. "am I missing something"). In fact, the users found it difficult to look around in the environment. At the same time, all of the participants mentioned that they were too focused on the chat window when solving the task ("felt carried away with discussing"). They did not feel immersed in the virtual world, because they were highly concentrated on reading the comments of the other participants. *Because of this observation, it was decided to introduce "chat bubbles" in the next trial.* Chat bubbles display the chat text above the communicating avatar. They improve awareness, as they can be seen even when not directly looking at an avatar [R. J. Moore, Gathman et al., 2007].

3.3.3.2.3 Third trial

Task: Lost at sea
Date: 4. April 2008
Participants: Inexperienced users of Second Life (in their 20s)

Task duration (main part): 30min; entry part: 5min
Additional configuration: Chat bubbles

The introduction of chat bubbles did not solve the issue observed in trial 2. Although chat bubbles *allow* one to keep track of a conversation, chat bubbles do not necessarily provoke that behavior in participants. The trial participants kept reading the public chat window instead. It seems that during a task requiring high concentration, any information sources besides the object of attention loose their value.

Besides being mainly new users to the Second Life, the trial participants also did not collaborate before. Therefore, the group formation started during the trial. A certain amount of time is taken up to coordinate the task process. In this trial, shortly after starting to work on the task, one user suggested that he will write the group answers in the Google document. Nevertheless, the coordination took up too much time. The participants were in a hurry to agree on a certain ranking and finalize their solution.

In this trial, it could still happen that it was difficult to be able to read the task according to where the avatars were standing. Many participants thus preferred to be in a seated position, where the camera view cannot have a combining effect with the avatar movement, but is fixed to a certain range. *As a result of this observation, the task was presented on two screens in our environment instead of one during the next trial.* Another option to solve the matter was a transparent screen, which allows the view of both task description and avatars at the same time. However, it would also make the text harder to read and add an element of confusion.

3.3.3.2.4 Fourth trial

Task: Lost on moon
Date: 8th of April 2008

Participants: Inexperienced users of Second Life (in their 30s)
Task duration (main part): 30 min; entry part: 8min
Additional configuration: Two screens for task presentation

The integration of two screens for the task presentation was successfully adopted by the participants. Thus participants do not have to redirect their view as much as before and the issues regarding task presentation vanished (see 4.1.3).

The other issues observed in the fourth trial were similar to earlier experiences. The participants do not spend much attention to their own or other avatars, and simply focus on the chat communication when collaborating. Like in the third trial, one user mainly wrote the group answers in Google Docs. However, in this trial he did not announce this explicitly and just started typing. The other participants gradually became aware of this situation.

Overall in the fourth trial it was observed that no facilitator was needed anymore during the meeting itself (no questions had to be answered compared to earlier trials). The participants came up with a solution in time and did not get carried away with coordination or technical problems. The discussion was more profound, while at the same time allowing a high amount of social talk during the task.

3.3.3.3 Trial data analysis

This section provides an overview of the analyzed chat data, based on the coding methods presented earlier (see 3.3.2.1). The interpretation and discussion follows in section 4.1.

3.3.3.3.1 Chat conversation: Trial 1 vs. 2. vs. 3 vs. 4

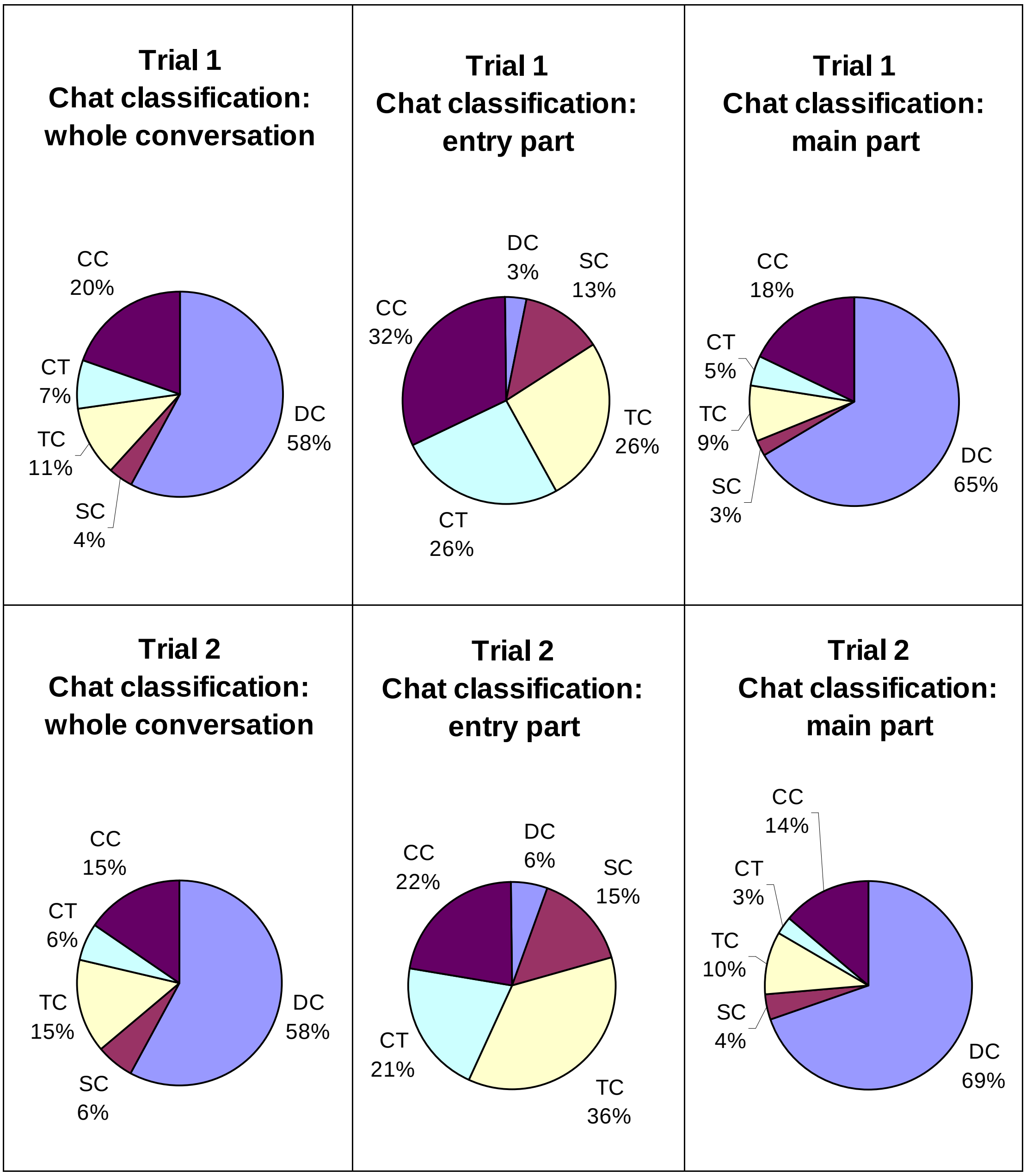


Figure 28: Chat classification in trial 1 and 2

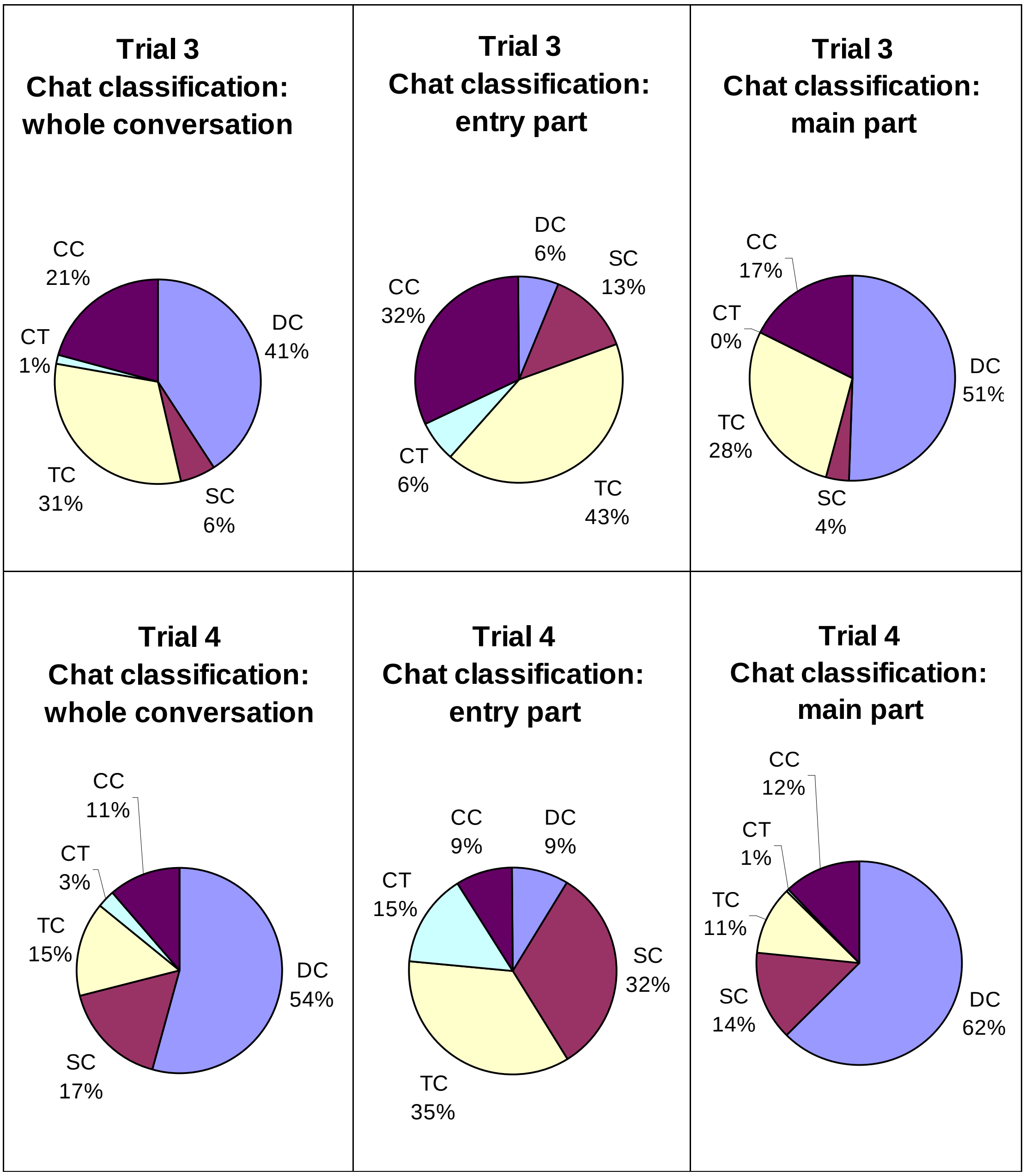


Figure 29: Chat classification in trial 3 and 4

The comparison between the four trials shows various patterns. An immediate observation is that while design communication (DC) is largely absent in the entry part, a shift towards it occurs in the main part. Design communication takes up more than half of all the utterances in three out of four trials. Task coordination (TC) and communication control (CC) together take up at least a fourth of the conversation in all trials. Social communication (SC) has a minor influence except in the last trial. Chat regarding communication technology (CT) stays well below ten percent in each trial. All categories except design communication could thus collectively be termed "*minority categories*".

The first two trials seem rather similar. Namely, in the entry part of the first two trials, communication control, task coordination and communication technology dominate. In the main part, design communication is followed in relevance by communication control and task coordination. The similarity between trial 1 and 2 is so profound that a tendency towards this pattern could be assumed for further trials. However, the third and fourth trials show a different pattern, also among themselves.

While a distribution over the whole time of the task might show interesting differences between the categories, it does not allow us to make any statements regarding the continuous progress of the five categories. Thus an analysis of the *chat evolution* follows (see 3.3.3.3.2). An abstraction level in-between the two forms is provided by the *phases of chat*, which highlight the differences between quarters of a meeting (see 3.3.3.3.3). The methods for data analysis further clarify this distinction (see 3.3.2).

3.3.3.3.2 Evolution of chat: Trial 1 vs. 3

For the evolution of the chat communication over time (see 3.3.2.1.2), it was decided to compare trial 1 and trial 3, because they highlight interesting patterns (as a helpful, but not necessary condition of this comparison we also investigate trials which used exactly the same task, i.e. "Lost at sea"). The respective diagrams of trial 2 and 4 can be found in the appendix (see 6.3).

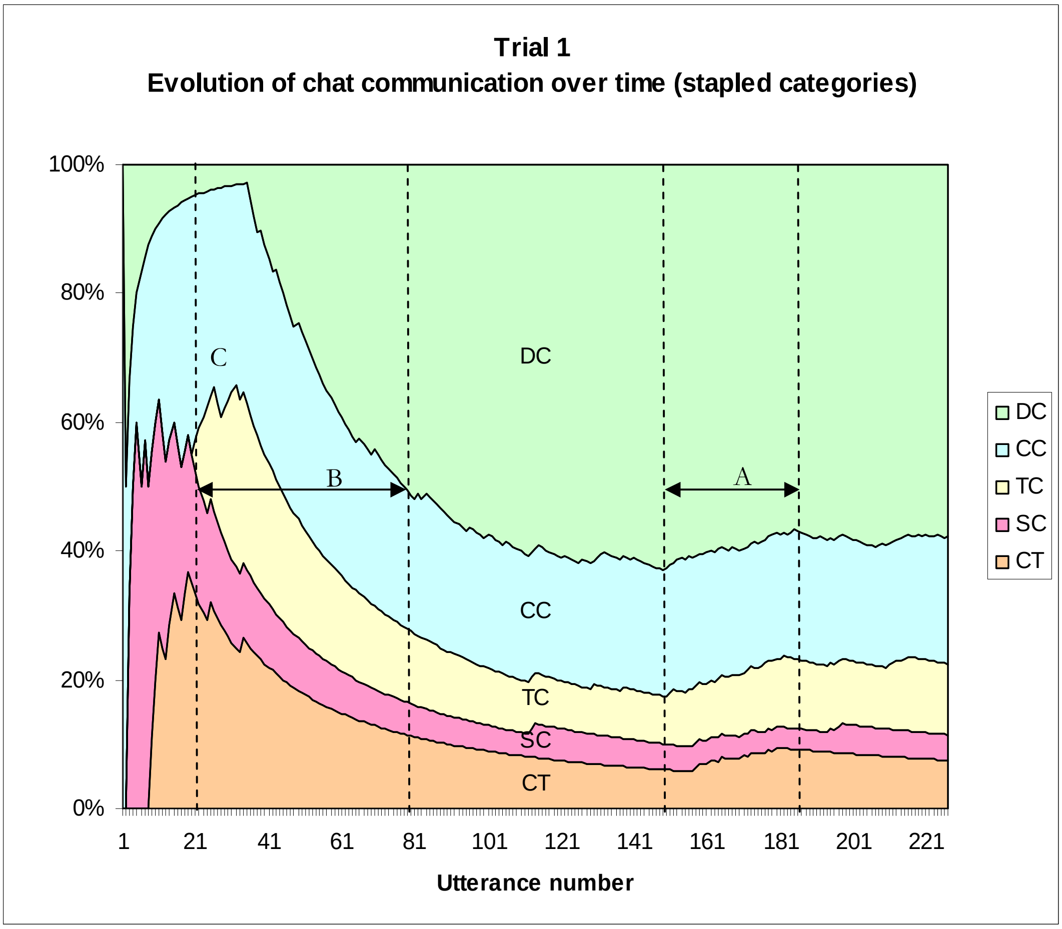


Figure 30: Trial 1 - Evolution of chat communication over time (stapled categories)

Line C (see Figure 30) indicates that until the first 21 utterances, mainly social talk, communication technology and communication coordination dominate. A little later, task coordination gains weight. Until utterance 81, i.e. around one third in the trial, these categories rapidly loose ground and design communication overtakes (see arrow B, Figure 30). Especially communication technology looses ground (notice the stapled categories in the diagram). After utterance 81, design communication grows less rapidly and the other categories stay largely equal. Around utterance 150 (see arrow A, Figure 30), design communication looses a bit ground compared to the other categories (mainly because of a rise in communication technology and task coordination). However, design communication remains the largest category and stops loosing ground for the final part of the trial.

The observed pattern could be coined "*wave pattern*" for the obvious, visual reasons. It did occur in all four trials, although not to the same extent. For comparison, the same diagram is displayed here for trial 3 (see Figure 31). In trial 3, design communication also dominated, but not as much as in trial 1. This can be identified by the smaller area covered in the diagram. One reason for this is that design communication was absent until after utterance 21 in trial 3 (see arrow A, Figure 31). Then until utterance 61 the most characterizing part of the wave pattern started: Design communication gains rapidly weight compared to the other categories (see arrow B, Figure 31). After utterance 61, design communication makes up the largest part of the conversation, but task coordination keeps a fair share and sees a rise towards the end.

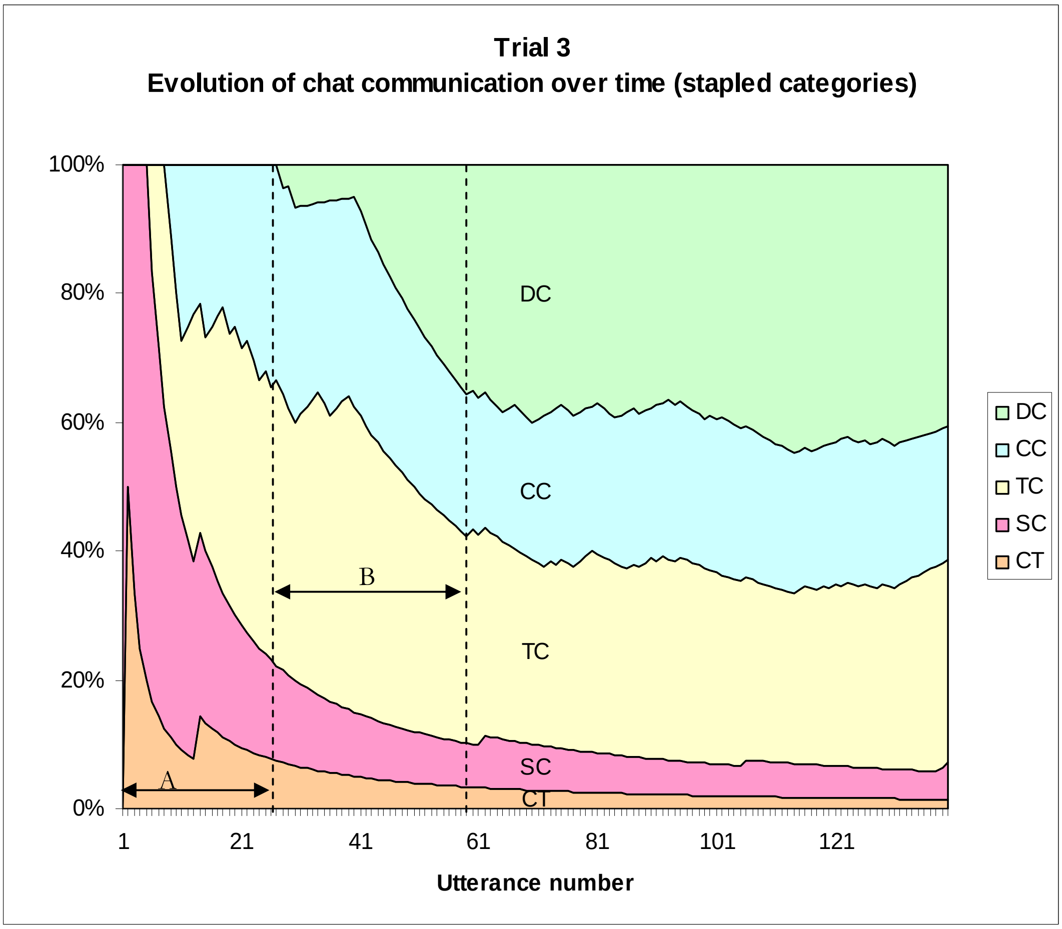


Figure 31: Trial 3 – Evolution of chat communication over time (stapled categories)

Another illustration of trial 1 vs. trial 3 is provided by the following two diagrams (see Figure 32 and Figure 33). What is well visible in trial 1 is that the development of communication coordination follows an almost linear curve over the whole trial (see line A, Figure 32). This would suggest that communication coordination is an auxiliary, but necessary part for a chat conversation (because it rises equally over the whole time). Trial 3 shows the relativity of this statement, because there are phases where communication coordination pauses (see Figure 33). Trial 1 demonstrates the dominance of design communication, while in trial 3 this dominance is less strong. In trial 3, task coordination and communication control take up a considerable amount compared to the other trials. Nevertheless, design communication rises very quickly above the other categories (see arrow A, Figure 33). It is also worth a note that social talk and communication technology stay well below all other categories in trial 3 (see arrow B, Figure 33).

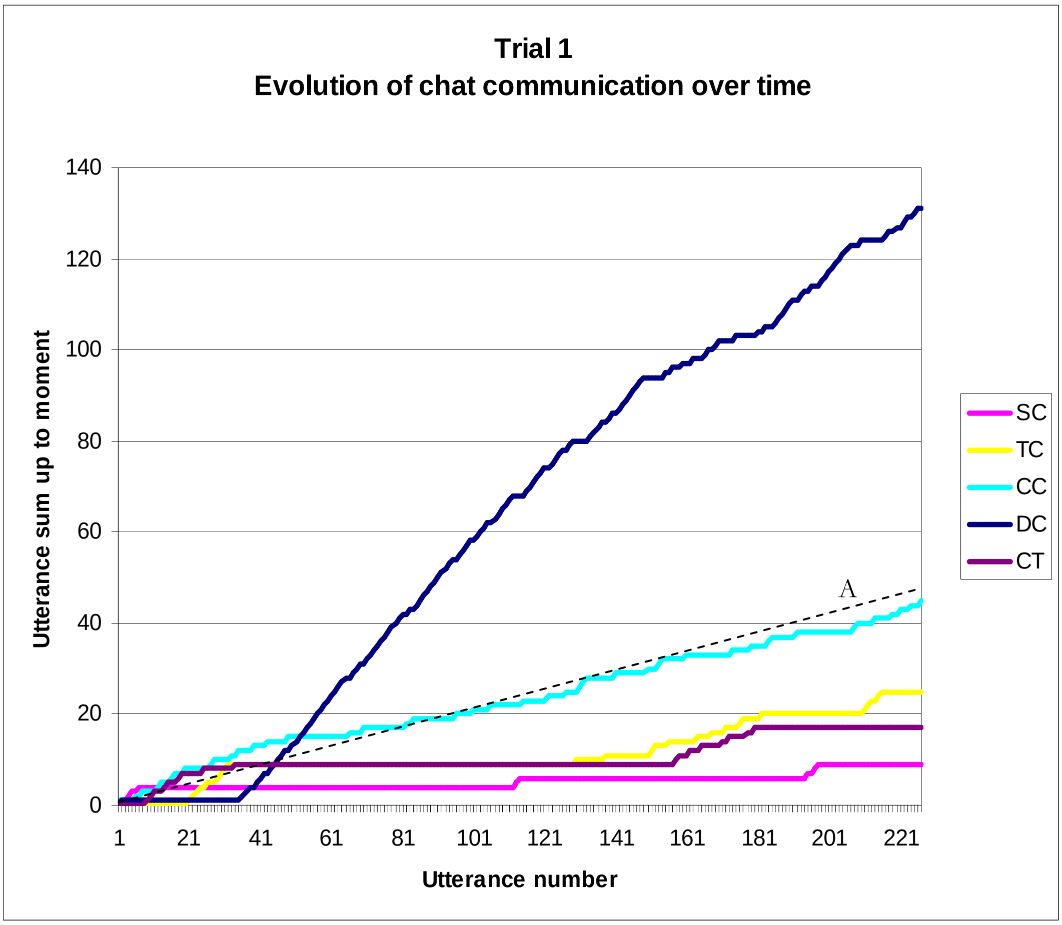


Figure 32: Trial 1 - Evolution of chat communication over time

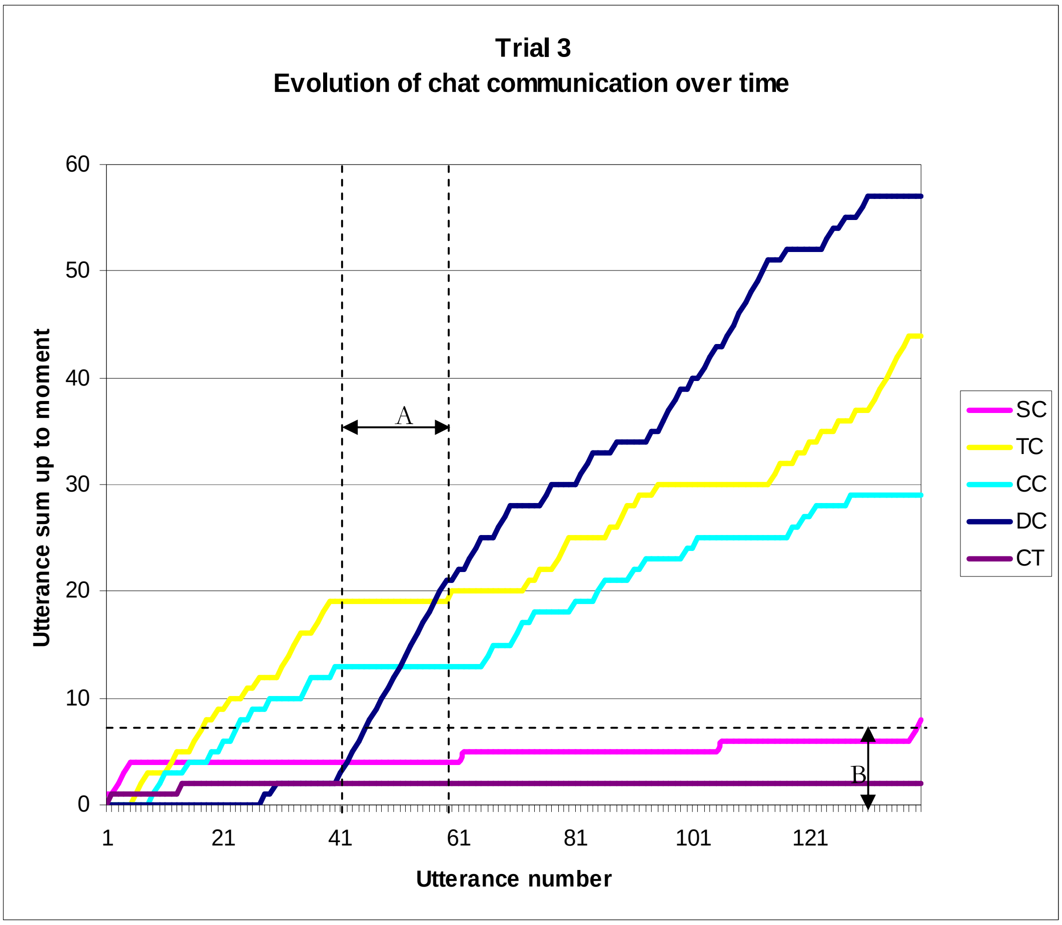


Figure 33: Trial 3 - Evolution of chat communication over time

3.3.3.3.3 *Phases of chat: Trial 2 vs. 4*

It was decided to compare trial 2 and trial 4 for the phases of the chat communication over time (see 3.3.2.1.2), because they highlight interesting patterns. As a helpful, but not necessary condition of this comparison we also investigate trials which used exactly the same task, i.e. "Lost on moon". The respective diagrams of trial 1 and 3 can be found in the appendix (see 6.3).

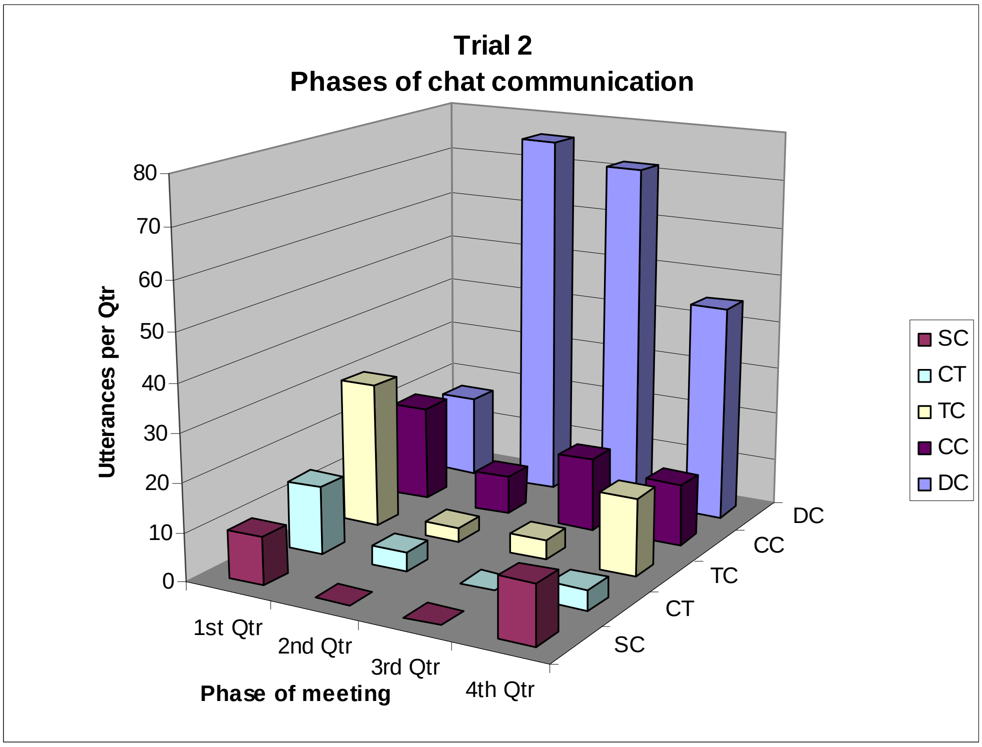


Figure 34: Trial 2 - Phases of chat communication

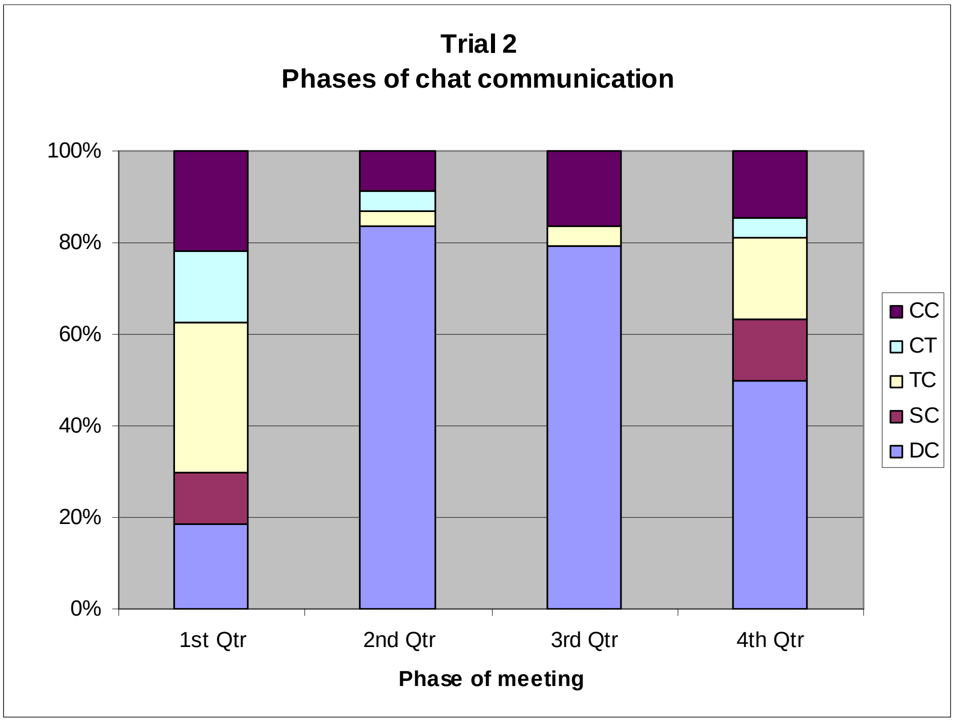


Figure 35: Trial 2 - Phases of chat communication (percentage)

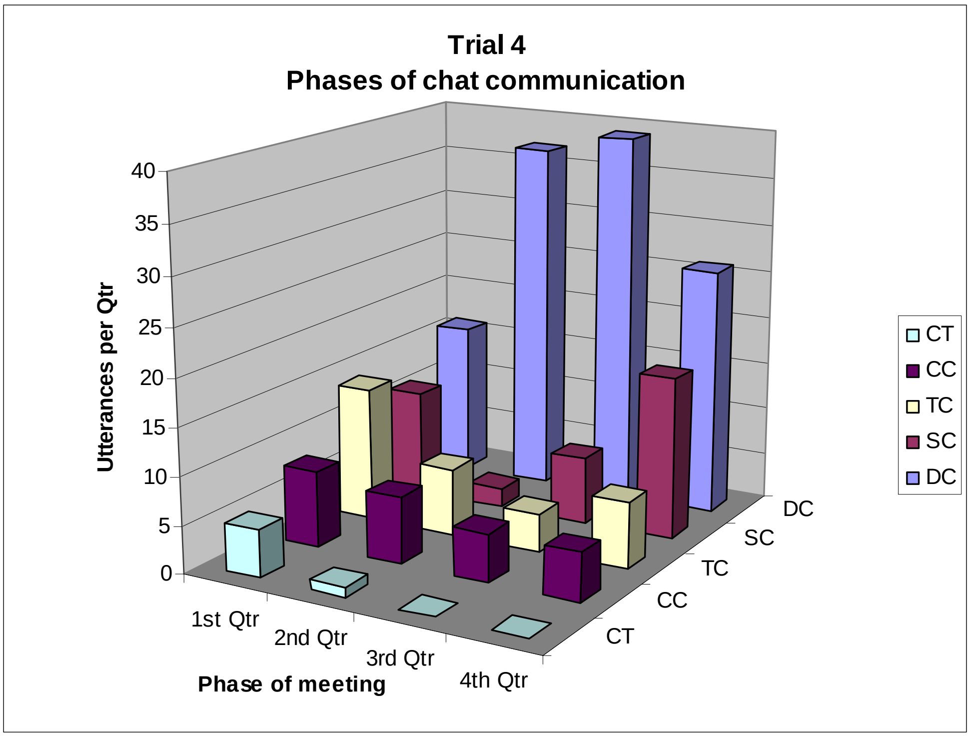


Figure 36: Trial 4 - Phases of chat communication

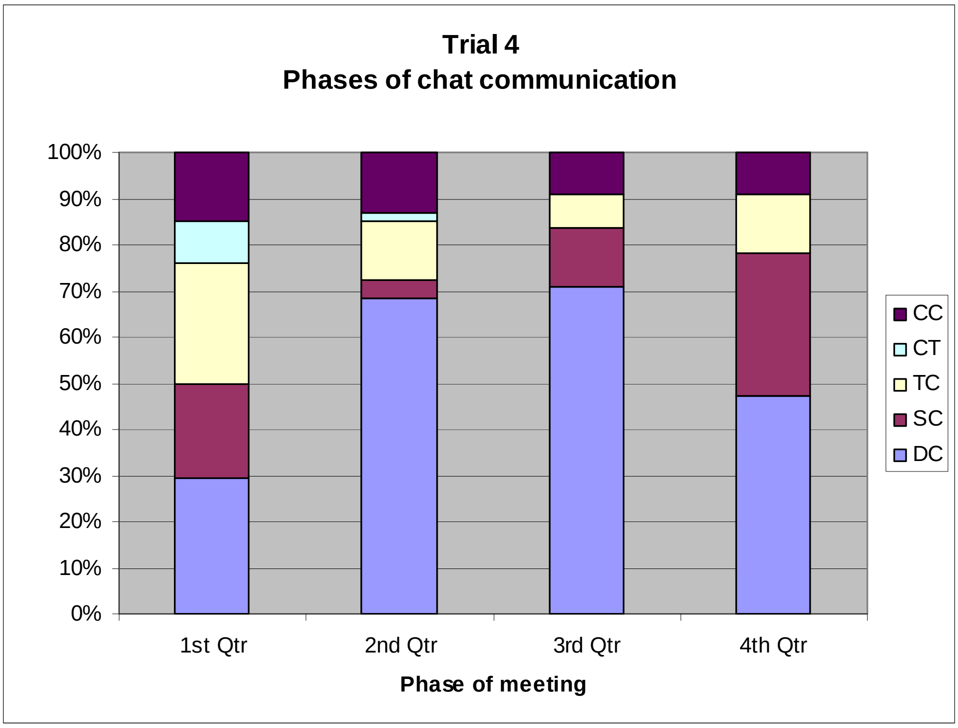


Figure 37: Trial 4 - Phases of chat communication (percentage)

In the phases of chat communication analysis, all trials showed a similar pattern (see also 6.3). Namely, the design communication is concentrated in the middle part of the meeting (2nd and 3rd quarter) and takes up much more utterances than the other categories. As a result of this, the visualization shows two high columns standing out (see Figure 34 and Figure 36). The pattern could thus be called "*twin-tower pattern*", and is basically an outgrowth of the wave pattern observed earlier (see 3.3.3.3.2). The lower amount of design communication during the fourth quarter in the twin tower pattern is reflected in the slight rise of the minority categories towards the end in the wave pattern. As a side note, with the exception of trial 4, design communication is particularly high in the second quarter.

In general, all the other categories (minority categories) show an opposite trend. Namely, the further away from the middle section of the meeting, the higher are the respective utterance numbers (see Figure 34 and Figure 36). The need for communication technology appears to be highest particularly in the first quarter.

In trial 4, task coordination was distributed rather evenly over the four quarters compared to the other trials. In the contrasting trial 2, a large sum of those utterances fell in the first and last quarter (see Figure 34). Thus the question arises as to how the group of trial 4 could achieve a more distributed task coordination than the group of trial 2.

4 DISCUSSION

The discussion spans three parts: Interpretation of our trial experiments; evaluation of media naturalness in Second Life; and implications from our findings (for practice and industry, as well as for future research work).

4.1 Trial experiments

Second Life demonstrated its ability to support the divergent collaboration process (idea brainstorming) in all trials. This confirms the results of related groupware experiments (see 2.1.2.1.2). The convergent process (finalizing a group solution) was successfully facilitated with a mash-up tool.

Another profound observation from our trials is that the participants did not feel immersed in a 3D-virtual environment. Neither the integration of chat bubbles in the trials (which should direct the view of the participants towards the environment), nor the constant evaluation of helpful tools in Second Life could change the situation. Media naturalness would predict an increased physiological arousal in virtual worlds compared to more simple communication media, because avatars enable body language and gestures (see 4.2.2.3). However, our interviews did not suggest an increase in excitement. In fact, the trial participants spent most of the time in discussions closely related to the task (see 3.3.3.3.1). They did not wander off to explore the environment and discuss new topics, which could lead to a more creative design of the actual task. The question arises whether the "problem" lies within the tasks used in our trials. The tasks themselves do not encourage the user to explore the environment. It is simply not a necessity to move around in a 3D space when collaborating on a fixed task. All the instructions were given in our meeting environment and all participants could also be found there. Furthermore, the time limit of the tasks might have had an influence on the suppressed creative behavior of the participants (see 2.2.1.3). Thus it is suggested that different tasks are used for a more thorough usability evaluation of Second Life (see 4.3.2.2.2). The tasks should encourage the user to explore the environment, building on the discussed advantages of 3D-collaboration environments such as chance encounters and long-term awareness. Indeed, also newer studies show that virtual worlds rather encourage new collaborations, than facilitate existing real-world collaborations [Hut, 2008]. *"Seeing each other regularly, and becoming familiar with each others' interests, they began to spawn new ideas, some of which led to new projects, with little connection to the original motivation for them to enter the virtual world where they had met"* [Hut, 2008, p. 8].

Overall, more real-world collaboration is still needed to get things working, rather than collaboration actually happening in Second Life. To a large extent, the issues are not related to our created environment, but to how virtual worlds currently support collaboration. Users who are not familiar with the environment cannot just start to work on a task, even if they think they are set up. Unexpected issues turned up, especially because the user interface is non-standardized. Thus an implication from the trials is that a facilitator is needed to conduct a proper meeting. However, this became less significant in the last trial experiment and may not be relevant anymore if the environment will be enhanced in the future. Trial 3 and 4 suggest that our created environment reached a certain degree of maturation. Only 1, respective 3 percent were spent on communication technology compared to 6 and 7 percent in the first two trials. Overall, the introduction of new configurations enhancing usability seems to have had a small, but non-negligible effect.

Interestingly, we received similar results with the coding schema like in a related evaluation of a virtual learning environment (equal dominance of design communication and small amount of communication technology) [M. Maher et al., 2001]. Figure 38 shows the results for two experiments in the respective virtual learning environment (communication for orientation mainly concerns our task coordination). Such an occurrence does not allow us to make any conclusions about the maturity of the coding schema (because of the different situation involved), but it can be speculated that the coding schema produces similar results for chat conversations in virtual environments. Further testing (e.g. inter-coder reliability) would be helpful to assess the maturity of the coding schema.

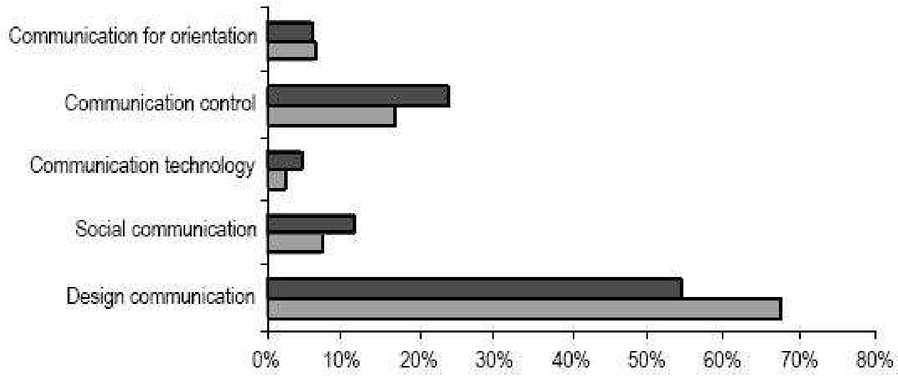


Figure 38: Conversation classification in a related experiment [M. Maher et al., 2001]

4.1.1 First trial

In the first trial, the convergent process of co-deciding on a priority list failed. There was no dedicated tool for writing up the task solution. Thus the users decided on the group chat feature. However, the group chat does not allow concurrent editing of a single solution. After the trial, it was assumed that the reason for failure lay in the absence of a tool supporting the convergent process. Thus a corresponding tool was integrated in our environment. However, in the third trial the situation reappeared in a different form (the participants did not finish the priority list in time). Without an allocated coordinator, nobody felt the urgent need to put together a solution. This could be because it would involve asking several participants questions, which requires a certain effort (see *principle of least collaborative effort*: 4.2.2.2). More likely, the unfamiliarity with the environment of the group in trial 3 contributed to the failure. Indeed, the integration of Google Docs as a tool supporting the convergent process was successful both in trial 2 and 4.

When looking at the chat classification of trial 1 (see Figure 28, section 3.3.3.3.1), it becomes obvious that slightly more than half of all utterances cover actual communication relating to the solution (i.e. design communication). Although this is a large sum, it is also not surprising that a lot of utterances cover non-design related communication, because the users first have to become familiar with the technology and the task process. Of the non-design related communication, a major part is taken up by communication control. *Media naturalness* theory suggests a strong increase in cognitive effort when using chat communication, partly because users need to clarify their messages. This could explain the relative high share of communication control compared to the other trials.

In the entry part of the conversation in trial 1, communication covering the technology equals task-related communication in quantity (see Figure 28, section 3.3.3.3.1). This is certainly an issue, because understanding and structuring the task is important for a successful outcome. On the other hand, communication regarding the technology has only an indirect influence on a successful outcome and should thus be minimized.

The smallest part is social communication in trial 1 (see Figure 28, section 3.3.3.3.1). A pessimistic explanation would be that the environment does not support social communication. In fact, *media naturalness* theory would explain this phenomenon by the decreased physiological arousal when using chat communication. Such an explanation is not sufficient in this case though, because the abundant use of emoticons suggests an adequate user familiarity with expressing feelings in a mediated environment. More likely, the low social communication amount can be explained by the fact that the participants already knew each other well before starting to work on the task.

4.1.2 Second trial

Although the second trial shows similar numbers like the first trial, there is a visible difference, especially in the entry part (see Figure 28, section 3.3.3.3.1). By percentage, much more utterances cover task coordination in trial 2 than in trial 1 (mainly on behalf communication control). One explanation is based on the influence of an unintentional factor, namely the reduced time duration for the task. From trial 2 onwards, the task was shortened to 30min (see 3.3.3.2.1). Therefore, the users needed to coordinate more in order to finish on time. However, this explanation is not sufficient. In the beginning, the new participants of trial 2 could not estimate how much task coordination is needed and thus adapt so quickly to the situation. Likewise in the entry part, the trial 1 participants could not grasp if one hour was enough time and change their communication behavior accordingly. Instead, the surge in task coordination could be explained by the introduction of Google Docs. The integration of this tool made it necessary to coordinate more "who is doing what and when" than in the situation where the final solution could be posted in the group chat (trial 1). Task coordination was particularly high in the first and last quarter (see Figure 34, section 3.3.3.3.3). This reflects a rather expected pattern. People tend to coordinate in the beginnings, and have to decide again shortly before the end (deadline-effect).

Interestingly, communication regarding technology did not increase with the introduction of Google Docs. Neither the feeling of insecurity, nor the lack of awareness (see 3.3.3.2.2) increased the communication technology amount substantially during any time of the meeting (see 6.3). It appears that users do not voice their concerns with technology, especially if they are working on a task with limited duration.

Trial 2 showed a much higher number of total utterances than the other tasks of the same duration. One explanation is that experienced Second Life users were participating, who are faster at communicating in the environment. *Media naturalness* suggests that the more natural a tool is for the user, the higher communication fluency will be, and thus a lower cognitive effort will result (see 2.1.1.3.4). Therefore, we would have to expect a higher perceived cognitive effort in the following trials with inexperienced users. However, according to the conducted interviews, this was only the case in trial 3, but not in trial 4.

In the second trial it was observed that Second Life gestures are seldom used during a meeting. Thus according to *media naturalness* the physiological arousal is lower than the medium would allow (see 4.2.2.3). This could be due to the cognitive effort needed to find the gesture interface on the client software. Another reason could be the lack of concrete gestures for the actual situation. However, a further investigation after the trial revealed that even when using a facial expression HUD (an interface overlay which included additional, user-generated gestures in a simple menu), the usage of gestures did not increase. Thus a facial expression or animation HUD was not included in any further trial.

4.1.3 *Third trial*

In the third trial, task coordination takes up a much larger part than in the other trials (see Figure 29, section 3.3.3.3.1). This confirms our observations of coordination difficulties among the participants of trial 3. Interestingly, but also reflecting trial 2, communication technology did not play a major role for trial 3. It seems that inexperienced users may not be able to articulate their difficulties with the new technology.

Communication control takes up the largest amount in trial 3 compared to the other trials. Trial 1 showed a similar situation and the high amount of communication control was explained by the need to clarify the messages. Regarding *media naturalness*, this not only has an influence on cognitive effort, but also on the communication ambiguity in Second Life. Media naturalness suggests that compensatory adaptation (mainly on behalf of the decoder) takes place when communication ambiguity is high (see 2.1.1.3.3). For example, a participant might ask: "How do you mean this", because the chat conversation was not precise enough.

So far, input and output devices of groupware only generate a fraction of the perceptual information that is available in a face-to-face workplace [Gutwin & Greenberg, 2002]. The same situation also applies to Second Life. Especially the participants of trial number three were not sure if they were always aware of all the action going on around them. This observation is contrary to expectation. One would predict that the capability of being able to have an adjustable 360 degree vision would increase the awareness of the participants, but empirical investigation suggested otherwise. In this light, it must be questioned if it makes sense to offer the user more camera options, as suggested in a recent review of virtual worlds [Taylor & Duclos, 2007]. More options lead to more confusion. Gutwin & Greenberg conclude that although awareness is usually a secondary goal after task achievement, awareness definitely raises the usability of groupware [Gutwin & Greenberg, 2002]. We assume therefore that the lack of awareness had a substantial influence on the moderate perceived usability of the prototype environment in trial 3.

4.1.4 Fourth trial

The fourth trial stands out due to the higher amount of social communication (see Figure 29, section 3.3.3.3.1). Because of the reasonable solution outcome, it seems that social talk did not have a negative effect on performance, even during a task with a limited time period. Indeed, the interviews revealed that the higher share of social communication increased satisfaction of the trial participants. The increase in social talk also raised physiological arousal (speaking in *media naturalness* terminology), because the participants were obviously using emotional expressions for conveying their social communication.

The group could achieve more distributed task coordination (see Figure 36, section 3.3.3.3.3). The different group characteristics (group with more life experience in coordination tasks) could be a factor (see 3.3.3.2.4), but no final statement can be made without further knowledge. If surveys are part of a future investigation, it would thus make sense to assess not only the perceived usability of a technology, but also group characteristics.

Furthermore, the low need for communication control in trial 4 deserves attention (see Figure 29, section 3.3.3.3.1). *Media naturalness* theory would assume a high naturalness of the medium if communication control is low, because only little time is spent on compensatory adaptation (encoding, decoding) of the conversation (i.e. communication control in our case). However, we only observed a *lower* communication control amount, and can thus not say if communication control is *low* at all in our final environment. Consequently, we cannot make a final conclusion from this observation about the naturalness of the virtual world medium. Media naturalness in Second Life is discussed in more detail in the next section (see 4.2).

4.2 Media naturalness

Either an increase or decrease in traditional richness (see 2.1.1.1) compared to the face-to-face medium leads to a reduction of naturalness [Kock, 2004]. To visualize the previous statement, face-to-face communication lies in the middle of a one dimensional scale, where any point further away from the centre is less natural (Figure 39) [DeRosa et al., 2004]. Consequently, virtual reality, which may include more communicative stimuli than the face-to-face medium, will also lead to an increased cognitive effort [Kock, 2004]. The corresponding construct in media richness theory (see 2.1.1.1) is the "area of effective communication": Neither overcomplication nor oversimplification takes place.

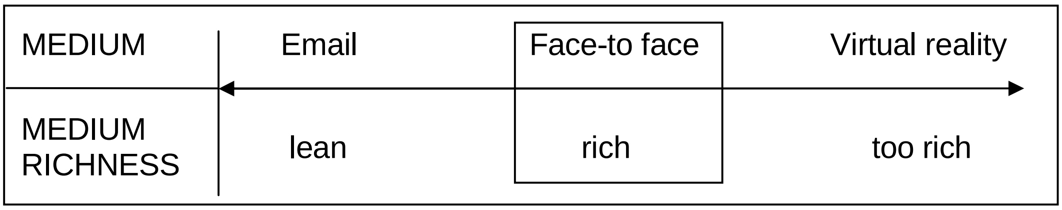


Figure 39: Ideal media richness according to media naturalness theory

Second Life will now be discussed concerning media naturalness. To justify the relevance of the next section, the author of media naturalness theory was contacted personally (see 6.5). He stated that: "*…the notions of media naturalness and compensatory adaptation can be used as a basis for research in virtual worlds"* (see 6.5).

4.2.1 Naturalness attributes

Media naturalness gives five attributes for naturalness, which are discussed in the following textbox according to their relevance in Second Life. The judgments are based on experience gained through activity in the Second Life environment.

Naturalness attribute: **A high degree of collocation**

Rating: Moderate

Collocation is probably the most uncertain aspect regarding media naturalness when in a virtual environment. Avatars are collocated, but avatars are not humans. They represent a transformed human personality, lacking the physical characteristics of the human body. However, the transformation will become more lifelike in the future and real-world body language may be integrated. So conclusions regarding avatars and thus collocation are difficult to draw. At the current state, however, the feeling of collocation is only moderate.

Naturalness attribute: **A high degree of synchronicity**

Rating: Moderate

Synchronicity in the sense of media synchronicity theory (see 2.1.1.2) is average in Second Life, as the speed of feedback is high, but the counteracting factor parallelism is high, too.

Speed of feedback is high because of the following factors:

- A virtual world shows the activities and their effects in real-time. This is true both for the controlled avatar, as well as the co-avatars in the environment.
- The chat allows fast answers.
- The voice channel allows even faster answers.

Parallelism is high because a message can potentially be transmitted over chat, voice, gestures and interaction with the environment at the same time (practical limitations neglected). This is true both for one recipient and for a group of recipients.

For convergent processes, high synchronicity is needed, i.e. fast feedback and low parallelism. Hence, the exclusive use of the voice channel is most applicable, because the feedback is real-time and parallelism is reduced, as the conversation is naturally limited to one thread (humans cannot talk about different topics at the same time).

For divergent processes, low synchronicity is adequate, i.e. slow feedback and high parallelism. Thus, the chat medium combined with other forms of communication is most suitable. For example, brainstorming can be supported by a public chat conversation and writing a notecard of the collected ideas.

Naturalness attribute: **Ability to convey and observe facial expressions**

Rating: Very low

- Convey: There are only a few gestures, which make use of facial expressions.

- Observe: The poor approximations of faces through emoticons are frustrating, because they lack information expressed by real faces [Kock, 2008]. It is especially difficult to note facial expressions of other avatars, as the face is usually a small spot in the view frustum.

Naturalness attribute: **Ability to convey and observe body language**

Rating: Low

- Convey: Some gestures support basic body language. Although nonverbal communication or nonverbal cues may exist in virtual worlds, they are hardly used. In real life nonverbal interaction is a continuous process and mostly unconscious [Friedman et al., 2007]. It would be helpful to have user-controlled gesture duration in a virtual world in order to solve at least the timeliness aspect [R. J. Moore, Ducheneaut et al., 2007]. Unconscious body language transmission could only be achieved through video recognition, which imposes several new operational issues.
- Observe: Body language is more easily observable than facial expressions from a 3rd person perspective. Avatars can further move around, which is an indication of non-verbal behavior (e.g. take a step back).

Naturalness attribute: **Ability to convey and listen to speech**

Rating: High

- Convey: Audio communication, once established, is comparable to a telephone conversation.
- Observe: The voice integration in Second Life is not just a simple voice channel, but avatars sound more distant when they are far away. Avatars on the left side are heard on the left speaker. Thus, a more natural sound experience results in a 3D environment. This is especially true for listening to speech compared to common voice-over-IP tools. It has been demonstrated that 3D-sound enhances depth perception, task performance and collaboration in virtual environments ([Junglas et al., 2007] quoting [Zhou, 2004]).

Media naturalness does not give a strict order of importance for the above factors. Thus, if one takes the average of the rating for the five factors, Second Life shows "low-moderate" naturalness. However, the question here should not be if Second Life as a whole is a "natural medium", but if the communication activities in it reflect and support a natural behavior. Furthermore, these activities depend on the context of the interaction. For instance, the environment might be considered suitable for brainstorming (divergent process) using the chat function (with high concurrency, editability and anonymity), but a conversation regarding the choice of a long-term supplier (convergent process) may seem unnatural in a virtual world.

4.2.2 Consequences

According to media naturalness, virtual reality leads to an increased *cognitive effort* because of information overload [Kock, 2004]. Media naturalness does not talk specifically about the effect of virtual worlds on the following two media naturalness outcomes: *Communication ambiguity* and *physiological arousal*. Thus the following overview is based on an analysis and judgment of the author.

4.2.2.1 Cognitive effort

Cognitive load is the amount of mental energy required to process a given number of information elements [Ang et al., 2007]. The working memory is often said to be able to process seven plus/minus two chunk items, so chunking (through the use of patterns, categories and groupings) is often pursued. When cognitive load on the working memory is high there is no spare capacity for the user to keep up with other stimulus: Prioritizing is then absent and the user becomes vulnerable to interference by irrelevant distracters [Ang et al., 2007].

A virtual world like Second Life is basically a combination of different media types (chat, audio, asynchronous tools like notecards etc.), with an augmented virtual reality environment (which allows for limited real-time body language through gestures). This means that not just one, but several different mediums can be selected at a time. Consequently, the cognitive effort for communication is raised. However, this may only be true for novice users, because on the other hand, "*systems in which players can use their voice to talk, their bodies to gesture, and their faces to emote would dramatically reduce the current workload…and increase the ease and fluidity of expression"* [R. J. Moore, Ducheneaut et al., 2007, p. 302]. The potential of virtual worlds is further enforced by the user's ability to adapt and evolve to a new medium (compensatory adaptation). This was also observed in study using a complex online game, where players developed strategies to overcome the high cognitive loads [Ang et al., 2007].

On the other hand, we want an activity that is easy enough to learn, but not too easy, so it remains challenging. Hence, games intentionally overload the player's cognitive capacities in order to increase the challenge [Ang et al., 2007]. Indeed, it was observed that the pleasure of collaborative activities in virtual worlds comes in part from the difficulty of coordinating actions together [B. Brown & Bell, 2004]. Finally and more speculatively, this provoked challenge could also apply to Second Life, in which the required cognitive effort for interaction is substantially higher than in the real world.

4.2.2.2 Communication ambiguity

The *principle of least collaborative effort* suggests that people use minimum effort to compose a phrase in order to get the message across to the listener (e.g. "do you think it will fit" is used instead of "do you think that the smaller of the two arches will fit at the top of the tower that's at the right side of the picture") ([Gutwin & Greenberg, 2002] quoting [H. H. Clark & Brennan, 1991]). Thus *communication ambiguity* arises.

Furthermore, due to the different communication channels, it is likely that communication ambiguity is influenced as follows:

- A message through one channel can be *contradicted* by a communication through another channel. For instance, a voice statement might be augmented by a gesture that gives it a different meaning (e.g. saying: "You are so clever" and blinking an eye at the same time). This example reflects a natural behavior. However, in the case of a limited choice of symbols or a lean medium this contradiction might happen involuntarily.

- A message through one channel can be made *clearer* by a communication through another channel. This happens always voluntarily, as it involves the active participation of the sender. For example, an unclear statement by voice can be repeated by writing a text message.

Thus, it is shown that communication ambiguity can either be raised or lowered by using Second Life.

4.2.2.3 Physiological arousal

Physiological arousal is higher, compared to other computer-mediated communication media (e.g. chat or simple voice), but still lower than in face-to-face communication. It is higher, because avatars are embodied, make use of gestures and body language (which relieve the medium's cognitive strain [Verhulsdonck, 2007]), and avatars are situated in a similar setting like humans. Thus, reflecting on the discussion of mirror neurons (see 1), physiological arousal is raised. However, avatar representation still lacks many details of human bodies and expression, thus physiological arousal is lower in Second Life than in face-to-face communication (like in other CMC, but not the same extent). From this point of view, and also because the user needs to consciously apply gestures, Second Life puts a burden on the participant compared to "same-place interaction".

4.3 Implications

It should be mentioned that the findings from one virtual world may be driven by idiosyncrasies or particular mechanics and thus might not apply to other virtual worlds. However, when looking at Second Life competitors, similar findings were retrieved like in our trials. Players in the virtual world "There" have appropriated everyday structures of interaction to overcome the limitations of the system, but in some cases it would make sense to augment the system with 2D interfaces, e.g. for collaborative web browsing [B. Brown & Bell, 2004].

Our results so far are suggestive rather than conclusive, and thus it is too early to make any final conclusion as to whether collaboration will ever be better supported in virtual worlds than in other environments. More research is needed in this regard. Here follows an overview of suggestions for two different stakeholders:

- Practice and industry (corporations practicing virtual collaboration)
- Future research work

4.3.1 *Practice and industry*

Corporations depending on virtual collaboration can potentially benefit from virtual worlds. For instance, long-term awareness (see 2.2.4.1) makes it possible to stay up-to-date on the developments of other members in a virtual team. By visiting the same location in a virtual world, one will find her or his team-members according to their availability for collaborative interaction. This could turn into a habit during the span of a long-term project and improve collaboration. It was found that the social networks inhabiting virtual worlds make them "sticky", i.e. users stay long-term ([R. J. Moore, Gathman et al., 2007] quoting [Bartle, 2004]). In fact, communities inhabiting virtual worlds reflect a promising opportunity to build social networks based more on common interests than on physical location [Isbister et al., 2000]. This could prove helpful in a business environment, where after-work clubs are often established to increase the sociability of the team members.

4.3.1.1 Commercial opportunities

It seems virtual worlds are about to make a shift from a domain belonging exclusively to computer savvy users: Sony recently announced the intention to create its own virtual world "Home" and thus sees a great market potential for such environments entering our daily lives [Sony]. Another example is the virtual world Entropia Universe, which agreed and once established real-world money withdrawal from banks ATM's, charging their virtual accounts [Bray & Konsynski, 2007]. Thus it seems a certain critical mass of currency transfer between virtual and real worlds is achieved. Pointing in the same direction, the U.S. Department of Homeland Security has owned a virtual island in Second Life, monitoring inter-world transactions for abnormal situations [Bray & Konsynski, 2007].

Commercial opportunities for virtual worlds exist in varied fields, such as simulation. Virtual reality in general is enabling visualization of 3D-models, representing spatial relationships between objects. Virtual reality allows to design what is not possible in the real world and provide a safe and cost effective environment for this [Dieterle & Clarke, 2006]. Now these models can be explored and worked on collaboratively in virtual worlds. Forterra Systems builds collaborative virtual environments for corporate, healthcare, government and entertainment industries, which enable them to train, plan, rehearse and collaborate in a private, secure, reliable and extensible space (see Figure 40) [Forterra Systems].

Figure 40: Forterra Systems medical simulator [Forterra Systems]

4.3.1.2 Second Life as a tool

The question arises as to whether Second Life at the current development phase proves useful for real-time collaboration in a business context. Second Life still has to improve in many ways to become an efficient and effective meeting support tool. Low *security and data availability* in Second Life [Olivier & Pinkwart, 2007] pose an obstacle in a business context. In addition, the *hardware requirements* of Second Life pose an entry barrier not so much for commercial companies, but for many research labs in schools and colleges, especially with regards to graphics cards [Kemp & Livingstone, 2006]. This situation is likely to stay, because the graphical complexity of Second Life is going to rise over time to keep ahead of the competition. *Maintenance* issues are other obstacles. Second Life needs frequent updates, and as the graphical quality of the 3D world improves, so do the hardware requirements. An IT department often still operates on a prefixed budget. Hardware updates are not just costly, but also interrupt the day-to-day workflow (i.e. systems which are out of service). Reductions in efficiency are to be expected. Furthermore, virtual teams often use different hardware at different sites. Thus, if one user can run Second Life, this does not imply any benefit to the team. Only if each member is connected, a fruitful collaboration can be achieved.

Besides the discussed hardware restrictions of the environment, a more lasting influence is hampering the adoption of Second Life in corporations. Namely, the environment can only be mastered with sufficient knowledge of its user interface, functions and social conventions. It takes a long time to become used to the abundance of features and interaction possibilities. This implies a great deal of *user training*. However, this will likely result in the choice of an alternative environment (e.g. Skype). Training is expensive in a corporate environment. Furthermore, frequent changes in the hardware of corporate IT departments lower the chance of a continuous use of Second Life. However, a continuous use is a necessary condition for the successful integration of Second Life. It seems that without a profound introduction into the capabilities and the spirit of Second Life, the tool will soon be abandoned in a task-driven, formal working environment.

Recommendations

Recommendations for the suitability of Second Life for the following areas can be drawn:

- Social interaction
    - Enabling *chance encounters (*see 2.2.2.1) and *long-term awareness* (see 4.3.1 and 2.2.4.1)
    - Establishing *virtual communities* depending on *place.* (see 2.2.1 and 4.3.1)
    - *Expressing personality* not possible otherwise, especially for disabled people (see 2.2.3.1)
- Prototyping ideas
    - Second Life's *active community of practitioners* (see 3.2.1.1) leads to support during the whole phase of an in-world project (design, programming, support etc.).
    - *Economies of scale* in the generation of freely available and customizable content (see 3.2.1.1).
    - *Visualizing creativity* in three dimensions (see 3.2.2).
- Collaboration tool
    - *Communication media* adaptable to situation (see 4.2.1), with chat, audio and limited body language (gestures, animations).
    - Proven support for *divergent collaboration processes* (see 4.1).
- Marketing tool (see 2.2.3.6.2)

4.3.1.3 Outlook: Qwaq Forums

At the end of our usability evaluation of Second Life a new 3D-collaborative virtual environment became available for public testing that was not included in our review (see 2.2.2.1). Qwaq Forums addresses many of our observed issues with Second Life. It offers new functionality helpful for collaboration and is more likely to diffuse in a business context (see paragraph below). However, Qwaq Forums would not have fulfilled our criteria for this project, as it does not allow data monitoring to the same extent as Second Life and it is a costly, proprietary tool. Qwaq Forums has a Software as a Service (SaaS) business model, which requires the user to pay a flat fee each month.

Qwaq Forums [Qwaq] takes a different approach to collaboration in virtual environments by focusing on the core requirements of office work. It offers a persistent space for users to collaborate both during and in-between sessions. Qwaq Forums is built upon the Croquet platform presented earlier (see 2.2.2.1) and thus uses a peer-to-peer architecture, with the advantage that as more users join the space, the more CPU and graphics power is available to support them and the space. As part of an initial investigation, all the basic functionality Qwaq offers works very well (e.g. interactive whiteboard, voice-over-ip with spatially located sound sources, internal web browser). The real benefit of Qwaq however lies with application sharing. Qwaq supports common file formats like Word, Excel, Powerpoint or PDF documents. These can easily be dragged and dropped from the local desktop into Qwaq Forums to share them with other users. All allowed users in the 3D space can see the shared documents, make their own contributions and save the files back on their local machine. During co-editing, different colors highlight which user is currently working on the document. Qwaq is definitely geared towards business use. Several features enhance the chance of a successful adoption in a corporation: Qwaq Forums is designed to be deployed behind a firewall for self-hosted use. This addresses the main concern regarding Second Life of many companies, in which certain data is preferably not stored on an external server. Furthermore, fully encrypted communications links protect communications between users (incl. voice). It integrates with corporate access control systems and allows existing user permissions to be used in Qwaq Forums (e.g. checking credentials against Active Directory or LDAP).

4.3.2 Future research work

The results from our experiments show limitations, mainly because of the low numbers of subjects involved. The limitations lead to future research. The discussion is split between a further data analysis from our trials and further experiments in the environment.

4.3.2.1 Data analysis

The already collected data can be further analyzed:

- **Performance evaluation**: The *group performance* from the trials can be measured by comparing the group rating of an item with the expert rating of an item (resulting in a numerical deviation value). The deviation sum over all items can then be compared between trials. Figure 41 illustrates the idea with the actual group solution of trial number 4.

Trial 4			
Item	Group Rating	Expert Rating	Deviation
Oxygen	1	1	0
Water	2	1	0
Stellar map	3	1	0
Food	4	1	0
Dehydrated milk	5	12	7
Compass	6	14	8
Signal flares	7	10	3
Radio	8	5	3
Nylon rope	9	6	3
First aid kit	10	7	3
Portable heating unit	11	13	2
Parachute silk	12	8	4
Guns	13	11	2
Life raft	14	9	5
Matches	15	15	0
		Overall Deviation	40

Figure 41: Potential performance analysis of the conducted group trials

- **Artifact development:** A connection between the conversation about artifact and the artifact itself may explain some observed phenomena. The Google Docs *revision history* (see 3.2.3.3) of the group solution might give answers as to why a sudden rise of design communication occurred between utterance 41 and 61 in trial 3 (see arrow A, Figure 33, section 3.3.3.3.2). For example, a word count over all document versions could be linked to the chat evolution curve.

- **Coding schema:** A more detailed *coding schema* could be used. We received high amounts of design communication over all trials. It would be interesting to know what exactly constituted design communication. Thus it would make sense to introduce subcategories for our coding schema. A continuous development of the coding schema would be part of a grounded theory approach (see 3.1.2).

- **Avatar data:** So far, the *avatar coordinates* or *rotation* data were not further processed. Interesting analysis opportunities could be found in investigating the *spatial movement of avatars over a period of time* (see Figure 42). For example, one could assess whether there exists a correlation between avatar movement and communication amount. The trials lead to the vague hypothesis that the more avatars walk or fly in space, the less time they spend on communicating with other avatars, either through chat or audio. The collected avatar data from our trials also suggested that there is an *inverse correlation between concentration on a task and avatar movement as well as avatar orientation* (see 4.1). This could be further investigated by looking for changes in avatar coordinates and avatar orientation over a longer period of time. Another possibility is to analyze the interpersonal *distance between avatars over time*, as illustrated in the next illustration (see Figure 42). This might allow conclusions about the similarity of real-world and virtual world communication behaviors.

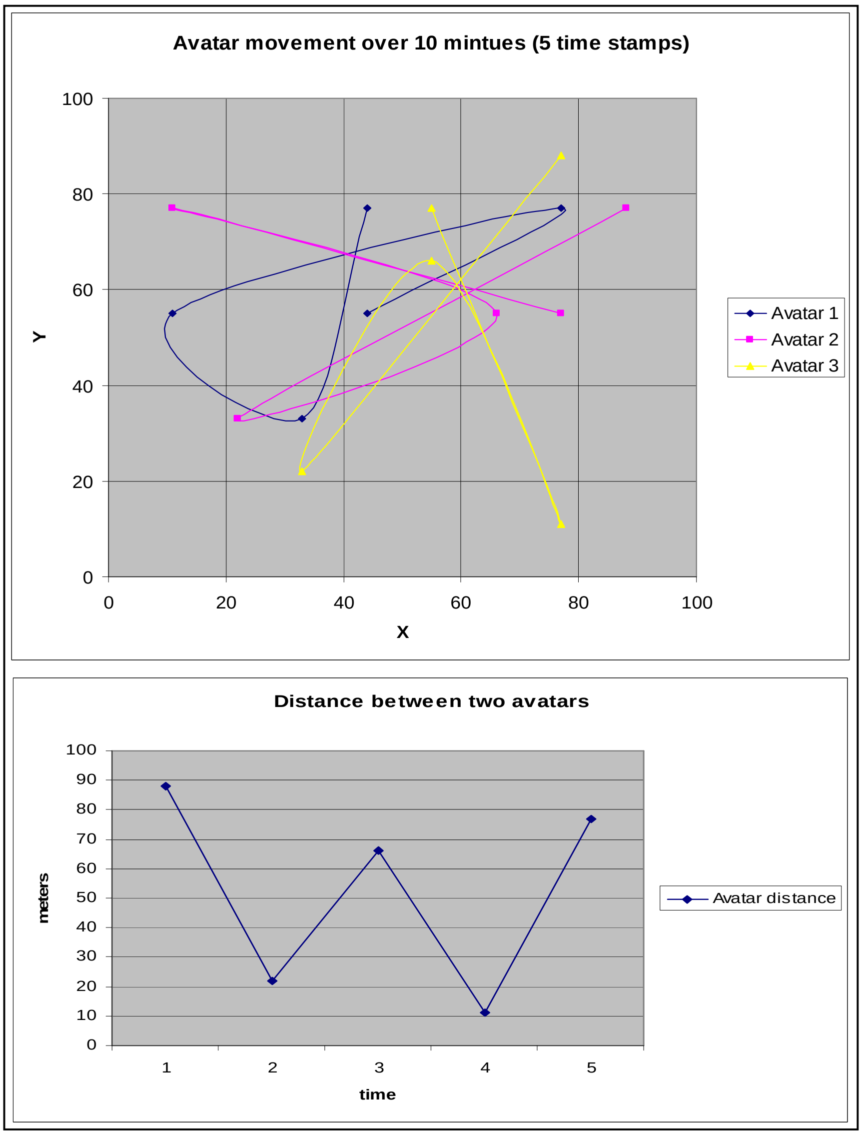


Figure 42: Examples of potential data analysis

4.3.2.2 Experiments

Besides an additional data analysis, Second Life holds potential for further experiments, either with similar or different tasks used in our trials.

4.3.2.2.1 Similar task

Further experiments can be conducted in our created environment (using participants solving a similar task):

- **Participants**: The number of participants for a single trial can be raised (as Second Life theoretically supports a vast number of participants in the same location). Alternatively, the participants can have a specific background and be divided into groups (e.g. age, gender) to allow further findings.
- **Number of experiments**: Besides the number of participants, the frequency of trials can be raised in order to allow a quantitative analysis of the collected data (i.e. application of statistical methods). For example, the satisfaction surveys from the appendix can be distributed to participants (see 6.7).
- **Communication behavior**: A virtual meeting room is a test-bed for validation of social interaction models [Nijholt et al., 2005]. For example, *dominance detection* can be investigated by looking at the floor grabs of a participant and the number of turns someone took; or *addressee detection* by a set of utterance, gaze and contextual features. The influence of these behaviors on communication and vice-versa can be studied. However, Second Life must first make technological progress, so that for example gaze direction becomes more natural. In real world meetings, an intuitively high share of 40% is used for one-to-one communication [Simon, 2006]. What we could not directly assess in our trials is *how the participants speak to each other* (e.g. speaking one-to-one vs. addressing the whole group). Further experiments could investigate "who is addressed how often" during a task, ultimately leading to models of dominance (see 2.2.3.5).
- **Observation methods:** *Eye tracking* installations could be used to measure the eye movement of participants during trial experiments. This has been done before in the case of virtual learning environments, and ultimately revealed that gaze density is clearly much higher in the chat window than in the video window [Tscholl et al., 2005]. Thus one would know where on the Second Life user interface the gaze rests for a longer period of time. This would allow further conclusions whether users focus substantially on the chat window during a task (as suggested by our trials).

Consequently, this could explain the suppressed immersion feeling of our participants (see 4.1).

- **Experiment conditions**: In our trials, not all participants used exactly the same computers and thus had slightly different hardware capabilities. As a result, not all the graphical settings were equal on all machines (e.g. depending on the resolution and detail settings avatars are more or less structured, which results in higher or lower recognition of gestures). Another issue came from the monitors, i.e. some displayed the environment too dark. Due to the different conditions, the trial participants were confronted with different realities. Besides these physical differences, one also has to assume variances in the user's individual perception of the environment. It is therefore suggested to conduct further trials in a *laboratory environment*, which has exactly the same computers and no interfering distractions during the experiment (however, see limitations of laboratory experiments in 3.3).

4.3.2.2.2 Different tasks

Further experiments can be conducted with new exercises:

- **Tasks:** The trials can consist of different tasks in order to make more general statements about the usability of Second Life for various purposes. Especially it is suggested to use tasks that lead the user to explore the environment (see 4.1). Short tasks limit the potential of the virtual world medium.
- **Asynchronous research:** With different tasks, especially asynchronous collaboration experiments, research can then lay a focus on other aspects of virtual worlds:
    - Observing *social interaction* and *behavior* of avatars (not humans).
    - Observing *long-term collaboration processes* between individuals, groups and communities in a computer-mediated environment.
    - Investigate the *long-term awareness* support of the virtual world medium.
    - Observe how users adjust to tools or mediums in the virtual world, ultimately expanding *media stickiness theory* (see 2.1.1)

    - Investigate *motives* for contributing in communities in virtual worlds (see 2.2.3.2).

- **Environment design:** The trials can have different environment designs to assess various hypotheses. One could test if open spaces are better for collaboration than closed spaces, because they allow for a more free movement. Although complex structures like houses can be built in a virtual world, they often pose obstacles to see other people, so generally open spaces are better for socializing [Prasolova-Førland & Divitini, 2003]. Also, players can better coordinate their actions when they can see what the other is doing [R. J. Moore, Ducheneaut et al., 2007]. Additionally, one could be interested in how a natural room layout influences the communication behavior among participants (see 2.2.1.1). The results may show that traditional rooms with furniture enhance the user acceptance of the environment.

5 CONCLUSION

The usability evaluation of a meeting environment in Second Life highlighted application-specific, current, and lasting issues of virtual worlds for synchronous collaboration. As part of our usability evaluation cycle, grounded theory was supposed to guide our data analysis. However, after the constant interplay of data collection and data analysis from our environment, we have not yet reached the point of theoretical saturation. And to a much lesser extent, could we form so-called mini-theories. We could only detect patterns in our data analysis and interpret them with the framework of media naturalness theory.

Virtual worlds might be a considerable technological evolution from earlier virtual reality environments, but contrary to first impression, social interaction in virtual worlds is currently *"…not very complex in comparison with the immense variety of face-to-face interaction in the physical world"* [Schroeder et al., 2006, p. 655]. Accordingly, the developed prototype environment in Second Life could, also by definition, not result in a final product ready for use in a distributed, collaborative setting. Further time and work of specialists (additional scripting) would be needed to achieve this. However, an environment which supports collaboration to a certain degree (convergent processes) has now been established. Technological advancements of the virtual world medium will allow a more realistic collaboration support in both academic and commercial institutions. Our media naturalness theory analysis of Second Life indeed revealed that the virtual world medium is subject to a strong surge in naturalness, because of the increasing fidelity as a result of advancing technology. The analysis of naturalness attributes further demonstrated where the weaknesses of the virtual world medium lie, but only to a certain degree. Specific recommendations are unlikely to come out of such an investigation at the current development stage of media naturalness theory. Consequently, media naturalness might be better suited for informing the design of technology, rather than for evaluating technology according to specific criteria.

Virtual worlds are always part of the real world, and all technologies, especially new ones, require set-up and maintenance effort. Thus a great deal of collaboration in the real world is required to successfully collaborate online [Bowers et al., 1996]. During the thesis project we could observe that virtual worlds may well support cooperative work, but more interestingly, they certainly require it. Therefore virtual world developers should be designing for two worlds instead of just one. "*No matter how complicated the next new technology may seem, it is still the human that is the most complex, flexible, and a adaptive part of the system*" [DeRosa et al., 2004, p. 228].

In our trial experiments, the users did not feel immersed in the spatial environment. In relation to this observation, collaborating on a time-limited task revealed two characteristic patterns during our data analysis. These patterns showed that communication covering the solution of a task (design communication) dominated in the middle part of a session. Design communication was nearly absent in the beginning of the meeting and reduced towards the end. The communication during the middle part was focused to such a degree that everything outside the object of attention (i.e. the developed artifact in our case) lost its *inherent* value. Consequently, even if virtual worlds support various aspects leading to collaboration, they can only demonstrate their potential in specific situations. Ultimately, the perceived value of virtual worlds is often lower than expected.

"*The computer revolution will be judged not by the complexity or power of technology, but by the service to human needs"* [Shneiderman, 1992, p. 434]. In the same line, virtual worlds have to demonstrate a service to human needs. We assessed their value for virtual meetings in the case of Second Life. However, virtual worlds are by far not the only tool for distributed meetings. Various two dimensional environments exist for the same purpose. Even if 3D-environments are required, virtual words are not necessary in every case. For example, 3D-simulations can provide the same visualization and functionality without the increased cognitive effort and distraction coming as a side-effect of customizable avatars. *"In the long run, we expect to see two types of environment for remote meetings: Specialized meeting rooms, fully equipped with whatever hardware is needed and available for meetings on the one hand, and far more basic, single user environments based upon equipment that happens to be available. The current version of virtual meeting room requires manual control, using classical input devices such as keyboard or mouse, in order to look around, interact with objects and so on. It seems unlikely that in a more realistic setting people participating in a real meeting would like to do that. Simpler interaction, based upon gaze detection but also on speech recognition should replace this situation* [Nijholt et al., 2006]". It is speculated here that Second Life does not provide the right architecture to replace face-to-face meetings in industry. Second Life at the current stage, literally, might be better suited for exploring a "second life", rather than to be integrated as a meeting tool in "first life". However, what applies to Second Life does not need to apply to virtual worlds in general.

Virtual worlds are a technology in rapid development and thus it is hard to draw any conclusions regarding the potential for collaboration. Changes simply happen too quickly to make any closing statements. And *"as always in a new medium, the most interesting developments will be those that nobody expected"* [Hut, 2008, p. 10]. However, regardless of the technology development, collaboration usually happens between people who are supposed to work together (and ideally know each other). In our trials, we "forced" participants (with no previous experience working together) to collaborate, by giving them a concrete task. The characteristic chance encounters of virtual worlds could not occur in our situation. Nonetheless, even if chance encounters lead to further collaboration, they certainly do not imply it. Very likely, collaboration is not occurring when an avatar meets a potential collaborator for the first time. Establishing a collaborative relationship requires time. In fact, just here lies the potential of virtual worlds. Virtual worlds support this process by building a long-term awareness between participants and their environment. "*After a number of meetings with various stimulating conversations, the regulars want to keep coming back to the familiar setting, where they know they can meet other interesting people, old friends as well as new acquaintances. Being able to visit such a space at the click of a button is a great asset. Whether at home or at work, or briefly logged in at an airport, the virtual space is always there…it can function like a tea room in an academic department, but then in a portable form, always and everywhere within reach"* [Hut, 2008, p. 9].

6 APPENDICES

6.1 Referencing

A distinction between *primary references* and *secondary references* is made in the main body of this thesis. Primary references are direct resources which were consulted by the author of the thesis. Secondary references are exclusively references that are referred to by primary references. Besides non-accessible resources, the reason for this split is transparency: Resources which were consulted in-depth are separated from references that refer to out-of-scope content for the thesis. One can easily see if a reference refers to a primary resource: Secondary resources are always mentioned after the corresponding primary reference and the term "quoting" (e.g.: [X, 2005] quoting [Y, 2002]). To provide a better searchable reference list at the end of the thesis, the distinction between primary and secondary reference is not made in this case. References include one or two main authors, for more authors the main author is mentioned with "et al.". In case of a reference to a website the URL can be found in the reference list. The reference itself includes the author name for an online article or the company name for a product. The year is omitted in the reference in case of a constantly updated website, but the last access date can always be found in the reference list.

6.2 Task descriptions

6.2.1 Lost at sea

This task is slightly adapted from the original source [Training-Manager].

Situation

- You and your team have chartered a yacht. None of you have any previous sailing experience, and you have hired an experienced skipper and two-person crew.
- As you sail through the Southern Pacific Ocean a fire breaks out and much of the yacht and its contents are destroyed.
- The yacht is slowly sinking.
- Your location is unclear because vital navigational and radio equipment has been damaged.
- The yacht skipper and crew have been lost whilst trying to fight the fire.
- Your best "guestimate" is that you are approximately 1000 miles South West of the nearest landfall.
- You and your friends have managed to save the following 15 items, undamaged and intact after the fire.
    - 1. A sextant
    - 2. A shaving mirror
    - 3. Mosquito netting
    - 4. 15 liters of drinking water
    - 5. A case of army rations
    - 6. Maps of the Pacific Ocean

- 7. A floating seat cushion
- 8. A 7 liter can of oil/petrol mixture
- 9. A small transistor radio
- 10. 2 square meter of plastic sheeting
- 11. Shark repellent
- 12. One liter of 80 per cent rum
- 13. 5 meter nylon rope
- 14. 2 boxes of chocolate bars
- 15. A fishing kit

In addition to the above, you have salvaged a four man rubber life craft. The total contents of your combined pocket's amounts to a packet of cigarettes, 3 boxes of matches and 3 five dollar notes.

Task

DISCUSS (PUBLIC CHAT, AUDIO) WITH THE OTHER USERS IN THE AREA WHICH ITEMS ARE MOST IMPORTANT AND WHY. MAKE A PRIORITY LIST OF THE 15 ITEMS (1ST, 2ND ETC.) AND PRESENT YOUR RESULTS. YOUR CHANCES OF SURVIVAL WILL DEPEND ON THE RELATIVE ORDER OF IMPORTANCE OF THE ITEMS. YOU ARE ONLY ALLOWED TO USE SECOND LIFE FOR THIS TASK.

Solution

According to experts form the US coastguard, the following is the order of ranking the items in their importance to survival.

1. Shaving mirror	Critical for signaling	9. Floating seat cushion	A life preserver if someone fell overboard
2. 7 liters can of oil/petrol mixture	Critical for signaling. The mixture will float on water and could be ignited with one of the 5$ notes and a match	10. Shark repellent	Obvious.
3. 15 liters of water	Necessary to replenish fluids lost through perspiration	11. One liter of 80 per cent rum	Enough alcohol content to be used as an antiseptic for any injuries, otherwise of little value – would cause dehydration if ingested.
4. One case of army rations	Basic food intake	12. Small transistor radio	Of not use without a transmitter. You would also be out of range of any radio station.
5. 2 square meters of opaque plastic	Can be utilized to collect rain water and provide shelter from the elements	13. Maps of Pacific Ocean	Worthless without navigation equipment.
6. Two boxes of	Reserve food supply	14. Mosquito	There are no

chocolate bars		netting	mosquitoes in the mid-pacific ocean. As for fishing the fishing kit fits better.
7. Fishing kit	Ranked lower than chocolate as there is no guarantee to catch any fish.	15. Sextant	Useless without relevant tables and a chronometer.
8. 5 meters of nylon rope	Could be used to lash people or equipment together to prevent it being washed overboard.		

6.2.2 *Survival on the moon*

This task is slightly adapted from the original source [NASA].

Situation You are a member of a space crew originally scheduled to rendezvous with a mother ship on the lighted surface of the moon. However, due to mechanical difficulties, your ship was forced to land at a spot some 200 miles from the rendezvous point. During reentry and landing, much of the equipment aboard was damaged and, since survival depends on reaching the mother ship, the most critical items available must be chosen for the 200-mile trip. Below are listed the 15 items left intact and undamaged after landing.
Task DISCUSS WITH THE OTHER USERS IN THE AREA WHICH ITEMS ARE MOST

IMPORTANT AND WHY. MAKE A PRIORITY LIST OF THE 15 ITEMS (1ST, 2ND ETC.) AND PRESENT YOUR RESULTS. YOUR CHANCES OF SURVIVAL WILL DEPEND ON THE RELATIVE ORDER OF IMPORTANCE OF THE ITEMS. YOU ARE ONLY ALLOWED TO USE SECOND LIFE FOR THIS TASK.

- Box of matches
- Food concentrate
- 50 feet of nylon rope
- Parachute silk
- Portable heating unit
- Two .45 caliber pistols
- One case of dehydrated milk
- Two 100 lb. tanks of oxygen
- Stellar map
- Self-inflating life raft
- Magnetic compass
- 5 gallons of water
- Signal flares
- First aid kit, including injection needle
- Solar-powered FM receiver-transmitter

Solution

Item	NASA ranking	NASA's reasoning

Box of matches	15	Virtually worthless – there's no oxygen on the moon to sustain combustion
Food concentrate	4	Efficient means of supplying energy requirements
50 feet of nylon rope	6	Useful in scaling cliffs and tying injured together
Parachute silk	8	Protection from the sun's rays
Portable heating unit	13	Not needed unless on the dark side
Two .45 caliber pistols	11	Possible means of self-propulsion
One dehydrated milk	12	Bulkier duplication of food concentrate
Two 100 lb. tanks of oxygen	1	Most pressing survival need (weight is not a factor since gravity is one-sixth of the earth's – each tank would weigh only about 17lbs. on the moon)
Stellar map	3	Primary means of navigation – star patterns appear essentially identical on the moon as on earth.
Self-inflating life raft	9	CO2 bottle in military raft may be used for propulsion
Magnetic compass	14	The magnetic field on the moon is not polarized, so it's worthless for navigation
5 gallons of water	2	Needed for replacement of tremendous liquid

		loss on the light side
Signal flares	10	Use as distress signal when the mother ship is sighted
First aid kit, including injection needle	7	Needles connected to vials of vitamins, medicines, etc. will fit special aperture in NASA space suit
Solar-powered FM receiver-transmitter	5	For communication with mother ship (but FM requires line-of-sight transmission and can only be used over short ranges)

6.2.3 *Additional task: Automatic post office*

The following task is adapted from Olson et al. [J. S. Olson et al., 1993] and was initially considered for our trial experiments, but then abandoned because of the lack of a sophisticated in-world whiteboard in Second Life.

Situation
You are an employee of an innovative corporation with 30 employees. You have an idea for a new product – an unattended, self-service *automatic post office*. This machine offers similar services of a traditional post office, just in the form of an automat (similar to an automatic teller machine – ATM). With this machine you have the opportunity to improve the services of a post office. The CEO of your company told you to start the project. He expects a report, which states the current and potential services of such a machine. The potential services should be realizable in the near future.
Task

The report includes the following important points:

A separate description of:

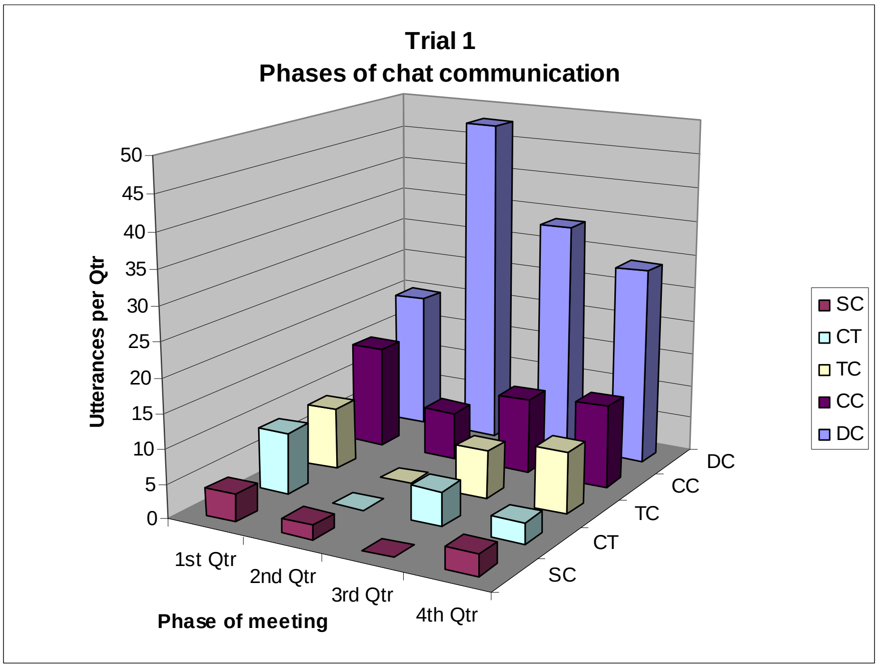
- the features (which services are offered to the customer)
- the functionality (user interface architecture and menu, etc.)
- the equipment (which hardware is used, how is the appearance of the automat etc.)

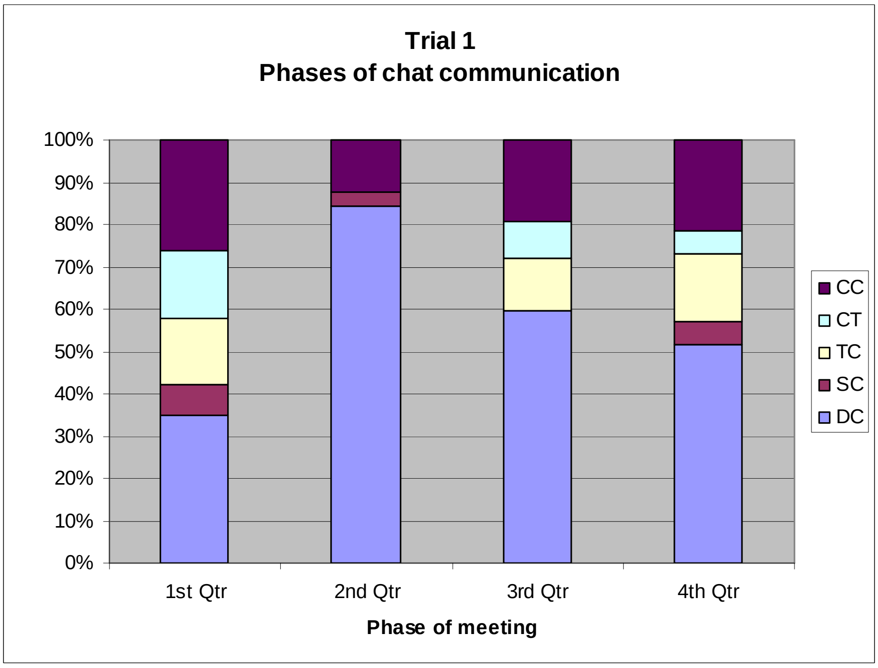
Consider idea richness (creativity), comprehensibility (understandability), and feasibility (practicability) of the project in your answers.

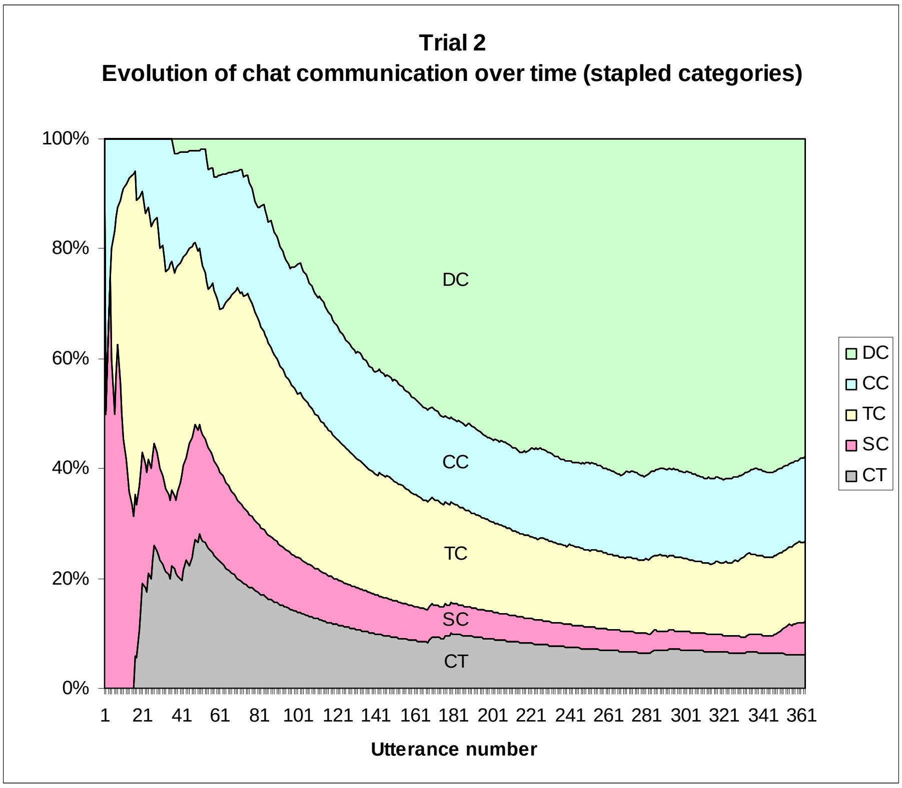
Regarding the state of technology you can make assumptions. You have a maximum of 45 minutes time to complete the task. The quality of the ideas and the required time has an influence on the judgment of your design. Optimal would be highest quality in the shortest time. It's an honor to be part of the development team in such an early phase. Your success with the project can lead the future of the company.

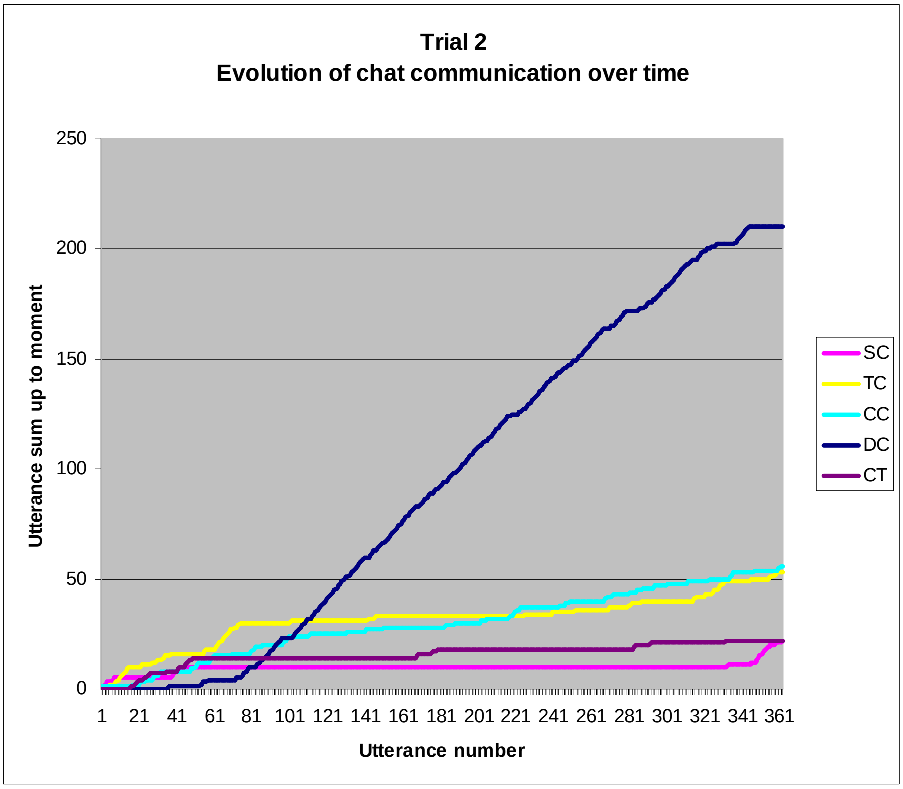
6.3 Data analysis diagrams

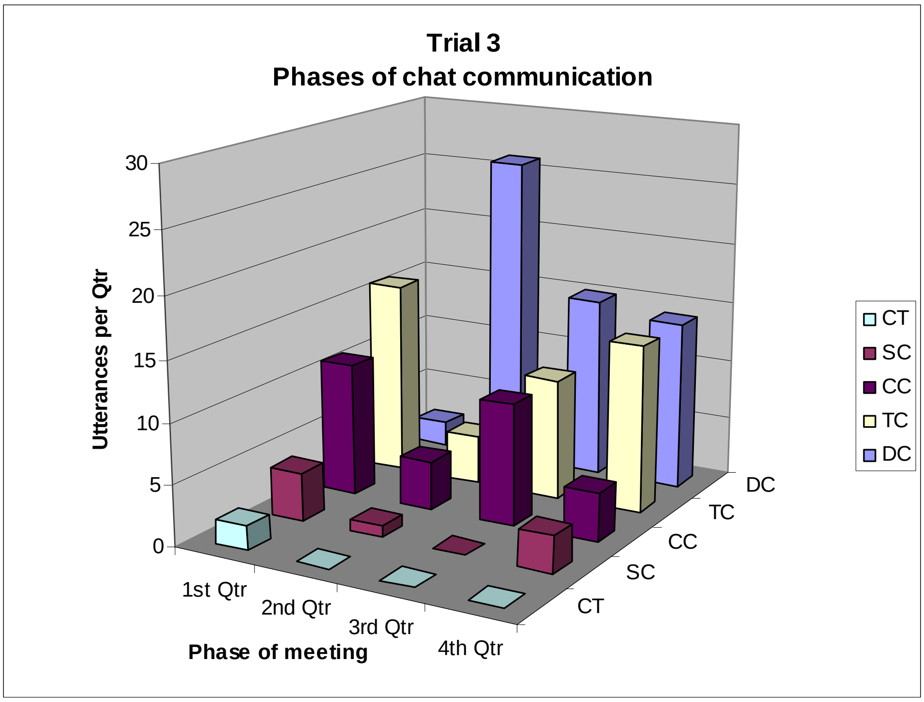
In the results section not all diagrams for each trial were presented. Here follow the remaining diagrams.



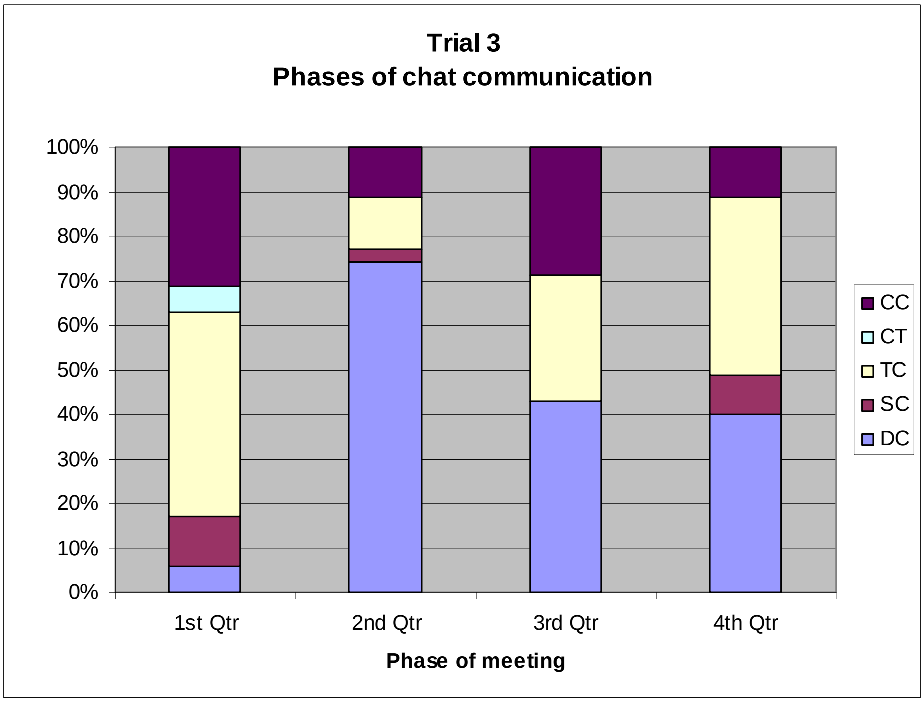



Trial 2
Evolution of chat communication over time (stapled categories)
100%
80%
60%
40%
20%
0%
DC
CC
TC
SC
CT
1 21 41 61 81 101 121 141 161 181 201 221 241 261 281 301 321 341 361
Utterance number

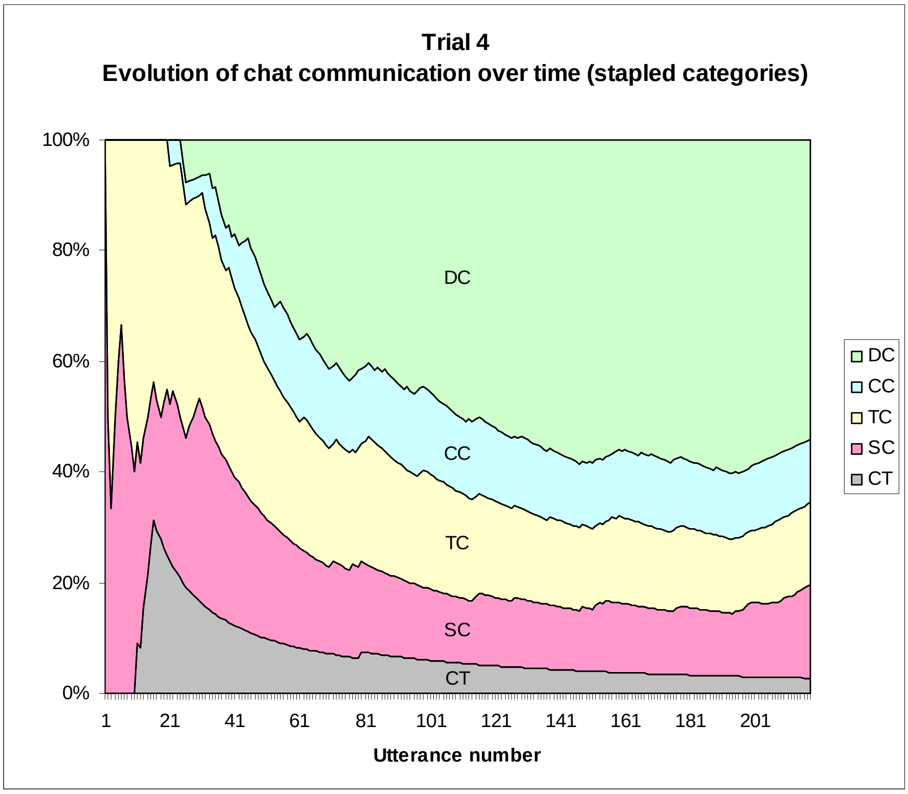

Trial 2
Evolution of chat communication over time
250
200
150
100
50
0
Utterance sum up to moment
SC
TC
CC
DC
CT
1 21 41 61 81 101 121 141 161 181 201 221 241 261 281 301 321 341 361
Utterance number

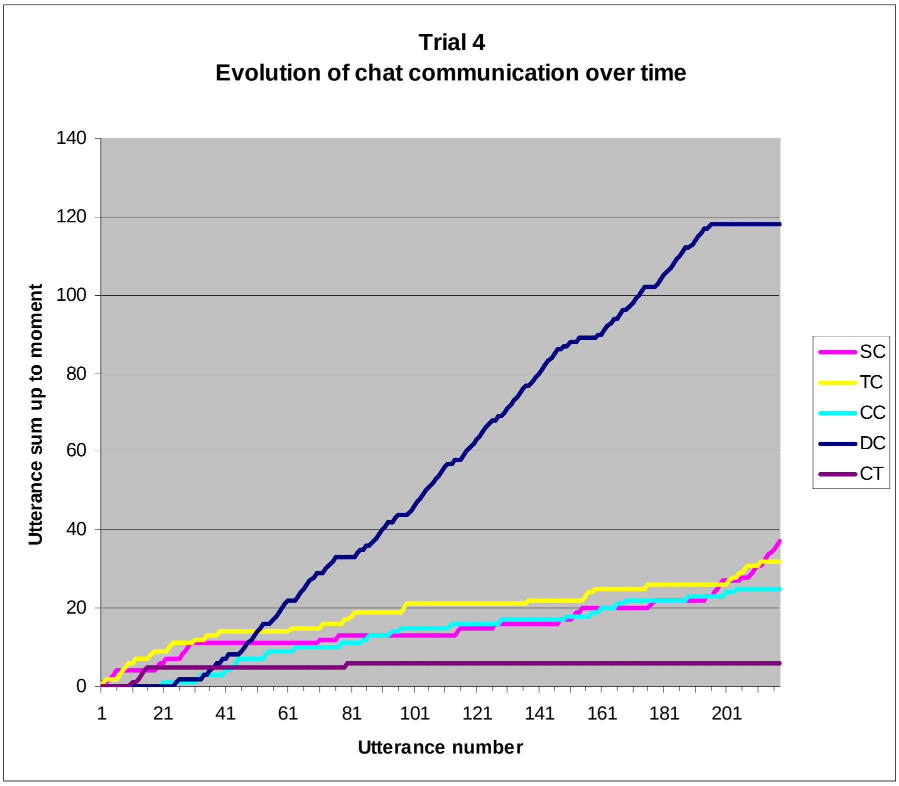


Trial 3
Phases of chat communication
Utterances per Qtr
30
25
20
15
10
5
0
1st Qtr
2nd Qtr
3rd Qtr
4th Qtr
Phase of meeting
CT
SC
CC
TC
DC



Trial 3
Phases of chat communication
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1st Qtr
2nd Qtr
3rd Qtr
4th Qtr
Phase of meeting
CC
CT
TC
SC
DC


Trial 4
Evolution of chat communication over time (stapled categories)
100%
80%
60%
40%
20%
0%
DC
CC
TC
SC
CT
1
21
41
61
81
101
121
141
161
181
201
Utterance number
DC
CC
TC
SC
CT


Trial 4
Evolution of chat communication over time
140
120
100
80
60
40
20
0
Utterance sum up to moment
1
21
41
61
81
101
121
141
161
181
201
Utterance number
SC
TC
CC
DC
CT

6.4 Data collection script

```
//Data Extraction
//This script records avatar info and chat, and sends the data over email on a timed interval.

integer sendDataIntervel = 5; //Send the data every minute or so
integer collectDataIntervel = 5; //Record updated info every 10 seconds or so. Doing this too
often while having a long sendDataInterval will result in script memory issues.


list avatarData;
string chatBuffer;
string HoverText = "Collecting positions";

list chat;

 // search 'src' and replace all occurences of 'find' with 'replace'
    string ReplaceString(string src, string find, string replace)
    {
        return llDumpList2String(llParseStringKeepNulls(src, [find], []), replace);
    }


default
{
    on_rez(integer param)
    {
        llResetScript();
    }
    state_entry()
    {
        llSetText(HoverText, <1,1,1>, 1.0);
        llSetTimerEvent(sendDataIntervel);
        //llSensorRepeat("","",AGENT,96,PI,collectDataIntervel); //Run a scan for agents

        llListen(0,"","",""); //A listen event to record Chat
        llSensorRepeat("","",AGENT,96,PI,collectDataIntervel); //Run a scan for agents
    }

    sensor(integer num)
    {
        integer index;
        for (index=0;index<num;index++)
        {
            avatarData+="\n";
            avatarData += llGetTimestamp(); //TimeStamp for the data
            avatarData+= llDetectedName(index);//Agents Name
            avatarData+= llDetectedPos(index); //His Position
            avatarData+= llRot2Euler(llDetectedRot(index)) * RAD_TO_DEG; //His Rotation
           // avatarData+= "\n";

            float distance = llVecDist(llDetectedPos(index),llGetPos());
            avatarData+=(string)llFloor(distance) + "m,"+llGetAnimation(llDetectedKey(index));

         }
    }

    listen(integer channel, string name, key id, string message)
```

```
    {
        string temp;
        integer index=0;
        //temp=chatBuffer;

        temp=(string)chat;
        temp= ReplaceString(message, ",","COMMA");

        chat+="\n"+llGetTimestamp()+","+name+","+temp;
        //chatBuffer+="\n"+llGetTimestamp()+","+name + ","+temp;
    }

    timer()
    {
        llListSort(avatarData, 4, TRUE);
        //llSay(0,"Mail Sent");

        list buffer;
        buffer=chat;
        //avatarData = (list)llDeleteSubString((string)avatarData, 0,
//llSubStringIndex((string)avatarData, "\n\n") + 1);

        //llEmail("sl_5@live.com"," ", llList2CSV(avatarData)+"\n"+chatBuffer+"\n");

       llEmail("secondlife@unisa.x10hosting.com"," ",llList2CSV(avatarData));
       llEmail("chat@unisa.x10hosting.com"," ",llList2CSV(buffer));


       // llEmail(emailAddress2," ", "\n"+chatBuffer);

       //  llHTTPRequest("http://unisa.x10hosting.com/test.txt", [HTTP_METHOD, "PUT"],
"chatBuffer" );

       chatBuffer = "";
       buffer = [];
       avatarData = [];

    }
}
```

6.5 Correspondence

Email to Ned Kock (media naturalness): 8. February 2008

Dear Professor Kock

I'm an information systems student from University of Zurich, currently writing my master thesis at the University of South Australia. We are researching the collaborative potential of virtual worlds for distributed teams and will conduct usability experiments (fixed task) in Second Life. Data will be collected both real-time (avatar information) and post-hoc (qualitative interviews).

Lately I came across media naturalness theory and the compensatory adaptation model. They strike me as an interesting perspective on media choice, also regarding virtual worlds. I did a preliminary analysis of the five naturalness factors (collocation, synchronicity, facial expressions, body language and speech) in virtual worlds from my experience in Second Life. I also looked at the three outcomes when interacting in a different manner than face-to-face (increased cognitive effort/communication ambiguity, decreased physiological arousal). Later on these insights might help me interpret the collected data from the experiments. I am a critical user of Second Life, and media naturalness helps me explain these concerns. I only found one explicit reference of media naturalness regarding virtual reality, namely in "The Psychobiological Model: Towards a New Theory of Computer-Mediated Communication Based on Darwinian Evolution." It's mentioned that super-rich media will cause an information overload for the user.

My question is if you think it is reasonable to observe the naturalness potential of virtual worlds. I do understand that you are probably too busy to read what I wrote so far. Just in case, I attached my thoughts below (please excuse my English as a non-native speaker).

Kind Regards,

Oliver Stanek

Email reply form Ned Kock (media naturalness): 11. February 2008

Hi Oliver.

Yes, I do think that the notions of media naturalness and compensatory adaptation can be used as a basis for research in virtual worlds. In fact, I've recently written a little editorial paper on the subject. The paper is forthcoming in the International Journal of e-Collaboration. If you would like to take a look at it, the link to the PDF file is:

http://cits.tamiu.edu/kock/Temp/Kock_2008_IJeC_EcollabSecondLife.pdf

I wish you all the best with your work.

Ned

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Texas A&M International University
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6.6 Diploma Thesis proposal

DEVELOPMENT AND ANALYSIS OF A CREATIVE TEAM ENVIRONMENT IN A VIRTUAL WORLD

Introduction

This Master Thesis is enabled generally by recent CSCW research – how teamwork can be effectively supported by computer devices, and in particular by the work undertaken by Prof. Swatman as head of the CreWS (Creative Work Support) team at the InSyL laboratory (e.g. Exploration and Evaluation Harness, EEH).

The research objective addressed now is to build a collaboration environment within the virtual environment Second Life. This environment must possess several qualities, among them synchronous, distributed collaboration capabilities. It must also be instrumented for collaboration and requirements engineering analysis in order to enable ad hoc collaboration support.

Background

The work will be based on certain key assumptions, which have been investigated before as part of the CreWS project (e.g. catastrophe-cycle model).

An alternative approach for the prototype compared to available technologies is chosen mainly because a commercial ICT video-conferencing solution (e.g. HP's "Halo" system) is too expensive for many applications, particularly in smaller companies. On the other hand, a cheaper solution enables virtual meetings that would not be held at all otherwise, but would instead lead to more simple communication forms (e.g. email, telephone).

Therefore, the means are not to replicate the real world as is done with video-conferencing, but to find and build a "small budget" collaboration environment.

Motivation

The motivation for this project lies both in the contribution to research (importance of topic) and in the practical appliance for effective teamwork, which will also lead to further research in this field.

The contribution to research will be a broader understanding of software and requirements engineering for creative teams, which have proved to follow a different scheme than teams dealing with highly structured processes (see Prof. Swatman's catastrophe-cycle model).

The practical appliance is encouraged by the relationship with Thales Australia, a subsidiary of a global software development company. Thales is looking for control over new software engineering processes for geographically distributed or co-located teams, to increase predictability of effectiveness, efficiency and quality of its products.

Goals

There are two primary *deliverables* envisioned for this thesis (expected outcomes or "what needs to be done"):

- To develop a prototype in a virtual world supporting collaboration with the above mentioned qualities (build a meeting facility) and documentation for later analysis.
- An initial analytic study of distributed team interaction in this environment

A result from these goals should be an enhanced capability in research into Creative Teamwork Support.
In more detail, the prototype should at least fulfil the following *aims* regarding distributed meetings in a virtual environment (according to Prof. Swatman):
- *Parity*: Every participant should have the same access to the discussion thread(s) – the same chance of being heard, etc. as they would have had in a meeting being held conventionally.
- *Awareness/Presence*: Every participant should have intuition of the availability and "readiness to participate" of other participants – the analogy is to observing colleagues working at their desks or "paying attention" in meetings.
- *Opportunity for network building/socialisation*: A significant benefit of face-to-face meetings is the opportunity for pairs of participants, or larger groups, to break off for a chat, which may or may not be a part of, or even relevant to, the meeting.

On the other hand, there are certain *limitations* to this study, some of them already becoming obvious in this initial stage:
- The developed prototype can by definition not result in a final product that could be used by a partner (e.g. Thales). Further time and work of specialists would be needed to achieve this, if it is a requirement at all.
- Also, the expected outcomes from the analytical study will have limited significance if the number of experiment objects is too small. Further experiments are likely to be conducted after the research time allocated for this Diplomarbeit.

The main part of this work will be of conceptual and empirical nature and not require profound coding knowledge in a particular programming language.
Future *enhancements*, which depend on the results achieved, could be additional support tools for the collaboration environment.

Plan

Official timeframe of the thesis: 16th November 2007 - 16th Mai 2008 (hand-in date after 6 months).
The study will take place at the University of South Australia over nearly six months (26th November – 16th Mai, 25 weeks) and should result in a final report in the form of a Diplomarbeit (master thesis).
A more detailed outline including milestones will be set-up once work starts (see Week 3).

General plan ("when what needs to be done"):
- *Week 1:* Joining the research group and familiarize with available resources in the InSyL laboratory and as part of the CreWS team.
Deliverable A: Short report about CreWS members/responsibilities and available resources (about 2 pages; will be partly integrated in the final report).

- *Week 2:* Study of previous CreWS research.
Deliverable B: Report of the previous CreWS work helpful for the Diplomarbeit (about 3 pages; to be integrated in the final report).

- *Week 3:* Literature review, check what has been done before in this field (worldwide) to avoid redundancies. Set up of a more detailed research plan.

Deliverable C: Report of research at other higher institutions relating to the Diplomarbeit (about 3 pages; to be integrated in the final report).

- *Week 4-5:* Research theoretical background (CSCW, groupware, creativity, software/requirements engineering etc.) for the final report.
Deliverable D: Report of the scientific frame in which the Diplomarbeit takes place (about 6 pages; to be integrated in the final report)

- *Week 6-12:* Development of a prototype world.
Deliverable E: Report of the progress, methods and resources used (will be partly integrated in the final report). Additional documentation for future use.

- *Week 13-14:* Development or choice of the analytic instruments for the prototype world.
Deliverable F: Report which analyzing method was chosen and why (to be integrated in the final report).

- *Week 15-21:* Analytic study of the prototype world
Deliverable G: Report detailing the experiment resulting in conclusions and implications

- *Week 22:* Structuring gained knowledge and giving suggestions for further research.
Deliverable H: Putting the above information together and starting a final document (incl. section: further research).

- *Week 23-25:* Final editing of the report adhering to the guidelines and rules for a Diplomarbeit at the Department of Informatics, University of Zurich. Sending the work to the University of Zurich (no physical attendance required).
Deliverable I: The final Diplomarbeit version.

Resources
Certain hardware and software components will be required to carry out the work, as well as access to scientific literature.
- Library usage at the University of South Australia
- Computer with internet access at the InSyL laboratory capable of running Second Life and corresponding development tools
- Information on the CreWS BSCW server
- Support of the other CreWS members (questions regarding content; assistance in urgent or technical cases)
- Support of the Information Management Research Group at the University of Zurich (format and content regarding the final report; contribution in the analytical study)
- Cooperation with Thales Australia

6.7 Suggested surveys

The following two surveys measure the satisfaction component of usability. They can be useful if a large number of participants are investigated and if statistical analysis will be applied.

6.7.1 Enjoyment

Our investigation of the user acceptance of Second Life was influenced by the *hedonic framework* (see 2.2.3.4), but the framework was not directly applied. It is still in an early development phase, which does not provide concrete methods for researching the user acceptance in a virtual world like Second Life. However, a selection of survey questions relating to playfulness can be taken over from the corresponding paper [Holsapple & Wu, 2007]. Because the questions are geared more towards games they initially needed to be adapted and not all of them proved applicable. They can be answered yes, unsure or no.

Role Projection (RP) RP1 Playing Second Life enables me to project myself into a particular role. RP2 Playing Second Life enables me to project myself into a particular character. RP3 Playing Second Life enables me to project myself into a particular task.	Emotional Involvement (EI) EI1 When I am playing Second Life, I feel "carried off" by the virtual world. EI2 When I am playing Second Life, I feel as if I am part of the virtual world. EI3 When I am playing Second Life, I feel deeply about the virtual world.
Escapism (ES) ES1 Playing Second Life helps me escape from the world of reality. ES2 Playing Second Life helps me escape from problems and pressures.	Arousal (AR) AR1 Playing Second Life makes me excited. AR2 Playing Second Life makes me inspired.
Enjoyment (EN)	

EN1 I have fun playing Second Life. EN2 Playing Second Life provides me with a lot of enjoyment.	

6.7.2 Acceptance

The following survey questions [Brooke, 1996] assess the system usability and the user acceptance of the technology, which are both part of the satisfaction component of usability. The system usability scale has been used before for the automatic post office task [Löber et al., 2007].

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

6.8 Comparison of virtual worlds

The following comparison of Croquet, Second Life, Active Worlds and There gives an overview of relevant criteria for research in virtual worlds [Taylor & Duclos, 2007].

	Croquet	Second Life	Active Worlds	There.com
Launched	Still in development	2003 (according to http://secondlife.com/whatis/)	Beta began in 1995. Officially launched in1997 (according to http://www.virtualworldsreview.com/activeworlds)	2003 (reconstructed timeline based on information from the press releases at http://www.there.com/press.html)
Website	http://www.croquetconsortium.org	http://www.secondlife.com	http://www.activeworlds.com/	http://www.there.com
Overall ease of use for beginner to access	Difficult. Requires being very comfortable with your computer. If your graphics card isn't quite right, it requires having enough computer savvy to edit the registry. Even once it is installed, it can be confusing to use and there is little documentation for an end user.	Somewhat difficult to get started as many people get stuck on Orientation Island. Even with years of gaming experience, the program took some time to get used to. The Orientation Island feature borrows from the "training level" of video games, but is poorly implemented.	Relatively easy to get started in. There is no tutorial such as Second Life's Orientation Island but the interface is much simpler.	Mostly okay but to read the privacy policy one has to leave the registration screen and the program won't allow one back in, unless one goes back to the homepage. Thankfully, it remembers where in the session one was and continues from that point. Also, after registration it doesn't launch the application as other sites do. It leaves one in an interface that looks similar to a browser but not exactly. When one clicks on a link from there it tells one that it is necessary to have the 3D client open already, which requires a re-launch of the program. This is not the easiest implementation for users who are not technically inclined.
System type	Open-source	Proprietary	Proprietary	Proprietary
Membership costs	Free to join for end users.	Free to join for a basic account. A premium account (for a general user) costs 9.95/month or 72.00/year and gives you the ability to own land and access to premium user support services. Discounts are available for educators and non-profit organizations.	Free to join for a basic (tourist) account and 6.95/month or 96.95/year for a citizen account that allows a permanent user id, unlimited access, ability to own and build property that persists over time, more avatar choices, more options for communicating with other citizens and rights to post on community message boards.	Free to join for a basic account. A premium account is a one-time 9.95 charge.
Starting point	The Croquet menu screen from which one picks what world one	Orientation Island for first-time users. Every time after, the user starts	AWGate world	There.com Visitor's Guide webpage shows up but otherwise one is stuck in a no-man's land when one first begins.

	wants to enter.	off where they finished their last session or the user can set a "home" starting point.		Every session after the first one starts the user at the place they ended their last session.
Community of practitioners	Community of developers established. There is not yet a cohesive community of end users or educators.	Many listservs, wikis, websites and forums.	A few wikis and forums.	None established.
Used for education	Yes. Several schools have projects in development.	Yes. Educational listservs, an educational wiki, and many in-world projects run by educators and accredited institutions are available.	Yes. There's an educational version called Active Worlds EDU that has 61 worlds. It did not appear that any were run by institutions though a few looked like they might be run by a particular class. However it was hard to tell as the names are only 8 letters and there are no descriptions for the worlds, and most of the worlds were empty or inactive.	Possibly. Press releases report a partnership with New York Law School to offer classes through stateofplayacademy.com. However, exploration of that website shows no updates since spring.
Organizing spatial metaphor	Worlds accessed by portals.	Islands	Worlds	Places. These are on islands and categorized by landmark, hotspot, hangout, neighborhood, waypoint, fun zone.
Basic avatar customization	Demos show a girl and a giant rabbit as possible avatars, which indicates that full avatar customization will likely be possible.	Can choose from 4 male and 4 female choices, and then customize hair, skin, facial features, etc. Can find free clothes or non-human avatars at free shops quite early on.	Start out with either a male or female tourist. All are dressed in khaki shorts, Hawaiian shirts and a hat. To get avatar customization, one must upgrade to the pay service, then pick the avatar from the ones offered for that world. To get a fixed avatar available in all worlds, must buy a Personal Avatar (PAR).	Upon starting, one chooses from 3 female and 3 male avatars and the only choices are blond, black or brown hair and vanilla, caramel or chocolate skin tone. Further customization can happen later at a spa. However, no spa was found during research to determine how much one could customize their avatar's appearance.
Non-human avatars	Yes	Yes	Yes	Cannot verify with certainty, but evidence indicates no.
Can run 3rd party software in-world	Yes. Can run any 3rd party software inside because it is a virtual OS.	No. Audio and video can be streamed through it, and people have made games to play inside it (for example, Tringo), but there is no inherent ability to play other applications in-world. Even web browsing is done separately from the Second Life window.	Web browser runs in a window on top of the screen for accessing web.	No

Content levels	No info available, but given the educational nature, adult content levels can be reasonably excluded from possibility.	In theory there are PG worlds and Mature worlds, but in reality there are no clear boundaries and mature content can be found on all islands.	G, PG, PG-13, R, X, though there are no worlds above a PG listed on the tourist index and during the conversations I participated in, the cultural norm was to discourage any talk or behavior that can be construed as offensive. Clothes cannot be removed from the avatar.	No discernable content levels. Out of the 2 places and 5 people I found, mature topics and profanity were evident.
Inventory	No clear evidence of inventory capabilities.	Yes, for clothes, objects, scripts, vehicles, houses, note cards, etc.	No	For clothes, makeup, accessories and gear.
In-world currency system	No	Linden Dollars	Shopping is available according to the website but is nonexistent according to participating members.	ThereBucks
Voice chat available	Yes	Yes	Yes, though up to the world owner to enable it. It is very rare for a world to use voice chat in Active Worlds.	Only with a premium membership
Video support	Yes. Supports streaming video and webcams.	Supports streaming video through QuickTime.	Supports streaming video through Windows Media Player, though it is not widely used.	Not able to verify.
Machinima	Yes	Yes	Yes	Not able to verify.
Sound files supported	Yes	Yes	Yes	Yes
Ability to customize	High, based on information from the developers and the website.	High. Tools are available for building objects and scripting actions.	High. Tools available for building objects.	Low. No evidence of ways to "mod" objects.
Bandwidth issues	With a peer-to-peer network, the pipeline will be shared among all computers, thus reducing bandwidth issues.	Huge lag times on islands that are heavily visited and frequent outages. During one test, the lag was so bad it slowed down the whole application to a crawl. No way to check how many people were in-world, but every place visited had at least 15 people in the immediate vicinity, which is crowded for a virtual world.	Very minor lag in some conversations, comparable to what one would find in a text chat room. This is likely due to the fact that there were only 156 people in the entire environment at the time.	No lag, but in 2 hours I only found 5 people and there's no way to check to see how many people are in-world.
Listed system requirements	Runs on all major platforms (Windows, MacOS, Linux). Graphics card: 32 MB	Broadband internet Computer memory: 512 MB or more. PC: Microsoft Windows 2000, XP, or Vista with an	Broadband internet Microsoft Windows 98, NT, Me, 2000, XP or Vista (The Active Worlds browser does not work on Mac or Linux).	56k Internet connection IE 5.01 or later Microsoft Windows Vista, XP, 2000 with 256MB RAM and 500MB free hard disc space and a graphics card

	of memory with hardware/driver support for stencil buffers and at least 16 bit depth buffer (32 bits better) while under OpenGL 1.3 and higher. Must install OpenAL.	800 MHz or better processor. Mac OS: Mac OS X 10.3.9 or better with a 1 GHz G4 or better processor Linux: 32-bit Linux environment with an 800 MHz or better processor. Graphics card: nVidia GeForce 2, GeForce 4 MX, or better or ATI Radeon 8500, 9250, or better		with 32MB of VRAM and supports DirectX 8 (Mac and Linux not supported).
Identity Authentication	Plans are underway for authentication servers that would require student authentication for entry into the world.	No. Users can have multiple accounts. Though the site says that Linden Lab may require you to submit proof of identity in the account registration process, in reality if you register for a free account you do not provide a credit card, and thus there is no way to identify you as a unique individual.	No. Users can change their name and email address every time they log on.	Users can sign up for multiple accounts. It's not tied to a credit card or any other verification system.
Method of movement	Walking is the only method seen in demos, and it is done through keyboard. To drive your avatar around, press and hold the right mouse button within the Croquet window, at some distance from the center of the window. The closer your mouse is towards the top, the faster you move forward. The closer your mouse is towards the bottom, the faster you move backwards. Similarly for turning	Movement is done only through the keyboard. The arrow keys control direction. When flying, page up and page down control altitude. Users can walk, fly, sit, or drive a vehicle. Ctrl-R will make the user walk faster (doesn't affect flying). User can also select "Movement Controls" from the "View" menu to see an 8-part movement interface that allows for slightly finer control and can be used by clicking on arrows.	Users can use either the keyboard or mouse, or both simultaneously, to move. Holding the Ctrl key will make the user move faster. Users can walk, fly or use a vehicle, called a "Mover." When using the keyboard, the up and down arrow moves the avatar forward and back. The left and right arrow keys shift the camera, and the user then pushes the up arrow to continue forward. To move side to side, hold down the shift key while using the left and right arrow keys. To stop instantly (used for precise positioning), push the 5 key on the keypad. Can move through objects by holding the shift key and pushing the number keys.	Users can use the keyboard to move. Users can walk or float or drive a vehicle. When using the keyboard, the up and down arrow moves the avatar forward and back. The left and right arrow keys shift the camera, and the user then pushes the up arrow to continue forward. To move side to side, hold down the shift key while using the left and right arrow keys. To run, hold down the ctrl key while walking.

	left or right. If you also hold down the shift key, you will look up and down rather than moving forwards or backwards, respectively.		When using the mouse, push the mouse forward and backward to move, and left and right to pan.	
Movement between locations	Users can open a portal to a new world anywhere.	Users can teleport between islands by typing in a SLURL or by searching for a site and clicking "teleport" in the dialogue box	Teleport by clicking Teleport and typing the name of the world, or opening the teleport tab and choosing a world.	Multiple methods- can click "Places – Find a Place" to see common places; "Places – Map" or "Explore the World" to get a map from which you can click on a place to teleport there.
Viewpoints/Camera angles	3rd person: the camera is behind the avatar. No information available about how customizable camera angles are.	3rd person: the camera is behind the avatar (default). Mouse Look: the camera looks through the avatar's eyes. Also, can use "Camera Controls" to customize a view of the avatar along the x, y and z axes, however, once the avatar moves, the view reverts back to 3rd person.	1st person: the camera looks through the avatar's eyes. This is the default. Overhead: the camera is behind and above the avatar. Chase camera: the camera is directly behind the avatar. Front camera: the camera is in front of and facing the avatar.	Aerial view: the camera looks down from above; the avatar isn't even visible. There are 5 zoom levels in this view- low, medium, high, super, world. Standard: the camera is behind the avatar. Body mirror: camera several feet in front of and facing avatar- can see whole body. Face mirror: same thing as body mirror but zoomed in to show only the face. 1st person: through the eyes of the avatar.
Gestures	Demo video shows gestures. Screen shots don't show an inventory of movements but movements will likely be scriptable.	There are 30 standard gestures for men and 36 for women. Other gestures can be scripted.	There are a handful of gestures. They change depending on the world and there are never more than 10 at a time. No evidence of whether they can be scripted or not.	Gestures are broken down into "flirt (8)," "banter (9)" "gestures (9)," and "movement (5)." Cannot be scripted, but movements can be combined together to create hybrids.
Text communication with others	Whisper, chat windows	Typing in a chat window to chat and click "say" (or hit enter) to talk to those nearby or click "Shout" to talk to people a distance away.	Typing in a chat window to chat and hit enter for others to see it. Anyone within 200 virtual meters can read what you "say." To say something to only one person, you can use "Whisper" mode which allows only the person you specify to hear what you said. There's also a telegram feature that allows you to send a message to a buddy in another world.	No chat window, just start typing. It appears automatically in a balloon above your head as you type. Chains of balloons with your conversation show over your head and anyone within a several meter radius can read the conversation. This is problematic for anyone who wants to think about what they are typing before they telegraph it. For multi-party conversations there actually is a chat window.

				Conversation members can be distant enough from each other that they are not visible to each other.
Keeping track of people	Contacts List. Can also lead people, follow people, or join groups.	Create friends lists and join groups.	Create a "users" list.	Communicator list; join groups.
Interacting with objects	Click on them.	Click to view notes, websites and videos. Right-click for a context menu to use or edit objects.	Click to use. Right click to modify.	Click to use.
Proximity-based volume	Yes	No	No	Yes
Finding places within a world	Can search on people, places or things	Search dialog allows searches by people, places, or groups.	Opening the teleport tab and choosing a world.	Multiple methods- can click "Places – Find a Place to see common places; Places – Map or "Explore the World" to get a map from which you can click on a place to teleport there.
Member numbers	Not available	10,678,556, with 999,667 logged in during the last 30 days (as of November 1st, 2007 according to http://secondlife.com/whatis/economy_stats.php)	70,000 reported registered citizens (according to http://www.activeworlds.com/info/index.asp). 603 worlds with 156 users in the main active worlds and 61 worlds with 3 users on the educational side (direct observation).	1 million registered users, according to http://www.kzero.co.uk/blog/?p=961 (July 2007).
Overall impressions	Due to the focus on education and the determination to revolutionize computing rather than making a profit at the expense of innovation, they have the potential to do well. However, currently they are hampered by a product that is only semi-functional, difficult to use and primarily supported by developers.	There were many things to do and see. The glitches in Orientation Island made it feel more difficult and overwhelming than it needed to be. There were people everywhere I visited. However, the racy content even in PG sections can be a turnoff. However, it shows great potential for allowing personal creativity. The question remains whether the "wild west," "anything goes" extreme of creativity that is evident now will overwhelm it, or whether the creativity can be harnessed constructively	This world felt very comfortable to use and move around in due to its simple interface, but it was clear from talking to residents that there were many opportunities to build your own worlds and objects without programming help. The differentiation between visitors, citizens and public speakers made it very easy to seek out live help, so I got answers right away. The clear establishment and social enforcement of conservative social norms by established members can either be seen as creating a safe harbor for educational ventures or as stifling depending on context and viewpoint, but it looks like it can be a good educational medium.	There were no apparent tools to build or radically customize objects. The lack of a central point or hub, the numerous categories for places and the multiple ways to access places made me feel quite lost. Also, again perhaps due to lack of a central point, I could not find a single soul to talk to. When I tried to teleport to a conversation, I got an error message. This platform feels more appropriate to teenagers looking to chat and hang out than as a venue for a serious educational venture.

		through current and future educational and commercial partnerships. Unfortunately, having no clear way to distinguish mentors or older residents from novices makes it harder to find information.		

REFERENCE LIST

Ackerman, M. S. (2000). The Intellectual Challenge of CSCW: The Gap Between Social Requirements and Technical Feasibility. *Human-Computer Interaction, 15*(2/3), 179-203.

Active Worlds. Active Worlds client. Retrieved 23. January, 2008, from http://www.activeworlds.com

Adams, J. S. (1965). Inequity in social exchange. L. Berkowitz. *Advances in experimental social psychology, 2*, 267-299.

Adobe. Adobe Atmosphere. Retrieved 23. January, 2008, from http://en.wikipedia.org/wiki/Adobe_Atmosphere

Agarwal, R., & Karahanna, E. (2000). Time Flies When You're Having Fun: Cognitive Absorption and Beliefs about Information Technology Usage. *MIS Quarterly, 24*(4), 665-694.

Anderson, R. J., Hughes, J. A., & Sharrock, W. W. (1985). *The Sociology Game: An Introduction to Sociological Reasoning*: Longman.

Andriessen, J. H. E. (2002). *Working with Groupware: Understanding and Evaluating Collaboration Technology*: Springer.

Ang, C. S., Zaphiris, P., & Mahmood, S. (2007). A model of cognitive loads in massively multiplayer online role playing games. *Interacting with Computers, 19*(2), 167-179.

Anson, R., & Munkvold, B. E. (2004). Beyond Face-to-Face: A Field Study of Electronic Meetings in Different Time and Place Modes. *Journal of Organizational Computing and Electronic Commerce, 14*(2), 127-152.

Argyle, M. (1988). Bodily Communication New York: Methuen & Co: Ltd.

Armstrong, D. J., & Cole, P. (2002). Managing Distances and Differences in Geographically Distributed Work Groups. *Distributed Work*.

Austin, J. (1962). How to do things with words: Oxford University press.

Bailenson, J. N., Beall, A. C., Loomis, J., Blascovich, J., & Turk, M. (2004). Transformed Social Interaction: Decoupling Representation from Behavior and Form in Collaborative Virtual Environments. *Presence: Teleoperators and Virtual Environments, 13*(4), 428-441.

Bajwa, D. S., Lewis, L. F., Pervan, G., Lai, V., Munkvold, B. E., & Schwabe, G. (2007). Organizational Assimilation of Collaborative Information Technologies: Global Comparisons. *Proceedings of the 40th Annual Hawaii International Conference on System Sciences*.

Bales, R. F., Cohen, S. P., & Williamson, S. A. (1979). *Symlog: A System for the Multiple Level Observation of Groups*: Free Press.

Barley, S. R., Dutton, W. H., Kiesler, S., Resnick, P., Kraut, R. E., & Yates, J. A. (2004). Does CSCW need organization theory? *Proceedings of the 2004 ACM conference on Computer supported cooperative work*, 122-124.

Bartle, R. A. (2004). *Designing Virtual Worlds*: New Riders.

Becker, B., & Mark, G. (1998). Social Conventions in Collaborative Virtual Environments. *Proceedings of Collaborative Virtual Environments 1998 (CVE'98)*, 17-19.

Becker, B., & Mark, G. (1999). Constructing social systems through computer-mediated communication. *Virtual Reality, 4*(1), 60-73.

Beise, C., Evaristo, R., & Niederman, F. (2003). Virtual meetings and tasks: from GSS to DGSS to project management. *System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on*, 9.

Berdahl, J. L., & Craig, K. M. (1995). Equality of participation and influence in groups: The effects of communication medium and sex composition. *Computer Supported Cooperative Work (CSCW), 4*(2), 179-201.

Bishop, J. (2007). Increasing participation in online communities: A framework for human-computer interaction. *Computers in Human Behavior, 23*(4), 1881-1893.

Bouras, C., Giannaka, E., Panagopoulos, A., & Tsiatsos, T. (2006). A platform for virtual collaboration spaces and educational communities: the case of EVE. *Multimedia Systems, 11*(3), 290-303.

Bowers, J. (1994). The work to make a network work: studying CSCW in action. *Proceedings of the 1994 ACM conference on Computer supported cooperative work*, 287-298.

Bowers, J., O'Brien, J., & Pycock, J. (1996). Practically accomplishing immersion: cooperation in and for virtual environments. *Proceedings of the 1996 ACM conference on Computer supported cooperative work*, 380-389.

Bowman, D., Gabbard, J. L., & Hix, D. (2002). A Survey of Usability Evaluation in Virtual Environments: Classification and Comparison of Methods. *Presence: Teleoperators and Virtual Environments, 11*(4), 404-424.

Bray, D. A., & Konsynski, B. R. (2007). Virtual worlds: multi-disciplinary research opportunities. *The DATA BASE for Advances in Information Systems, 38*(4), 17-25.

Briggs, R. O., Reinig, B. A., & de Vreede, G. J. (2006). Meeting Satisfaction for Technology-Supported Groups: An Empirical Validation of a Goal-Attainment Model. *Small Group Research, 37*(6), 585.

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry*, 189-194.

Brophy, D. R. (1998). Understanding, Measuring, and Enhancing Individual Creative Problem-Solving Efforts. *Creativity Research Journal, 11*(2), 123-150.

Brown, B., & Bell, M. (2004). CSCW at play:'there'as a collaborative virtual environment. *Proceedings of the 2004 ACM conference on Computer supported cooperative work*, 350-359.

Brown, V., Tumeo, M., Larey, T. S., & Paulus, P. B. (1998). Modeling Cognitive Interactions During Group Brainstorming. *Small Group Research, 29*(4), 495.

Byrne, R. (1995). *The thinking ape: evolutionary origins of intelligence*: Oxford University Press.

Canny, J. (2006). The future of human-computer interaction. *Queue, 4*(6), 24-32.

Carasik, R. P., & Grantham, C. E. (1988). A case study of CSCW in a dispersed organization. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 61-66.

Chen, V. H., & Duh, H. B. L. (2007). Understanding social interaction in world of warcraft. *Proceedings of the international conference on Advances in computer entertainment technology*, 21-24.

Chiu, C. M., Hsu, M. H., & Wang, E. T. G. (2006). Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories. *Decision Support Systems, 42*(3), 1872-1888.

Churchill, E. F., Snowdon, D. N., & Munro, A. J. (2002). Collaborative Virtual Environments: Digital Places and Spaces for Interaction. *Educational Technology & Society, 5*, 4.

Ciborra, C. (2002). *The Labyrinth of Information - Challenging the Wisdom of Systems*: Oxford University Press.

Clark, D. (2008). Virtual World Gets Another Life. Retrieved 17. April, 2008, from http://online.wsj.com/article/SB120719726445485981.html?mod=todays_us_marketplace
Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. *Perspectives on socially shared cognition*, 127-149.
Clement, A. (1990). Cooperative support for computer work: a social perspective on the empowering of end users. *Proceedings of the 1990 ACM conference on Computer-supported cooperative work*, 223-236.
Cohen, A. L., Cash, D., & Muller, M. J. (1999). *Awareness, planning and joint attention in collaborative writing: From fieldwork to design*: Domino Research IBM.
Convertino, G., Farooq, U., Rosson, M. B., & Carroll, J. M. (2005). Old is Gold: Integrating Older Workers in CSCW. *Proceedings of the Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS'05)-Track 1-Volume 01*.
Convertino, G., Moran, T. P., & Smith, B. A. (2007). Studying activity patterns in CSCW. *Conference on Human Factors in Computing Systems: CHI'07 extended abstracts on Human factors in computing systems, 28*, 2339-2344.
Crabtree, A., Rodden, T., & Benford, S. (2005). Moving with the Times: IT Research and the Boundaries of CSCW. *Computer Supported Cooperative Work (CSCW), 14*(3), 217-251.
Cracknell, M. (2000). "A cyberstar is born". *Marketing Week, 23,* 54.
Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*: Harper & Row USA;.
Dabbagh, N. (2007). The Online Learner: Characteristics and Pedagogical Implications. *Contemporary Issues in Technology and Teacher Education, 7*(3), 217-226.
Daft, R. L., & Lengel, R. H. (1984). Information richness: A new approach to managerial behavior and organizational design. *Research in Organizational Behavior, 6*(2), 191-233.
Davidow, W. H., & Malone, M. S. (1992). *The virtual corporation*: Harper Collins.
Davis, J. H. S. (2000). Traditional vs. On-line learning: It's not an either/or proposition. *Employment Relations Today, 27*(1), 47-60.
Dawkins, R. (1988). *The blind watchmaker*: Penguin, Harmondsworth, Middlesex.
De Nood, D., & Attema, J. (2006). *The Second Life of virtual reality*: EPN, The Hague.
De Vreede, G. J., Vogel, D., Kolfschoten, G., & Wien, J. (2003). Fifteen years of GSS in the field: a comparison across time and national boundaries. *System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on*, 9.
DeFranco-Tommarello, J., & Deek, F. P. (2002). Collaborative software development: a discussion of problem solving models and groupware technologies. *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on*, 568-577.
Dekeyser, S., & Watson, R. (2007). *Extending Google Docs to Collaborate on Research Papers*: Technical report, The University of Southern Queensland, Australia.
DeLuca, D. C., Gasson, S., & Kock, N. (2006). Adaptations that virtual teams make so that complex tasks can be performed using simple e-collaboration technologies. *International Journal of e-Collaboration, 2*(3), 64-85.
Dennis, A. R. (2002). Investigating the Moderators of the Group Support Systems Use with Meta-Analysis. *Journal of Management Information Systems, 18*(3), 235-257.
Dennis, A. R., Haley, B. J., & Vandenberg, R. J. (1996). A meta-analysis of effectiveness, efficiency, and participant satisfaction in group support systems research. *Proceedings of the 17th International Conference on Information Systems*, 278-289.

Dennis, A. R., & Valacich, J. S. (1999). Rethinking media richness: towards a theory of media synchronicity. *System Sciences, 1999. HICSS-32. Proceedings of the 32nd Annual Hawaii International Conference on*.

DeRosa, D. M., Hantula, D. A., Kock, N., & D'Arcy, J. (2004). Trust and leadership in virtual teamwork: A media naturalness perspective. *Human Resource Management, 43*(2-3), 219-232.

DeRosa, D. M., Smith, C. L., & Hantula, D. A. (2007). The medium matters: Mining the long-promised merit of group interaction in creative idea generation tasks in a meta-analysis of the electronic group brainstorming literature. *Computers in Human Behavior, 23*(3), 1549-1581.

Dickey, M. D. (2005). Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education. *British Journal of Educational Technology, 36*(3), 439-451.

Dieterle, E., & Clarke, J. (2006). Multi-user virtual environments for teaching and learning. *Encyclopedia of multimedia technology and networking (2nd ed). Hershey, PA: Idea Group, Inc. Retrieved November, 10*.

Dillon, A. (2000). Group dynamics meet cognition: Combining socio-technical concepts and usability engineering in the design of information systems. *E. Coakes & D. Willis, R. Lloyd-Jones (Eds.), The New Sociotech: Graffiti on the Long Wall*, 119-126.

Dougiamas, M. Moodle. Retrieved 23. January 2008, 2008, from http://moodle.com/

Elmarzouqi, N., Garcia, E., Lapayre, J. C., & de Franche, L. L. I. (2007). ACCM: a New Architecture Model for CSCW. *Computer Supported Cooperative Work in Design, 2007. CSCWD 2007. 11th International Conference on*, 84-91.

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(1), 32-64.

Engeström, Y. (1987). *Learning by expanding: an activity-theoretical approach to developmental research*: Orienta-Konsultit Oy.

Erickson, T., & McDonald, D. W. (2008). *HCI remixed*: MIT Press.

Fabri, M., Gerhard, M., Moore, D. J., & Hobbs, D. J. (1999). *Perceiving the Others: Cognitive Processes in Collaborative Virtual Environments.* Paper presented at the Proceedings of 17th Eurographics-UK Conference, Cambridge, UK.

Faulkner, L. (2003). Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. *Behavior Research Methods, Instruments, & Computers, 35*(3), 379-383.

Feenberg, A., & Bakardjieva, M. (2004). Virtual Community: no killer implication. *New Media & Society, 6*(1), 37-43.

Fetscherin, M., & Lattemann, C. (2007). *User acceptance of virtual worlds - an explorative study about Second Life*: Rollins College, University of Potsdam.

Fjermestad, J. (2004). An analysis of communication mode in group support systems research. *Decision Support Systems, 37*(2), 239-263.

Fjermestad, J., & Hiltz, S. R. (1998). An assessment of group support systems experimental research: methodology and results. *Journal of Management Information Systems, 15*(3), 7-149.

Forterra Systems. Forterra virtual world. Retrieved 23. January, 2008, from http://www.forterrainc.com/

Fraser, M., Glover, T., Vaghi, I., Benford, S., Greenhalgh, C., Hindmarsh, J., et al. (2000). Revealing the realities of collaborative virtual reality. *Proceedings of the third international conference on Collaborative virtual environments*, 29-37.

Frécon, E., & Nöu, A. A. (1998). Building distributed virtual environments to support collaborative work. *Proceedings of the ACM symposium on Virtual reality software and technology*, 105-113.

Friedman, D., Steed, A., & Slater, M. (2007). Spatial Social Behavior in Second Life. In *Lecture notes in Computer Science* (pp. 252-263). Berlin Heidelberg: Springer.

Gardiner, H. (1993). Creating Minds: Basic Books, New York.

Gasson, S. (2005). The Dynamics of Sensemaking, Knowledge, and Expertise in Collaborative, Boundary-Spanning Design. *Journal of Computer-Mediated Communication, 10*(4).

Gates, B. (1999). "Gates sees personal data, telepresence as future software issues". Retrieved January 19th, 2008, from http://web.mit.edu/newsoffice/1999/gates2-0414.html

Geer, R., & Barnes, A. (2007). Beyond media stickiness and cognitive imprinting: Rethinking creativity in cooperative work & learning with ICTs. *Education and Information Technologies, 12*(3), 123-136.

Gifford, B. R., & Enyedy, N. D. (1999). Activity centered design: towards a theoretical framework for CSCL. *Proceedings of the 1999 conference on Computer support for collaborative learning*.

Gilbert, J. (1999). "LivePerson focuses on the human touch". *Advertising Age, 70,* 62.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: strategies for qualitative research*. London: Weidenfeld and Nicolson.

Goffman, E. (1971). Relations in public: Microstudies of the social order: New York: Basic Books.

Goldin-Meadow, S. (2003). *Hearing Gesture: How Our Hands Help Us Think*: Belknap Press.

Google. Google Docs. Retrieved 28. March, 2008, from http://docs.google.com

Grenier, R., & Metes, G. (1995). Going Virtual: Moving Your Organization in the 21st Century: Prentice Hall, Upper Saddle River, NJ.

Grèzes, J., & Decety, J. (2002). Does visual perception of object afford action? Evidence from a neuroimaging study. *Neuropsychologia, 40*(2), 212-222.

Grudin, J. (1988). *Why CSCW applications fail: problems in the design and evaluation of organization of organizational interfaces*. Paper presented at the Proceedings of the 1988 ACM conference on Computer-supported cooperative work, Portland, Oregon, United States.

Grudin, J. (1994). Computer-supported cooperative work: history and focus. *Computer, 27*(5), 19-26.

Gu, E., & Badler, N. I. (2006). Visual Attention and Eye Gaze During Multiparty Conversations with Distractions. *Proc. Int. Conf. Intelligent Virtual Agents, 6*, 193–204.

Gutwin, C., & Greenberg, S. (2002). A Descriptive Framework of Workspace Awareness for Real-Time Groupware. *Computer Supported Cooperative Work (CSCW), 11*(3), 411-446.

Guzdial, M., Kolodner, J., Hmelo, C., Narayanan, H., Carlson, D., Rappin, N., et al. (1996). Computer support for learning through complex problem solving. *Communications of the ACM, 39*(4), 43-45.

Hall, H. (2001). *Social exchange for knowledge exchange*. Paper presented at the Managing knowledge: conversations and critiques.

Halverson, C. A. (2002). Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories? *Computer Supported Cooperative Work (CSCW), 11*(1), 243-267.

Harrison, S., & Dourish, P. (1996). Re-place-ing space: the roles of place and space in collaborative systems. *Proceedings of the 1996 ACM conference on Computer supported cooperative work*, 67-76.

Hayes, E. R. (2006). Situated Learning in Virtual Worlds: The Learning Ecology of Second Life. *AERC Conference Proceedings.*

Heath, H., & Cowley, S. (2004). Developing a grounded theory approach: a comparison of Glaser and Strauss. *International Journal of Nursing Studies, 41*(2), 141-150.

Heldal, I., Steed, A., & Schroeder, R. (2005). Evaluating Collaboration in Distributed Virtual Environments for a Puzzle-solving Task. *Proceeding of the 11th International Conference on Human Computer Interaction (HCII'11), Las Vegas.*

Hewett, T. T. (2005). Informing the design of computer-based environments to support creativity. *International Journal of Human-Computer Studies, 63*(4-5), 383-409.

Hewett, T. T., & Adelson, B. (1998). Psychological science and analogical reminding in the design of artificats. *Behavior research methods, instruments & computers, 30*(2), 314-319.

Hiltz, S. R., & Johnson, K. (1990). User Satisfaction with Computer-Mediated Communication Systems. *Management Science, 36*(6), 739-764.

Hindmarsh, J., Heath, C., & Fraser, M. (2006). (Im) materiality, virtual reality and interaction: grounding the virtual in studies of technology in action. *The Sociological Review, 54*(4), 795-817.

Hinds, P. J., & Bailey, D. E. (2003). Out of Sight, Out of Sync: Understanding Conflict in Distributed Teams. *Organization Science, 14*(6), 615-632.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI), 7*(2), 174-196.

Hollingshead, A. B., McGrath, J. E., & O'Connor, K. M. (1993). Group Task Performance and Communication Technology: A Longitudinal Study of Computer-Mediated Versus Face-to-Face Work Groups. *Small Group Research, 24*(3), 307.

Holsapple, C. W., & Wu, J. (2007). User acceptance of virtual worlds: the Hedonic framework. *The DATA BASE for Advances in Information Systems, 38*(4), 86-89.

HP. HP Halo. Retrieved 23. Jan., 2008, from www.hp.com/halo/index.html

Huang, W., Olson, J. S., & Olson, G. M. (2002). Camera angle affects dominance in video-mediated communication. *Conference on Human Factors in Computing Systems*, 716-717.

Hughes, J. A., O'Brien, J., Randall, D., Rouncefield, M., & Tolmie, P. (2001). Some'real' problems of'virtual' organisation. *New Technology Work and Employment, 16*(1), 49-64.

Huizinga, J. (1949). Homo Ludens. *London, Routledge and Kegan Paul.*

Hut, P. (2008). *Virtual Laboratories and Virtual Worlds.* Paper presented at the Dynamical Evolution of Dense Stellar Systems, Proceedings IAU Symposium No. 246, Institute for Advanced Study, Princeton, NJ 08540, USA.

Huysman, M., Steinfield, C., Jang, C. Y., David, K., in't Veld, M. H., Poot, J., et al. (2003). Virtual Teams and the Appropriation of Communication Technology: Exploring the Concept of Media Stickiness. *Computer Supported Cooperative Work (CSCW), 12*(4), 411-436.

Isbister, K., Nakanishi, H., Ishida, T., & Nass, C. (2000). Helper agent: designing an assistant for human-human interaction in a virtual meeting space. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 57-64.

Jakala, M., & Pekkola, S. (2007). From technology engineering to social engineering: 15 years of research on virtual worlds. *ACM SIGMIS Database, 38*(4), 11-16.

Jeffery, C., Dabholkar, A., Tachtevrenidis, K., & Kim, Y. (2005). A Framework for Prototyping Collaborative Virtual Environments. *Groupware: Design, Implementation, and Use: 11th International Workshop, CRIWG 2005, Porto de Galinhas, Brazil, September 25-29, 2005: Proceedings.*

Jenny, P. (1994). *Human-computer interaction*: Addison-Wesley.

Johansen, R. (1988). *GroupWare: Computer Support for Business Teams*: The Free Press New York, NY, USA.

Junglas, I. A., Johnson, N. A., Steel, D. J., Abraham, D. C., & Mac Loughlin, P. (2007). Identity formation, learning styles and trust in virtual worlds. *The DATA BASE for Advances in Information Systems, 38*(4), 90-96.

Kadavasal, M. S., Dhara, K. K., Wu, X., & Krishnaswamy, V. (2007). Mixed reality for enhancing business communications using virtual worlds. *Proceedings of the 2007 ACM symposium on Virtual reality software and technology*, 233-234.

Kaneva. Kaneva client. Retrieved 23. January, 2008, from http://www.kaneva.com

Kaptelinin, V. (1996). Activity Theory: Implications for Human-Computer Interaction. *Context and consciousness: Activity theory and human-computer interaction*, 102-116.

Kemp, J., & Livingstone, D. (2006). Putting a Second LIfe "Metaverse" skin on learning management systems. *Proceedings of the Second Life Education Workshop at SLCC, San Francisco*, 13-18.

Kock, N. (1998). Can communication medium limitations foster better group outcomes? An action research study. *Information & Management, 34*(5), 295-305.

Kock, N. (2002). Evolution and media naturalness: A look at e-communication through a Darwinian theoretical lens. *Proceedings of the 23rd International Conference on Information Systems*, 373–382.

Kock, N. (2004). The Psychobiological Model: Towards a New Theory of Computer-Mediated Communication Based on Darwinian Evolution. *Organization Science, 15*(3), 327-348.

Kock, N. (2005). Media richness or media naturalness? The evolution of our biological communication apparatus and its influence on our behavior toward E-communication tools. *Professional Communication, IEEE Transactions on, 48*(2), 117-130.

Kock, N. (2007). Media naturalness and compensatory encoding: The burden of electronic media obstacles is on senders. *Decision Support Systems, 44*(1), 175-187.

Kock, N. (2008). E-collaboration and e-commerce in virtual worlds: The potential of Second Life and World of Warcraft. *International Journal of e-Collaboration.*

Kock, N., Verville, J., & Garza, V. (2007). Media Naturalness and Online Learning: Findings Supporting Both the Significant-and No-Significant-Difference Perspectives. *Decision Sciences Journal of Innovative Education, 5*(2), 333-355.

Korpela, M., & Mursu, A. (2003). Means for cooperative work and activity networks: An analytical framework. *Unpublished, available as ECSCW 2003 workshop material in URL: http://www.uku.fi/atkk/actad/ecscw2003-at/.*

Kozlov, S., & Reinhold, N. (2007). *To play or not to play: Can companies learn to be n00bs, LFG, and lvl-up?* : Philips Design.

Kuijpers, N., & Jacobs, H. (1997). Teleconferencing and Collaboration in Virtual Environments. *HPCN Europe, 97.*

Kuutti, K. (1996). Activity Theory as a Potential Framework for Human-Computer Interaction Research. *Context and Consciousness: Activity Theory and Human-Computer Interaction*, 17-44.

Laitman, J. T. (1984). The anatomy of human speech. *Natural History, 20*(7), 20-27.
Lee, F. S. L., Vogel, D., & Limayem, M. (2002). Virtual community informatics: what we know and what we need to know. *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on*, 2863-2872.
Leont'ev, A. N. (1978). *Activity, consciousness, and personality*: Prentice-Hall Englewood Cliffs, NJ.
Leung, W. H., & Chen, T. (2003). A Multi-User 3-D Virtual Environment with Interactive Collaboration and Shared Whiteboard Technologies. *Multimedia Tools and Applications, 20*(1), 7-23.
Lew, M., Sebe, N., & Huang, T. S. (2007). The age of human computer interaction. *Image and Vision Computing, 25*(12), 1833-1835.
Lewin, K. (1951). Field theory in social science: Selected theoretical papers (D. Cartwright, Ed.). *New York: Harpers.*
Lewis, L. F., Bajwa, D. S., Pervan, G., King, V. L. S., & Munkvold, B. E. (2007). A Cross-Regional Exploration of Barriers to the Adoption and Use of Electronic Meeting Systems. *Group Decision and Negotiation, 16*(4), 381-398.
Lieberman, P. (1998). *Eve spoke*: W. W. Norton New York.
Linden Labs (a). Second Life user statistics. Retrieved 16. April, 2008, from http://secondlife.com/whatis/economy_stats.php
Linden Labs (b). Second Life user statistics. Retrieved 16. April, 2008, from http://blog.secondlife.com/category/economy/
Linden Labs (c). Second Life system requirements. Retrieved 17. April, 2008, from http://secondlife.com/corporate/sysreqs.php
Linden Labs (d). Second Life, UUID. Retrieved 17. April, 2008, from http://wiki.secondlife.com/wiki/Category:LSL_Key
Linden Labs (e). Second Life physics engine. Retrieved 17. April, 2008, from http://wiki.secondlife.com/wiki/Physics_engine
Löber, A., Schwabe, G., & Grimm, S. (2007). Audio vs. Chat: The Effects of Group Size on Media Choice. *Proceedings of the 40th Annual Hawaii International Conference on System Sciences*.
Loftin, R. B. (1997). Hands Across the Atlantic. *IEEE Computer Graphics & Applications, 17*(2), 78-79.
Lutters, W. G. (2002). Storytelling in collaborative work: the challenge of preserving sensitive interactions. *ACM SIGGROUP Bulletin, 23*(2), 22-23.
Macedonia, M. (2007). Generation 3D: Living in Virtual Worlds. *Computer, 40*(10), 99-101.
Maher, M., Simonoff, S. J., & Clark, S. (2001). Learner-Centered Open Virtual Environments as Places. *Proceedings of CSCL 2001*.
Maher, M. L., Simoff, S., Gu, N., & Lau, K. H. (2000). Designing virtual architecture. *Proceedings of CAADRIA 2000*, 481-490.
Majchrzak, A., Rice, R. E., King, N., Malhotra, A., & Ba, S. (2000). Computer-Mediated Inter-Organizational Knowledge-Sharing: Insights from a Virtual Team Innovating Using a Collaborative Tool. *Information Resources Management Journal, 13*(1), 44-53.
Makena Technologies. There client. Retrieved 23. January, 2008, from http://www.there.com
Mao, Y., Vassileva, J., & Grassmann, W. (2007). A System Dynamics Approach to Study Virtual Communities. *Proceedings of the 40th Annual Hawaii International Conference on System Sciences*.
Martin, H. J. (1995). *The History and Power of Writing*: University Of Chicago Press.

Matarazzo, G., & Sellen, A. (2000). The value of video in work at a distance: addition or distraction? *Behaviour & Information Technology, 19*(5), 339-348.

McGhee, G., Marland, G. R., & Atkinson, J. (2007). Grounded theory research: literature reviewing and reflexivity. *Journal of Advanced Nursing, 60*(3), 334-342.

McGrath, J. E. (1991). Time, Interaction, and Performance (TIP): A Theory of Groups. *Small Group Research, 22*(2), 147.

Medynskiy, Y. E., & Bruckman, A. (2007). *The Effects of Conversations with Regulars and Administrators on the Participation of New Users in a Virtual Learning Community.* Paper presented at the Proc. Computer Supported Collaborative Learning, New Brunswick, NJ.

Mehrabian, A. (1972). *Nonverbal Communication*: Aldine De Gruyter.

Merola, N., Penas, J., & Hancock, J. (2006). Avatar color and social identity effects: On attitudes and group dynamics in virtual realities: ICA.

Microsoft (a). Microsoft Task Gallery. Retrieved 23. January, 2008, from http://research.microsoft.com/adapt/taskgallery/

Microsoft (b). Microsoft Surface. Retrieved 23. 1., 2008, from www.microsoft.com/surface

Moore, D., Cheng, Y., McGrath, P., & Powell, N. J. (2005). Collaborative Virtual Environment Technology for People With Autism. *Focus on Autism and Other Developmental Disabilities, 20*(4), 231-243.

Moore, R. J., Ducheneaut, N., & Nickell, E. (2007). Doing Virtually Nothing: Awareness and Accountability in Massively Multiplayer Online Worlds. *Computer Supported Cooperative Work (CSCW), 16*(3), 265-305.

Moore, R. J., Gathman, E. C. H., Ducheneaut, N., & Nickell, E. (2007). Coordinating joint activity in avatar-mediated interaction. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 21-30.

Moran, T. P. (2006). Activity: Analysis, Design, and Management. *Theories and Practice in Interaction Design*.

Moran, T. P., Palen, L., Harrison, S., Chiu, P., Kimber, D., Minneman, S., et al. (1997). "I'll get that off the audio": a case study of salvaging multimedia meeting records. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 202-209.

Murphy, K. L., Drabier, R., & Epps, M. L. (1998). A constructivist look at interaction and collaboration via computer conferencing. *International Journal of Educational Telecommunications, 4*(2/3), 237-261.

Myers, B. A. (1998). A brief history of human-computer interaction technology. *Interactions, 5*(2), 44-54.

Nabeth, T., Roda, C., Angehrn, A. A., & Mittal, P. K. (2005). Using artificial agents to stimulate participation in virtual communities. *IADIS International Conference CELDA (Cognition and Exploratory Learning in Digital Age).*

Nardi, B., & Harris, J. (2006). Strangers and friends: collaborative play in world of warcraft. *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work*, 149-158.

NASA. Lost on moon exercise. Retrieved 2. April, 2008, from http://www.bpccs.com/lcas/Articles/survive.htm

Ned Kock, Gary S. Lynn, Kevin E. Dow, & Ali E. Akguen. (2006). Team adaptation to electronic communication media: evidence of compensatory adaptation in new product development teams. *European Journal of Information Systems, 15*, 331-341.

Neisser, U. (1976). *Cognition and reality*: WH Freeman.

Ngwenyama, O. K., & Lee, A. S. (1997). Communication Richness in Electronic Mail: Critical Social Theory and the Contextuality of Meaning. *MIS Quarterly, 21*(2), 145-167.

Nicolopoulou, K., Koštomaj, M., & Campos, A. (2006). How to address group dynamics in virtual worlds. *AI & Society, 20*(3), 351-371.

Nielsen, J. Ten Usability Heuristics. Retrieved 8. May, 2008, from http://www.useit.com/papers/heuristic/heuristic_list.html

Nielsen, J. (1993). *Usability Engineering*: Morgan Kaufmann.

Nijholt, A. (2008). Google home: Experience, support and re-experience of social home activities. *Information Sciences, 178*(3), 612-630.

Nijholt, A., op den Akker, R., & Heylen, D. (2004). Meetings and meeting modeling in smart surroundings. *Social Intelligence Design*, 145-158.

Nijholt, A., Rienks, R., Zwiers, J., & Reidsma, D. (2006). Online and off-line visualization of meeting information and meeting support. *The Visual Computer, 22*(12), 965-976.

Nijholt, A., Zwiers, J., & Peciva, J. (2005). The Distributed Virtual Meeting Room Exercise. *Proceedings ICMI*, 93-99.

Noël, S., & Robert, J. M. (2004). Empirical Study on Collaborative Writing: What Do Co-authors Do, Use, and Like? *Computer Supported Cooperative Work (CSCW), 13*(1), 63-89.

Nonneeke, B., & Preeee, J. (2000). *Lurker demographics: Counting the silent.* Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems, Hague, Netherlands.

Norman, D. A. (1998). The Design of Everyday Things: Cambridge, MA: MIT Press.

Nuseibeh, B., & Easterbrook, S. (2000). Requirements engineering: a roadmap. *Proceedings of the Conference on The Future of Software Engineering*, 35-46.

Ocker, R. J. (2005). Influences on creativity in asynchronous virtual teams: a qualitative analysis of experimental teams. *Professional Communication, IEEE Transactions on, 48*(1), 22-39.

Olivier, H., & Pinkwart, N. (2007). *Computer supported cooperative work in the second life?* : Clausthal University of Technology.

Olson, G. M., & Olson, J. S. (2003). Human-Computer Interaction: Psychological Aspects of the Human Use of Computing. *Annual Review of Psychology, 54*(1), 491-516.

Olson, J. S., Olson, G. M., Storrøsten, M., & Carter, M. (1993). Groupwork close up: a comparison of the group design process with and without a simple group editor. *ACM Transactions on Information Systems (TOIS), 11*(4), 321-348.

OnRez. OnRez client. Retrieved 3. March, 2008, from http://viewer.onrez.com/

Orlikowski, W. J. (1992). The duality of technology. *Organization Science, 3*(3), 157–186.

Orlikowski, W. J. (1996). Learning from Notes: Organizational Issues in Groupware Implementation'. *Computerization and Controversy: Value Conflicts and Social Choices.*

Osborn, A. F. (1957). Applied Imagination, rev. ed. *New York: Scribner.*

Palen, L., & Grudin, J. (2002). Discretionary adoption of group support software: Lessons from calendar applications. *Organizational implementation of collaboration technology. Springer.*

Park, K. S., Kapoor, A., & Leigh, J. (2000). Lessons learned from employing multiple perspectives in a collaborative virtual environment for visualizing scientific data. *Proceedings of the third international conference on Collaborative virtual environments*, 73-82.

Park, K. S., & Kenyon, R. V. (1999). Effects of network characteristics on human performance in acollaborative virtual environment. *Virtual Reality, 1999. Proceedings., IEEE*, 104-111.
Pekkola, S. (2002). Critical approach to 3D virtual realities for group work. *Proceedings of the second Nordic conference on Human-computer interaction*, 129-138.
Pekkola, S., Robinson, M., Saarinen, M. J. O., Korhonen, J., Hujala, S., & Toivonen, T. (2000). Collaborative virtual environments in the year of the dragon. *Proceedings of the third international conference on Collaborative virtual environments*, 11-18.
Pena, J., Walther, J. B., & Hancock, J. T. (2007). Effects of Geographic Distribution on Dominance Perceptions in Computer-Mediated Groups. *Communication Research, 34*(3), 313.
Penichet, V. M. R., Marin, I., Gallud, J. A., Lozano, M. D., & Tesoriero, R. (2007). A Classification Method for CSCW Systems. *Electronic Notes in Theoretical Computer Science, 168*, 237-247.
Pfister, H. R., Schuckmann, C., Beck-Wilson, J., & Wessner, M. (1997). The Metaphor of Virtual Rooms in the Cooperative Learning Environment CLear. *Cooperative Buildings-Proceedings of CoBuild, 98*, 107-113.
Pinker, S. (1994). The Language Instinct. New York: William Morrow and Company: Inc.
Pinker, S. (1997). *How the Mind Works*: Norton.
Pissarra, J., & Jesuino, J. C. (2005). Idea Generation through Computer-Mediated Communication. *Journal of Managerial Psychology, 20*(3/4), 275-291.
Poppe, R., & Rienks, R. (2007). Evaluating the Future of HCI: Challenges for the Evaluation of Emerging Applications. *AI for Human Computing (AI4HC'07).*
Powell, A., Piccoli, G., & Ives, B. (2004). Virtual teams: a review of current literature and directions for future research. *ACM SIGMIS Database, 35*(1), 6-36.
Prasolova-Førland, E., & Divitini, M. (2003). Collaborative virtual environments for supporting learning communities: an experience of use. *Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work*, 58-67.
Qureshi, S., Min, L., & Vogel, D. (2005). *A Grounded Theory Analysis of E-Collaboration Effects for Distributed Project Management.*
Qwaq. Qwaq Forums. Retrieved 3. Mai, 2008, from http://www.qwaq.com/
Rasters, G., Vissers, G., & Dankbaar, B. (2002). An Inside Look: Rich Communication Through Lean Media in a Virtual Research Team. *Small Group Research, 33*(6), 718.
Redfern, S., & Naughton, N. (2002). Collaborative Virtual Environments to Support Communication and Community in Internet-Based Distance Education. *Journal of Information Technology Education, 1*(3), 201-211.
Reichwald, R. (2000). *Telekooperation: Verteilte Arbeits-und Organisationsformen*: Springer.
Reidsma, D., op den Akker, R., Rienks, R., Poppe, R., Nijholt, A., Heylen, D., et al. (2007). Virtual meeting rooms: from observation to simulation. *AI & Society, 22*(2), 133-144.
Reinig, B. A. (2003). Toward an Understanding of Satisfaction with the Process and Outcomes of Teamwork. *Journal of Management Information Systems, 19*(4), 65-83.
Reinig, B. A., Briggs, R. O., Shepherd, M. M., Yen, J., & Nunamaker Jr, J. F. (1995). Affective reward and the adoption of group support systems: productivity is not always enough. *Journal of Management Information Systems, 12*(3), 171-185.
Rengger, R. E. (1991). Human Aspects in Computing: Design and Use of Interactive Systems with Terminals, chapter Indicators of Usability based on performance: Elsevier, Amsterdam, The Netherlands.

Rienks, R., Poppe, R., Nijholt, A., Heylen, D., & Jovanovic, N. (2005). Multi-party Interaction in a Virtual Meeting Room. *Proceedings measuring behavior. Fifth international conference on methods and techniques in behavioral research, Wageningen (to appear).*

Robbins, E. (1994). *Why Architects Draw*: MIT Press.

Robles-De-La-Torre, G. (2006). The Importance of the Sense of Touch in Virtual and Real Environments. *IEEE MultiMedia, 13*(3), 24-30.

Rogers, Y. (2004). New Theoretical approaches for Human-Computer Interaction. *Annual Review of Information, Science and Technology, 38*, 87-143.

Ruhleder, K., & Jordan, B. (1999). Meaning-Making Across Remote Sites How Delays in Transmission Affect Interaction. *Ecscw'99: Proceedings of the Sixth European Conference on Computer Supported Cooperative Work, 12-16 September 1999, Copenhagen, Denmark*.

Saba. Centra software. Retrieved 23. January, 2008, from http://www.saba.com/products/centra/

Schmidt, K. (2002). The Problem with 'Awareness'. *Computer Supported Cooperative Work, 11*(3), 285–298.

Schroeder, R., Heldal, I., & Tromp, J. (2006). The usability of collaborative virtual environments and methods for the analysis of interaction. *Presence: Teleoperators and Virtual Environments, 15*(6), 655-667.

Schwabe, G., Haake, J., & Wessner, M. (2004). Medienwahl. *CSCL-Kompendium, Oldenbourg, München et al.*

Segal, L. (1995). Designing Team Workstations: The Choreography of Teamwork. *Local Applications of the Ecological Approach to Human-Machine Systems, 2*.

Shao-Qing, W., Ling, C., & Gen-Cai, C. (2004). A framework for Java 3D based collaborative virtual environment. *Computer Supported Cooperative Work in Design, 2004. Proceedings. The 8th International Conference on, 1*.

Shneiderman, B. (1992). *Designing the user interface: strategies for effective human-computer interaction*: Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA.

Shneiderman, B. (2002). HCI theory is like the public library. Posting to CHIplace online discussion forum, 15. October, 2002. Retrieved 12. January, 2003

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: Wiley.

Simon, A. F. (2006). Computer-Mediated Communication: Task Performance and Satisfaction. *The Journal of Social Psychology, 146*(3), 349-379.

Singhal, S., & Zyda, M. (1999). *Networked virtual environments*: Addison-Wesley Reading, Mass.

Skrbl. Skrbl online whiteboard. Retrieved 8. April, 2008, from http://skrbl.com/

Smith, D. A., Kay, A., Raab, A., & Reed, D. P. Croquet–A Collaboration System Architecture. *Proceedings of the First Conference on Creating, Connecting, and Collaborating through Computing (C5'03)*, 2–9.

Snowdon, D., & Tromp, J. (1997). Virtual body language: Providing appropriate user interfaces in collaborative virtual environments. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST'97)*, 37–44.

Sony. Sony Home. Retrieved 23. January, 2008, from http://www.news.com/2100-1043_3-6165180.html

Stacey, E. (1999). Collaborative Learning in an Online Environment. *Journal of Distance Education, 14*(2).

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. *Cambridge handbook of the learning sciences. Cambridge, UK: Cambridge University Press.*

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., & Jenkins, D. P. (2005). *Human Factors Methods*: Ashgate.

Steed, A., & Tromp, J. (1998). Experiences with the evaluation of CVE applications. *Proceedings of Collaborative Virtual Environments.*

Steinfield, C. (2002). Realizing the benefits of virtual teams. *Computer, 35*(3), 104-106.

Suchman, L. A. (1987). *Plans and situated actions*: Cambridge University Press Cambridge.

Suddaby, R. O. Y. (2006). From the editors: What grounded theory is not. *The Academy of Management Journal, 49*(4), 633-642.

Suh, A., & Shin, K. (2007). A Framework for Workgroup Collaboration in a Vir tual Environment: Theoretical Synthesis and Empir ical Exploration. *Proceedings of the 40th Annual Hawaii International Conference on System Sciences.*

Sun. MPK20: Sun's Virtual Workplace. Retrieved 23. January, 2008, from http://research.sun.com/projects/mc/mpk20.html

Sutherland, I. E. (1965). The Ultimate Display. *Proceedings of the IFIP Congress, 2*(506-508).

Taylor, T., & Duclos, K. (2007). Competitive analysis report. from http://it.coe.uga.edu/itforum/SecondLifeRpt/CompetitiveAnalysisReport.pdf

Training-Manager. Priority list exercises. Retrieved 3. March, 2008, from http://www.training-manager.co.uk/livenup.html

Tromp, J. G., Steed, A., & Wilson, J. R. (2003). Systematic usability evaluation and design issues for collaborative virtual environments. *Presence: Teleoperators and Virtual Environments, 12*(3), 241-267.

Tscholl, M., McCarthy, J., & Scholl, J. (2005). The effect of video-augmented chat on collaborative learning with cases. *Proceedings of th2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years!*, 682-686.

Turkle, S. (1995). *Life on the screen*: Simon & Schuster New York.

van Welie, M., van der Veer, G. C., & Eliëns, A. (1999). Breaking down Usability. *Proceedings of INTERACT, 99*, 613–620.

Vasalou, A., Joinson, A. N., & Pitt, J. (2007). Constructing my online self: avatars that increase self-focused attention. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 445-448.

Verhulsdonck, G. (2007). Issues of designing gestures into online interactions: implications for communicating in virtual environments. *Proceedings of the 25th annual ACM international conference on Design of communication*, 26-33.

Vinayagamoorthy, V., Steed, A., & Slater, M. (2005). Building Characters: Lessons Drawn from Virtual Environments. *Proceedings of Toward Social Mechanisms of Android Science: A CogSci 2005 Workshop*, 119–126.

Vinsonhaler, J. F., Johnson, J. J., Braunstein, L., Henderson, D., Boman, R., & Gilliland, R. (1998). A Comparison of Collaborative Problem Solving Using Face to Face versus Desktop Video Conferencing. *Proceedings of the Thirty-First Annual Hawaii International Conference on System Sciences-Volume 1-Volume 1.*

Wagner, M. (2007). Inside Second Life's Data Centers. Retrieved 17. April, 2008, from http://www.informationweek.com/news/showArticle.jhtml?articleID=19780017 9

Wainfan, L., & Davis, P. K. (2004). *Challenges in Virtual Collaboration: Videoconferencing, Audioconferencing, and Computer-mediated Communications*: RAND Corporation.

Walker, D., & Myrick, F. (2006). Grounded Theory: An Exploration of Process and Procedure. *Qualitative Health Research, 16*(4), 547.

Walther, J. B. (1994). Anticipated ongoing interaction versus channel effects on relational communication in computer-mediated interaction. *Human Communication Research, 20*(4), 473-501.

Walther, J. B. (1997). Group and interpersonal effects in international computer-mediated collaboration. *Human Communication Research, 23*(3), 342-369.

Walther, J. B., & Bazarova, N. N. (2007). Misattribution in Virtual Groups: The Effects of Member Distribution on Self-Serving Bias and Partner Blame. *Human Communication Research, 33*(1), 1-2626.

Walther, J. B., & Bunz, U. (2005). The Rules of Virtual Groups: Trust, Liking, and Performance in Computer-Mediated Communication. *Journal of Communication, 55*(4), 828-846.

Wang, C. C., & Lai, C. Y. (2006). Knowledge Contribution in the Online Virtual Community: Capability and Motivation. *Proceedings of the 1st International Conference on Knowledge Science, Engineering and Management.*

Watson, V. R. (2001). Supporting scientific analysis within collaborative problem solving environments. *System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on*, 9.

Woolrych, A., & Cockton, G. (2001). Why and when five test users aren't enough. *Proceedings of IHM-HCI 2001 Conference, 2*, 105–108.

Yee, N., & Bailenson, J. (2007). The Proteus effect: The Effect of transformed self-representation on behavior. *Human communication research, 33*(3), 271-290.

Yee, N., Bailenson, J. N., Urbanek, M., Chang, F., & Merget, D. (2007). *The unbearable likeness of being digital: the persistence of nonverbal social norms in online virtual enviornments*: Stanford University, Portland State University.

Zhou, Z. Y. (2004). The Role of 3D Sound in Human Reaction and Performance in Augmented Reality Gaming Environments. *Interacting with Computers, 16*(6), 1043-1068.