Designing Collaboration Experiences for 3D Virtual Worlds

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Abstract

Working together benefits from colleagues, team members, or peers being at the same place. With collaborating teams being more and more dispersed in an increasingly networked world, people and organizations turn to the Internet as a medium to work and learn together. Collaborative virtual environments (CVE) in general attempt to provide settings in which the users or participants feel co-present, the sensation of ‘being there together’. Different types of CVE make for different intensities of co-presence. One type of CVE facilitating particularly immersive real-time activities is that of virtual worlds.

Virtual worlds are three-dimensional CVE accessed with standard computers. People meet online in shared spaces, all represented through animated virtual characters, so-called avatars. Being in control of a highly customizable virtual embodiment, in a 3D environment configurable with virtually no limits, and the possibility of creating responsive environments and interactive tools, are some of the key distinct features of the medium. However, while virtual worlds have been around for years, it is still unclear what value virtual worlds can add to the existing modes of communication and collaboration, and which virtual world features should be made use of – and how – in order to maximize the benefit of using the medium for collaborative activities. This doctoral thesis addresses these issues by investigating the design of collaboration experiences for virtual worlds.

The main goal of this dissertation is to improve collaboration practices in 3D virtual worlds, following the premise that making explicit use of the medium’s distinct features allows for innovative, valuable new forms of working and learning together. The work pursues a pattern-based approach in order to investigate and describe existing practices and to develop a structured framework for the goal-oriented design of novel collaboration patterns. It further empirically investigates the value of the visual character of the medium as well as different approaches for designing collaboration tasks and environments in it. With these two strands, the research addresses both the process and the product of the design of virtual world collaboration experiences. The thesis presents two controlled experiments and derived design guidelines, the conceptual development and an initial application of the Avatar-Based Collaboration (ABC) Framework, following the principles of design science research, and an illustrative exploration study.

As one main contribution of the thesis, the ABC Framework is intended to help improve the process of designing for collaboration experiences and facilitate sharing and organizing of collaboration patterns. As the other main outcome of the thesis, the gathered empirical data indicate that making active use of the distinct features of virtual worlds can have a positive impact on collaboration in various ways. Applying a highly comprehensive approach, the work builds on an interdisciplinary theoretical background.

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And last but not least Elena, amore, thank God for making our paths cross, and thank you for being the very woman I had always hoped to meet.

Overview of Contents

Detailed Table of Contents

Chapter 1: Introduction

Chapter 1: Introduction

1.1. Context and Motivation

Working in teams is becoming more and more important (Todorova et al. 2008, Wutchy et al. 2007). In an increasingly networked world, more and more people, companies, and institutions turn to the Internet as a medium to work and learn together. However, collaboration benefits from participants, be it co-workers, project team members, peers, friends or family, being present in the same place (Salomon 2009, Hollan & Stornetta 1992).

Collaborative virtual environments (CVE) in general attempt to provide settings that provoke the sensation of co-presence (Ijsselstein & Riva 2003, Beck et al. 2011), i.e. the feeling of 'being there together', even though the participants might be dispersed all over the planet. Different types of CVE make for different intensities of co-presence; one type of CVE specifically designed for synchronous, real-time activities is that of virtual worlds.

Virtual worlds are three-dimensional collaborative virtual environments that are commonly used with traditional hardware (i.e., they are displayed on two-dimensional screens, controlled with keyboard and mouse). People meet in shared spaces, all represented through animated virtual characters, so-called avatars. Virtual worlds as a communication platform enable users to create and design spaces and to customize and personalize avatars virtually without restrictions. However, while they have been around for years, it is still unclear what value virtual worlds can add to the existing modes of communication and collaboration. Moreover, it is still unclear which virtual world features should be made use of and which enhancements are needed to maximize the benefit of using them for collaborative activities (Bainbridge 2007).

The thesis at hand addresses these issues by following a Design Science (DS; sometimes also equated with Design Science Research, DSR) approach (cf. Hevner et al. 1994, Venable 2010, Piirainen et al. 2010). This means, the aim of the work is not only to investigate collaboration practices and design of collaborative activities for virtual worlds, but also to create an artifact that helps address the issue of designing for fruitful collaboration for virtual worlds. In doing so, the work aims to strike a balance between academic rigor and practical relevance, following the tradition of DS, especially in the Information Systems field (Piirainen et al. 2010). Design science research has only been used recently in the field of virtual worlds, for a workshop *in* a virtual world (Helms et al. 2010); the thesis at hand applies DSR *on* virtual worlds.

For the scientific community, answers to the posed questions and the findings, emerging concepts and theoretical contributions of the research at hand are therefore of interest in a number of academic disciplines, including Information Systems and Human-Computer Interaction (in particular the fields of Computer-Supported Cooperative Work and Interaction Design), Knowledge Management (and Knowledge Visualization), and Education (with the fields of Computer-Supported Collaborative Learning and eLearning). Figure 1.1 illustrates the positioning of the thesis in its interdisciplinary scientific context. Findings of the research will add to the knowledge base of effective design of virtual worlds – and collaborative activities in them – and can help open up research on novel and innovative approaches of working and learning together online, harnessing new possibilities recent advancements of information and communication technology (ICT) have brought. The research builds on, tests, and extends relevant theories and concepts from the mentioned relevant academic disciplines.

In practice, virtual worlds are used more and more (KZero 2012), yet the design of environments and activities is still largely not based on scientific evidence, rather strongly inspired by traditional practices and amended by visually-impressive designs. Practical contributions of this work can therefore support and improve the design of collaborative activities and environments in virtual worlds, and thus render the use of virtual worlds and 3D collaborative virtual environments in general more worthwhile for collaborative work, education, scientific and social events, marketing, corporate communication, and other applications and use cases.

The often-cited strengths of virtual worlds (e.g. Bainbridge 2007, Kapp & O’Driscoll 2010) can be made use of in a more efficient way when the design of collaborative activities for the medium is based on a combination of a theoretical foundation from related fields of science and an empirical research with emerging guidelines and practices. This comprehensive and complementary approach this thesis follows aims to ensure the balance between academic rigor and practical relevance.

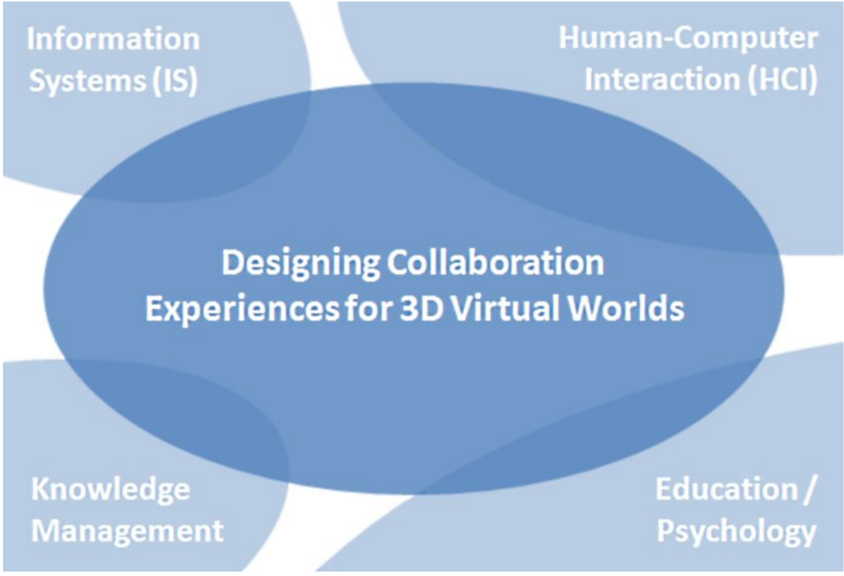

Figure 1.1. Positioning of the thesis in the scientific context

On another note, from conceptual and empirical research on the design of collaborative activities in virtual worlds, ideas and guidelines for the design of collaborative activities for other digitally-augmented settings can be inferred (e.g., for the office of the future, the classroom of the future, mobile learning, museums, exhibition and other cultural centers, etc.). Findings might even inspire collaborative activities in settings without any digital augmentation, for example could educators transfer concepts and patterns that are proven to work with avatars in virtual worlds to activities in schools in the actual world. This would take the implications of this research well beyond the scientific context laid out in Figure 1.1 and thus further extend the scope of impact of the work at hand.

1.2. Research Objectives and Methodology

Virtual worlds are visual, online environments that on one hand resemble the actual world (i.e., the physical world) in its basic design and look-and-feel, and on the other hand introduce novel features and various possibilities for interaction among users as well as between users and the responsive environment. Main technical differences to other online communication platforms are the rich user representation (i.e., users are represented as highly customizable avatars that they navigate through the virtual world), the configurable 3D environment (world, landscape, architecture, objects and tools in it can be designed and configured virtually without restrictions), and the level of immersion (people and data or information share the same space).

Studies have shown that rich user representations (i.e., avatars) enhance awareness of collaborators and their actions and are therefore beneficial to collaboration (Casanueva

& Blake 2000, Yee & Bailenson 2009), and that three-dimensional environments can be conducive to collaborative activities (Minocha & Reeves 2010, Jakobsson 2002). However, only few studies have been carried out so far to investigate the benefits of using virtual worlds for specific collaboration tasks or entire collaboration meetings (for an exception see Olivier & Pinkwart 2011). This research gap motivates the first research question of the thesis at hand (RQ1): *Can virtual worlds support collaborative activities, and if so, how?* On one side, this question targets the merits of using the medium virtual world for collaboration, in terms of supporting collaboration processes. On the other hand, it questions which features of the medium make it valuable as a collaboration medium. This latter aspect of RQ1 directly addresses a major issue about virtual worlds that is still unclear, as stated by Bainbridge (2007), namely what value the medium can add to existing modes of collaboration.

The second major open issue stated by Bainbridge (2007), namely which virtual world features should be harnessed in order to maximize the benefit of using the medium for collaborative activities, motivates the second and third research questions of this thesis, which both address the design of collaboration activities for virtual worlds. Research question RQ2 addresses the design process: *How can we support the process of designing for fruitful collaboration experiences for virtual worlds?* This research question was developed out of the lack of a formalism of collaborative activities for virtual worlds. The literature around designing collaboration for virtual worlds (e.g. Kapp & O'Driscoll 2010) still shows a gap for the structured description and formalization of collaborative activities, approaches exist only for collaboration in general (e.g. Briggs et al. 2003). As design science, the research paradigm in which this thesis is positioned, is a systematic form of designing (Fuller & McHale 1963), there is a strong need for structure and formalization for the design of fruitful collaboration in virtual worlds.

A general gap in the scientific literature around the empirical evaluation of virtual world features and design approaches motivates the third research question (RQ3), which addresses the product or outcome of design: *How should collaborative activities for virtual worlds be designed in order to best utilize the medium?* This directly addresses Bainbridge's (2007) second open issue, as described above. Regarding the design of collaborative activities, the virtual worlds community calls for guidelines. While Tromp et al. (2003) provide an approach for constructing usability guidelines, van der Land et al. (2011) approach the topic from a theoretical perspective and provide a formalization of virtual world features. The development of guidelines for the design of collaborative activities for virtual worlds based on empirical research forms a research gap that RQ3 addresses.

Table 1.1 lists the three research questions of the thesis at hand and states their respective targets.

	Research question	Target
RQ1	Can virtual worlds support collaborative activities, and if so, how?	Value of the medium for collaboration
RQ2	How can we support the process of designing for fruitful collaboration experiences for virtual worlds?	Design process
RQ3	How should collaborative activities for virtual worlds be designed in order to best utilize the medium?	Design product / outcome; design approach

Table 1.1. The research questions of the thesis and their targets.

The premise of this doctoral thesis is thus that the distinct features of virtual worlds allow for innovative, valuable new forms of collaborating. Its overall goal is to improve online collaborative work and learning by first understanding if and how virtual worlds can support collaborative activities and by then providing a structured framework for the design of valuable virtual world collaboration patterns, along with a set of design guidelines backed by empirical research. The overall research design includes pre-studies with the aim to understand how virtual worlds are used and what advantages they have over other online communication platforms, the conceptual framework development, and an empirical research on virtual world design approaches and aspects.

To address the complex and interdisciplinary research questions described above, the following research design was implemented:

- Conduct pre-studies in order to understand
  a) how virtual worlds are currently used for collaborative work and learning, and
  b) what main advantages using the platform brings when compared to other online collaboration media
- Develop a framework for the structured creation of collaboration activities (regarding the process of designing collaboration in virtual worlds)
- Empirically compare different design approaches for collaboration activities in virtual worlds and analyze occurring effects in order to infer design guidelines (regarding the product of designing collaboration in virtual worlds)

The research endeavor was thus divided into four research activities. The pre-studies were necessary since there had not been done any extensive research on neither current practices of using virtual worlds as a collaboration platform, nor on the advantages over other online collaboration platforms. These two studies are subsumed in one chapter as pre-studies to the main parts of the research. The main parts in turn, the conceptual and the empirical part, are presented and discussed in their respective chapters. Here, an overview of the four research objectives is given, along with the respective methodology that was applied.

The objective of the first pre-study was to investigate existing ways of collaboration in virtual worlds. In order to find out how virtual worlds are used in practice, we explored the largest and most popular virtual world Second Life (Second Life 2012) and observed groups of users in it, with the aim to find out how people interact with each other and with the environment when working and learning together. Further, we examined scientific literature and relevant online media, including news, blogs and online magazines. Using a pattern-based approach, we developed a first description logic to formalize collaboration patterns in virtual worlds, and classified them according to the design effort they require and to the added value the particular collaboration patterns bring.

The second pre-study is an experimental comparison of virtual worlds and text chat as collaboration platforms. A controlled experiment was conducted, in which participants needed to share information and make decisions with team members online, in a simulated project kick-off meeting. Five experimental groups collaborated in a virtual world, five control groups in text chat sessions. Opposing these two collaboration platforms, the essential characteristics of virtual worlds could be extrapolated.

With positive findings from the empirical investigation and the collection and classification of collaboration patterns in hand, the basis for a structured formalism was set. On this basis we developed a framework for avatar-based collaboration in virtual environments, formalizing the necessary elements, and structuring their interplay. The framework builds on the semiotic triad, that is the pragmatic, semantic, and syntactic layers. To formalize and structure the elements necessary to design collaboration patterns classifications and constructs from the academic literature in Human-Computer Interaction and Sociology were examined and used as conceptual guidelines in the development of the framework. The framework can be used both as a descriptive structure to formalize existing collaboration patterns and as a blueprint in order to guide users and virtual environment designers in the creation of new collaboration patterns.

Guidelines on how to design usable virtual worlds and objects in them have long been identified as a major requirement for improving the usability of 3D collaborative virtual environments (Tromp et al. 2003). The last main step of the research thus concerns the experimental evaluation of different approaches for the design of collaborative activities in virtual worlds. Results and findings from this controlled experiment were used as an empirical basis on which to construct a set of guidelines to be used along with the framework. The experiment compares three different collaboration patterns; as the independent variable the setup of objects and tools in the virtual environments was chosen. In the three implemented conditions, particularly the effects of using 3D objects for collaboration and the effect of spatially structuring tools and tasks in the virtual environment were examined.

1.3. Outline and Structure of the Thesis

Table 1.2 (on page 10) provides an overview of the research and its structure, outlining research objectives, methodologies applied, and respective and overall outcomes.

This thesis is divided into six chapters. Following this introductory chapter that presents the context of the work and outlines the research, Chapter 2 describes the scientific background and related work in the relevant academic disciplines and research areas. It presents a narrative from the application domain of collaboration and collaborative learning through the enabling domain of collaborative virtual environments in general and virtual worlds in particular and ends with a background research on fields relevant to the design of collaboration, particularly the young discipline of experience design.

In scope of Chapter 3 are the two pre-studies that were conducted before the main conceptual and empirical parts of the thesis. First, the exploratory study to investigate the current use of virtual worlds for collaborative activities is presented, illustrating the collaboration patterns found and conceptualized in an overview classification. Second, the experimental comparison between virtual worlds and text chat is described, including its motivation, the experimental design and setup, and showing the results and findings of the study and its implications to the later parts of this work in particular and future research in general.

Chapter 4 describes the conceptual development of the Avatar-Based Collaboration Framework (ABC Framework) including detailed descriptions of the steps of development of its single parts, and illustrates its use by presenting case studies of the first applications of the framework.

In Chapter 5, the experiment comparing three different virtual world setups for the same collaboration tasks is described. The chapter discusses the motivation for the experiment, describes the experimental design and the virtual world setups in detail, presents the experiment results, and illustrates its findings. The chapter concludes with the description of the development of the set of guidelines inferred from the experiment findings.

Finally, Chapter 6 concludes the thesis by presenting how the main outcomes of the research fit together to form a concise contribution to research and practice.

Overall research goal			
Understand if and how virtual worlds can support collaboration and provide a structure and guidelines for the design of collaborative activities			
Specific research objectives			
PRE-STUDIES (Chapter 3)		CONCEPTUAL PART (Chapter 4)	EMPIRICAL PART (Chapter 5)
Current use of virtual worlds for learning and collaboration tasks	Added value of using virtual worlds for collaboration tasks	Structured approach and method for the design of collaboration experiences in virtual worlds	Comparison of different design approaches for collaboration tasks in virtual worlds
Methodology			
Exploration study	Experiment	DSR (design science research); case study	Experiment
Main outcome			
Classification of learning & collaboration patterns	Virtual worlds have a positive impact on retention	Avatar-Based Collaboration Framework (ABC Framework)	Set of guidelines for collaboration tasks, based on analyses of the experiment results
Overall outcome			
A framework and guidelines for the design of collaboration tasks for virtual worlds, with the aim of making online collaboration more engaging, satisfying, and memorable			

Table 1.2. Overview and structure of the research

Appendix A shows the persona profiles used in both the conducted experiments. Appendices B and C then present the questionnaires used in the experiments. Appendix D shows a collection of exemplary collaboration patterns described in the formalism of the ABC Framework, and Appendix E provides an empty blueprint of the ABC Framework for the reader to copy and use.

Chapter 2: Background

Chapter 2: Background

In order to provide a comprehensive background for this thesis, it is necessary to look at several research areas from diverse academic disciplines. The thesis connects two disjoint domains:

- its application domain of collaborative work and collaborative learning, spanning across the academic disciplines of Knowledge Management and Education
- its enabling domain: the communication platform of virtual worlds, which is a collaborative virtual environment (CVE) and thus related to the academic disciplines of Information Systems and Human-Computer Interaction and to the research area of Computer-Supported Cooperative Work

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This chapter is partially based on the following publications:

Schmeil, A., & Eppler, M. J. (2009a). Knowledge Sharing and Collaborative Learning in Second Life: A Classification of Virtual 3D Group Interaction Scripts. *International Journal of Universal Computer Science*, 15(3), 665-677.

Schmeil, A., & Eppler, M. J. (2008). *Collaboration Patterns for Knowledge Sharing and Integration in Second Life: A Classification of Virtual 3D Group Interaction Scripts.* Proceedings of I-KNOW 2008, September 3-5, Graz, Austria.

This chapter forms a consistent narrative, showing how the relevant research areas build upon each other in this context – starting from the application domain, traversing through the enabling domain, and ultimately ending in a design discipline that emerges as the connecting link. Figure 2.1 illustrates how the path through the academic disciplines and research areas relevant for the thesis leads up to the discipline of design, and how it connects back to the application domain.

The narrative begins with the introduction of basic concepts of collaboration and ways to structure and formalize collaborative activities in section 2.1. On that ground, it enters into the enabling domain by introducing the benefits of space for collaboration in section 2.2. Section 2.3 then advances into 3D space and introduces the concepts of immersion and presence, before section 2.4 gives an extensive overview of virtual worlds. Section 2.5 introduces how a design discipline is the logical emerging link between a collaboration support system and its application domain. Section 2.6 then provides an introduction of the theoretical foundations of the thesis, before section 2.7 presents a synthesis of the chapter.

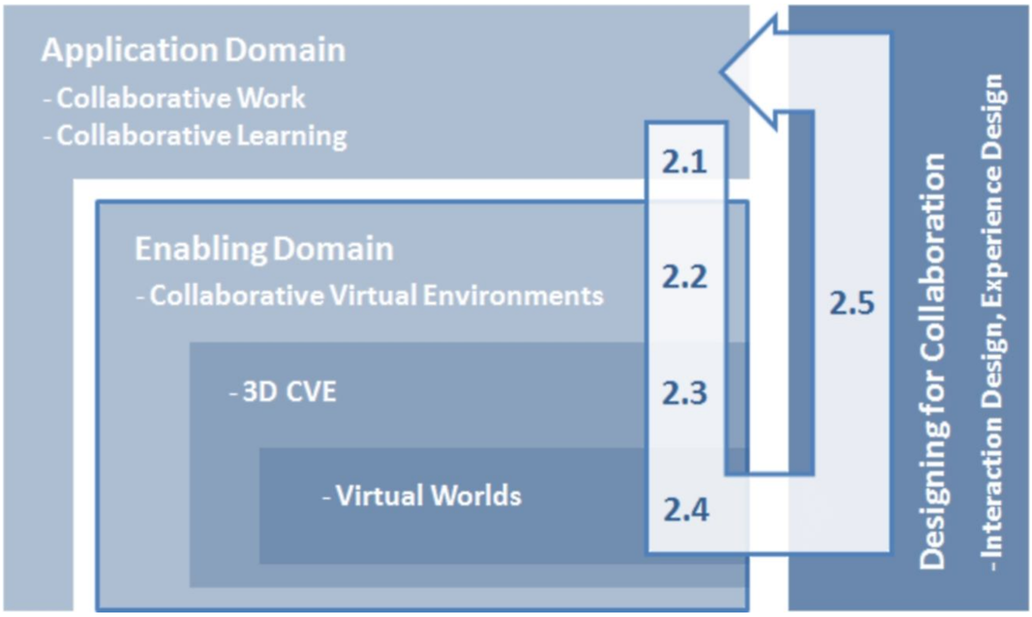

Figure 2.1. The path through relevant disciplines – how a design discipline connects the enabling domain to its application domain.

2.1. The Application Domain of Collaboration

In collaboration, individuals work together in a group, sharing a common goal. This situation involves interactions between participants, synchronous communication, negotiation and effects (Dillenbourg 1999). Roschelle & Teasley (1995) define collaboration as *"a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem"* (p. 70). For the latter – that is the shared conception of a problem – they coin the term joined problem space. This is closely related to the basic concept of common ground, the intended result of the process of grounding, where collaborating partners establish a common basis for their collective actions (Clark & Brennan 1991). Dillenbourg (1999) also emphasizes the importance of constructing and maintaining a shared comprehension of a problem and its role in collaboration when he refers to mutual modeling. Mutual modeling denotes the process of individuals building a representation of the knowledge, plans, and intentions of their collaboration partners (Nova et al. 2003). Hence, collaboration uses and relies on communication processes, in which individuals exchange signs of understanding. It is first and foremost these communication processes that enable and drive collaboration.

In distinction from collaborative work – collaboration aiming to accomplish a common goal by using and combining knowledge already existent in a group of individuals – collaborative learning is concerned with the creation of new knowledge within the group. Hence, it would be misleading to define collaborative learning as a part of collaborative work. Commonly, however, the scientific community understands learning as to occur as a side-effect of collaborative problem-solving; that is, as a result of collaborative work (Dillenbourg 1999). Therefore, collaborative work and collaborative learning can be subsumed under the umbrella term of collaboration. In this thesis the term collaboration is used to cover both collaborative work and learning, unless it is crucial to explicitly distinguish between the two.

Since the thesis is ultimately concerned with design – to be more precise, with structuring collaboration activities and arranging collaboration spaces – it is important to discuss diverse approaches to structuring and formalizing collaboration. The following subsections address these topics separately.

2.1.1. Structuring Collaboration

In his highly successful book *The Design of Everyday Things*, Norman (1988) discusses precise and imprecise human behavior. Referring to a notional task, he argues that precise behavior can emerge from imprecise knowledge in the following three cases:

- *Enough information is present for the grade of precision that is required*. The task at hand does not require more information than the imprecise knowledge that is present, in order for it to be solved with high enough precision.
- *Parts of the information required for a task is in the world instead of only in the head(s) of the individual(s) who engage in the task.* Memory does not have to be all in the head; it can partly be outsourced into the world instead, by adding reminders or explanations to objects in the environment.

- *Constraints are present.* Constraints limit the number of alternatives and can be of physical nature (i.e., physically constraining possible actions), of semantic nature (i.e., requiring a meaning), of cultural nature (i.e., requiring the alignment with conventions or standards), or of logical nature (i.e., demanding a valid logic to be applicable).

This argument is highly relevant for the discussion of how to structure collaboration, as precise behavior is conducive to collaboration. While the first case is rather trivial and does not deliver a basis for any design guidelines, the second and third cases are all the more substantial. Both the distinction between knowledge in the head and knowledge in the world and the approach of constraining behavior in a collaboration environment are particularly interesting for the design of collaboration tools and the arrangement of collaboration space, since it refers to structuring the content of collaboration, and thus highly relevant for research question RQ3 of this thesis. The notion of knowledge in the head vs. knowledge in the world is further addressed in the following. An introduction about making use of constraints for the design of collaboration follows in the treatment of designing for collaboration in section 2.5.

Knowledge in the Head

Collaboration situations where relevant information is not equally distributed in the group, that is in which collaborating partners have only partial and biased information has been labeled *hidden profile situation* (Stasser & Titus 1985). With the aim of getting insights on how to improve collaboration and especially information sharing, hidden profile situations have been subject to a number of experimental studies (e.g. Stasser et al. 2000, Schulz-Hardt et al. 2006).

The related theory of *transactive memory* postulated by Wegner (1987) regards constellations in which the members of a collaborating group do not all have the same shared information. Instead, the individuals' partial information and knowledge complement the others' domains of expertise. Thus, the collaborating partners become part of a larger system, they develop a group mind.

Knowledge in the World

Nonaka et al. (2000) define *Ba* as a context which harbors meaning. This context can be understood as a foundation for knowledge creation, as a shared space in which individual or collective knowledge can be created or extended. Ba can be either a physical, virtual or mental place. Such a shared context constitutes a crucial requisite for collaboration, as it allows for a shared conception of a problem to be created and maintained (cf. joined problem space, Roschelle & Teasley 1995; see also the theory of Distributed Cognition, Hutchins 1995). These concepts are of utmost relevance for answering research question RQ3 of this thesis, as they give indications on the importance of space and the structured use thereof, for collaboration purposes.

Furthermore, it is advantageous to exploit the structure and the features of the environment, and to be aware of information in it as well as of the presence of others and their ongoing activities (Harrison & Dourish 1996). The following sections introduce and discuss the notions of presence and awareness in detail.

2.1.2. Formalizing Collaboration

In order to effectively discuss, document, and share forms of collaboration, a comprehensive formalization is required. For different fields and applications, different approaches to describing situations and processes have formed and prevailed. This subsection introduces the most relevant ones: patterns, scripts, and scenarios. ThinkLets are introduced as a more recently developed approach of combining patterns and scripts. These approaches of formalizing collaboration are of high relevance for the process of designing collaborative activities for virtual worlds, thus for research question RQ2 of the thesis.

The Pattern Approach

The concept of collaboration patterns is one powerful approach to structure and formalize, and also pre-construct collaboration processes. A *pattern* in its most general sense is defined as *“a solution to a recurrent problem, in a context”* (Alexander et al. 1977). Expressing it in more detail, Alexander et al. originally developed the concept for the field of architecture, describing patterns as (1977, p. x):

> *“Each pattern describes a problem which occurs over and over again in our environment and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over without ever doing it the same way twice.”*

Regarding the structural layout, a pattern is often also described as pairing a problem statement and the description of a solution to it. It therefore has to be as specific as possible to precisely describe the problem in its context as well as its proposed solution, but at the same time abstract enough to encompass all desired problems in the selected context, and to allow for the pattern user to apply slight alterations to the solution, where appropriate. As the main structural aspects of a pattern in their definition, Alexander et al. (1977) list:

- *A recurring problem.* The root of the description of a pattern is a problem to be solved. It is a situation in the environment or field of the pattern user that can be described by the problem description.
- *A core solution.* A brief overview or summary of the solution to the problem that needs to be general enough to be applicable to all problems describable with the problem description.

- *System of forces.* This rather vaguely defined aspect of the pattern definition comprises a more detailed explanation of the solution to the problem, delineating the process of the solution more extensively.

In their scope, patterns can be anywhere on a broad range from very general through very specific. Alexander et al. go on and define a *pattern language* as an organized collection of patterns that is in most cases developed as a set of good design practices within a certain field. A pattern language can be hierarchical; more abstract (high-level) patterns can include lower-level patterns.

Patterns are nowadays applied not only in architecture but in various other domains, including software engineering (Gamma et al. 1995), human-computer interaction (Borchers 2001), usability (Henninger 2007), service interaction, business workflows, knowledge workflows (Sarnikar & Zhao 2008), education and technology-enhanced learning (Derntl 2004; for a collection of applications see Goodyear & Retalis 2010).

Collaboration Patterns

Among very few formal definitions, a *collaboration pattern* has been described as *"a set of techniques, behaviors, and activities for people who share a common goal of working together in a group"* (Gottesdiener 2001). The definition focuses on the solution and forces of a pattern and therefore constitutes a rather practical definition of the concept. As a rather descriptive wording the definition comes without a dedicated formalization.

An alternative definition postulated by Papageorgiou et al. (2009) declares a collaboration pattern *"a prescription which addresses a collaborative problem that may occur repeatedly in the environment. It describes the forms of collaboration and the proven solutions to a collaboration problem and appears as a recurring group of actions […]"* (p. 63). They go on to define it as enabling efficiency in both communication and implementation of a successful solution. Along with this definition, which is less descriptive in wording than Gottesdiener's, the authors present a formalization and an example pattern. Their interpretation of collaboration patterns emphasizes the description of the situation, whereas the structure for the description of the solution (the forces/actions to solve the collaboration problem) is left for the pattern designers to define.

De Moor (2006) presents a typology of collaboration patterns. He distinguishes between *goal patterns* (patterns describing context and goals of collaboration), *communication patterns* (patterns describing communication), *information patterns* (patterns describing essential content knowledge), *task patterns* (patterns needed for action or interaction goals), and *meta-patterns* (patterns that interpret, link, and assess the quality of other patterns). While these attempts to define and classify collaboration patterns exist, the concept is still far from standardized.

Scripts

Scripts – or, *collaboration scripts* – were conceived in the academic discipline of education and defined as *"didactic scenarios that aim to structure and guide the collaborative learning process by specifying the way in which learners interact with one another"* (Kobbe et al. 2007). According to their definition, a script consists of phases, which in turn consists of the descriptions of the following attributes:

- the type of the task to be performed
- the composition of the group
- the task distribution (among group members)
- the interaction and communication mode
- the time duration of the script

Scripts are composed by sequences of phases. Scripts can – similar to patterns – be of diverse granularity and therefore distinguished in (a) macro-scripts (focusing on organizing and structuring collaborative activities), and (b) micro-scripts (focusing on a deeper, more psychological level, supporting individuals in order to enhance their skills for fruitful collaboration; Dillenbourg & Tchounikine, 2007).

While scripts are a well-accepted approach to structuring collaborative learning – in particular, computer-supported collaborative learning (CSCL) – concerns about over-scripting CSCL have been raised (Dillenbourg 2002). Applying too many or too stringent scripts can have a negative effect on learning.

Scenarios

Another alternative approach to formalize collaboration is to describe collaborative situations as *scenarios*. A scenario is briefly defined as an *"informal narrative description"* (Carroll 2000). Scenarios are used for requirements analyses in software engineering, and are usually illustrated using directed graphs that connect states through state transitions.

Smith & Willans (2006) implement the concept of scenarios for a requirements analysis of virtual objects. For their application a detailed and low-level scenario-based approach features the appropriate granularity. For the structured description or goal-driven development of collaboration activities however, scenarios have not been adapted so far.

ThinkLets

In the academic discipline of Information Systems (IS), a research area has originated out of the lack of formal possibilities to structure and formalize collaboration: the field of *Collaboration Engineering* (de Vreede & Briggs 2005). Collaboration engineering aims to structure and manage repeatable collaborative processes in order for solutions to be reusable and adaptable for related situations. Briggs et al. (2003) introduce *ThinkLets* as a way to develop and document these repeatable processes. ThinkLets are building blocks for collaborative repeatable processes. The concept was developed as a formalization of patterns of collaboration for a broad spectrum of group support systems (GSS).

In structure, a ThinkLet is a construct comprised of a description of the tool to use, a configuration of the collaborating group, the environment, and the materials to be used, and a script that describes the steps of the collaboration. As such, in structure, a ThinkLet is similar to a pattern; in fact, ThinkLets can be understood as one rare formalization of a pattern for collaboration. Interestingly, the concept has not been accepted by the broader scientific community.

Table 2.1 presents a comparison of approached to formalize collaboration, based on the introductions of the different approaches above.

	Pattern	**Script**	**Scenario**	**ThinkLet**
Idea	Solution to recurring problem	Step-by-step script for interaction	Informal narrative description	Building block for collaborative repeatable process
Formalization	• Problem • Solution • Forces (actions)	• Phases • Attributes	• States • Transitions	• Tool • Configuration • Script
Extent	Approx. 1 page	Approx. 1 page	State-transition graph	Approx. 1 page
Originating discipline	Architecture	Collaborative learning	Interactive systems design	Groups support systems (GSS)
Application context	Highly flexible; adaptable to various areas	Structured descriptions of group interaction	Can express state-transition processes only	Purpose-built for collaborative processes, tools

Table 2.1. Comparison of approaches to formalize collaboration.

2.2. Entering the Enabling Domain: Collaborative Virtual Environments

The passage from collaboration to collaborative virtual environments (CVE) marks the entry into the realm of computer-supported cooperative work (CSCW) and computer-supported collaborative learning (CSCL). This transition to the use of computers and information systems with the purpose of supporting collaborative work can be seen as an essential step on the way to present-day work life (Dourish 2001).

Dourish further believes that *"probably the most significant transition, in terms of […] user interface models that are familiar to us today, was the transition from text to graphical interaction"* (p. 11). Here, this corresponds to the transition from using email and pure textual communication only to utilizing graphical collaborative virtual environments. Following Dourish's line of reasoning, this transition denotes the passage from using only one-dimensional streams of characters to using two-dimensional spaces, where the locus of action and attention can move around the computer screen from place to place. Dourish concludes his argumentation with the statement *"The task of managing information became one of managing space"*. These findings give again positive indications that space and the management of space is a central aspect in the design of collaborative activities in virtual environments, and thus highly relevant for RQ3.

The academic discipline of Human-Computer Interaction (HCI) is the study of interaction between people and computers (Sears & Jacko 2007). It investigates how people can make better use of computers, or, expressed from the other perspective, how computers and interfaces can be designed in more intuitive ways for people to be able to manage the systems more easily. To this end, the desktop metaphor has been a successful design approach for computer systems, although not optimal by far; new design solutions for interactive environments implementing novel approaches that go beyond the desktop metaphor arise (Kaptelinin & Czerwinski 2007).

In light of these conceptual developments and technological advancements, the field of Computer-Supported Cooperative Work (CSCW) is changing. 27 years after its first mention (for a review of the first decade of CSCW see Grudin & Poltrock 1997), the scope of CSCW is no longer limited to flat 'desktop' spaces, but need to be understood in a broader sense (Kaptelinin & Czerwinski 2007). A collaborative virtual environment therefore can take any shape or dimension. Tomek (2001) defines a CVE in its general sense as a software environment that creates a configurable universe that emulates a number of serviceable aspects of physical reality, such as the concept of space (as treated above), movable objects, navigation, and communication between (representations of) humans. The most relevant of the several motivations Tomek gives for his claim that CVE can enhance sharing and integration of knowledge are:

- The emulation of physical topology as a natural metaphor is a prerequisite for successful groupware
- CVE allow for organizing both people and information spatially
- Awareness of co-workers and usage policies for objects and tools is enhanced
- Allocated space can be separated at will to allow privacy and group restrictions
- Computer-mediated communication between disjoint places provides a good basis for recording in context (as all communication can be logged instantly)

Collaborative virtual environments thus promise to enhance sharing and integration of knowledge. This positive prospect of CVE for knowledge-related tasks is a motivation for research question RQ1 of this thesis. The advent of CSCW tools in organizations was also the foundation of the development of the concept of organization memory and is now the driving motor in the field of knowledge management (KM). KM is a highly relevant research field for the research project described in this dissertation due to its focus on knowledge-related tasks and the management of knowledge in business and other collaboration contexts.

Where the field KM (and traditionally also CSCW) is interested in all tools that support ‘cooperative’ work, meaning both synchronous and asynchronous tools and systems, the focus of interest in research and practice has moved in recent years, towards ‘collaborative’ work, meaning only synchronous tools and systems. The more recently developed abbreviation CSCL for example uses the adjective ‘collaborative’ instead of ‘cooperative’, as CSCW does.

2.3. Characteristics of 3D Collaborative Virtual Environments

Three-dimensional (3D) graphical CVE are rich in representation and support embodied avatars (customizable, controllable representations of users) and 3D objects in spatial relation to each other. In comparison to 2D (or ‘flat’) graphical CVE, a virtual environment fully based on three spatial dimensions can enhance functionality and usability in a number of respects.

It is hypothesized that the use of 3D CVE can upgrade knowledge management processes even more than those operating in two dimensions. This claim can be made also for situations and requirements that go beyond visualizing data or reviewing spatial models in applications like architecture and design, based on a number of publications by scholars from diverse fields. Most importantly, 3D environments provide ways to experience and view information that is dynamic and interactive (Krange et al. 2002). A more accurate approximation of physical reality can be provided, which can ease first access to the system and improve overall usability. Hillis (1999) states that „*the roots of yearning for a virtual world [or a 3D CVE in general] are partly anchored by an ongoing western belief in the eye as the most noble organ, and in vision as a sensual metaphor for extending understanding*" (p. 37). In the same sense, a "*feeling of immersion, a perceptual and psychological sense of being in the digital environment*" is evoked (McLellan 1996, p. 457). Also the feeling of presence is enhanced, by the sense of orientation and position in space. People and information can be organized in a very natural way in three dimensions, also making use of real space instead of very limited areas on flat screens. Kraut et al. (2003) show that the sharing of a visual space increases the use of pointing and deictic expressions ("that", "here", etc.) and thus improves collaboration. Providing virtual spaces for collaborative work also enables individuals to use a rich set of social spatial skills (Benford et al. 1994). McLellan (1996) further states that 3D CVE are proclaimed to be appropriate for model building and problem solving, which makes them particularly suitable for CSCW. This literature gives positive indications as to the value of 3D CVE for collaboration, referring to research question RQ1 of this thesis.

As for experimental research, the scientific literature demonstrates a research gap around the value of 3D CVE for collaboration. Olivier & Pinkwart (2011) provide an exception with their experimental study of different riddle tasks comparing the medium virtual world to an online/2D condition and face-to-face collaboration. Unfortunately, the results of the study are not very meaningful and give only weak indications for the value of virtual environments for collaboration activities. This gap in the research on the investigation of the value of three-dimensional collaborative virtual environments is the main motivation for the research question RQ1 of this thesis.

Other empirical studies around 3D CVE include the following: Casanueva & Blake (2000) present experiment results showing that the awareness of collaborators and their actions can be significantly enhanced by more realistic representations of persons. Embodied avatars have a better effect on awareness and collaboration than flat pictorial representations (Yee & Bailenson 2009). Furthermore, usage policies for tools and objects can be illustrated more clearly and in a more natural way employing the theory of affordances (Norman 1988). This goes in line with Norman's notion of knowledge in the head vs. knowledge in the world (see subsection 2.1.1); a configurable 3D space allows for the insertion and placement of knowledge into the virtual 3D environment (i.e., the virtual world). And finally, the level of privacy of allocated spaces is continuously adjustable in a natural way (cf. the office design metaphor: open office vs. combo office vs. private office).

2.3.1. Immersion and Presence

Virtual environments in general attempt to provide an environment where the user or spectator feels immersed and present. This *presence* is a psychological phenomenon that was broadly defined as the sense of "being there" in an environment, emerging from the technologically – if not physically – founded basis of *immersion* (Slater et al. 1994). A more recent paper of Beck et al. (2011) provides a closer look and an extensive overview of the research in the field, presenting an analysis of 97 research articles that deal substantively with presence. The authors developed an excellent descriptive ontology of the concept(s) of presence and its relation to two different types of immersion. A commonly used ontology for these concepts is needed, as the existing variety of used terms and definitions suggests (cf. Bowman & McMahan 2007).

Immersion

Immersion in the traditional sense denotes the technology of a virtual environment and its user interface that aim to lead to the sense of presence. It can be achieved to varying degrees, stimulating a variable number of human senses. However, the expression of immersion is often also used for online virtual environments that are accessed by standard computers and controlled by standard devices like keyboard and mouse. The scientific community therefore developed a formal distinction between physical immersion and mental immersion (Sherman & Craig 2003):

- *Physical immersion* is the *"passive involvement with physical human-computer interface software or hardware devices"* (Beck et al. 2011, p. 17). In order to immerse an individual into a virtual environment, their senses are superimposed by technological means, for example by a combination of visual, auditory, tactile, kinesthetic, and olfactory output devices. To a variable extent, the surrounding physical reality is blocked out. In an exaggerating manner of speaking, an individual is immersed using brute force.
- *Mental immersion* is a *"feeling of transportation or going there"*, not or only indirectly induced by technological means. An example of mental immersion in its purest form would be being in a dream (Beck et al. 2011, p. 18). This type of immersion refers to a psychological state, as opposed to the physiological conditions that create physical immersion.

The fact alone that both these fundamentally diverse types of immersion fall into the realm of Human-Computer Interaction demonstrates how all-encompassing this umbrella scientific discipline is.

Outside of the scientific community, the game design community on the other hand distinguishes between *tactical immersion* (short-term, high concentration), *strategic immersion* (mental challenge), and *narrative immersion* (involvement in a story;

Adams 2004), and elsewhere between *senso-motoric immersion* (physical immersion), *cognitive immersion* (consistent reality logic), *emotional immersion* (identification with the representation of oneself and/or others), and *spatial immersion* (perception of game space as real; Björk & Holopainen 2005).

This imbalance between the different understandings and uses of immersion can be attributed to the different motivations of the different communities; while the scientific community seeks means and formalisms for distinguishing between physiological and psychological effects, game developers seek ways to describe best practices in game design that lead to higher engagement of game players. The distinction(s) used in game design therefore majorly focus on the psychological side, while the scientific community sustains a broader, more encompassing understanding of immersion.

Presence

It was long assumed that presence could only be created as a result of physical immersion; research has shown however that also non-physical immersion can lead to presence (Schubert et al. 2001). The concept of presence has been subdivided into two categories as well, according to its sentient aspect (Beck et al 2011):

- *Non-sentient presence* is the “sense of being there” within an environment. This matches with the original definition of presence (Slater et al. 1994). An individual experiencing non-sentient presence is in a *“psychological state, in which virtual objects are experienced as actual objects in either sensory or non-sensory ways”* (Lee 2004, p. 32).
- *Sentient presence* is the “sense of being there with others”, where “others” are not limited to other people, but can also be robots, cartoon characters, talking plants, smart objects and anything else that demonstrates some level of intelligence. This type of presence had earlier been defined and referred to as *co-presence*, then however excluding non-human “others” (Slater et al. 2000, Casanueva & Blake 2001). Sentient presence can thus be understood as a more openly defined concept than that of co-presence.

Especially when speaking of online virtual environments, the term *virtual presence* (and virtual co-presence) has been established, putting extra emphasis on the absence of physical presence. Hence, the term found application for online virtual worlds, where all data is stored on online servers instead of in a local database (see below). Nowadays however, presence is oftentimes assumed to refer to online situations, and the adjective ‘virtual’ is omitted.

2.3.2. Types of 3D CVE

Mostly in line with these reviewed different types of presence and immersion, a distinction in defining 3D CVE is made. However, it has to be noted first that the term *Virtual Reality (VR)* merely denotes the approach and technology which creates physical immersion, and not, as in a common misconception, a type of virtual environment itself.

Locally-installed three-dimensional virtual environments are called *Virtual Reality systems*, often also *immersive VR systems*. The technical setups of these systems take on different forms, from relatively simple ones like stereographic projections with one single screen (see Bowman & McMahan 2007) to systems with multiple projection screens, through high-end installations like Cave Automatic Virtual Environments (CAVE), which provide high degrees of physical immersion through surrounding the user with six or even more stereographic projection walls (e.g. DeFanti et al. 2009). Due to technological limitations, these stereo projections still deliver a correct image to only one user, while other users – potential collaborators – cannot fully experience the 3D effect. These highly expensive installations are not very widespread, and are used mostly for product design prototyping, testing, and demonstrations.

Desktop-based 3D CVE are most widely referred to as *virtual worlds*. All data is held online, the worlds run virtually non-stop. This allows for persistent world states, and the worlds are accessible from anywhere at any time. The quality and realism of the graphics is usually lower than in VR systems; the '3D effect' is an imagined one, as virtual worlds are accessed by standard computers and viewed on standard screens. Virtual worlds were developed for social interaction instead of graphical realism. Table 2.2 presents a comparison between VR systems and virtual worlds.

	Virtual Reality System	**Virtual World**
Installation	Local; physical installation (e.g. CAVE systems)	Online; data is held on servers
Access	Local, using expensive, special hardware	Log in from anywhere, using standard computers or laptops
Predominant type of immersion	Physical immersion	Mental immersion
Predominant type of presence	Non-sentient presence	Sentient presence
Predominant user representation	Not in focus	Customizable avatars

Table 2.2. Comparison of the two main types of 3D Collaborative Virtual Environments.

2.4. Virtual Worlds

This doctoral thesis focuses on virtual worlds as opposed to locally installed multi-user VR systems, a decision that was made for the following two reasons:

- The major benefit of utilizing 3D virtual environments is widely believed to be the possibility to have instant team or group meetings without the need to travel.
- Second, collaboration both within and among companies and other institutions is not likely to take place in immersive VR centers (due to availability, accessibility, costs, complexity, and constant need for technical staff).

2.4.1. History and Definitions

Although the initial notions of *cyberspace* (a digital space allowing for global communication and interaction) and *metaverse* (a fully 3D immersive virtual cyberspace) were coined by William Gibson's novel Neuromancer (1984) and Neal Stephenson's Snow Crash (1992) even before the breakthrough of the World Wide Web, formal definitions of virtual worlds and related concepts are still generally rare. To date, a virtual world is agreed to be a special type of 3D CVE. Virtual worlds are also referred to as *multi-user virtual environments* (MUVE), due to the fact that huge numbers of users logging in from anywhere in the world can be present at the same time and meet, communicate, interact, and navigate in a shared space (e.g. Nelson & Ketelhut 2007). This focus on social interaction stems from their ancestor. Historically, virtual worlds derive from multiplayer video games, from so-called *Massively Multiplayer Online Role-Playing Games* (MMORPG). The great success and growth of MMORPG in providing online environments – or, worlds – for people from all across the planet to meet and interact, led to the use of virtual worlds for areas other than gaming, as Balkin (2004, p. 2043) accurately predicted:

> *"As multiplayer game platforms become increasingly powerful and lifelike, they will inevitably be used for more than storytelling and entertainment. In the future, virtual world platforms will be adopted for commerce, for education, for professional, military, and vocational training, for medical consultation and psychotherapy, and even for social and economic experimentation to test how social norms develop. Although most virtual worlds today are currently an outgrowth of the gaming industry, they will become much more than that in time."*

Virtual worlds are thus a generalization of MMORPG, harnessing the powerful concept of online worlds in order to engage people to interact in many diverse areas. When referring to virtual worlds but explicitly excluding games, the term *social virtual worlds* is often used (e.g. KZero 2012). In this thesis, the term *virtual world* is used, unless the distinction is crucial for the argument.

In the ongoing scientific discourse about the lack of a formal definition, the concept virtual world has been described as *"a synchronous, persistent network of people, represented as avatars, facilitated by networked computers"* (Bell 2008, p. 2). Especially the aspect of persistency and the focus on people differentiate virtual worlds in this definition from other types of CVE, where virtual spaces can potentially exist for the duration of a single demonstration or meeting only, and for a single user (see subsection 2.3.2 above for a comparison of the main types of CVE). Already this very general, vague definition of virtual worlds – and the lack of more definite ones – indicate that virtual worlds and their constituent elements have yet to be formalized, and their opportunities examined in depth (Davis et al. 2009).

Emphasizing the fact that what happens in a virtual world is not less real than what happens in our physical world, Boellstorff (2008) makes the argument that the 'real world' we humans live in should be called *actual world* (as a complement to the adjective 'virtual'). This nomenclature is applied in the thesis at hand.

Throughout this thesis, a rather narrow definition of a virtual world is used, framing the medium by its technological elements and features:

> *A virtual world is a three-dimensional, online virtual collaborative environment that is commonly interfaced with traditional hardware, in which people, represented through customizable avatars, meet in shared spaces to interact with each other and with the responsive, configurable environment.*

In other words, we define a virtual world as a particular type of 3D CVE, one which is accessible from virtually everywhere (*online*), accessible by virtually everyone (*traditional hardware,* i.e., keyboard and mouse, computer or laptop monitor). Virtual world users are represented by animated characters, the appearance and behavior of which can be customized and/or personalized (*customizable avatars*). The virtual world itself consists of spaces that can be made accessible to others (*shared spaces*) in order to meet and communicate, and use, create, and share objects (*interact*). Furthermore, it is possible to create and modify places and/or their features as well as objects in it and their behavior (*responsive, configurable environment*). The 'synchronous' aspect of Bell's (2008) definition is implied through the use of the terms *meet* and *interact.*

2.4.2. Distinct Features

There are some main features to (social) virtual worlds that distinguish them from other online CVE, as well as from MMORPG. The most pivotal of these distinct features are the following:

- avatars (i.e., representations of users) are highly customizable
- the virtual environment is highly configurable
- most – if not all – of a virtual world is designed and created by its users

Each of these three main distinct features of virtual worlds is introduced in detail in this subsection.

Avatars

The term avatar denotes *"a graphical representation of a user within the environment which is under his or her direct control"* (Allbeck & Badler 2002, p. 313). It has its origin in the Sanskrit term *avatârah*, meaning "he who crosses down" (ava: "down", tarah "he crosses"). Traditionally, avatârah refers to the incarnation of a deity within the physical world (Isdale et al. 2002, p. 530).

Virtual worlds combine media-rich 3D CVE and avatars with text-chat systems (similar to Internet Relay Chat (IRC) or Instant Messaging), which users use to verbally communicate to one another. The result is a form of virtual social interaction that has been purposefully designed to resemble face-to-face conversation in many ways: avatars can approach each other, face each other, gesture to each other, in some cases exchange facial expressions, and more. Also voice chat was introduced.

However, an interesting tendency was observed in the most popular virtual world platform *Second Life* (on platforms see subsection 2.4.3 below): users would deliberately turn off voice chat, and rather keep to text chat only. After a qualitative investigation of the issue, Wadley et al. (2009) report that this is due to the fact that voice chat projects a very high degree of social presence into the virtual world – too high for many of its users. This decision of how much social presence to project into the world also heavily influences how users design their avatars, as avatars can present valuable identity information solely by their appearance. Williams (2007) notes that avatars are chosen as either a 'front face' (according to him, weak people choose large and strong avatars, people feeling fat or ugly choose sexy avatars) or a 'real face' (nice or conservative people). This issue is addressed in more detail in subsection 2.4.4 below.

Spatial social behavior and nonverbal norms – the ways in which individuals move and make use of their avatar in a virtual world – is largely shaped by the established ways users are familiar with from behaving in the actual world (Yee et al. 2007, Friedman et al. 2007). Virtual world designers can therefore rely on the emergence of certain behaviors known from the actual world.

Configurable Environment

Benford et al. (1994) describe virtual space as being inhabited by objects at measurable positions that are able to move around and interact with one another through a combination of media or interfaces (e.g. vision, audio, or text). In their *spatial model of interaction,* the concept of object subsumes representations of people, information, and other artifacts. They define the *aura* of an object as the area in which it is able to interact (respective to a particular medium/interface); thus, the intersection of two or more objects' auras is the space where it is possible for them to interact with each other. Their model further understands awareness as the combination of *focus* and *nimbus*, with focus being defined as the space and the objects a particular object is overseeing, and nimbus being defined as the space from where a particular object can be overseen. In the same model Benford et al. also define populated information terrains as spaces that harbor objects with attached information or meaning.

Dourish & Bellotti (1992) show that awareness and coordination is increased when information about collaborating partners' roles and activities is displayed – or otherwise communicated – in the shared workspace itself. A spatial separation of awareness information from the actual collaboration taking place, as it had been practice, is not conducive to a coordinated work process. It is thus advantageous to have an environment in which information and materials of the collaboration as well as updated information about the collaborating partners share the same space.

Harrison & Dourish (1996), referring to a range of architectural and urban theorists, distinguish between the notion of *place* versus that of *space*. According to their much-cited paper, space denotes the geometrical arrangement that can be set up to structure interaction or collaboration, whereas place describes the meaning of the arrangement for the resulting interaction or collaboration. In order to explain further, they declared space as the opportunity, and place as the (understood) reality.

User-generated Content

With the advent of the now established *Web 2.0* around 2004, the concept of user-generated content became first widely known, and came to broad use. Not only the website administrators developed and designed the World Wide Web, but more and more the users themselves, deploying wikis, blogs, mash-ups, and sharing sites.

Inspired by this or not, a similar development unfolded around the time when the platform Second Life set off a marketing hype around virtual worlds, making the medium popular in little time. In contrast to games, virtual worlds rely on user-generated content. Most, if not all, of a virtual world is designed, created, and maintained by its users. A participatory culture came to be, just as it was the case when the Web 2.0 shaped up (Ondrejka 2008). The options of creating and importing just about any desired 2D or 3D object and equipping it with functionality through scripts and software modules opened up possibilities for the creation of wide ranges of interactive tools and responsive environments.

These distinct features of virtual worlds open up vast possibilities for the design of collaborative activities for the medium. This is highly relevant for research question RQ3 of this thesis, as a deeper understanding of how these features can – and should – be utilized, can guide the design of collaborative activities in order to yield more fruitful and effective collaboration. A good understanding of the distinct features of virtual worlds is important also for research question RQ2, as a formalization of the features is required for the structured design (see the design science approach, Fuller & McHale 1963) of collaboration in virtual worlds.

A different approach was developed by van der Land et al. (2011). As for distinct features of virtual worlds, they base their work on Davis et al. (2009) and extend the two features (i.e., 3D environment in which participants are immersed, and avatar-based interaction through which all communication takes place) by subcategories: presence, realism, and interactivity as subcategories of the 3D environment, and social presence and self presentation as subcategories of avatar-based interaction.

2.4.3. Virtual World Platforms

The term *virtual world platform* denotes all the software components that provide a virtual world to users, and allow them to access the virtual world from their computers. In most cases, only the client application is important to a user (since it needs to be installed on their computer); the server application and the world database behind it run on servers on the Internet and are administrated by the virtual world provider. Some platforms do not require the users to install an application on their computers but instead provide a Java Applet (i.e., a smaller program that downloads and installs itself and runs within a web browser).

While some platforms are built to make profit by having their users pay a monthly fee for accessing their virtual world or for creating and importing objects, other platforms are free to use. The latter are often open source platforms.

To date, there is abundance of platforms available, for all age groups and for many different areas of interest. Most of the available virtual worlds are held online by the operators on their proprietary servers, but some can be installed on one's own servers on the Internet, or within an Intranet. While systems like *Second Life*, *OpenSim* and *Active Worlds* enable users to design their worlds and to create static and interactive content themselves, others like *Open Wonderland* and *OpenQwaq* focus on productivity in conventional tasks like editing of text documents, spreadsheets and presentation slides, and conversations using audio and video streaming. In these latter worlds, only the up- and download of documents and the repositioning of furniture is possible. Still others like *Forterra's OLIVE* focus on providing training scenarios, implementing quality graphics and realistic physics. Their approach is to provide a fully designed world as a service to their customers; in this model there is no user content creation. New virtual worlds are launched almost monthly, and it seems like each new one tries to fill another niche (Salomon 2009 provides an overview of current platforms and big companies using them). Table 2.3 presents an overview of some of the major virtual world platforms used for collaborative work or collaborative learning, compared by the aspects introduced in this section.

	Customizable avatars	**Configurable environment**	**Content creation**	**Software / in-browser**	**Open source**
Second Life	yes	mostly	yes, in-world	software	no
OpenSim	yes	yes	yes, in-world	software	yes
Active Worlds	yes	yes	yes, no scripting	software	no
Open Wonderland	yes	yes	import	browser applet	yes
OpenQwaq	yes	to some extent	import	software	yes
Forterra's OLIVE	no	no	no	software	no

Table 2.3. A comparative overview of some major virtual world platforms.

KZero (2012) create and maintain graphs that sort all major virtual worlds by the average age of their users. Comparing the 2008 and the 2011 versions, the growth in the virtual world market is evident. However, not all the virtual worlds that focus on collaborative work are listed. An ever-changing environment makes it a difficult task to keep an updated overview of all existing virtual worlds.

2.4.4. Applications

Two cultural logics have emerged in virtual worlds: *immersionists* and *augmentationists* (Bennetsen 2006). The former seek a second identity (or more secondary identities) that is (are) different from – and not connected to – their real one, and thus use virtual worlds as places to escape to from their normal lives. The latter group, augmentationists understand virtual worlds as communication and collaboration platforms, as a new medium to augment their digital proficiency, as a tool to support real life objectives and goals. Wadley (2008) illustrates the main differences between immersionists and augmentationists in his chart that is reprinted in Figure 2.2.

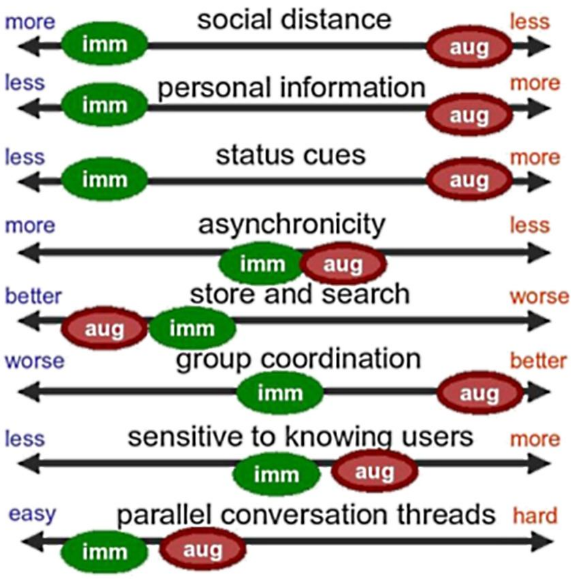

Figure 2.2. Immersionists (imm) vs. augmentationists (aug; from Wadley 2008).

While immersionists exist primarily in MMOGs and social virtual worlds, augmentationists are constituted by people interested in new media and innovative techniques for CSCW and CSCL. Thus, a phenomenon labeled "emotional disappearance of the computer" (i.e., the effect of users not realizing any more that they are using a computer or technological device, due to the high emotional load that immerses them; cf. presence and immersion in subsection 2.3.1), described by Streitz (2001) is more likely to occur to the immersionists than to the augmentationists: gamers and members of social communities are more likely to get more emotionally involved in their identity and their actions in the virtual world than those who merely use it as a tool, as a place to meet with colleagues. This may be one aspect of an explanation for the rather balking acceptance of virtual worlds as a mainstream tool for collaboration.

Millions of people interact on a daily basis in virtual worlds – however, the most populated and thus successful virtual worlds (still) serve the primary purposes of playing and socializing. Between 2006 and 2007, the virtual world Second Life set off a virtual world marketing hype: numerous companies and other brands created branch offices in the virtual world, believing to have found an innovative way to win new customers and ultimately make profits. Also the education community has identified virtual worlds (particularly Second Life) as a novel environment for education, although with substantially fewer members, compared to the numbers of MMOG subscribers. A number of in-world conferences have emerged in Second Life, such as *Virtual Worlds Best Practices in Education* (VWBPE), *The Virtual World Conference* (TVWC), SLEDcc, the *Second Life Education Workshop*, and SLCC. There are very active mailing lists, of which the most populous are SLED (Second Life Education List) and SLRL (Second Life Research List).

The marketing hype eventually turned into disillusionment. According to business analysts Gartner, virtual worlds were at the bottom of the Trough of Disillusionment in their 2009 Special Hype Cycle Report (Gartner 2009). The report prognosticated that virtual worlds would hit the mainstream in less than five years from then, before they bring real benefit. Two years after that report however, Gartner business analysts see virtual worlds still at the same point, in the Trough of Disillusionment (Gartner 2011).

Today we can observe a large growth in the virtual worlds market, numerous universities and research institutions holding lectures, classes, and conducting exercises in virtual worlds. Also, numerous companies like IBM, Sun, Cisco, Xerox, Accenture, Sony, Microsoft, and others make use of virtual worlds to hold meetings and recruiting events.

However, virtual worlds for serious tasks have still not yet hit mainstream, and Bainbridge's (2007) remarks that it is still unclear what value virtual worlds might add to the existing modes of communication and collaboration, and that it also remains unclear which features and enhancements are needed to maximize the benefit of using virtual worlds, still hold true (see also Davis et al. 2009, van der Land et al. 2011). The thesis at hand addresses both these issues.

2.4.5. Research in and on Virtual Worlds

There is a growing literature body on virtual worlds, with the most seminal works investigating their economy (Castronova 2001), the culture emerging in them (Boellstorff 2008), and discussing approaches of developing them (Bartle 2003), and providing approaches and guidance to design immersive learning environments and tasks (Kapp & O'Driscoll 2010).

Few studies so far have focused on the mechanics of the social interaction systems in these environments (Brown & Bell 2004). It is only in recent years that such studies are conducted: Moore et al. (2007) for example study awareness and accountability across several online worlds; Ducheneaut et al. (2007) investigate player-to-player interactions in a virtual world; Wadley & Ducheneaut (2009) experimentally examine collaboration in Second Life; Olivier & Pinkwart (2011) compare collaboration tasks (solving different kinds of riddles) in a virtual world environment to a selection of other collaboration media including text chat, collaboration through a website, and a face-to-face setting. These efforts are especially motivated by

a) the insight that in virtual worlds the focus has traditionally been much more on visual realism than on interactional realism and verbal as well as non-verbal communication, although these aspects are at least as important as the former (Moore et al. 2005), and
b) findings from CSCW research showing that awareness information is critical for the success of systems that support remote collaboration; in this context, *"awareness is the understanding of the activities of others, which provides a context for your own activity"* (Dourish & Bellotti 1992, p. 107).

Due to its media richness and the distinct virtual world features introduced above in this section, Second Life has become a promising environment for education research (as well as education practice). Learners can be addressed in an entirely novel way, and modern education paradigms and learning theories as the following have been implemented successfully:

- situated learning – learners are immersed in the context environment where they learn (Hayes 2006)
- constructivist learning – playing or creating objects and so creating correlations and knowledge from current structures is inherent in Second Life (Antonacci & Modaress 2005)
- social/collaborative learning – inherent collaboration between avatars
- resource-based learning – a variety of virtual objects and human resources are possible in Second Life
- problem-based learning – solving of problems collaboratively with several avatars is supported in Second Life
- experiential learning – learning through immersive experiences (Kapp & O'Driscoll 2010)

Research Methods and Tools

Social science methods are often praised as being particularly suitable instruments for conducting research in virtual worlds, and in MMORPG (e.g. Ducheneaut et al. 2010). The authors highlight opportunities for and challenges in conducting (virtual) ethnography in virtual worlds and present computational tools, which automatically update, log, and analyze quantitative measurements. These measurements can be displayed and plotted or exported for later analyses.

Automations like the one described also serve as valuable tools to collect longitudinal behavioral data on avatars and their social interaction with others, as well as with the environment (Yee and Bailenson 2008). As the authors demonstrate with their data collection tools they developed for an investigation in Second Life, scripting can be used as a powerful tool for the development of custom data collection instruments – where available.

Both Boellstorff (2008) and Williams (2007) investigate virtual worlds using participant observation and virtual ethnography. They report that the participatory and open culture predominant in virtual worlds (cf. Ondrejka 2008) is particularly inviting to virtual world researchers.

Others conduct 'quasi-experiments' in virtual worlds (e.g. Wadley & Ducheneaut 2009). Although the possibilities are there to conduct fully-fledged controlled experiments in virtual worlds, interestingly few have been published so far. All the more it is reported that virtual worlds and MMORPG offer vast possibilities for all kinds of research, using the most diverse methods and approaches (cf. Bainbridge 2007; for a comparison between quantitative and qualitative methods in collaborative virtual environments see Schroeder et al. 2006).

2.5. Designing for Collaboration

As noted in the introduction of this chapter, at the end of the path it took starting in the application domain of the research, namely collaboration, and leading through the multi-layered enabling domain of collaborative virtual environments and in particular virtual worlds, a missing link emerges. In order to appropriately meet the requirements of the application domain, the enabling domain needs to consider a suitable structuring approach. In other words, in order to appropriately meet the requirements of fruitful online collaborative work and learning, the application of the collaborative virtual environment in use has to be structured in the most suitable way. The thematic path this chapter has taken thus ends with the introduction of relevant design disciplines that serve as possible approaches to ultimately structure and organize a virtual world as a collaborative virtual environment for CSCW and CSCL purposes.

Design is a complex process of realizing that which does not yet exist (Nelson & Stolterman 2003). The complexity of the term design alone is reflected by the following – grammatically and semantically legitimate – definition: *"Design is to design a design to produce a design"* (Saffer 2010). In order to form a background on research question RQ2 of the thesis, which addresses the process of designing virtual world collaboration, it is necessary to look at the fields Interaction Design and Experience Design.

2.5.1. Interaction Design

Between the academic disciplines of human-computer interaction and design, as well as the field of software engineering, the design field *interaction design* (IxD) was defined as *"the practice of designing interactive digital products, environments, systems, and services"* (Cooper et al. 2007, p. 610).

Subsections 2.1.1 and 2.1.2 introduced the importance of structuring and formalizing collaboration, respectively. IxD in this sense encompasses collaboration, as interaction is a broader concept. Interaction designers focus on users and incorporate emotion when creating appropriate solutions; they use ideation and prototyping, while drawing on a wide range of influences (Saffer 2010).

Feenberg (2002) signalizes the significance of the experiences people have when they interact with technology in stating *"What human beings are and will become is decided in the shape of our tools no less than in the action of statesmen and political movements" (p. 1).* This, applied to the field of computer-supported collaborative work and learning, suggests inferences about the impact of the design of CSCW experiences on engagement and motivation.

Streitz et al. (2005) realized the need to address an office environment they were designing as an integrated organization, comprising both needs at the organization's collective level and at the worker's personal level. The need for an integrated approach of designing for entire experiences instead of merely structuring information became apparent.

2.5.2. Experience Design

The relatively young discipline of *experience design* came into being in the field of marketing: the fundamental idea was to market and sell whole compelling experiences instead of just mere products, in order to distinguish a particular brand from competitors and create a bond between customer and brand (Pine & Gilmore 1999). It has now become a growingly important discipline in various fields, and is being recognized as a full-fledged design discipline (Buxton 2007, Hassenzahl 2010).

Designing for experiences is already prominent for the design of games and leisure activities for future home environments. The entry of experience design into the realm of collaboration and CSCW was marked when Streitz et al. (2005) were setting up innovative office environments, and led to pursue a how they then called it "experience-oriented approach" for designing tools for a physical but technologically augmented collaborative workspace.

Designing Engaging Experiences for Virtual Worlds

In regard to virtual worlds or CVE in general, experience design has not yet been mentioned in the scientific discourse. Friesen (2009) shows how hermeneutic phenomenology, the study of lived design and its meanings, influences the design of technology. It has been shown that poorly designed virtual world experiences lead to anger of the users, although no inferences were made about how to design more effective experiences (Sanchez 2007). Design guidelines on how to increase effectiveness of social interaction in virtual worlds so far mostly stem from the gaming field (Moore et al. 2007). Ducheneaut et al. (2007) speak of the player's experience that game designers should optimize. They encourage them *"to rely on the flexibility of digital environments […] instead of reproducing an organization of space that might be familiar"* (p. 164).

Designing Engaging Experiences for Collaboration in Virtual Worlds

Ducheneaut et al. (2007) state that *"game design has become a social problem in its own right, and it is a domain where sociology could have much influence both by recommending best practices and evaluating the effects of virtual social environments on their visitors"* (p. 164). A similar trend for the design of collaboration experiences can be observed (Briggs et al. 2003); this would imply it to be advantageous also for virtual world builders and designers to draw from social science research on communication and collaboration and use specific findings in order to re-adjust virtual worlds for collaboration. Friesen (2010) remarks this paradigm shift is already in progress. In a broader sense, the design of instruments and tools people use has a considerable influence on how people perceive themselves (Feenberg 2002). Findings of Moore et al. (2005), indicating that the social experience is critical to the success of virtual worlds in general, and to the long-term retention of players (or, users) in particular, support this argument. A Gartner article (2008) further supports it by pointing out that businesses have focused on technology rather than the requirements of the users when trying out virtual worlds, which they believe is one of the main reasons for the failure of 90% of first-time corporate virtual world projects, as anticipated by Gartner. In this context, the users' requirements can be understood as the desired collaborative experience they seek when using virtual worlds, which in turn should aim for delivering a real value to the users.

Further, experience design applied to collaborative work and learning has to be understood as comprising more than the related discipline of User Experience Design (UXD), which is prominent in designing sites and platforms for the World Wide Web, but mostly regards the aspects functionality, efficiency, and desirability (Kuniavsky 2003). For the design of fruitful collaboration experiences, social, communicational, and interactional factors, just to mention a few, have to be taken into account as well. For the field of CSCW the experience design approach can mean a transition from system-oriented, importunate smartness to people-oriented, empowering smartness (Streitz et al. 2001). "*The design of technology is thus an ontological decision fraught with political consequences*" – as Feenberg (2002) explains suitably.

One major fact that the scientific community around virtual worlds, massively-multiplayer games, and other virtual environments agrees upon, is that whatever it is that the virtual environment is designed to aim for, lessons from 2D environments, from Computer-Supported Cooperative Work (CSCW) and Learning (CSCL) should be migrated, not just copied par for par (Benford et al. 2001, Davis et al. 2009, Ducheneaut et al. 2007, Santos 2010, van der Land et al. 2011). This implies that a method for the design of virtual environments is required that takes into account both the technical infrastructure of the target platform and the context in which the resulting environment is meant to be deployed. A new design discipline that designs for the entire experience is needed, instead of one that focuses on either the graphical, spatial, or architectural design of the environment or merely the planning of activities (Bardzell & Odom 2008, Santos 2010). Van der Land et al. (2011) add that designing virtual worlds with an emphasis on the distinct features of the medium (they refer to 3D environment and avatar-based interaction), can improve effective team collaboration.

Furthermore in the realm of virtual environments, a trend is conceivable that transforms the notion of developing the construct of teaching and learning into the orchestration (or, 'scaffolding') of holistic learning experiences, based upon exploratory and experiential learning rather than on knowledge-centered approaches (de Freitas & Neumann 2009, Santos 2010, Kapp & O'Driscoll 2010). The hopes of educators – and researchers – are that this approach will lead to more effective learning, accelerated learning, and greater learner motivation and engagement. Virtual worlds are a fast-prototyping environment for the most various sorts of experiences, and also because of this, a magnificent environment for the most various fields of research (Bainbridge 2007; see also section 2.4.5).

2.6. Theoretical Background of the Thesis

In order to clarify the theoretical foundation and background on which this thesis builds, it is necessary to look at the field of collaboration in virtual worlds in the context of the relevant academic disciplines. As introduced in Chapter 1: (Figure 1.1), the disciplines relevant for the topic of this thesis are Information Systems, Human-Computer Interaction, Knowledge Management, and Education. This section provides an introduction to the theoretical framework spanned by the interrelation of the academic disciplines and the theories and concepts of these disciplines that are used and referred to in this thesis. After the following introduction of the theories and concepts structured in separate paragraphs for each of the disciplines, Figure 2.3 illustrates the scientific context, naming main authors and publishing years of the relevant theories and constructs that are referred to. As most of the relevant academic disciplines are relatively young, they deploy, extend, and develop theories and methodologies that are based on theoretical foundations from a number of academic disciplines; it would not be possible to display the entire ancestral chart. For this reason, the theories and concepts introduced in the following appear under the academic discipline in which they are most prominent.

Information Systems

The term design science research (DSR) defines research using design as a research method or technique. In a seminal paper, Hevner et al. (2004) developed the basic methodology of DSR. Their article is still a cornerstone in the IS community (cf. Venable 2010, Piirainen et al. 2010). Hevner et al. present seven guidelines for good design science research. Among the most central aspects of DSR is that knowledge is created through the development of an artifact (i.e., a construct, a model, a method, or an instantiation). The methodology is described in more detail in section 4.3.

A widely used theory is *Media Richness Theory* (Daft & Lengel 1986), which states that richer media are more suitable for messages that contain equivocality or uncertainty. According to the theory, text chat is more suitable for clear and straightforward tasks, while the richer medium of virtual worlds is be more suitable for more complex tasks. *Media Synchronicity Theory* (Dennis & Valacich 1999), which was originally proposed as an alternative to Media Richness Theory, defines synchronicity as the (beneficial) state in which individuals are working together at the same time with a common focus.

In the field of Group Support Systems (GSS), de Vreede & Briggs (2005) founded the new field of *Collaboration Engineering*, defining it as an approach to designing and deploying recurring collaborative work practices for recurring tasks. It was conceived due to the lack of scientific discourse and methodologies around the structured development of patterns of collaboration (Briggs et al. 2003), but has interestingly so far not been accepted by a broader research community.

Human-Computer Interaction

One of the main theories used in this thesis is the *Embodied Social Presence Theory* (Mennecke et al. 2010), which finds home in the broad academic discipline of Human-Computer Interaction (HCI). Embodied Social Presence Theory is an extension of the social presence theory from the field of Computer-Mediated Communication (CMC) to the realm of virtual environments and posits that having an embodied representation leads to higher levels of engagement in shared activities and communication. Being a new theory, it still lacks of empirical validations. This thesis is one of the first to provide empirical research using Embodied Social Presence Theory.

Highly relevant to the formalization of virtual worlds, in the field of Virtual Reality (VR) and 3D User Interfaces (3D UI) there is a generally accepted distinction among different types of interaction techniques (Bowman et al. 2005): navigation techniques consist of techniques for moving one's position and for changing one's view; manipulation techniques designate all interaction methods that select and transform or modify objects in a virtual space; system control consists of all actions that serve to change modes and modify parameters to alter the virtual experience itself; symbolic input describes the communication of symbolic information (text, numbers, and other symbols or marks) to the system.

Regarding the design of interactive systems, in HCI there are also theories and formal methods on designing interactive systems. However, these address specific user interface design issues for websites and traditional 2D software applications and are not relevant for this thesis.

Knowledge Management

Numerous studies have produced evidence that pictures yield better results than simple text in terms of recalled items and comprehension; this effect has been labeled *Pictorial Superiority Effect* (Nelson et al. 1976, for a review see Snodgrass & Vanderwart 1980). The empirically validated Pictorial Superiority Effect states that the use of images in cognitive tasks leads to systematically higher recall (and recognition) than the mere use of words (because of the additional encoding enabled by pictures and their distinctiveness, see Snodgrass & Vanderwart, 1980, p. 177). The theory that underlies the Pictorial Superiority Effect is called *Dual Coding Theory* (Paivio 1986). It postulates that the human mind processes verbal and visual information in different ways, which leads to the creation of different representations of gathered information, or in other words, the information is encoded in two different ways.

Nonaka et al. (2000) define the concept of *Ba* as a context which harbors meaning. It can be understood as a shared space of engagement, a space in which knowledge is shared and can be created and put into practice through collaboration. It was developed out of their well-known SECI model (Nonaka & Takeuchi 1995). The concept of Ba is similar to *Transactive Memory Theory* (Wegner 1987), which regards constellations in which the members of a collaborating group do not all have the same shared information. Instead, the individuals' partial information and knowledge complement the others' domains of expertise. The collaborating partners become part of a larger system, they develop a group mind.

Education and Psychology

Distributed Cognition (Hutchins 1995) is a theory that emphasizes the social aspects of cognition. It regards individuals, artifacts, the environment, and the interaction between these entities and constructs a cognitive ecosystem in which information is embedded in artifacts and in representations of interaction, and action can be coordinated using ecological approaches. The theory finds application in several fields, including *Computer-Supported Collaborative Learning* (CSCL; Dillenbourg 1999). As Distributed Cognition views a system as a set of representations, it relates to *semiotic theory*, or *semiotics* (Eco 1978). Semiotics is the science of signs, investigated in the interpretation of signals in interpersonal communication.

Figure 2.3. Theoretical foundations of the thesis in its scientific context, listing the authors and publishing years of major publications.

Table 2.4 presents a comparison of selected collaboration modalities and their capabilities or suitability regarding theories and concepts relevant for this thesis. The approach of this comparison is similar to that of van der Land et al. (2011) who compare selected media and their levels of presence, realism, interactivity, social presence, and self presentation, following their theoretical model of shared understanding and effective team collaboration in virtual worlds.

	Collaboration modality		
Theory or concept	Text chat	Avatar-based (3D)	Face-to-face
Media richness	Low	Medium	High
Immersion	Low	Medium-High	High
Presence	Low-Medium	Medium-High	High
Embodied Social Presence	-	Medium-High	High
Pictorial superiority	-	High	Medium-High
Memorability	Low	Medium-High	High
Collaboration Engineering	Low	High	Medium
Media synchronicity	Low	High	High

Table 2.4. Comparison of selected collaboration modalities and their capability or suitability regarding theories and concepts relevant for the thesis.

In terms of media richness, text chat is due to its mono-modality inferior to avatar-based / 3D virtual worlds, which in turn is inferior to face-to-face, as collaboration in actual world settings address more senses than that in virtual settings. For immersion and presence, the capabilities of text chat are very limited, whereas when using virtual worlds, almost face-to-face-like levels of immersion and presence can be achieved. Embodied social presence and pictorial superiority are not applicable for text chat. In virtual worlds the capability to create and promote embodied social presence is still inferior to face-to-face situations, but pictorial superiority can even be higher than in face-to-face settings, due to focus issues: a full-screen image can be perceived much stronger than a large display in an actual-world setting, because of the distractions around (i.e., the face-to-face modality can be too rich; cf. Wadley et al. 2009). Also depending on the handling of focus, memorability can be high in avatar-based collaboration, but probably not as high as in face-to-face meetings (in a traditional perspective; heavy gamers might disagree). For the field of Collaboration Engineering (and Experience Design), avatar-based 3D environments promise higher capabilities than actual-world settings, due to the virtually unlimited possibilities to design, create, and script the environment and interactive objects with it; for face-to-face settings, collaboration engineering and the design of engaging collaboration experiences is heavily limited by physical and technological constraints. The one-dimensional medium of text chat is rather unsuitable for orchestrated collaborative activities. The rating of suitability for media synchronicity – regarding the orchestration of synchronicity – is connected to this point; virtual worlds and face-to-face settings can be designed or engineered for the collaborators to focus on the same topic or element at the same time, whereas awareness of others in text chat is too low to achieve high synchronicity.

2.7. Synthesis

This chapter has presented the background to the thesis at hand by forming a coherent narrative, starting from the application domain of collaboration, moving through the enabling domain of collaborative virtual environments, and closing the circle with a design discipline.

The narrative has first defined the basics of collaborative work and collaborative learning, shown the importance of the concept of space for the purpose of structuring collaboration, and introduced formalization approaches for the structured description and design of collaboration, of which the pattern approach seems to be most suitable for the formalization of collaboration in virtual worlds. Then entering the domain of computer-supported cooperative work the chapter has shown the benefits of virtual environments for knowledge work and collaboration. Most of these benefits seem to directly result from focusing on the management of space and the structuring of interaction. Introducing three-dimensional CVE, the concepts and different types of immersion and presence were discussed, showing their central role in the field of 3D CVE. Subsequently, the different main types of 3D CVE were compared. The fundamental advantages of virtual worlds over local immersive VR systems as 3D CVE were presented, based on its inexpensive, fully-online aspects and the resulting benefits for social and collaborative purposes.

The subsequent section treated virtual worlds as a particular type of 3D CVE in detail, first discussing the medium's distinct features, which were determined as being avatars, the configurable environment, and user-generated content. These features open up a range of possibilities for collaboration. Some major existing virtual world platforms were presented and compared, of which OpenSim seems to be one of the most flexible ones, providing freedom for design. Different applications of virtual worlds were discussed, and a background on research in and on virtual worlds was given. Concluding the narrative of the chapter was the introduction of design disciplines and approaches relevant to the design of collaboration experiences for virtual worlds. A design discipline serves as the important link between the enabling domain of collaborative virtual environments and the application domain of collaboration.

Section 2.6 provided an introduction and discussion of the theoretical framework that grounds this thesis. Following a highly comprehensive approach to collaboration in 3D virtual worlds, this thesis links a number of disciplines and uses several theories.

Chapter 3: Virtual Worlds as a Medium for Collaboration

Chapter 3: Virtual Worlds as a Medium for Collaboration

3.1. Motivation for the Pre-Studies

Virtual worlds have not yet reached mainstream adoption. This is remarkably illustrated by the fact that Gartner business analysts still see them in the ”Through of

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This chapter is partially based on the following publications:

Schmeil, A., Eppler, M. J., & Gubler, M. (2009). An Experimental Comparison of 3D Virtual Environments and Text Chat as Collaboration Tools. *Electronic Journal of Knowledge Management,* 7(5), 637-646.

Schmeil, A., Eppler, M. J., & Gubler, M. (2009). *An Experimental Evaluation of 3D Avatar-Based Collaboration in Comparison to Text Chat.* In Proceedings of International Conference on Intellectual Capital, Knowledge Management & Organizational Learning (ICICKM 2009), October 1-2, Montreal, Canada.

Schmeil, A., & Eppler, M. J. (2009a). Knowledge Sharing and Collaborative Learning in Second Life: A Classification of Virtual 3D Group Interaction Scripts. *International Journal of Universal Computer Science*, 15(3), 665-677.

Schmeil, A., & Eppler, M. J. (2008). *Collaboration Patterns for Knowledge Sharing and Integration in Second Life: A Classification of Virtual 3D Group Interaction Scripts.* Proceedings of I-KNOW 2008, September 3-5, Graz, Austria.

Disillusionment" of their yearly hype cycle special report – for the third year in a row (Gartner 2009-2011). While in their 2009 report they expected virtual worlds to reach main stream and to yield productivity within 5 years from then, the situation has changed. According to their latest report (2011), virtual worlds are expected to reach main stream in 5-10 years. This shed some light on the speed of adoption of virtual worlds after the marketing hype around Second Life ended in 2007/2008. For many, the 'experiment' virtual worlds ended with that marketing hype; today, not many people outside academia and outside businesses that actively use virtual worlds know that Second Life still exists, and that there is a plethora of platforms now in place, developed to serve the particular needs of many diverse target groups (cf. subsection 2.4.3).

Virtual world users know that there are some usable platforms. The premise when starting this thesis project was that the available virtual world platforms are already capable of adding significant value to collaborative work and collaborative learning; the only problem being that it was still unclear how they were to be used in order for them to bring real added value for different collaboration purposes (Bainbridge 2007, Kahai et al. 2007).

In order to test this premise, we prepared two studies, which would later be integral parts of this doctoral thesis as the pre-studies that opened up the way for the entire research. This chapter describes these pre-studies in detail:

- An exploration study, conducted in the most popular (and most populated) virtual world Second Life, with the aim of understanding how virtual worlds are used for collaborative activities, and how they potentially could be used
- An empirical media comparison study, conducted in a controlled environment using our own virtual world environment and another online collaboration tool, with the aim of investigation *if* the distinct features of virtual worlds bring added value to online collaboration.

While we agree with Davis et al. (2010) and a number of other scholars that the research field of virtual worlds still requires fundamental research addressing for example the technological features of the medium, the sensation of presence, and the various forms of immersion in different situations and conditions, we believe that at the same time research is needed that goes already one step further. The pre-studies presented in this chapter look at existing applications of virtual worlds, at potential uses, and address more realistic situations.

3.2. An Exploration of the Use of Virtual Worlds

Gartner (2008) predict that 90% of first-time virtual world projects of any company or other organization will fail, due to an initial too strong focus on technology instead of on the collaborating people. A more human-focused approach on designing interaction and collaboration in virtual worlds is one option that might improve these odds (cf. Streitz et al. 2005, Hassenzahl 2010). As treated in section 2.5, drawing from social science methods can inform the design and organization of collaboration in virtual worlds. As a first step towards understanding how collaboration in this new medium can be approached in a more structured way and ultimately improved, we conducted an exploration of the use of virtual worlds.

The planned results of this first pre-study, namely a systematic description structure for collaboration activities in 3D virtual worlds and a classification of these activities, can help facilitate and enhance team collaboration and knowledge management by providing reusable patterns that leverage the ample possibilities and distinct features only three-dimensional virtual environments offer.

3.2.1. Research Objectives and Method

As the venue for our investigation of the use of virtual worlds we chose the most popular and most populated virtual world Second Life. Mostly due to the marketing hype it set off around 2006/2007, it established as the leading virtual world platform, and has most registered users still today (early 2012). Many non-virtual-world experts equate virtual worlds with Second Life, as it is the one platform that had continuous coverage in the mainstream media for a certain period of time.

With the aim of getting a broad understanding of how teams and groups make use of virtual worlds as a communication platform for their collaborative activities, we conducted an exploration study in-world. A number of researchers have praised social science methods for studies and investigations in virtual worlds, in particular qualitative research methods like ethnography and participant observation (Williams 2007, Boellstorff 2008, Ducheneaut et al. 2010). While collaborating groups in the virtual world were the subject of our exploration study, the goal was not to study their behavior in-depth, but rather to see what activities they were engaging in and how they had set up the virtual environment to implement them accordingly.

In addition, we sought inspiration for own developments of collaborative activities. This exploratory study was never meant to be more than a pre-study within the overarching research that is described in this dissertation. As such, the exploration was intended to yield insights that would inform the design of the main research activities of the thesis project (which are described in Chapter 4 and Chapter 5).

Starting without a formal structure for describing collaboration in virtual worlds, the research objectives of this explorative study thus are the following:

- Discover ways of collaborating in a virtual world. This includes not only collaboration practices already in use, but also prospective activities that can be implemented with the current state-of-the-art in virtual world technology.
- Develop a first description structure for collaboration activities and practices in virtual worlds, using a pattern-based approach. Such resulting collaboration patterns promise to be a potent formalization that would facilitate describing discussing, sharing, designing, and co-designing collaboration for virtual worlds (on patterns and collaboration patterns in general see subsection 2.1.2 above).
- Create a classification of collaboration patterns, according to their design effort (i.e., their complexity) and their 3D added value (i.e., the additional value that arises from implementing a collaboration pattern in a virtual world). This objective has the intent of resulting in an understanding of both the questions what virtual worlds are used for and what *can* they be used for. Of particular interest is the discrepancy between these two cases, for this notion addresses the degree of utilization of the novel possibilities offered by the medium.

3.2.2. A First Formalization for Virtual World Collaboration

Looking at the fast-growing literature body on virtual worlds that not uncommonly also addresses collective activities taking place in virtual worlds, it is surprising that no structure to formally describe collaboration activities has ever been created. This is especially remarkable due to the fact that the academic discipline of education is very present in virtual worlds and also upholds a vivid scientific discourse (see Nelson & Ketelhut 2007, Hew & Cheung 2010 for reviews); there are numerous scientific conferences discussing virtual worlds, both in the actual world and in the virtual world (mostly in Second Life, but also spreading to other platforms; see subsection 2.4.5).

Few existing research papers mention collaboration patterns in virtual worlds. Krange et al. (2002) use the method of interaction analysis in order to understand how students collaborate and construct knowledge together. The authors look primarily at the verbal interaction between the students and distinguish patterns of collaboration into two groups. However, while they explicitly discuss elements that would constitute a structural model of patterns, they do not develop such a formalization.

While looking at – and jotting down – different kinds of virtual world collaboration activities during the exploration study, the development of a common formalism to be used for the description of different types of patterns became inevitable.

In the following we introduce a systematic description structure which we developed as a means to formalize collaboration patterns in virtual worlds. This description structure was applied for the description of the various patterns that emerged in our exploration in Second Life. To exemplify, this subsection also presents in detail the descriptions of two key collaboration patterns for collaborative work and two key patterns for collaborative learning. In total, we concluded the study with 13 collaboration patterns.

Table 3.1 shows our description structure in its first version, with two example patterns of collaborative work, *virtual meeting* and *virtual design studio*, described in the developed formalism. A collaboration pattern is described among other criteria through its usage situation (i.e., the context in which the virtual environment is used), the objective of the usage, and the maximum size for the collaborating group. Further elements of the formalization are the intensity of the participants' interaction (i.e., the degree of involvement and interaction), what artifacts are required, common actions for the avatars, and risks or caveats of the pattern. As the last component the structure contains an element we labeled design effort, which refers to the amount of effort required to design and implement the environment for the collaboration pattern. Figure 3.1 shows screenshots of the two described example patterns. Table 3.2 and Figure 3.2 accordingly present two patterns of collaborative learning in the developed description structure, followed by associated screenshots.

Pattern Name	**Virtual Meeting**	**Virtual Design Studio**
Usage Situations	project meeting, team meeting	product development/design, architectural design
Objective	knowledge transfer and decision making	design of a physical (or virtual) object
# Participants	< 15	< 5
Interaction Intensity	low to medium	high
Typical Duration	up to 1 hour	up to 4 hours
Required Artifacts	places to sit, information displays	designing tools, sketching tools, plans
Avatar Actions	chatting, showing	modeling, designing, sketching
Risks	not making use of 3D features	design influenced by limited functionality of design studio
Design Effort	medium: room design and projections	very high: design tools, sketching tools; interaction design

Table 3.1. A first description structure for collaboration patterns in virtual worlds, applied to two example collaborative work patterns.

Figure 3.1. Screenshots of collaborative work patterns in the virtual world Second Life: a virtual meeting (left; Jarmon & Sanchez 2008), and a virtual design studio (right; Maher et al. 2006).

Pattern Name	**Scavenger Hunt**	**Role Play**
Usage Situations	Learn spatially distributed content	Role-playing historic or political characters, people in different life situations
Objective	Informal learning: creating knowledge by finding learning content	Informal learning: experience a historic period, experience life of a political person
# Participants	< 5 in group	< 10
Interaction Intensity	Low to medium	High
Typical Duration	Up to 2 hours	Up to 2 hours
Required Artifacts	Learning content, hints	Scene, costumes, artifacts
Avatar Actions	Interacting with environment, navigating	Talking (also monologues), moving, gesticulating
Risks	Getting lost, neglecting the learning content	Not playing a particular character correctly
Design Effort	Low to medium; Learning content design, hints design and placement	Medium; Scenography, animations

Table 3.2. Two example collaborative learning patterns in the description structure.

Figure 3.2. Screenshots of collaborative learning patterns in the virtual world Second Life: a scavenger hunt (left; Pearce 2008), and role play (right; Harvey et al. 2007).

3.2.3. Classifying Collaboration Patterns by Design Effort and 3D Added Value

The 13 initial collaboration patterns that arose from the exploration study needed to be put in order and in relation to each other. We therefore developed a classification of collaboration patterns in virtual worlds by arranging them in two dimensions according to their design effort and their 3D added value. We chose these two dimensions to put into relation the effort of designing a virtual 3D experience with the outcome gained from it. The following explains the classification axes in detail; Figure 3.3 shows the classification of the 13 initial collaboration patterns.

- By *design effort* we mean the amount of work that is necessary to stage the particular collaboration pattern. A pattern's design effort could be gauged in measuring the time and manpower required to plan the collaboration activity, to design the collaboration setting, to model the scene for/in the virtual world, and to implement and ensure the functionality of the in-world tools and other scripted objects (cf. user-generated content in subsection 2.4.2). In the final setting this is heavily influenced by the array of interaction functions and the quantity of sophisticated interactive objects that need to be created.
- *3D added value* can be seen as a compound measurement comprising the increase in efficiency and quality of the collaborative work and its outcomes – or, for learning patterns, the quality of learning and its learning outcomes. This axis is more complex to measure. To position the patterns in the classification space we looked at the added value in terms of how the spatial character of the environment and the fact that collaborators are represented by avatars, can give additional information or hints. For example is it possible to remember locations, offices or people and find them even without any names, just by coming back to the place. Other forms of 3D added value would be the obvious benefit of viewing 3D data in three dimensions, the generation of an additional communication layer by moving through the environment with avatars and group building, and the very important characteristic of being immersed in a virtual world. All these interpretations of 3D added value and thus also the compound axis should not be understood as measurable and comparable quantitative values, but as tendencies. Especially in this early stage of research (hence, pre-study), both measurements were operationalized qualitatively. Choosing these criteria allowed us to distinguish real value adding collaboration and learning patterns from merely cosmetic ones.

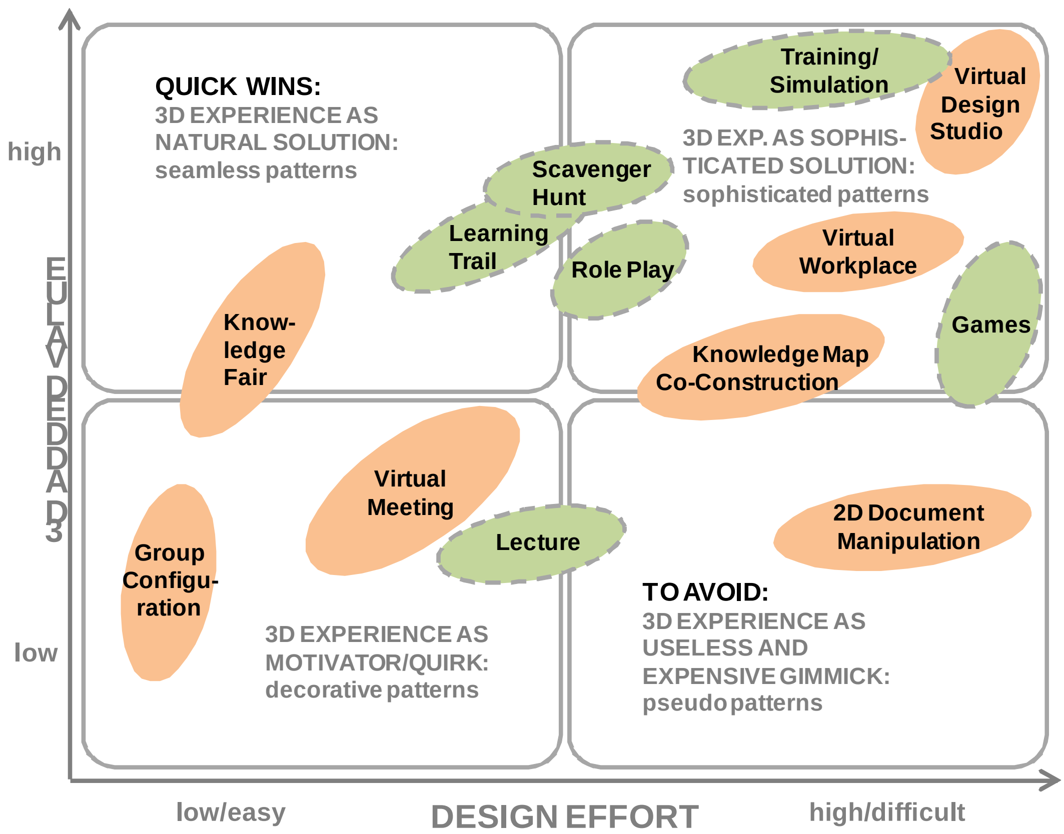

Figure 3.3. The classification of collaborative work and learning patterns.

In the figure, ellipses with dotted outlines resemble collaborative learning patterns, the ones with straight outlines collaborative work patterns. We decided not to distinguish between patterns we actually found in the virtual world and such we ideated ourselves using inspirations gathered in our exploration and on relevant websites. We found several good but unrealized ideas for collaboration patterns (more on that below).

Using elliptic elements instead of circular ones in the figure is to indicate that one and the same pattern can occur in different manifestations. That is, a pattern can be implemented in different ways, from simple to complex, resulting in a lower or higher 3D added value. In fact, following this approach most ellipses could span across the whole diagram, but for readability we chose to convey their most common or most probable use cases and thus keep the elliptic shapes within a certain size range. Many of the classified patterns share the fact that putting more design effort into the collaboration pattern leads to more added value; this can be seen both by the orientation of some ellipses from the left-lower corner to the right-upper corner and by the alignment of most patterns in the diagonal between said corners.

In order to categorize all the diverse collaboration activities we gathered and ideated, we not only subsumed them in the 13 collaboration patterns, but further distinguish between the four quadrants, as seen in Figure 3.3. The four quadrants and the collaboration patterns associated with them are described in the following.

3D Experience as a Sophisticated Solution – Sophisticated Patterns

The upper extreme in added value would be a collaboration pattern that is time-efficient (e.g. product modeling and reviewing/testing at the same time), saves costs (e.g. in physical prototype production) and can result in a higher quality (by e.g. seeing a product in its designated usage context), like the earlier described *Virtual Design Studio* pattern. The design effort in this case is high, due to the necessary a-priori implementation of design and modeling functionalities and tools. The *Virtual Workplace* pattern describes the mirroring of ongoing work and workplaces in the actual world into the virtual, e.g. casting the computer screens of employees while they are working (called ‘screencasting’) onto walls or other in-world projections. Co-workers can thus get an overview of what everybody is currently working on by wandering through the virtual workplace and can give help in particular cases. Another example pattern of collaborative work is *Knowledge Map Co-Construction*. Collaborators construct and modify a knowledge map in the CVE. The 3D added value here is based around collaborative interaction as well as viewing and editing multiple designs of a knowledge map in context (using 3D space).

For the learning patterns, the most sophisticated is most likely to be *Training/ Simulation*, which might also be the most widely used 3D interaction pattern. It is used in a broad range, spanning from the training of employees to operate machines or vehicles (or planes), through architectural simulations, combat training, the simulation of and training for emergency situations, to the treatment of phobias by systematic desensitization, where patients are put into controlled fear situations. The design effort ranges from medium, focusing more on collaboration and avatars to high, if sophisticated virtual objects and interfaces are required. *Games* are more and more used for education, with collaboration often playing a big role. One major argument for using 3D virtual environments and games for education is that today’s youth should be addressed by settings familiar to them, rather than only confronted with traditional learning methods and materials. As a subcategory of educational game, *Role Play* gives the opportunity to immerse in historic or political settings and lets the learners experience circumstances and personated characters, as described above. *Scavenger Hunt,* also earlier described, is another form of informal learning, where learners are required to find items in the 3D environment and thus construct knowledge in a playful way.

3D Experience as a Natural Solution – Seamless Patterns

A *Learning Trail* is a means for providing stepwise knowledge acquisition by positioning objects of any complexity as learning content along a trail in the virtual world. People share and perceive common interests implicitly by meeting in front of the same objects. This concept of premeditated serendipity is also applied in the *Knowledge Fair* pattern, which differs from the learning trail in terms of time scheduling. Where a learning trail is a persistent exposition, a knowledge fair is more of a short-term event. The two patterns are different also in terms of complexity of the presented objects, as at knowledge fairs mostly simple elements like posters and video/slideshow presentations are on display. We label this class, which comprises 3D experiences as a natural solution to problems, “Quick Wins” to emphasize the great 3D added value compared to a rather low designing effort required.

3D Experience as a Motivator/Quirk – Decorative Patterns

Descending the axis of 3D added value, three patterns emerged that use the 3D experience primarily as a means for motivating collaborators to participate and to increase engagement in the collaboration; we call them “decorative patterns”. The *Virtual Meeting* pattern in the simplest form merely constitutes the staging of a meeting room where collaborators can chat and talk to each other and hold presentations. Also in this case, as illustrated in Figure 3.3, adding more functionality to get a higher added value comes with an increase in implementation effort. The *Lecture* learning pattern seeks to describe all settings that include a lecturer and an audience. Collaboration is implemented in group discussions and the possible collaborative work on a learning object. The *Group Configuration* pattern comprises all group activities that follow the “voting by feet” principle, in other words, patterns using localization, navigation, and other spatial cues as an indication of personal preference. For example, a group of people can divide into disjoint subgroups to vote on a cause or to answer a question. The collaboration process and its results and emerging tendencies are visualized immediately; participants thus communicate and make decision or vote in a non-verbal way, using their virtual embodiment.

3D Experience as a Useless and Expensive Gimmick – Pseudo Patterns

An example of a 3D experience as a useless and expensive gimmick we have come across in several occasions is the creation and editing of a PowerPoint presentation on a Second Life collaborative design wall. In the classification this is represented by the pseudo pattern *2D Document Manipulation*. The complex user interface that needs to be implemented to enable several people to work on a 2D document together in a 3D virtual environment could be done easier and more convenient in a 2D CVE, for example a web application like Google Docs. Today, many virtual world platforms build on this pattern as an approach to effective collaboration.

3.2.4. Discussion

The presented classification was intended to sensitize designers and users to the fact that not all collaboration and learning scenarios envisioned for use in a virtual world may generate the added value that the amount of effort put in might promise. A second application we hoped it could find was for it to be used as a tool to estimate which approaches were likely to lead to a high 'return-on-investment', in other words, which expensive features and functionality were more worth implementing and which less. The quadrant categorization was developed as an decision-support tool; similar to the BCG-Matrix (the Growth-Share Matrix), it could be consulted to support strategic decisions, concerning virtual world design and application. In the thesis project however, it was early work, scientific proof was still to be developed. Nonetheless, already its first form that was presented here could help researchers, designers, and practitioners to assess a 3D collaboration or learning setting in terms of its scope and benefits.

The weakest aspect of the classification may well be the rather vague definition of the vertical axis, 3D added value. This very informal construct is in its described form (a) impossible to measure and hard to assess, and (b) not empirically investigated and thus hard to design for – in other words, it is unclear what the benefits of using 3D environments are and how to systematically maximize them (Bainbridge 2007).

The exploration of collaborative activities in the virtual world Second Life has further shown that companies and institutions, as well as educators for the most part do not make use of the distinct features of a virtual world. It may be these distinct features and opportunities virtual worlds offer that make them an interesting new medium for collaborative activities, much more than the possibility of simulating the physical world (Irani et al. 2008). Although there were promising ideas and approaches to find in-world, in the research community, and on relevant websites, the reality of virtual world usage relied mostly on simple patterns and not-too-innovative approaches. Today, a number of researchers agree that in order to fully benefit from virtual worlds, the medium's capabilities have to be examined in depth, and key features need to be explicitly considered when designing for effective and valuable collaboration experiences (Bainbridge 2007, Davis et al. 2009, van der Land et al. 2011).

It has to be noted as well that when the exploration study described in this section was conducted in 2008, there was still a strong focus on the platform Second Life, mostly because of its popularity and the resulting great opportunity to conduct research (due to the larger number of participants and events), as compared to other virtual world platforms. However, a weaker focus on Second Life would most likely not have changed the results by a great deal, as it can still be seen as the most innovative of all virtual world platforms; other platforms focus even more on 2D collaboration in the 3D environment and less on the use of distinct features like responsive environment and virtual embodiment (see subsection 2.4.3).

3.3. Investigating the Added Value of Virtual Worlds

What value do virtual worlds add to existing modes of collaboration? This question is a key issue still unsolved for both the scientific community and commercial users, as well as for private users of virtual worlds. The previous section presented a classification of collaboration patterns according to their design effort and their 3D added value. This latter aspect, as discussed, is a vague construct in need to be (re)defined on the basis of empirical research results. The term 3D added value is usually mentioned in the scientific literature in the context of using 3D computer graphics to display spatial data and information. In the context of virtual worlds it had not been mentioned prior to the investigation presented in this section. Only years after, it was referred to as the benefits of using avatars in conjunction with narratives in 3D virtual learning environments for the formation of learner identities and for community-building (Wan et al. 2011).

The meaning we had attributed to the term 3D added value, however, was different. On the lines of Media Richness Theory (Daft & Lengel 1986), we defined 3D added value as the sum of all advantages of using the medium virtual world over a synchronous non-3D collaborative virtual environment, like video conferencing, collaborative drawing tools, or text chat. It would thus stem from the distinct features that virtual worlds offer, as distinguished from other media, namely customizable avatars, configurable space, and user-created, possibly interactive, content (see subsection 2.4.2 for a detailed introduction to these features). This 3D added value would further differ from application to application, meaning two different collaboration patterns would yield different degrees of 3D added value.

Since it would take a series of diverse studies and investigations to formally define a construct like this 3D added value on the basis of empirical research, the investigation described in this section only addresses it in part. The idea that led to the study stemmed from pondering on the main characteristic that distinguishes the medium virtual world from other media used for synchronous collaborative work and learning: its heavy use of graphics. We identified the visual character of virtual worlds as the first and foremost aspect that could lead to an added value for collaboration and therefore selected it as the subject of an empirical investigation.

3.3.1. Motivation and Research Question

Virtual worlds do not only make heavy use of graphics and visual cues, but are entirely based on it – on the provision of a vivid, visual environment. In contrast to most other media used for online collaboration, in virtual worlds textual and verbal communication plays a secondary role. This key distinction was oftentimes indirectly mentioned in the scientific discourse, but had never been empirically investigated.

We thus designed a controlled experiment to empirically compare collaboration in a virtual world with collaboration using another common online medium, in order to get an indication of what the real added value that results from the visual character of virtual worlds might be.

The decision of which collaboration medium to compare a virtual world to directly affected the design of the experiment and the outcome to be expected (and therefore our hypotheses). The intention was to select a medium similar to that of virtual worlds, though lacking the distinct features of customizable embodiment (i.e., avatars) and configurable environment (i.e., space and objects), as described above. This reasoning, combined with the substantial literature around the *Pictorial Superiority Effect* – introduced in the following paragraphs – led to text chat as the collaboration tool to compare virtual worlds against.

The Superiority of Visual Communication

There is empirical evidence that pictures yield better results than simple text in terms of recalled items and comprehension (this effect has been labeled *Pictorial Superiority Effect* (Nelson et al. 1976; see also section 2.6). The effect however is contingent on certain conditions that depend on the application context of images (Sternberg et al. 1995). Collaboration and information sharing in teams are one such context in which the Pictorial Superiority Effect has not been analyzed through experiments (for an exception see Stewart & Stewart 2001). The study presented in this section thus aims at examining the added value of visual communication for collaboration, based on the premise that the Pictorial Superiority Effect is also relevant for collaborative settings. Based on these existing findings, we extend the Pictorial Superiority Effect to the realm of team communication and hypothesize that cognitive and communicative tasks performed heavily using visual information lead to superior results than text-only supported ones. With this hypothesis holding true, these superior effects should not only be limited to recall, but also regard team productivity and group work quality.

Another theory relevant to the derivation of the hypotheses for the experiment is *Media Richness Theory,* which posits that a richer medium is more suitable for tasks with high ambiguity or uncertainty (Daft & Lengel 1986). In the case of the experiment at hand, the virtual world is the richer medium. In a simplified view, a virtual world can be seen as a text chat environment augmented by (a) the concept of space, (b) the fact of being represented or embodied as a customized avatar in that virtual space, and (c) the feeling of being there together as a team (i.e., presence, see subsection 2.3.1). Thus, by opposing these two media, the experiment was designed to let us examine the value of these latter notions separately, and to extrapolate the supposed added value of working in a virtual world, when dealing with real collaboration tasks.

A Common Collaboration Situation

A key prerequisite for effective team collaboration concerns the team members' knowledge about their different backgrounds, skills and experiences (i.e., their professional profiles). This situation, in which collaborating partners have only partial and biased information, has been labeled a *Hidden Profile Situation* (Stasser & Titus 1985; cf. subsection 2.1.1). While face-to-face interaction provides multiple opportunities for learning about these vital personal elements informally, a computer-mediated communication setting may make knowledge sharing about team members and their specific backgrounds more difficult. This knowledge sharing, however, may be crucial in order to assign roles or tasks according to abilities, to foster mutual understanding, and to ensure team cohesion and trust. Thus, it should be supported also in remote settings and other situations when people choose to work together online, mediated by computers.

Consequently, in the experiment described here we simulated a project kick-off meeting including three common tasks: the participants first need to present themselves to the team, then jointly clarify the main goals of the project. They further need to assign project roles to each member, based on their specific expertise, skills, and education.

The investigation was aimed at providing evidence for the existence of advantages in using 3D environments for collaboration tasks, thus aimed at partly answering research question RQ1 of this thesis. The research question for this experiment was *Can the distinct features of virtual worlds bring added value to collaborating online?* The approach to address this research question was to compare a collaboration meeting of groups in virtual worlds to groups using simple text chat.

3.3.2. Experiment Design

We implemented a 2x3 experimental design, with three tasks: (1) information sharing, (2) grounding and team discussion, and (3) decision making, and two conditions: (I) collaboration in a virtual world, and (II) collaboration in pure text chat. The independent variable was the environment for online collaboration, and the dependent variables were: satisfaction with process and outcome, productivity of the collaboration, and retention (memorability).

Hypotheses

Following previous research and the literature around the Dual Coding Theory and the Pictorial Superiority Effect introduced above, our first hypothesis was:

H1 Due to the visual character of the medium virtual world, collaboration in the virtual world leads to superior retention results than collaboration using pure text chat. (I > II)

Following the literature on *Embodied Social Presence Theory*, which posits that an embodied representation leads to higher engagement (Mennecke et al. 2010; see also section 2.6), our second hypothesis was:

H2 Being embodied as avatars in a 3D virtual world environment leads to higher motivation and satisfaction with the collaboration process, compared to working in pure text chat. (I > II)

Tasks and Test Environment

The simulated project-kick-off meeting consisted of three tasks. First, participants were required to introduce their personas to their team members, second, the team should discuss the project and agree on main project goals, and third, the team should assign its members to project roles. These tasks were given to all groups. While the control condition groups could only communicate using pure text chat (in Skype), the experimental condition groups meeting in the virtual world (implemented using the OpenSim platform) could use all the functionality the virtual environment offered, including the inherent text chat functionality. No voice communication was used in neither of the conditions. Our OpenSim environment was structured and supported the tasks as described in the following.

Each of the five team members of a virtual world group had an avatar that resembled the persona they received on an information sheet just before starting the experiment. The avatars were designed to portray key characteristics of the persona (find the information sheet with the full profile descriptions in Appendix A).

Figure 3.4. The avatars used in the experiment (Anne, Robert, Marcus, Paul, Jennifer).

Upon login, all participants landed at the location for the first task (shown in Figure 3.5), facing a signboard on which the main instructions for the first task were given, namely to introduce and present oneself to the other team mates. Each avatar's appearance corresponded to the profile information given to each participant (in terms of age, profession or hobby).

For the first task of introducing all the team members to each other, the participants were provided with one table each, on top of which informative objects had been put that helped each subject present its persona to the others (as seen in Figure 3.6). These objects included a computer with a web portal loaded on the screen for the person with a web publishing hobby, books and chalk for the team member who had a writing and teaching background, or two editions of economic newspapers for the person having worked in journalism. For the person having worked on housing mortgages a thesis document and a number of model houses had been placed on a table. Each participant introduced him- or herself through the text chat function, and by activating customized gestures (mostly used for hobbies; e.g. a tennis serve, dancing, and yoga stance, and kick boxing moves).

Figure 3.5. Entry point and location for the first task in the OpenSim environment

Figure 3.6. One of the team members presenting himself to the others, with help of personal objects

As each participant began to type and to reveal information about their persona the curtain around their own table began to fade automatically (while simultaneously, the other curtains closed), thus revealing to the others the objects that illustrated the participants' background. The presentation task lasted for approximately ten minutes and allowed the team members to learn about each participant's background (important information for the final task of assigning people to project roles). In the far corner of this first meeting location, the participants could see a signpost board pointing to a path that lead to the next task location (seen in Figure 3.5). Thus, from this first location, the participants then moved on to the second meeting place in order to discuss the project's main goals. All five team members thus walked along the path, leaving the tables and their objects behind.

Having arrived at the location for the second task, they re-gathered in front of a large target or bull's eye sign. The participants faced another signboard indicating that they were required to discuss the project's goals. The brief instructions also indicated how to capture the main goals on the target board (see Figure 3.7). Also here, there was a signpost and a pathway in the background that indicated in which direction the participants needed to proceed once they had completed the project scope discussion and documented it on the large bull's eye canvas. The time given for this task was also approximately ten minutes.

Figure 3.7. Project team discussing the project scope to fulfill the second task

After their second walk on a pathway, the participants reached the final meeting destination for the third task (shown in Figure 3.8 and Figure 3.9). This meeting spot contained four main artifacts: a set of bricks representing the web development or construction role (with the text label ‘Development’ hovering over it), a megaphone representing the marketing role (labeled ‘Marketing’), a white canvas representing the content and graphic design role (labeled ‘Content’), and a top hat, representing the project manager role (also with a hovering text label, ‘PM Hat’). While the first three objects were fixed to the ground and connected with three color-coded lines, the top hat was placed in the middle. The participants were instructed (again with a wooden board at the entrance of the area) to position their avatar near the one or two roles that they agreed made sense for their profile (for a description of this collaboration pattern see subsection 3.2.2 above; cf. also Friedman et al. 2007). The person that was appointed as the project manager needed to take the top hat, wear it, and also position him-/herself close to one or in between two roles (as seen in Figure 3.9, where the Anne persona was appointed as project manager). In this way each participant was able to assume the relevant/matching project role(s). With the positioning, the participants had completed their final task, as well as the overall team meeting.

Figure 3.8. Project team during the assignment of roles by positioning their avatars.

Figure 3.9. Team during the assignment of roles, with project manager role assigned (avatar Anne with project manager hat, inside the triangle).

3.3.3. Methodology

As argued in detail in the motivation above, the experiment was designed to measure the added value of collaborating in a virtual world in comparison to collaboration through simple text chat. This systematic media comparison was intended to extrapolate the value of a 3D virtual environment's essential characteristics: the fact of being embodied as customizable avatars in a configurable three-dimensional space.

Participants

Our subjects were 65 bachelor, master and PhD students with 11 different mother tongues, and of an average age of 25.15 years. 51.6% were female, 48.4% were male. 97% of the participants stated they had prior experience in working in teams. We also asked about their prior experience in both the media that were to compare, yielding a significant higher result for pure text chat than for 3D environments – on a scale from -3 (no experience) to 3 (a lot of experience) the average results were 0.93 for text chat and -1.49 for 3D environments or video games. This difference is graphed as the leftmost column pair in Figure 3.10.

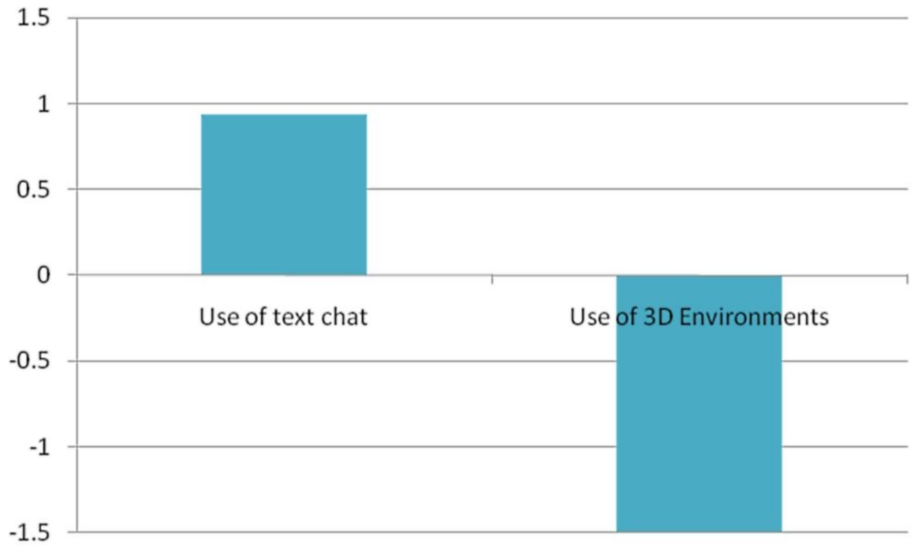

Figure 3.10. Participants' expertise with text chat (left) and with virtual worlds or 3D video games (right).

Procedure

The experimental groups used our configured virtual world to work on the collaboration tasks. The control groups worked on the same tasks in the control condition, using pure text chat. The virtual world groups used OpenSim (on virtual world platforms see subsection 2.4.3), while the text chat groups used Skype (a popular telephony and chat software, http://www.skype.com), without its audio and video conferencing functionalities. All participants were given the exact same information on the project and the tasks. Also the information on the persona profile was identical; the only difference between the information the groups received was the information needed to login to the virtual world, or sign on to Skype.

In order to ensure the simulation of a remote situation while still having a controlled experiment, we conducted it – in six sessions – in our university's computer labs, and paid heed to keep the participants from talking to each other. Only text chatting in the respective medium was permitted. Also, we understood it as crucial for the experiment results to not be influenced by any personal relations between the students, and thus seated the participants in a way that did not allow them to see the screens of other participants' in their groups. This way, their (hidden) profiles could only be shared communicating online, and could not be associated with a classmate's real identity, which could have significantly biased the retention results. The groups were randomly assigned by the experimenter, as suitable in most experiment settings (Friedman and Sunder 1994). Prior to these six sessions of which we analyzed the results, we conducted a pre-test with two groups of five students collaborating in our virtual world, and two smaller groups in text chat.

Measurements

Before commencing the online collaboration, the participants received a sheet containing all the required information about the collaboration tasks, the project context, as well as the detailed description of their profile to impersonate. With this sheet they received a first questionnaire that gathered demographic data including age, gender, mother tongue, and the subjective amount of prior experience in using text chat, and in using 3D virtual environments.

During the experiment itself we did not interrupt or interact with the participants, unless technical problems occurred. Any upcoming issues on software use were handled within the groups. The dependent variables were then measured with both objective and subjective measures, using two separate questionnaires as follows.

Directly after completion of the collaboration tasks the participants were asked to log out of the virtual environment, or to close the text chat, respectively. They were handed the first post-task questionnaire to retrieve subjective measurements: satisfaction with the collaboration process and outcome, perceived performance, communication characteristics, and the motivation or willingness to use the media for collaboration tasks again. In addition to 7-point Likert scales we used open questions to get the participants' subjective assessments and opinions about the respective media and its usefulness for collaboration tasks and meetings.

This first post-task questionnaire was followed by some unrelated announcements and discussion, which served the purpose to divert the participants from the experiment and its contents. Then, the participants were handed a second post-task questionnaire that tested the objective outcome of the meeting. For objective outcomes, in the experiment we focused on their recall of their team members' profiles and of the decisions made during the collaboration meeting. This second post-task questionnaire thus included two empty tables, merely with headings that structured the recalled items. The participants were asked to fill in all the information about their team mates they could recall into the first table, and make crosses in the second table to represent the assignment of project roles to team mates, as far as they could remember. For the analysis we counted the number of correctly remembered items. The used questionnaires are reprinted in Appendix B.

3.3.4. Results

The analysis of the main measurements of the experiment was done in three parts. The first part was a means analysis of the second questionnaire. Having used the same 7-point Likert scale from 'totally disagree' through 'totally agree' for all items, we switched the polarization of some categories for the graph in a way that for every item the positive value is upwards (i.e., the higher, the better). Figure 3.11 shows the graph of the means comparison; most items were rated positive in average. The uncut vertical axis ranges from -3 (very negative) through +3 (very positive). While we did not perform a firm statistical analysis to test for statistical significance (e.g. ANOVA) due to a large standard deviation throughout the data, a few implications from the means comparison can be extracted.

Subjective Measurements

Satisfaction (satisfaction of both process and outcome) was rated higher by the text chat groups, as were the items *No Personal Conflicts* (i.e., whether personal conflicts arose in the meeting), and *No Communication Difficulties* (i.e., whether communication difficulties arose in the meeting). Also the item *On-Topic* (i.e., an assessment of staying on topic vs. going off-topic) was rated more positively by the text chat groups.

The three task-related categories *Self-Presentation* (i.e., the perceived suitability of the respective medium for effectively presenting oneself to others; task 1), *Common Understanding* (i.e., if and how fast a common ground was reached; task 2), and *Role*

Assignment (i.e., if and how a reasonable role assignment was reached; task 3) were rated more positive (for tasks 1 and 3) by the virtual world groups than by the text chat groups, or equal (for task 2). The decision-making task was attributed with the highest average rating of the three, the self-presentation task with the lowest.

The categories *Media Feel/Re-use* (i.e., the assessment of how comfortable the participants were using the respective medium for the meeting and whether they would use it again), *Perceived Performance* (i.e., how well the participant and their team mates performed), and *Team Collaboration* (i.e., the overall rating of the collaboration) were on average rated equally positive by all groups in both conditions.

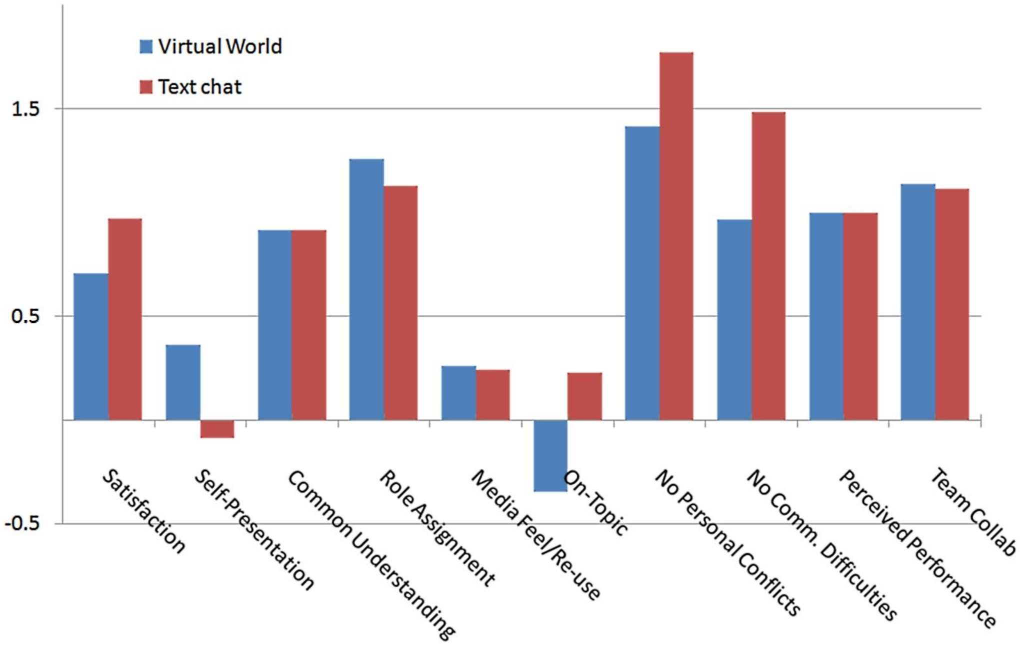

Figure 3.11. Means comparison of the subjective part of the questionnaire (value range of uncut vertical axis from -3: very negative through +3: very positive)

Due to the lack of a statistical significance of these results, we cannot reject our hypothesis H2, but it has to be noted that there is no indication pointing towards their verity. That is, the subjective measurements gathered in the experiment do not support the hypothesis that being embodied in a 3D virtual world environment improves the motivation and satisfaction of the collaboration process.

Objective Measurements: Retention

The second main part of the analysis was the coding and numeric comparison of the items the participants had recalled from the meeting. In the results, each correctly recalled item was marked (note: for the recalled age of the personas, an age interval of 8 years surrounding the actual age of the persona was interpreted as a correct answer). These as correct marked items were counted and put into comparison; the results are graphed in Figure 3.12. Although also here we did not conduct an ANOVA analysis to measure the statistical significance due to a large standard deviation in the data, the graph suggests a tentative tendency: the groups using the virtual world environment on average remembered more items about their team mates' profiles (for all the five different personas) as well as about the decisions made in the role assignment task. The unit of the vertical axis denotes the number of items recalled on average: for the profiles, there was a maximum of six items to remember, for the role assignment a maximum of four items.

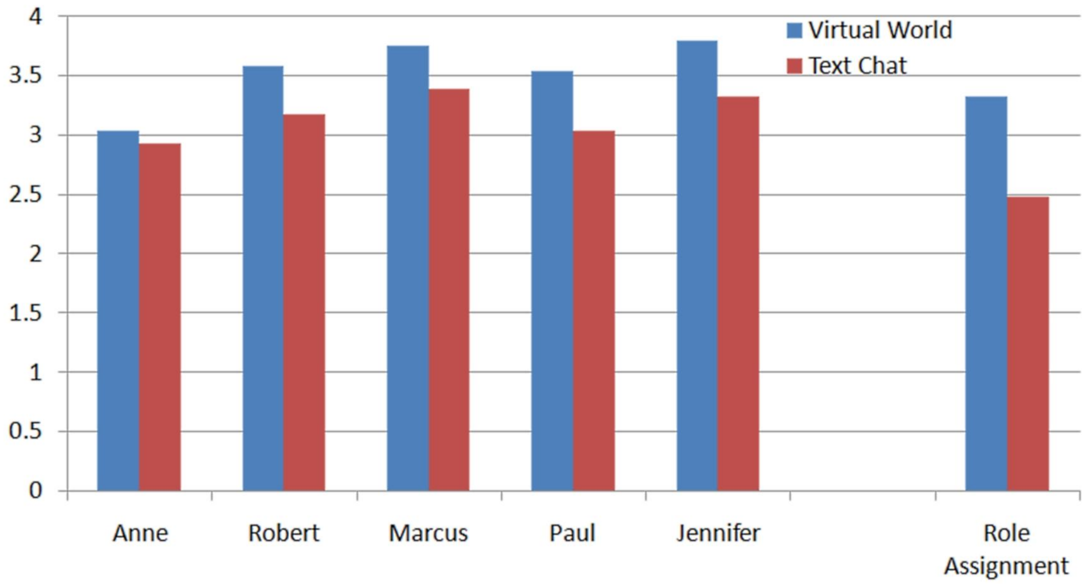

Figure 3.12. Objective retention measurements: recall of team mates' profiles and final role assignment (vertical axis: number of information items remembered in average)

While without a statistical significance of the results we cannot firmly state that the results confirm our hypothesis H1, the means comparison does give a tentative indication that virtual worlds may improve the recall of information and knowledge shared or created (decided upon) in a collaboration meeting in the environment, as opposed to collaboration using pure text chat.

Analysis of Text Chat

The third part of the analysis was a mixed quantitative and qualitative content analysis of the chat logs of both media environments. 10 of 13 groups communicated in English, three in the Italian language. A team meeting had a length of about 40 minutes in average, and consisted of about 1200 chat lines (these values are equal for both media). A first difference in chat usage we could observe was that participants in the virtual world environment entered shorter messages, but entered them more frequently than those participants in pure text chat. The use of emoticons was slightly higher in the text chat groups (7.8 emoticons in average per meeting, compared to 6.6 in the virtual world). The usage of capitalized text (usually for emphasis of speech, to 'shout') was used 2.2 times in average in the text chat, and only 0.8 times in an average virtual environment meeting. Participants were interrupted by their virtual team mates more often in the simple text chat condition (3.6 times in average, 1.0 times in the virtual world). We counted 14 deictic references in average in a meeting in the virtual environment (in the text chat groups, there were none – since deictic references are not applicable with pure text only).

Participants further stated in the open comment sections in the questionnaires that the pure text chat was often unstructured; virtual world users did not comment that once. Thus, it indicates that the concept of space and the environment design we used (above all the spatial separation of tasks with pathways) helped to structure the conversation and the team meeting in general. In debriefing sessions that were held in lectures of the students' master and bachelor programs, several participants confirmed that the several visual cues of different nature that were provided in the 3D collaborative virtual environment helped to memorize both information about the other participants and the decisions that were made during the online team collaboration meeting.

3.3.5. Discussion

For the interpretation of these results, we have to bear in mind the novelty effect of the medium virtual world: the polled expertise with the two media (graphed in Figure 3.10) shows that text chat is much more widespread than 3D virtual environments, and participants' comments also confirmed that the majority felt more comfortable in text chat, while some even reported a feeling of confusion when entering the three-dimensional virtual space. We expected this novelty effect to be visible in the questionnaire results and believe it to be a bias in the results in favor of text chat, and indeed some observed phenomena can be explained with it.

So does it seem probable that *Satisfaction* could be negatively biased by the discomfort and confusedness that many participants felt when they were in the virtual world. The subjective perception of the 3D environment (which we called *Media Feel*) and the participants' willingness to deliberately use the media for future collaboration tasks with colleagues or peers (*Media Re-use*) is also likely to be influenced by the novelty effect of the virtual environment. Again here, participants commented on their answers by stating that they did not feel at ease or that the medium was unfamiliar, and thus confirmed our interpretation of the novelty effect.

The biggest advantages for text chat in the subjective measurements, visible in the means comparison chart in Figure 3.11, appear to be in the categories *No Communication Difficulties*, *No Personal Conflicts,* and *On-Topic*. That is, more difficulties for communication seemed to have arisen in the virtual world groups, and participants seemed to get distracted more often, causing the effect to communicate off-topic. Unfortunately, we did not include a free-text comment option to these questions in the questionnaire which could have led to more insight for interpretation, but the possibility of the novelty effect causing a notable bias also here seems probable. An unfamiliar, media-rich, 3D environment can offer many different sources for distraction.

Two items that resulted in more positive mean ratings by the virtual world groups were two of the three task-related items; the third item was on average rated equally positive by all groups. The columns *Self-Presentation, Common Understanding,* and *Role Assignment* thus exceed or equal the mean ratings of the text chat groups. This diverse but portending task evaluation for virtual world collaboration gives two tentative indications, namely that (a) the medium virtual world may improve motivation for or satisfaction with collaboration when compared to pure text chat, and (b) the medium virtual world may lead to different magnitudes of (positive) effect for different types of collaboration tasks. Whether or not these measurements are negatively biased by the suspected novelty effect of the medium is unclear.

A possible superiority of virtual worlds over pure text chat was indicated by the retention measurements. These objective results, despite not statistically significant to prove our hypothesis, give a tentative indication that visual support and an immersive environment may improve recall of information and knowledge shared and created in online collaboration meetings. The fact that participants found collaboration in the virtual world condition to be more structured than in the text chat condition further suggests an importance of thoroughly designing and structuring the virtual environment for the collaboration that is planned to take place in it.

Purpose and Limitations of the Study

One negative outcome of the conduction of the experiment was that the presence – or rather, the absence – of a class's professor was reflected in the results of the satisfaction and the objective retention measurements. However, as this affected both conditions in equal shares we decided not to discard the data of the affected groups. Due to the fact that the open-source virtual world platform we used (OpenSim) was still under heavy development when we implemented our virtual environment, and due to the fact that it was the first time for us to run and host a virtual world on our own server, we ran into technical problems in two sessions. While we could resolve them in one case, the session was lost in the other case and we ultimately had to discard the data, decreasing the number of analyzable participant data sets to 65.

A flaw in the experiment design was that we failed to use pre-validated scales for the questionnaires, which resulted in large deviations of the entire data set, and thus results difficult to analyze. Using pre-validated scales would also pave the way for the use of inferential statistical analyses like ANOVA and ANCOVA methods.

Furthermore, it is to be assumed that collaboration outcomes other than retention can be quantitatively evaluated using similar experiment designs.

3.4. Conclusion of the Pre-Studies

This chapter has presented two pre-studies that were conducted prior to the main research steps of this doctoral thesis. The first pre-study was an exploration study in the virtual world Second Life, with the aim of understanding how collaborating teams and groups make use of virtual worlds. This exploration resulted in a first description structure that was necessary to formalize virtual world collaboration patterns, and in a classification of virtual world collaboration patterns according to their design effort and their 3D added value. As the second pre-study, a controlled experiment was conducted, investigating the added value of virtual worlds – in particular, of being represented by customizable avatars in a configurable 3D virtual environment – for collaboration, in the realistic setting of a project kick-off meeting. Besides gathering first positive indications about the usefulness of 3D virtual worlds for collaboration tasks we could put our virtual world environment to a first test and got valuable insights into conducting experiments with this medium.

With these pre-studies leading to first indications that (a) virtual worlds seem to offer a real added value to online team collaboration and that (b) a formalization using a pattern-based approach can be a very valuable asset for both research and practice, the motivation of the thesis project was fortified. Already the presented first description structure was by and large accepted by the scientific community; it had become evident that a more detailed and scientifically-grounded formalization or framework had to be developed. The experiment findings gained from the second pre-study on the other side gave motivation for a more thorough investigation of collaboration in virtual worlds, putting an emphasis on the design of the virtual environment and the collaborative activities in it.

Regarding research question RQ1 of the thesis, we can observe tentative indications towards an affirmative answer to the question of *if* 3D virtual environments can add real value to online collaboration. However, further empirical investigations are required to investigate the question *how* these virtual worlds add real value, and how designing the 3D collaborative environments could maximize this added value. As part of an answer to the question of *how* virtual worlds can support collaborative environments we can observe a positive indication as to the usefulness of harnessing the medium's distinct features, namely the visual character and the virtual embodiment. This tentative assertion is supported by theories (i.e., Pictorial Superiority Effect and dual coding theory, Embodied Social Presence Theory, Media Richness Theory) and by indications from the means comparison of the results of the experiment measurements. The pre-study experiment also showed that the distinction between different task types did make sense and has to be considered also for further investigations.

By giving indications of the usefulness of collaboration in virtual worlds, the pre-studies pointed the way ahead in two directions. Therefore, the remaining part – the main part – of the thesis project was designed as a logical continuation of the described research efforts. Chapter 4 describes the development of a sophisticated framework for avatar-based collaboration (addressing RQ2, and a continuation of the first pre-study), then Chapter 5 presents a more thorough experimental investigation of collaboration in virtual worlds, focusing on the design of the environment and the collaboration tools and activities in it (i.e., addressing research question RQ3), as anticipated above.

Chapter 4: A Framework for Avatar-Based Collaboration

Chapter 4: A Framework for Avatar-Based Collaboration

This chapter is partially based on the following publications:

Schmeil, A., Eppler., M.J., & de Freitas, S. (under second revision). A Structured Approach for Designing Collaboration Experiences for Virtual Worlds. *Journal of the Association for Information Systems (JAIS).*

Schmeil, A., & Eppler., M. J. (2009b). *Formalizing and Promoting Collaboration in 3D Virtual Environments – A Blueprint for the Creation of Group Interaction Patterns.* In Proceedings of First International Conference of Facets of Virtual Environments (FaVE 2009), July 27-29, Berlin, Germany.

4.1. Motivation

While 3D virtual worlds are being increasingly used as interactive environments for online collaborative work and learning, there is still no structured approach developed specifically for the combined design of 3D virtual environments and collaborative activities within them. Formalizing both the structural elements of virtual worlds and collaboration or didactic aspects of collaborative learning can help to develop fruitful collaborative work and learning experiences.

Addressing the second research question (RQ2) of the thesis, namely *How can we support the process of designing for fruitful collaboration experiences for virtual worlds*, this chapter presents the development of the Avatar-Based Collaboration Framework (ABC Framework). Based on semiotics theory, the framework puts the collaborating groups into the focus of the design and emphasizes the use of distinct features of 3D virtual worlds for utilization in collaborative learning environments and activities. It represents a blueprint of how collaborative group interaction patterns in virtual environments can be described or generated.

Along with the framework we present a case study of its first application for a global collaborative learning project. This chapter particularly addresses virtual world designers and other practitioners by thoroughly describing the process of creating rich collaboration and collaborative learning experiences for virtual worlds with the ABC Framework.

The Avatar-Based Collaboration Framework is intended to form a first important step in the process of formalizing collaboration in virtual environments – a task that is crucial in order to put forward the application of 3D virtual environments for serious and productive uses.

This chapter first reviews related work in developing frameworks for virtual worlds. It then describes the methodology applied in the creation of the framework and elaborates in detail on each of the elements of the framework, including the background and the implementation of the pattern-based approach (section 4.4), the use of the semiotic triad as an organizing schema (section 4.5), and the classifications of action in virtual environments (section 4.6) and virtual objects (4.7). Section 4.8 illustrates the resulting framework, before section 4.9 describes the framework's first use case.

4.2. Frameworks for 3D Virtual Environments

The development – and deployment – of conceptual frameworks conceived with the aim of guiding the purposeful design of virtual worlds and activities in virtual environments and virtual world applications has set in only in recent years. We could observe a handful of design frameworks and structured guides come up for the major application domains virtual worlds are used in. These frameworks range from very specific to very broad in scope. The following paragraphs first introduce the frameworks, before Table 4.1 gives an overview and shows a comparison.

De Freitas & Oliver (2006) combine the two main strands learning theory and human-computer interaction (HCI) in order to build their four-dimensional framework, which brings together the four elements of learner, learning theory, representation of environment, and context. The main purpose of their framework is the evaluation of games-based and simulation-based learning activities, but it can also be used as a guide for the development of learning games and simulations.

Minocha & Roberts (2008) apply the SECI model of Nonaka & Takeuchi (1995) to the design of activities involving a combination of 3D virtual worlds and 2D tools. Following this approach they developed a broad guide for the organization of 2D and 3D activities in distance education scenarios that guides the instructional designer in the decision when and for what purpose in the SECI process to use which 2D/3D media.

In the context of business and innovation, Nambisan & Nambisan (2008) present four sets of virtual customer environment (VCE) strategies and practices. Companies can apply these as a basis for the development of different strategies for the use of virtual collaborative environments, leading to predictable impacts on the customer experience. They propose to target four dimensions of experience: pragmatic, sociability, usability, hedonic. These have been applied in recent research regarding co-creation in virtual worlds (see Kohler et al. 2011).

Tuukkanen et al. (2010) point to the trend of a steadily growing number of children in virtual worlds and present a framework of children’s virtual participation in virtual worlds. Their framework is structured in four levels, considering the form of participation, the child’s role, the role of the virtual world, and the affordances of the virtual world.

In an extensive work, Kapp & O’Driscoll (2010) present a framework for the design of 3DLE (3D Learning Environments), the so-called 3DLE Architecture. Their framework builds on classifications of sensibilities (effects that virtual worlds trigger) and archetypes (exemplary collaboration patterns) into the four macrostructures of agency, exploration, connectedness, and experience. The correct alignment of the structural levels of the framework is key for successful design of 3DLE. Although this framework addresses virtually the same purpose we address, it is no answer to our research question, as it is solely based on experiences of the authors and select experts and does not provide a comprehensive formalization, let alone an implementable description structure.

While all these approaches provide guidance for the organization and broad conception of virtual world activities in their respective application domains, none of them assists virtual world designers or managers in the very design, setup, and implementation of engaging collaborative activities and innovative behavior patterns. The presented frameworks offer guidelines for

- when to deploy virtual worlds (in the case of Minocha & Roberts 2008),
- what to consider when deploying virtual worlds (as in de Freitas & Oliver's work, 2006),
- which strategies to apply for which virtual customer profiles (Nambisan & Nambisan 2008),
- how to involve participants (in the cited case, children; Tuukkanen et al. 2010), and
- which potential effects and design examples to consider when designing learning environments (Kapp & O'Driscoll 2010).

	Application domain	**Purpose**	**Structure**	**Main elements**
de Freitas & Oliver 2006	Game-based, simulation-based learning	Evaluation of educational games and simulations	4 dimen-sions	- Context - Learner - Learning theories - Representation, tools
Minocha & Roberts 2008	Distance education	Framing of virtual world activities in distance learning	4 stages	- Socialization - Externalization - Internalization - Combination
Nambisan & Nambisan 2008	Customer experience	Mapping of VCE strategies to customer profiles	4 sets of strategies	- Encourage innovation - Link external-internal - Manage expectations - Embed customer in CRM activities
Tuukkanen et al. 2010	Civic participation	Improvement of children's participation in virtual worlds	4 levels	- Form of participation - Child's role - World's role - Affordances
Kapp & O'Driscoll 2010	Learning	Design of engaging 3DLE according to a set of principles	4 levels	- Principles - Macrostructures - Archetypes - Sensibilities

Table 4.1. An overview and comparison of the introduced frameworks.

With all of the different types of frameworks manifesting themselves as rather broad guides, there is no reference of a structured framework in the form of a blueprint, aiming to guide the design of a virtual environment to meet specific needs, or to support the development of novel ways to interact and collaborate in the environment. Applying a more human-centric approach to the design of virtual world environments – and in particular the activities to take place in them – right from the start of the design, might solve the problem of the balking acceptance of virtual worlds as a mainstream collaboration platform (cf. Gartner 2008-2011; on a human-centric approach to designing cf. Streitz et al. 2005, Hassenzahl 2010).

The approach we followed in developing the Avatar-Based Collaboration Framework that is described in this chapter was therefore a human-centric one. The framework is intended to serve as a blueprint on which the most diverse kinds of collaborative work and collaborative learning tasks can be designed, formulated and executed. Before the presentation of the framework by means of an illustration in section 4.8, the preceding sections first describe the various steps taken in the development process.

4.3. Methodology

The methodology for the development of the framework is based on design science research (DSR). The term design science research defines research using design as a research method or technique. The seminal paper by Hevner et al. (2004) provides an overview of the application of DSR in the Information Systems (IS) field. They also present seven guidelines for conducting good design science research that were heavily cited in the almost-decade after the paper's publication, and thus significantly helped shape the relatively young research area. According to their guidelines, a design science research contribution requires the identification of a relevant and important problem, the lack of a solution, the development of a viable artifact that addresses the problem, a rigorous evaluation of the artifact, an articulation of the contribution to the relevant knowledge-base and to practice, and an explanation of the implications for management and practice (Piirainen et al. 2010). DSR has been applied *in* virtual worlds only recently (for innovation workshops in Second Life; Helms et al. 2010), but so far not on the topic of designing collaboration *for* virtual worlds. Santos (2010) proposes design-based research, an approach related to DSR, as a viable methodology for virtual worlds.

Our goal was not to meticulously satisfy all of these guidelines, some of which can be seen as too stringent or not applicable, as Venable (2010) argues. However, our methodology does meet a select subset of the so-called *design-science research guidelines* (Hevner et al. 2004, p. 83), as the following list illustrates:

- We address a relevant and important problem: as the scientific literature as well as business and market analyses show, both the evolution of virtual worlds and its acceptance as a mainstream collaboration tool are hindered by a lack of human-centered design, thus by the lack of structure and formalization.

- Our research produces a viable artifact: the artifact produced in our research comes in form of a framework. The framework is a detailed guide that serves both as a description structure and as a blueprint for development.
- We present a clearly explained new method for using the framework: the illustration of the framework in section 4.8 is accompanied by an explanation of the different ways the framework can be used.
- We present example instantiations of the framework: section 4.9 introduces the first use case for the framework and presents 13 example patterns created with it, three of which are explained in detail.
- We clearly identify the novelty, generality, and significance of the contribution: the discussion in section 4.10 addresses all these topics.
- We present the research to address both rigor for the academic audience and relevance for the professional audience: the ABC Framework was developed on scientific works, serves as a valuable description tool for further research, as a development tool for designers, and as a management tool for practitioners.

With the contribution presented in this chapter we aimed to provide the virtual world community with a viable tool for the design of engaging and memorable experiences, putting a focus on the making use of the distinct features of the medium. In the development of the framework we have drawn from best practices in instructional design and game design, research in HCI, and specific findings from our own empirical research investigating collaboration patterns in virtual worlds (cf. the pre-studies presented in Chapter 3).

A rigorous evaluation of the created artifact (i.e., the entire framework) is not possible in the scope of this thesis project, due to its complexity and the high number of variables. The subsequent Chapter 5: provides an evaluation of distinct virtual world features; it can be understood as an evaluation of parts of the framework. The discussion at the end of this chapter expands on the connection between this and the following chapter.

4.4. Describing Avatar-Based Collaboration through Patterns

While identifying group interaction patterns of collaborative work and learning in the virtual world Second Life (cf. section 3.2), the need for a solid formal framework that is capable of describing collaboration in virtual worlds in all its aspects became apparent. For this purpose, patterns are a very useful and concise approach. Due to the reproducibility, the transparency, the clarity, and the flexibility inherent to the pattern approach, describing and classifying different forms of online collaboration in a formalization based on a pattern approach promises to

- result in a format that allows to share patterns with others, to discuss patterns while being able to refer to specific elements in their description, and to accurately compare different patterns,
- facilitate the development of a (possibly hierarchical) pattern language of virtual world collaboration, and
- provide a detailed documentation not only helpful during the development and for reuse but can further be used as a basis for defining formal requirements to virtual world designers, object modelers, and script developers.

Subsection 2.1.2 introduces and explains the pattern approach and its applicability for formalizing collaboration in more detail.

We adapt the definition of a collaboration pattern as *"a set of techniques, behaviors, and activities for people who share a common goal of working together in a group"* from Gottesdiener (2001) by adding the notions of tools and a shared meeting location (representing the distinct feature of having responsive environment in virtual worlds), to result in the following new definition of a collaboration pattern:

> *A collaboration pattern is a set of tools, techniques, behaviors, and activities for people who meet at a place to work on a common goal, together in a group.*

How exactly this definition ultimately influenced the development and supported us with a foundation for the layout of the final resulting framework will be explained by means of an illustration in section 4.8.

4.5. The Semiotic Triad as an Organizing Schema

One of the main goals of the development of the Avatar-Based Collaboration Framework was to provide virtual world researchers and practitioners with a structured formalization. For this structure to stand on firm and stable ground, a proven organizing schema was needed as a foundation. Semiotics, also referred to as Semiotic Theory, offers a very suitable organization for this purpose, as it is shown in this section.

4.5.1. Semiotics

Semiotics is the science of signs, investigated in the interpretation of signals in interpersonal communication (Eco 1978). Semiotics is understood as applied linguistics, extending the concept of vocabulary beyond words, encompassing all possible types of signs. In the domain of virtual worlds, concepts from linguistics are (often implicitly) referred to when using terms like vocabulary to describe pools of available virtual artifacts, or alphabet to denote affordances in virtual worlds (Jarmon 2009). Semiotics can be applied to the domain of virtual worlds as follows.

From a theoretical point of view, one can conceive of collaboration activities as interpretive actions and of collaboration spaces as sign systems in need of joint interpretation. Visual, spatialized on-screen events have to be interpreted by users of a virtual environment as relevant, meaningful, context-dependent signs that contribute towards joint sense making and purposeful co-ordination. As is the case in any sign interpretation system or (visual) language, semiotic theory informs us that three different levels can be fruitfully distinguished, namely the syntactic, semantic, and pragmatic ones (Morris 1938). This threefold distinction has already been applied effectively to various forms of information systems or social online media (see for example Shanks 1999, or Schmid & Lindemann 1998).

4.5.2. Implementation

The three distinct interpretive layers syntactic, semantic, and pragmatic form the basic structure of the ABC Framework. They are applied as follows to 3D virtual worlds:

The Syntactic Layer

The syntactic layer of the ABC Framework encompasses the infrastructure, the main visible components of a collaboration pattern. They can be understood as building blocks, with which patterns are constructed. Through a clearly structured formalization of actions (see section 4.6) and virtual objects (see section 4.7), the syntactic dimension ensures the readability of a collaboration pattern. Also, it provides the necessary elements as well as mechanisms that can be combined to create new patterns.

The Semantic Layer

The semantic layer refers to the acquired meaning of elements and to the conventions used in a collaboration pattern. It outlines which infrastructure elements assume which kind of meaning within a context, or towards the solution of the problem. While the syntactic layer illustrates which elements a collaboration pattern contains, the semantic layer – the 'dramaturgy' – puts these in relations and defines meaningful combinations that make sense with regard to the goals of the pattern. In this sense the semantic level is a liaison layer between the virtual world and the participants' objectives.

The Pragmatic Layer

The pragmatic layer reflects the social context of the participants, and their practices, goals and expectations. It is these actions that need to be supported through the dramaturgy (semantic layer) and the infrastructure (syntactic layer). This layer clarifies in which situations which types and combinations of dramaturgy use and infrastructure use make sense.

Table 4.2 presents the application of the semiotic triad for the development of the Avatar-Based Collaboration Framework. It has to be noted that the layers described above are printed in the opposite order, as the syntactic layer is the most basic one, on which the others build. This order is the order also used in the framework.

Semiotic triad	**Layers in the ABC Framework**	**Subordinate layers in the ABC Framework**
Pragmatic layer	Context	
	Goal	
Semantic layer	Dramaturgy	
Syntactic layer	Infrastructure	Actions
		Objects

Table 4.2. The application of the semiotic triad in the development of the Avatar-Based Collaboration Framework.

Using the semiotic triad as an organizing scheme for the development of the final framework has proven to be a coherent and solid foundation, as the illustration section 4.8 and the description of the first use case in section 4.9 will explain in more detail.

4.6. Action and Interaction in 3D Virtual Environments

In our understanding, the support of action and interaction forms a major part of a virtual environment's infrastructure. It determines how users can act and affects their behavior in both lonely jaunts and group settings. Moreover, the way users can control their avatars and perform actions can heavily influence the level of satisfaction of the user and thus may in the end determine whether or not collaborative work or other planned tasks in the virtual environment succeed or fail (cf. Davis et al. 2009). In order to manage action and interaction, we believe that a formalization of the concept in various forms in virtual environments on a high abstraction level is required.

4.6.1. Related Classifications

Manninen applied a social theory framework in order to create a taxonomy of interaction, resulting in a classification consisting of eight categories: Language-based Communication, Control & Coordination, Object-based Interactions, World Modifications, Autonomous Interactions, Gestures, Avatar Appearance, and Physical Contacts (Manninen 2000). While this is a useful and accurate description of the expressive repertoire available in virtual worlds, this classification is only based on studies in multi-player online action and role-playing games, where different requirements regarding interaction must be assumed than for serious collaborative tasks. Also, as the author also concedes himself, the social theory framework might have put the study too much in a language-centered perspective and might have neglected some of the genuinely visual aspects of virtual worlds. Furthermore, the end result (i.e., the classification) lacks a formal rationale and does not entirely meet the criteria of a taxonomy (i.e., empirically derived, disjunctive and exhaustive groups, single classification principle per level, etc.).

In the field of Human Computer Interaction (HCI) and particularly Virtual Reality (VR) and 3D User Interfaces (3D UI) there is a generally accepted distinction among navigation and manipulation techniques (Bowman et al. 2005). Navigation techniques consist of techniques for moving one's position and for changing one's view. Manipulation techniques designate all interaction methods that select and transform or modify objects in a virtual space. In some cases, the side category System Control is used, consisting of all actions that serve to change modes and modify parameters, as well as other functions that alter the virtual experience itself. 3D user interface expert Doug Bowman and colleagues refine this classification by adding a fourth category Symbolic Input, describing the communication of symbolic information (text, numbers, and other symbols or marks) to the system (Bowman et al. 2005).

Davis et al. (2009) categorize virtual world (or, 'metaverse') technology following a capabilities approach. They provide classifications of communication, rendering, and interaction capabilities in virtual environments. Much of their classification work addresses the technological capabilities of the medium virtual world itself, rather than the capabilities of action and interaction that exist for avatars inside a virtual world (i.e, in-world). However, the ones that are of interest to our goal of classifying action and interaction are their interaction categories Interactivity, Mobility, and Immediacy of artifacts, as well as their communication category Multiplicity of cues and channels. By interactivity they mean techniques for manipulating the virtual environment and objects in it (comparable to manipulation in the HCI classification), mobility describes the navigation category from the HCI classification, and the immediacy of artifacts refers to the creation of different forms of objects in virtual environments (which can be seen as a subcategory of manipulation techniques), while the multiplicity of cues and channels describes the fact that interaction in virtual worlds is potentially multimodal (i.e., a combination of verbal communication, gestures, voice and tone of voice, proxemics, see Yee et al. 2007). Therefore, in comparison, the 'traditional' HCI / 3D UI classification provides a clearer distinction, also from a terminological point of view.

4.6.2. Our Approach

For our purpose of formalizing (inter)actions for collaboration, we build on the clear classification from HCI / 3D UI and make adjustments to align it with the requirements of the area of virtual worlds. The following paragraphs describe the main classes of our classification, and Table 4.3 provides an overview and clarifying examples of the resulting two-level classification of action and interaction in virtual worlds.

Communicative Actions

The importance of communicating text, numbers, symbols, and also speech to the system (and thus to other avatars or users, interactive objects, or the environment itself) has increased significantly. We call this first category Communicative Actions. A sub-division differentiates between verbal (i.e., text and voice chat) and non-verbal communication (i.e., nodding, gesturing).

Navigation

Having combined navigation techniques and methods for changing the view in one shared category results from the fact that HCI and VR systems do not necessarily assume the existence of an avatar as a personalization device in the virtual environment; without this embodiment, navigating and changing the viewpoint can be considered as one and the same action. In our classification, changing one's view falls into the communicative actions category, as a non-verbal form of letting others know where the user's current focus of attention is, or to communicate a point or object of interest to others in the virtual environment. As a result, our second category, Navigation, merely comprises walking, flying and swimming, and teleporting.

Object-related Actions

We rename the manipulation techniques category (selecting and modifying objects) to Object-related Actions. Actions referring to the creation or insertion of virtual objects also belong to this category, along with selection and modification techniques. By insertion we mean the result of uploading or purchasing virtual objects, for instance.

All interactions concerning system control are much less important in contemporary virtual worlds than they are in classic Virtual Reality systems. Due to the often customized or prototype forms of VR applications, system control is in many cases developed and tailored to a single application. In virtual worlds, by contrast, the viewer software (i.e., the client application to enter the virtual environment) is usually standardized and provides a predefined set of system control options. Hence, we omit the system control category for the description of collaboration patterns.

Category	**Subcategory**	**Description**	**Specific examples or applications**
Communicative Actions	Verbal	Voice chat, text chat (public and private messages)	Oral presentation, discussion in local chat, private messages, podcasts
	Non-verbal	Gestures, gaze, facial expressions, body posture, avatar appearance	Waving goodbye, sad face, exhausted body pose, white beard
Navigation	Walk	Walking, running, moving sideways	Moving from A to B, walking around an object, getting closer to somebody
	Fly / Swim	Flying in air, floating, swimming/diving	Roaming a floating three-dimensional exhibition, diving for a treasure
	Teleport	Switching (‘beaming’) to another location without moving	Traveling long distances in an instant, bypass difficult terrain or obstacles
Object-Related Actions	Select	Putting objects in personal focus, e.g. for subsequent actions	Refer to objects during a presentation, start modifying an object
	Create / Insert	Creating new objects from scratch or importing objects	Making a chair to sit on, importing a model home created outside the world
	Modify	Transforming, moving, activating, reshaping, re-coloring an object	Making a couch wider, changing the wallpaper in a house, kicking a ball

Table 4.3. Two-level classification of action and interaction in virtual worlds.

4.6.3. Potential Alternative Approaches

If one were to put these actions on a continuous spectrum, they could also be distinguished in terms of their virtual world effects or their level of invasiveness or (space) intrusion. Chatting or changing one's avatar appearance, view, or position is far less intruding than moving an object, triggering a rocket, or blocking a door. It has to be noted that these distinctions and the resulting classification do not include virtual objects. Those require a separate classification that takes their manifold types and functions into account. In the following subsection, we discuss this other central element of a virtual environment's infrastructure.

4.7. Classifying Virtual Objects

In his successful book The Design of Everyday Things, Donald Norman postulates that people's actions and human behavior in general profits from everyday objects being designed as to provide straight forward affordances, i.e., they should communicate how they should be used (Norman 1988). He argues that less knowledge in the head is required (to perform well) when there is, what he calls "knowledge in the world". This insight can be fruitfully applied to virtual worlds by building on latent knowledge that users have and by providing cues that reuse appropriate representations (Smith & Harrison 2001). This not only gives motivation for practitioners to utilize virtual environments for collaborative tasks, but implies that objects in virtual environments and their design are of great importance. Hence, we understand virtual objects as to form another major part of a virtual environment's infrastructure that goes along with the previously discussed part of action and interaction. Affordances can (and should) be used to signal users how to interact with a particular object, or how objects with built-in behaviors may act without any direct influence from the user.

One problem that arises is that those mental representations – or mental models, as Norman calls them – may trigger more expectations as to how objects and the environment may behave than current virtual worlds may be able to provide (Norman 1988). In an opposite case users might not anticipate any functionality when acting in a virtual environment, and might get easily confused or disoriented when things happen without a direct command. As a result, for the time being, two extreme types of users of virtual environments are possible: underestimating and overestimating ones. This might in fact be part of an explanation to why it takes (or took) so long for virtual worlds to become accepted and be viewed as being more than just games, although they have been debated in research and practice for so many years. But that left aside, a fact is that for a long time virtual environments researchers and developers have focused largely on graphical representation and rendering issues.

4.7.1. Objects in Virtual Environments

With the launch (and most of all with the hype) of Second Life, a new era of accessible online virtual environments has begun. Following the trend of enabling users to create content, which is also an essential element of the definition of the Web 2.0, Second Life users could for the first time create and edit virtual objects, and also customize the appearance of their avatars, directly in a persistent virtual world (if we disregard Active Worlds, which provided content creation features long before, but unfortunately was never widely used). See also subsection 2.4.2 on user-generated content creation.

With the possibility of scripting objects, meaning programming them in order to make them responsive to user actions, execute animations or follow behaviors, or simply update their own states continuously, virtual objects have become a powerful instrument in designing memorable user experiences in virtual worlds. In fact, interactive virtual objects represent technology in virtual environments; without active and interactive objects, any virtual environment would be nothing more than a virtual version of a world without technology.

4.7.2. Related Classifications

In spite of their crucial functional importance, little research has been conducted on classifying virtual objects so far. More work has been done on the technical side; for instance, the approach of including detailed solutions for all possible interactions with an object into its definition has been proposed (Kallmann & Thalmann 1998). These so-called smart objects integrate descriptions for sub-objects on how to behave, on positions for avatars or agents to interact with, and provide gestures up to the precision of finger splay. Another later presented framework takes up on this idea and adds inter-object interaction definitions (Jorissen & Lamotte 2004). Currently at least the two virtual world platforms Second Life and OpenSim support defining avatar positions for interaction within an object definition, as well as inter-object communication.

A first informal classification of virtual objects was proposed by Smith and Willans while investigating the requirements of virtual objects in relation to interaction needs: the authors state that the task requirements of the user define the behavioral requirements of any object. Consequently, they distinguish between background objects, which are not critical to the scenario, contextual objects, being part of the scenario but not in the focus, and task objects, which are central to the scenario and the actions of the user (Smith & Willans 2006). While this distinction may be useful for determining the level of importance of virtual objects, i.e. in requirements analysis phase, it does not distinguish objects based on their actual functioning.

4.7.3. Our Approach

Hence, we present a classification of virtual objects in three categories. The following paragraphs describe the main classes of our classification, and Table 4.4 provides an overview and clarifying examples of the resulting two-level classification of action and interaction in virtual worlds.

Static Objects

Static Objects solely exist; they do not follow any kind of behavior and do not respond to any of the user's actions. We distinguish between fixed objects that are not meant to be moved (such as statues, furniture, architecture) and portable objects, meant to be picked up or carried around, held, or worn (such as handheld objects, items that hover over the avatar, and hats and distinctive clothes in general). This quality does not have to be persistent; the categorization should work in order to describe the collaboration pattern.

Automated Objects

Automated Objects either execute animations repeatedly or by being triggered. Alternatively they follow a behavior (ranging from simple behaving schemes such as e.g. following an avatar, to highly complex autonomous, intelligent behaviors). We further separate the most rudimentary of all object behavior forms into an extra sub-category – the behavior of merely continuously updating its state or contents.

Interactive Objects

Interactive Objects represent generally the notion of a tool or instrument; either they produce an output as a response to a given input, or they execute actions on direct user commands (e.g., a remote control), or they act as vehicles, meaning that the user directly controls their movement (with or without the user's avatar on it), using the primary navigation controls.

The border between automated and interactive objects may seem fuzzy at first, but it is clearly delineated by the differentiation whether a user triggers an object to act deliberately or not. It is to say that this classification does not aim for being formally mutually exclusive, it is rather meant to be applied as a means of structuring and formalizing objects by their primary function or characteristic in the particular collaboration pattern they occur.

Category	**Subcategory**	**Description**	**Specific examples**
Static Objects	Fixed	Objects that are fixed and not meant to be moved	Statues, symbols, buildings, most furniture, static plants and trees
	Portable	Objects that are portable and meant to be picked up and carried around	Flags, name tags, distinctive marks, symbols, teddy bears
Automated Objects	Update State	Objects that update their state over time or through external sources	Visitor counters, calendars, weather displays, webcam images
	Execute Animation	Objects that execute pre-defined animations (navigate or manipulate)	Machines, clocks, drifting or growing plants, animals, animated plays
	Follow Behavior	Objects that act according to given behavior rules and react to events	Robots and chat bots, complex plants and animals, 'non-player characters'
Interactive Objects	Input / Output	Objects that produce an output to discrete user input	Text and voice translators, calculators, web browsers, photo booths
	Tools, Instruments	Objects that execute actions as direct translation of user input	Remote controls, gadgets, weapons, chainsaws, machetes, fishing rods
	Vehicles	Objects that move as direct trans-lation of user navigation control	Cars, airplanes, helicopters, boats, unicycles, flying carpets, parachutes

Table 4.4. Two-level classification of objects in virtual worlds.

4.7.4. Alternative Approaches

Considering alternative classification properties, for example the distinction of size, whether virtual objects can be entered or not, or follow physical laws (e.g. moving in the wind), is in our belief of secondary importance – especially for the use cases we try to support with our contribution (i.e., collaboration tasks).

4.8. A Blueprint for Avatar-Based Collaboration

This section presents the developed Avatar-Based Collaboration Framework (ABC Framework). The ABC framework supports and fosters the development of innovative collaboration patterns for virtual worlds by providing a formalization that connects the distinct features of the medium (the infrastructure) with specific collaboration and learning goals in given contexts. To establish this connection it provides a dramaturgy layer that adds semantic values to the syntactic elements of the medium (i.e., available actions and objects), defining macro-actions, settings, roles, steps, timing, etc.

Figure 4.1 shows the framework based on the distinctions described in the previous sections. It is intended as a blueprint for avatar-based collaboration in virtual environments. As such, it can be used as a basis to describe collaboration patterns in virtual worlds, but also as a powerful development tool. Its three-tier architecture reflects the syntactic, semantic, and pragmatic levels (i.e., the semiotic triad) of the collaboration medium, as discussed in section 4.5.

To a similar degree it reflects our adapted definition of a collaboration pattern. Section 4.4 introduced our definition of a collaboration pattern as being *a set of tools, techniques, behaviors, and activities for people who meet at a place to work on a common goal, together in a group*. The fact that the framework is built on this definition as a foundation becomes clear when reading the definition element by element while traversing the framework in Figure 4.1 from bottom to top. This then reads as *a set of tools* (objects)*, techniques* (actions)*, behaviors* (what: rules)*, and activities* (what: macro-actions, steps) *for people* (who: participants) *who meet* (when: timing) *at a place* (where: setting) *to work on a common goal* (goal, context), *together in a group* (who: roles, relations). Therefore, using the wording of the framework, this translates to a set of objects, actions, rules, and steps for participants with roles who meet at a location to collaborate on a common goal in a given context. A developed collaboration pattern thus becomes an instance of the framework and can be defined using the parameters within the framework.

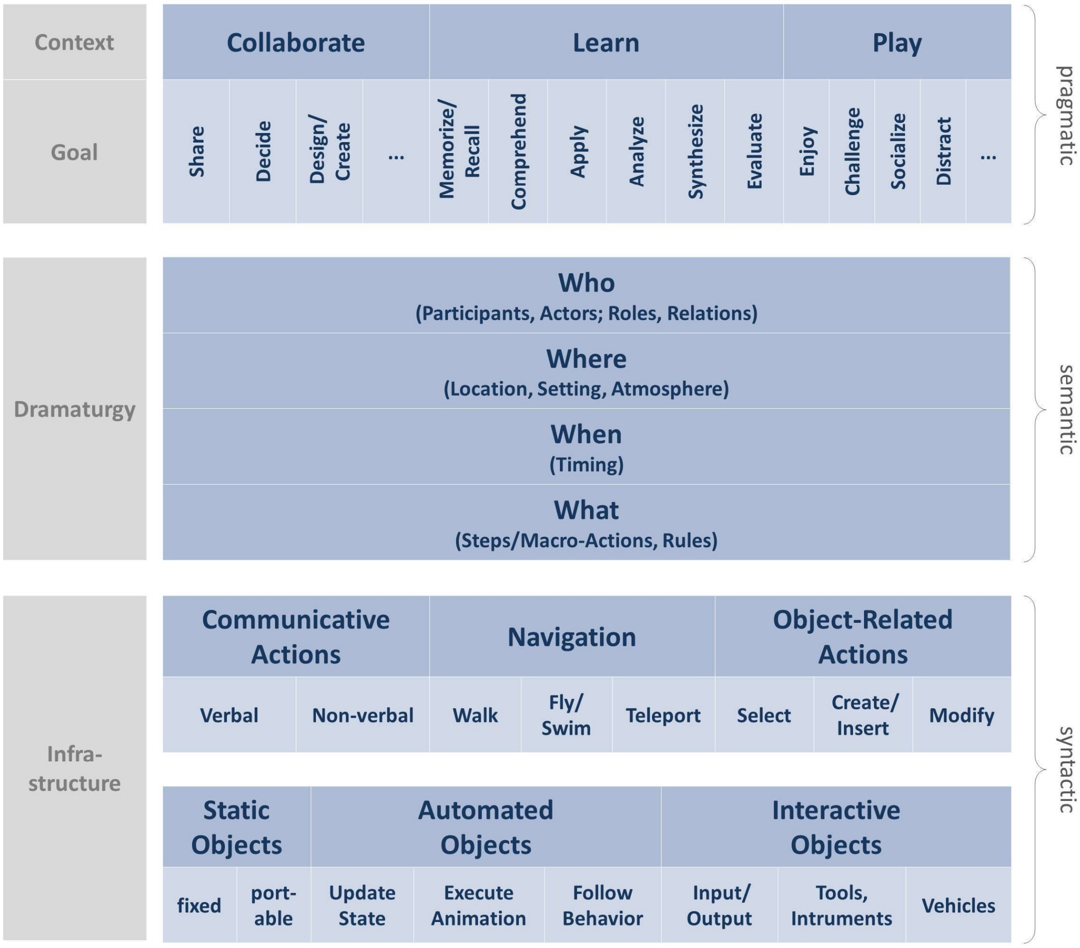

Figure 4.1. The Avatar-Based Collaboration Framework

The following subsections explain the integral parts of the framework, following a top-down order.

4.8.1. Context and Goal

The context describes the application domain of a collaboration pattern, while the goal defines more specifically what kind of activity a pattern aims to support. A first category comprises patterns that aim for collaborative work in the traditional sense, i.e. having main goals such as to share information or knowledge, collaboratively design or create a draft, a product, or a plan, assess or evaluate data or options, or make decisions etc. Since these goals do not necessarily have to be associated with work in the narrow sense of the word, we label the first context category Collaborate. The category Learn frames the domain of education. We assigned six goals to it, selected according to Bloom's Taxonomy of Educational Objectives (Bloom 1956). Bloom distinguishes between different levels of learning goals starting with simple memorizing or recalling information, to the more complex tasks of comprehending, being able to apply, analyzing, and being able to synthesize or even evaluate new knowledge regarding its limitations or risks. The category Play we classify into game oriented goals like competition, socializing or forming relationships, and distraction. This is an integration of Yee's (2007) three main motivation components *Achievement*, *Social*, and *Immersion* and Caillois' (1962) four fundamental categories of play, namely *competitive play* (Agôn), *chance-based play* (Alea), *role-playing and make-believe play* (Mimicry), and *playing with the physical sensation of vertigo* (Ilinx). We deemed the categories chance-based play and vertigo less important for the formalization of goal-driven collaboration patterns and thus left them out of the main categories we included in the framework. For both the Collaborate and Play contexts we included a wildcard category for the user to add their goals. These categorizations were not intended to be collectively exhaustive.

4.8.2. Dramaturgy

The term dramaturgy, describing a construct in which all interpersonal behaviors, rules, and activities are orchestrated, was first adapted into sociology from theatre by Goffman (1959); he explained social interactions using a theatre metaphor. The sociological perspective of symbolic interactionism, in which dramaturgy is embedded is closely related to semiotics (Denzin 1987). Thus, dramaturgy fits perfectly into the ABC Framework, designating the way in which the infrastructure in the virtual world is used to reach a specific collaboration goal or in other words support a group task. It consists of the necessary participants and their roles and relations (the 'who'), their interaction spaces and repertoire (the 'where'), as well as the timing and sequencing of their interactions (the 'when'). The dramaturgy also specifies the actions (the 'what') taken by the participants and the social norms and rules they should follow within a given collaboration pattern. While the goals and contexts specify the why of a collaboration pattern, and the infrastructure the how, this level consequently addresses the who, where, when and what of purpose-driven online interactions. The dramaturgy defines in which ways the infrastructure of a virtual world can be used by the participants to achieve a common goal.

4.8.3. Infrastructure

The final, most basic and thus fundamental level of the blueprint contains the previously discussed elements Actions and Objects. In sections 4.6 and 4.7, we discussed the categorization of action and interaction into communicative, navigational, and object-related actions, respectively that of virtual objects into among static, automated, and interactive virtual objects. In the functional principle of the framework, the infrastructure serves as a structure to create a pool of objects and actions available in a pattern.

4.8.4. Purpose, Use, and Limitations

As stated above, the intended purpose of the framework is to serve as a formalization in which to describe, discuss, share, and reuse virtual world collaboration patterns, and also as a tool for the development of patterns. As such, it is not intended to categorize contexts or goals of patterns in a mutually-exclusive manner. A collaboration pattern can aim for a number of different goals in different contexts at the same time, just as objects from different categories can be used and different types of actions can – and should – be integrated in a pattern.

On a similar note, the framework does not require the designer to pick one goal in one context in order to design a collaboration pattern. On the contrary, the framework supports multiple goals in multiple contexts for a collaboration pattern. This also means that selecting different goals or contexts does not have any direct consequences for the lower layers of the framework. This is true for the current version of the framework and might change in future revisions.

There are two distinct ways in which the above blueprint can be used for the creation of collaboration patterns: it can be used in a top-down manner from goal to infrastructure in order to specify how a given goal can be achieved using an online 3D virtual environment. Here, the given context(s) and the goal(s) of the pattern are specified first, then the dramaturgy is developed, before finally the required actions and objects are filled in. Alternatively, the blueprint can be used bottom-up in order to explore how an existing virtual world infrastructure can enable innovative dramaturgies that help achieve a certain collaboration (or learning) goal. Using this approach, existing objects and available actions are filled in first, a dramaturgy is developed on top of it, before finally the goal(s) and the context(s) is/are specified. The bottom-up approach seems more feasible for situations in which a virtual world including objects and tools is already available (or virtual world developers and 3D modelers to create infrastructure are unavailable), while the top-down approach may be the better choice to go about creating collaboration patterns when specific goals are to be achieved (or developers and modelers are available to create new content and functionality). The top-down and bottom-up approaches can also be mixed or used in combination or succession, as an iterative development process. Appendix E provides an empty version of the blueprint, ready for copy and use.

The case study in the next section illustrates the application of the ABC Framework in more detail, also pointing out advantages and difficulties in using it to develop collaboration tasks, in the case more precisely collaborative learning exercises.

4.9. A First Use Case

As a first use case the ABC Framework was deployed in 2009 and 2010 for the development of a dozen exercises for a 3D virtual world to accompany a global series of lectures on natural, artificial, and embodied intelligence, the ShanghAI Lectures (Hasler et al. 2009, Labhardt et al. 2012). This section describes the entire process from the ideation of collaborative learning patterns in the given context to the output of specific requirements to 3D designers and modelers on one side and virtual world developers and scripters on the other.

4.9.1. The ShanghAI Lectures

The ShanghAI Lectures (http://shanghailectures.org) is a cross-reality global teaching and international student collaboration project. Its core components are (a) a lecture series on natural, artificial, and embodied intelligence presented by the Artificial Intelligence Lab at the University of Zurich (AI Lab), and (b) exercise assignments for multicultural groups of students from all over the globe. The lectures are broadcasted via video-conference. Both in the first and the second year of the project, approximately 300 students collaborate in self-managed global virtual teams on weekly group assignments, view video-recorded lectures and expert talks together, and meet online with their peers and tutors, all embodied as avatars in a virtual world. As an environment for this purpose of work and socializing we created UNIworld, building on the virtual world platform Open Wonderland (open-source; formerly developed by Sun Microsystems, since 2010 independent), which enables the customized design of the virtual environment, collaboration features such as shared applications, the extension of communication tools, and the implementation of tailored extensions, such as authentication schemes and social software features. We further chose to create ShanghAI Island, a second virtual environment, using OpenSim (open-source; came out of the Second Life platform). The idea behind this was for the students to ‘travel’ to a virtual seminar location twice in the semester, in order to work on additional exercises, for extra credits. For the project it was an option to test a different virtual world platform, for a possible move away from Open Wonderland.

4.9.2. Main Development Task and Key Challenges

The fact that students from all around the globe work together in small groups for the exercises of the ShanghAI Lectures, and the fact that a virtual world was chosen as the single place to facilitate and foster this intercultural collaborative learning, make it a compelling case to be looked at in detail here.

The main development task was to create an appropriate number of exercises on the contents of the lecture series for groups of students to work on, together in a virtual world. Since these exercises constitute the key activity in UNIworld, the architectural design was heavily influenced by it. The final design of UNIworld was created around team ‘arenas’: team rooms that facilitate collaborative work in a private setting. In total, we developed 13 virtual world exercises to accompany seven lectures over the whole semester. With many of the students being first-time virtual world users, the first exercise needed to serve as a virtual world training task, to make the students familiar with navigating, communicating, and interacting with tools in UNIworld. As a second exercise not related to the topic of the lecture, a team-building task was required, as the groups were assigned randomly from all students (from 23 different universities). The eleven remaining exercises were developed on contents of the lecture.

Key challenges in the development of the exercises were to transfer exercises that accompanied an earlier (traditional) version of the same lecture from their paper-based form to a format for use in a virtual world, harnessing the distinct features of the medium – as the decision to deploy a virtual world as an environment in which to conduct the exercises came out of the thought of illustrating embodied intelligence in a more comprehensible way than having exercises solely on paper sheets or flat web pages. After this was achieved however, problems arose concerning the virtual world platform that had been chosen: promised functionality was not available, additional developers to solve this could not be hired, and system stability in general was not guaranteed. This led to a fundamental modification of the already developed collaboration patterns for the exercises, toward using much less interactive tools (or none at all) – which meant a significant decrease in quality, and in originality of the use of the virtual world. Eventually, the decision was made to include a second virtual world in order to host additional exercises in a ‘remote’ location. This implied an additional key challenge: to modify/redesign the collaboration patterns for the additional exercises in a way that respects the environment to be merely a place to work on the current exercise, not to socialize or have a team venue. This second virtual world, and the exercises in it, finally had to be designed as sort of a seminar getaway.

4.9.3. Approach and Design Process

As the main source of information and contextual input to the design of the collaboration patterns for the exercises, the lecture slides of an earlier (face-to-face) version of the lecture series were available, the (paper-based) exercise sheets to that lecture, and further contextual information about the domain and the contents of the lecture in form of a textbook that served as a basis for the lecture. As a source of inspiration for the development of innovative dramaturgies for the collaboration patterns, data from previous research was utilized: virtual world collaboration pattern descriptions from an exploratory investigation in Second Life (cf. section 3.2). The combination of these two sets of sources of input eventually led to novel ideas and innovative patterns for exercises to accompany the lecture series in the ShanghAI Lectures. The design process was not entirely defined at the beginning of the project, but rather evolved during this first application of the ABC Framework. It unfolds as follows.

As a first step for the development of a pattern, context(s) and goal(s) are specified roughly. The respective fields are filled with keywords or brief descriptions of the specific goals (note: a pattern can by all means address more than one goal, also in more than one context). Then, the designated procedure of the exercise in an initial rough form is drafted into the agenda section of the dramaturgy layer; this is the start of the first essentially creative part of the pattern creation. Using the rough idea as a scaffold, existing patterns and other sources are used as inspiration to ideate a dramaturgy for the exercise. While the dramaturgy layer gets filled in, single action and object elements are added in the infrastructure layer whenever their requirement for any of the sections in the dramaturgy gets apparent. Single fields in the actions and objects categories in the infrastructure layer are filled in with brief descriptions or explanatory keywords. When the upper parts of the dramaturgy layer are completed, the agenda and the context/goals sections are updated for a last time, if required. As a final step, with the context(s), goal(s) and the entire pattern in mind, the infrastructure layer is traversed section by section and field by field, with the aim to find out whether or not any additional actions or objects can be deployed for the pattern to make it more engaging or exciting. This step is done with the thought in mind to ensure the making use of the distinct features and capabilities of the medium. Whenever any amendments or modifications are made during this traversal, any affected sections in other parts of the framework are updated (and those in turn affected by that update, and so on).

The fully completed formalization of a collaboration pattern is then used to deduct requirements for 3D modelers (or architects), virtual world designers and developers/scripters. These are outlined as notes at the right edge of the framework sheet or formalized and given out on separate documents.

4.9.4. Implementation

Table 3 lists the final 13 exercises that were developed. It has to be noted here that due to the lack of functionality and stability of Open Wonderland as a virtual world platform and the lack of dedicated virtual world programmers and scripters in the ShanghAI Lectures project, a number of exercises had to be modified in order for them to be implemented.

Exercise name	**Description**	**Comments**
WL Tutorial (WL)	This ‘first contact with Wonderland’ exercise aims to make the students get to know and learn to use basic WL functionality, such as navigation, camera control, communication, and the use of different tools. Tasks and instructions are provided along a path in-world.	Individual exercise; basic tutorial
Design Team Room (WL)	The student teams work together to furniture their team room, in order to make it unique, to feel home, and to convey the spirit of the team in the room’s design. Ideally, the team rooms should look different from each other also from the outside. Drag & Drop-Import of 3D objects from the 3D model library Google Warehouse is supported.	Team-building exercise
Embodied Memory (WL)	Students stand in front of a 4-point-path and have to point in given directions. After, they move on the 4-point path and have to point in the same directions again, now being turned by moving on the 4-point path. Students should learn to orient themselves in this exercise.	
Anticipate Robot Behavior (WL)	After getting a robot design (as images in WL) the student team has to anticipate how the robot would behave in certain situations. The situations should be provided as images as well, for example a parcours the robot is (imaginatively) put into. The students use a whiteboard and a sticky notes board to put together their solution, alternatively they could be asked to perform a sort of role play for their tutor, as a more active solution.	Exercise simplified for use of whiteboard
Redesign Robots (WL)	Student teams are shown videos (or schematic designs) of robots that are not designed perfectly. For each video they discuss in their group and develop a redesign of that robot that is supposed to overcome the flaws students discover with the original design and resolve shortcomings. Whiteboard and sticky notes are used for this exercise.	Exercise simplified for use of whiteboard

Experience Situatedness (OS)	The student team mounts a robot. The robot starts driving around in a parcours, showing behavior typical for its model/type. The students get a situated experience, a 'first-person view'. After the performance, the students get off the robot and walk up a hill to watch the robot behave again, now as spectators from outside. They discuss the differences between the two experiences. With all this fresh in mind, they log out of OpenSim and get back to their team room in UNIworld, where they write down their comparison on a sticky note board.	
Tag and Annotate Videos and Images (WL)	In this exercise, student teams are asked to watch videos and images, discuss each of them and write down notes, comments, or comparisons on a sticky note board, or sketch something on a whiteboard. This is rather a scaffold for an exercise – content is fairly open here.	Exercise simplified for use of whiteboard
Which Robot Am I? (OS)	The student team watches a robot behave/move/act in an arena (a parcours) and guesses which kind of robot it is (the performing robot is initially 'cloaked': the team cannot tell what robot it is by appearance). After the student team comes to an agreement and makes their guess, the robot reveals its identity by 'decloaking' itself, illustrating whether or not the team's guess was correct. This is done for several robots. The student team makes their decision by 'voting by feet', that is by moving their avatars to robot prototypes (an agreement is made when all team members have moved to the same robot).	
Anticipate Self-Assembly (WL)	After getting a design of a self-assembly robot (as images in WL) the student team has to anticipate how the robot would self-assemble. The student team uses a whiteboard and a sticky notes board to put together their solution.	Exercise simplified for use of whiteboard
Categorize Robots in Framework (WL)	On a whiteboard with a framework as background image that allows categorizing robots according to different classifications, the student team marks the different robots they encounter during this exercise (robots can wait along a path, drive by, or simply park in a line).	Exercise simplified; not realized

Robot Colorization (WL)	The student team walks along a path at which (single-colored) robots are aligned. For each robot, they have to colorize its parts, according to a given categorization (e.g. sensors – actuators). This can be repeated for several robots, and for different categorizations per robot.	Exercise simplified; not realized
Robot Pantomime / Role Play (WL / OS)	Each student team designs and practices a choreography to illustrate typical behavior of a particular swarm of robots. One after another, the teams perform their play on stage in front of the other teams. The other teams have to guess what swarm or what swarm situation is illustrated.	not realized
Develop Own Virtual World Exercise	The student teams ideate and formalize their own virtual world exercise, making use of their experience in the virtual world, and choosing any content of the lecture as a contextual input.	not realized

Table 4.5. The 13 collaboration patterns developed for the ShanghAI Lectures 2010.

In the following, three of these 13 exercises are described in more detail, as examples of innovative collaboration patterns. A focus is put on which features of the medium are utilized by the particular exercises. Appendix D shows these three collaboration patterns in the structure of the ABC Framework.

Experience Situatedness:

This exercise demonstrates situatedness for the students. Using a 3D virtual world with an orchestrated immersive experience, the exercise aims to illustrate not only the meaning, but also the feel of situatedness. To this extent, students experience both a first-person and a third-person view of the same robot movement, and are asked to directly make a comparison between the two. In order to make the experience a memorable (and hopefully an exciting) one, the virtual world features of immersion and spatiality are harnessed: the sensation of sitting on a 'real' robot while it moves around on a parcours would be very difficult to deliver in a face-to-face setting (and close to impossible with hundreds of globally dispersed students); and videos of first-person and third-person views of a robot lack the interactive character of the experience.

Which Robot Am I?:

This exercise is one of a couple of exercises on robot behavior and artificial intelligence. It has a game-like character, incorporating interactive elements and a responsive environment. Thus, it harnesses the feature of a virtual world allowing for an extensively configurable and scriptable environment that can support collaboration and increase engagement. Among other sources, we were inspired by a children's TV show (for the voting by feet part) and aimed to develop a fun activity and an overall enjoyable experience for the students. Furthermore, the decloaking effect gives memorable immediate feedback to the student team's decisions, and the fact that the virtual world automatically sends an email containing the team's results for the exercise to their respective tutor demonstrates the interoperability of the medium.

Anticipate Robot Behavior (+ Robot Pantomime / Role Play):

This exercise requires the student teams to synthesize their knowledge in order to develop a performance about robot behavior. It was implemented as a combination with the not realized exercise Robot Pantomime / Role Play, as there was no significant surplus in implementation effort. Thus, the student teams deliver embodied experiences to their respective tutors, themselves profiting by both orchestrating the performance and participating in it by immersing into roles of robots. Moreover, the exercise emphasizes collaboration on various levels, requiring the students to work together as a team for both staging and delivering the performances.

4.9.5. Findings and Experiences from this First Use Case

First, it should be noted that the author of this first case report was also the author of this thesis, and thus not a neutral user of the ABC Framework, due to a heavy involvement in the development of the framework in the first place. In the application of the framework – the ideation and development of the 13 exercises – up to nine people were involved. Three of the main users of the framework read this case study description and judged it as authentic and representative; this should be enough proof that any positive bias of the main author is very limited.

Comments of users and otherwise involved people on the framework were generally positive, but also pointed out some shortcomings that should be looked at in future modifications of the framework.

On the positive side, the framework was found to help harness the distinct features of virtual worlds in order to develop more engaging ways of collaborating and learning together. Breaking down the infrastructure of virtual worlds does seem to foster innovative thinking. Having a pool of options for possible actions and objects in the virtual environment all laid out to pick from invites to try out different combinations. Innovation and 'thinking out of the box' is fostered by not forcing the combinations to adhere to any rules; any combination of actions and objects can be constructed with the framework – and consequentially implemented in a virtual environment. The enormous advantage of virtual worlds not having to adhere to actual-world physics and other (logical) limitations can be made use of already in the design of collaboration patterns, which is then likely to ultimately result in more innovative uses of the medium of virtual worlds, and thus in engaging and memorable experiences. The framework also seems to ensure for the collaboration designer not to overlook any options the medium offers to support engagement and interaction. This can be an important aspect for people with non-technical backgrounds, as they understand what is possible in virtual worlds by merely looking at the laid out infrastructure in the framework. This allows non-technical collaboration designers – or just those new to virtual worlds – to include even the most complex objects and actions in their patterns, which might pose challenges to scripters and modelers. A distinction between infrastructure elements easy to realize and such more complex to realize was deliberately suppressed in the development of the ABC Framework. It lays focus on the resulting experience, instead of being too mindful of how difficult to implement certain elements might be. This approach is even fortified by considering that it was conceived as a structure for all kinds of virtual worlds, not for one specific platform. The framework was also considered as a checklist, coming back to the point of not forgetting to make use of distinct features of the medium one might not think of when for example designing for a virtual world for the first time. Following a structure in the process of designing is beneficial for the design outcome. If that was not the case, fields like design science would not even exist (Fuller & McHale 1963), neither would design have principles (Suh 1990). The formalization offered with the ABC Framework aims to help designers structure their ideas and to support the process from initial thought to implementation. In this sense, following a structure gives much more guidance than writing just continuous descriptive text. One point we made sure to bear in mind here is that the structure must be open enough not to constrain the designers in their design thinking process in any way, but rather to provide a space for them to organize their thoughts.

Another point the first users of the framework brought up was that the framework serves as a tool for fast-prototyping, especially in combination with existing collaboration patterns (e.g., from actual-world classes, from face-to-face collaboration meeting agendas, from games) that provide inspiration and guidance. Having an idea of the process (i.e., the agenda and the major steps) that the pattern to design should implement is already a big step in the total design. This is because the 'black box' of dramaturgy, so to speak, is arguably the most difficult part in the pattern creation process, the part that requires most creativity and design thinking. With an already existing idea of the resulting pattern, the central part in the dramaturgy (i.e., the 'what' part) can be completed in short time, then the infrastructure parts are filled in following the idea, transferring the pattern to the medium of virtual words, making use of the medium's features.

Feedback from students who worked on the exercises created for the ShanghAI Lectures was very positive – moving, interacting, and exploring in a virtual environment was considered a great addition to traditional distance-based learning. This provides proof that the emphasis on making use of the medium's specific capabilities, its distinct features, bears fruit. This is an important point because students – or any other type of younger clients – have become very critical, in particular regarding technology. They are fast to say "you could do much more with this technology" and very often expect the latest functionality to be put to best use, in order to be satisfied with the product or service (or class) offered. To this end, the focus on making use of the distinct features of virtual worlds, an aspect we cannot stress enough, was key in the development of the framework.

On the negative side of the comments from the first users, the most notable point was that there is no description of where to start and how to go through the framework (for first use); a path to guide first-time users through the framework would be a valuable add-on to it. Here future research could provide insight on how to best design patterns. For example, a controlled experiment could be designed comparing the process and outcome of designers using the framework top-down and another group using it bottom-up. Thinking of readability, while the developer or designer of a pattern naturally can read and remember their own created patterns without a problem, a person not involved in the development of a pattern might have difficulties understanding it – guidelines for how to fill in the different sections to make patterns comprehensive for others might help resolve this issue, and also support the collaborative design of patterns. Other comments were that the process of constructing the output for 3D modelers and virtual world developers and scripters is not structured at all and that there is no option to connect the content to the patterns. This has to do with the lack of standards concerning virtual world objects and designs. Today, there is a plentitude of different virtual world platforms on the market, but efforts to agree on a common standard that would enable the transport of objects or even avatars from one world to another have not yielded any mentionable results yet. Apparently, the technology is still too young for cross-platform standards to emerge. The current policy of virtual world creators and providers is rather to develop and refine their proprietary systems and to secure the biggest possible market share. Open-source platforms have emerged and have a growing user base but are still small compared to the big player in the genre, Second Life.

4.10. Conclusion

In this chapter, we have presented the ABC Framework, a systematic framework that organizes the necessary elements for the design and implementation of collaboration patterns in virtual worlds. The framework is based on three layers, namely the pragmatic or contextual layer, including the goals of an online interaction, the semantic or dramaturgic layer, which defines how elements and actions are used (and interpreted) in time to achieve the collaboration goal, and the syntactic or infrastructure layer, consisting of the actual objects and (inter)actions that are combined to implement a collaboration dramaturgy. We have presented a first case study to describe an application of the framework that covered the whole process of developing collaboration patterns and showcased a list of 13 exercises that were developed for a global education project, and a more detailed description of three of these instantiations.

Research question RQ2 was answered using a design science research approach: an artifact was created that addresses the problem, namely the lack of a formalization and description structure for collaboration in virtual worlds.

The first use case indicates that the ABC Framework supports the design of novel collaboration patterns, and the realization of innovative ideas, in terms of collaboration activities, settings, or technological support. Through providing a blueprint, also non-designers are able to create environments and dramaturgies in it that yield fruitful, engaging, and memorable collaboration experiences. The framework was designed (and found) to be self-explanatory for the description and development of patterns and comes ready-to-use, without any training necessary. On the other hand, indications of how to use the framework for the design of collaboration experiences were asked for, and an associated design method would be a valuable addition to it. We have discussed these and other points raised by first users of the framework and the resulting critical insights that the ABC Framework offers.

As for current collaboration practices in contemporary virtual worlds, having established a systematic map of the elements required to devise and implement innovative and engaging collaboration patterns, the question nevertheless remains which patterns are more valuable than others in terms of their benefit in supporting knowledge-intensive collaboration tasks in groups, and which aspects of designing collaboration patterns support the intended goals better than others. Thus, the focus of investigation here turns from the design process to the outcome of virtual world collaboration design, as one main goal of the thesis was to address both process and outcome of the design. The empirical research described in the next chapter can be understood as an evaluation of a part of the ABC Framework, following another guideline for good design science research (Hevner et al. 2004). The investigation presented in the next chapter is at the same time a complementary step to the one presented in this chapter.

In their paper Beyond Being There, authors Hollan & Stornetta (1992) pose the question whether or not environments can be created that offer a higher richness than when physically ‘being there’ together, in a face-to-face setting. A number of researchers believe it will be possible soon, if we change the goal we are aiming for from trying to best simulate the actual world and face-to-face interaction to making best use of the distinct features of the environment at hand (cf. section 2.5, Kapp & O’Driscoll 2010). Different media offer different possibilities and can thus surpass plain face-to-face interaction in media richness, regarding specific categories. Investigating the power of online virtual worlds by evaluating different design approaches is one line of research we are pursuing.

One step that was not possible to take up in the scope of this thesis was to conduct a formal evaluation of the entire framework against a set of clear criteria, including validity, completeness, usefulness or meaningfulness, and ease of use. This would be a highly complex task due to the high number of variables. This task is planned to be tackled bit by bit in future research, as discussed in Chapter 6. Continuing to follow the iterative cycle of design science research, subsequent steps would then be to integrate the findings and experiences from the first use case and the evaluation in a refinement (or a redesign) of the framework and possible extensions to it. Following the DSR cycle, the framework is subject to perpetual change in ongoing design iterations. As the medium of virtual worlds develops and matures – and gets accepted by a broader subset of the general public – the infrastructure of the medium will change (due to technological advancements), priorities and preferences in terms of how to design collaborative activities will change (affecting the semantics of virtual world elements), and also societal change may demand modifications (concerning the pragmatics) of the design framework and method.

An alternative research direction that was not taken is to be to further evaluate the framework against criteria like performance, effectiveness, human effort, scalability, integration, and compatibility. This would lead towards two different investigations, one being a comparison to other design techniques and frameworks, the other one being addressing the question whether the semiotics-based approach for designing for collaboration experiences can be extended and/or transferred to support other digital and digitally-augmented environments (e.g., Pervasive and Ubiquitous Computing, Augmented Reality, web-based collaboration and distance learning, and physical Technology-Enhanced Learning environments).

Chapter 5: Evaluating Different Approaches for Designing Virtual World Collaboration Experiences

Chapter 5: Evaluating Different Approaches for Designing Virtual World Collaboration Experiences

5.1. Motivation

Teams and groups that meet in 3D virtual worlds to work together choose the medium for its distinct features and its potential advantages over other online media like text chat, video conferencing, or computer-supported cooperative work (CSCW) software and Web services. The academic and educational community often points to features like immersion, embodiment, and spatiality, which are claimed to lead to positive effects that are assumed to facilitate collaborative work, including enhanced presence and co-presence, improved team awareness, and higher engagement and greater motivation

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This chapter is partially based on the following publication:

Schmeil, A., & Hasler, B.S. (2012). *Designing for Effective Collaboration Experiences in Virtual Worlds.* In Proceedings of the 7th AISTED Conference on Human-Computer Interaction, May 14-16, Baltimore, USA.

(Mennecke et al. 2010, Kapp & O'Driscoll 2010, Yee & Bailenson 2009, Casanueva & Blake 2000; cf. section 2.4). However, empirical studies to evaluate these advantages are rare (Bainbridge 2007, Davis et al. 2009, Kahai et al. 2007).

As described as the second pre-study in section 3.3, we have empirically compared the medium virtual world against simple text chat, using three generic collaboration tasks that implemented information sharing, grounding, and decision-making. The results of the pre-study indicated that using virtual worlds for collaboration tasks improves retention: members of virtual world groups recalled more of the information shared and created in the meetings than those who collaborated using traditional 2D text chat.

Having a first positive empirical indication as to *if* virtual worlds can support collaboration tasks and having developed a powerful framework for the structured creation of collaboration patterns (see Chapter 4:), the question of how to design collaboration patterns in a way that they yield the best possible outcome of the collaboration tasks still remains (RQ3).

The research presented in this chapter can also be seen as a continuation of the experiment presented as the second pre-study in 3.3. The experiment described in this chapter was designed to systematically evaluate the main distinct features and possibly identify and understand how to avert perils of virtual worlds as a collaboration tool. It investigates how valuable collaboration experiences can be designed for. Part of its motivation was based on the following considerations.

Many of the virtual environments that have recently been advertised as offering great productivity boosts for collaborative work emphasize the collaborative editing of text documents, spreadsheets and presentation slides that are mounted on big virtual walls – a method of working together that may work just as well (or even better) without gathering in a three-dimensional virtual space. Kapp & O'Driscoll (2010, p. 56) state:

> *"Done right, 3DLEs provide the opportunity for instructional designers to overcome their captivation with the classroom and move in a direction that is more congruent with the needs of the increasingly digitized and virtualized enterprise. Done wrong, 3DLEs will remain the domain of digital avatars in digital classrooms discussing content on digitally rendered PowerPoint slides."*

Working on 2D tasks (on interactive walls) in a 3D environment can be understood as a step back in the ongoing paradigm shift in the design of interaction, and also ignoring the promising opportunities of embodied interaction; being embodied as the natural form of human existence lets collaborators interact and communicate naturally using their bodies (Dourish 2001, Mennecke et al. 2010). Virtual environments, featuring virtual embodiment (i.e., avatars), provide an interesting ecology of embodied interaction (Jarmon 2009). Fortifying the positive impact of having an embodiment in virtual worlds, research into mirror neurons and body language has shown it is of importance to people to see their body and the bodies of others (Bray & Konsynski 2007).

5.2. Research Question and Hypotheses

Ducheneaut et al. (2007) state that *"game design has become a social problem in its own right, and it is a domain where sociology could have much influence both by recommending best practices and evaluating the effects of virtual social environments on their visitors"* (p. 164). One can pick up on this point and make the conjecture that this is not only true for game design but also the design of collaborative work, whereby best practices can be recommended by social sciences and effects of virtual environments can be evaluated using social science methods, in order to find out what is required to provide for valuable and fruitful collaboration experiences. Gartner further supports this argument by pointing out that businesses focus on technology rather than the users' requirements when trying out virtual worlds, which they believe is one of the main reasons for the failure of 90% of current corporate virtual world projects, as anticipated by Gartner (2008). In this context, the users' requirements can be understood as the desired collaborative experience they seek when using virtual worlds.

The virtual environment in turn should aim for delivering a real added value for the collaborators by serving as an adequately arranged collaboration space providing the required functionality and ambience, offering a scaffold for the collaborative activities within the planned collaboration tasks. The overarching research question for this study is research question RQ3 of the thesis: *How should collaborative activities for virtual worlds be designed in order to best utilize the medium?* Since the methodology for the investigation was selected to be a controlled experiment (i.e., quantitative), the research question needs to be rephrased; experiments can provide answers only to *if*-, not to *how*-questions. The transformation of research question RQ3 for this experiment needs to take into account the overarching goal of this thesis (i.e., understand how to support collaboration; see also RQ1 on p. 7), and results in: *Does the explicit making use of the distinct features of virtual worlds in the design of collaborative activities support collaboration?*

This question addresses both the design of virtual world environments themselves – including space, landscape, structure, tools, instruments, ambience – and the design of activities in these environments – types of activities, use of embodiment, group configurations, roles, relations, rules, steps, timing. While the investigation addresses the design of both environment and activity (i.e., the design of whole experiences, cf. subsection 2.5.2), its scope does not include all mentioned aspects, but focuses on spatiality and embodiment – two of the main features that distinguish virtual worlds from other online collaboration media (Davis et al. 2009, van der Land et al. 2011).

By spatiality we refer to the feature of having at disposal an unlimited virtual space that is highly configurable, and in which objects can be created and equipped with interactivity and responsive behavior (on these distinct virtual world features see subsection 2.4.2, on the importance of space and the management of spaces and places see subsection 2.1.1 and Nonaka 2000, Harrison & Dourish 1996, as well as Dourish 2001, and Kapp & O'Driscoll 2010). This unlimited and rather effortless control of space and the spatial organization of the collaboration activities in a virtual world facilitate the spatial structuring of collaboration, which can be utilized to control focus of participants in a collaboration meeting. Media Synchronicity Theory defines synchronicity as the (beneficial) state in which individuals are working together at the same time with a common focus (Dennis & Valacich 1999). By spatially structuring a collaboration environment in a virtual world, this synchronicity could be artificially enhanced, having a positive impact on collaboration, in particular regarding retention. We base this hypothesis on findings and experiences from our pre-study experiment (section 3.3), but also on the mnemonic technique of Loci, which is a method of memory enhancement that makes use of imagined spaces and spatial relationships (de Beni & Cornoldi 1985).

By embodiment we refer to the distinct feature of being represented as a customizable avatar in a virtual world, a feature that has been shown to be powerful by a number of researchers (Yee & Bailenson 2009, Casanueva & Blake 2000, Bray & Konsynski 2007, Jarmon 2009; Dourish 2001). *Embodied Social Presence Theory* posits that being equipped with an embodied representation increases the engagement in shared activities and communication acts, therefore in collaboration tasks (Mennecke et al. 2010). Kapp & O'Driscoll (2010) argue that immersive experiences (i.e., interacting with 3D objects in a 3D space, being virtually embodied) lead to higher engagement; they postulate the figurative formula *Immersion x Interactivity = Engagement* (p. 55). Distributed Cognition (Hutchins 1995) posits that interactivity can be embedded in artifacts within the cognitive ecosystem spanned by individuals and artifacts in the environment.

On this basis, we extend the posit of Embodied Social Presence Theory by hypothesizing that deploying 3D objects (with embedded interactivity) in collaboration tasks and having all collaboration participants interact with them increases the participants' perceived feeling of being embodied, thus in turn leading to higher engagement in the collaboration (according to Embodied Social Presence Theory) and to higher awareness of their actions (and the actions of their virtual teammates; Casanueva & Blake 2000). The resulting higher involvement in their actions should then increase the subjective feeling of accomplishment and positively influence the participants' perceived (subjective) task performance.

On a third aspect, we hypothesize that making active use of avatars as a virtual embodiment (i.e., forcing the participants to navigate around the virtual environment) has a positive impact on awareness, thus improves the sensations of presence and co-presence (Yee & Bailenson 2009, Casanueva & Blake 2001). As a result, this increases the collaborators' engagement in the tasks and thus their satisfaction with, and subjective rating of, the task in the particular collaboration mode, measured in a task evaluation.

In summary, the three resulting hypotheses for the experiment are:

H1 Structuring the virtual world environment has a positive impact on the *objective task performance (retention)* compared to having all tasks at one and the same location.

H2 Utilizing 3D objects in collaboration tasks has a positive impact on *subjective task performance* compared to using traditional presentation slides and other interactive 2D screens.

H3 Making active use of the virtual embodiment (the representation as avatars) in collaboration activities has a positive impact on *task evaluation* compared to using avatars as mere props that visually embellish the collaboration scene.

5.3. Experimental Design

The experiment was designed in order to evaluate different collaboration tasks and collaboration modes during a fictitious project meeting in a simulated authentic collaboration context. Three types of tasks that are typical for an early-stage project meeting were implemented. The experiment was thus set up to evaluate these three tasks across three different collaboration modes in a virtual world.

This consideration resulted in a 3x3 mixed-factorial design with task type as the within-subject factor: (1) information sharing, (2) brainstorming, and (3) decision-making, and collaboration mode as the between-subject factor: (A) collaboration in a localized environment using 'traditional' 2D tools and objects, (B) collaboration in a localized environment using 3D objects and tools, and (C) collaboration in a separated environment using 3D objects and tools.

Table 5.1 formally presents the expected measurements following the hypotheses.

	Hypothesis	Measurement	Hypothesized result
H1	Structuring the virtual world environment	Objective task performance	C > B, A
H2	Utilizing 3D objects	Subjective task performance	C, B > A
H3	Making active use of (avatar) embodiment	Task evaluation	C > B, A

Table 5.1. Formal description of the hypothesized measurements for the three collaboration modes (A, B, C) for each of the hypotheses of the experiment.

The independent variable, the collaboration mode, is derived from the ABC Framework, in combination with Embodied Social Presence Theory, Media Richness Theory, and Distributed Cognition: the more the distinct features of the medium virtual world are explicitly made use of in the design of the collaboration activities / tasks, the better for collaboration, in particular regarding memorability, engagement, and satisfaction.
The choice of dependent variables follow this assertion and the respective theories cited above and are: objective task performance (here: memorability / retention of information from the meeting), subjective performance, and task evaluation. The selection of these dependent variables was further motivated by the pre-studies described in Chapter 3.
The following sub-sections elaborate on the collaboration tasks and modes.

5.3.2. Collaboration Tasks

The experiment was conducted with randomly assigned groups of five participants. Each of the participants was then randomly assigned one out of five fictitious personas, which they were asked to personify during the collaboration experiment in the virtual world. Each of the personas was represented by a specific avatar (3 male, 2 female). The scenario of the collaboration tasks was built around a virtual project team that meets for the first time, online, in a virtual world that was specially-designed for the kick-off meeting of a fictitious project they work on together (this background story is carried over from the experiment described in 0, and is therefore described rather briefly here; see subsection 3.3.2 for a more detailed description of the background story to the team meeting in the experiment). Also, the same avatars were re-used (shown in Figure 3.4).
The setup implemented a hidden profile situation: each participant initially only knows the profile information of the persona that was given to them – knowledge about others needs to be learned (through information sharing) and created during the meeting (on hidden profile situations see for example Stasser et al. 2000). The goal of the project was to create a website that explains the recent financial crisis to non-experts.

The agenda of the kick-off meeting consisted of these three tasks:

Task 1: Information sharing

The participants present themselves (or rather, their persona) to their team members, using the information on the profile sheet they received. Information to share includes age, profession, working history, mentionable expertise, and hobbies.

Task 2: Brainwriting

In this group creativity task the team members discuss the project and collaboratively develop basic ideas and concepts concerning the project approach and goals. This task is approached using a creativity technique called *brainwriting* (VanGundy 1984, Aiken et al. 2007): ideas about the project are written on a set of cards that are open for all team members to amend. This activity aims to result in a number of refined ideas, structured by topics on separate cards.

Task 3: Decision-making

The team members discuss and collaboratively decide on a role assignment: each of the team members is assigned to one or more of three available roles for the project: content, development, and marketing. Furthermore, a project manager must be appointed.

Brief instructions for the tasks and information about the fictitious project were given to the participants along with the profile of the assigned persona on a one-page information sheet, just before logging into the virtual world. As the five personas were designed to have skills that give clear indications on how to build an optimal team structure for the project, sharing the right information (Task 1) helps assign the project roles in an optimal way (Task 3). Task 2 creates the project context.

5.3.3. Collaboration Modes

The experiment was set up to compare the collaborative work on the described three tasks, in three dissimilar collaboration modes – different designs of the virtual world collaboration environment and of the tools in it. An overview of the collaboration modes is given in Table 5.2. The three modes are explained in detail in the following. Different from the experimental design in the pre-study that was explained in Chapter 3, in the experiment at hand all three conditions are virtual world conditions. The experiment does not aim to investigate the usefulness of the medium anymore but aims to empirically compare different design approaches of virtual world collaboration.

The purpose of the design of the three collaboration modes is to identify design aspects and approaches that support the process and foster the outcome of collaboration. To this end, we looked to investigate both the spatial setup of the work environment and the character of the tools in it. Both manipulations indirectly address the distinct virtual world feature of being embodied as a customizable avatar (cf. section 5.2 above).

	Collaboration environment	Objects and tools
A: Control condition	Localized (all tasks in one spot)	2D (text-based, interactive walls)
B: Experimental condition	Localized (all tasks in one spot)	3D (3D objects and tools)
C: Experimental condition	Separated (each task at separate location)	3D (3D objects and tools)

Table 5.2. The three experiment conditions manipulating the between-subject factor "collaboration mode" with varying levels of spatiality and embodiment.

Condition A: Localized environment, 2D objects

Condition A – the control condition – confines the team to a relatively small area. An invisible ‘glass cube’ was built in order to prevent the participants (or more precisely, their avatars) from going astray. The tools for the team to use for the three tasks are placed in juxtaposition with each other, as shown in Figure 5.1. The tools for this task each come with a sign post beside them, which summarize the particular task and explain how to use the tool, using brief phrases. Two of the three sign posts in this condition were equipped with additional hints that were fixed on the sign posts, right beneath the task explanations.

For Task 1, a screen displays profile presentation slides for each persona. The board changes to the next team member’s slide upon a single click. Each slide show a head shot of the avatar and sums up the profile information in keywords, in the wording the participants read it on their profile information sheets. The sign post next to the board says *Present yourself to your team, one by one. Click on the board to change slides.*

Task 2 features a board composed of brainwriting cards, on which participants could sketch their ideas in the form of keywords and short phrases. Upon left click on any line of a card the subsequent written statement of the participant appeared on it instead of in regular text chat. The sign post next to the board says *Develop first ideas for the project. Brainstorm! Click on card title or any line, then write into chat.* A hint adds *Write undo to cancel.*

In Task 3, the role assignment was accomplished by (re-)positioning name tags in a triangle on a board, the corners of which symbolize the three roles (the corners are marked textually). The project manager (PM) to be assigned could mark their name red, with a single click. Figure 5.2 shows a team during role assignment. The sign post next to the board says *Assign project roles by placing your names near or between the roles. Assign a project manager.* A hint adds *There is only one PM. Click your name to take the role.*

Figure 5.1. A persona presenting herself using her profile slide.

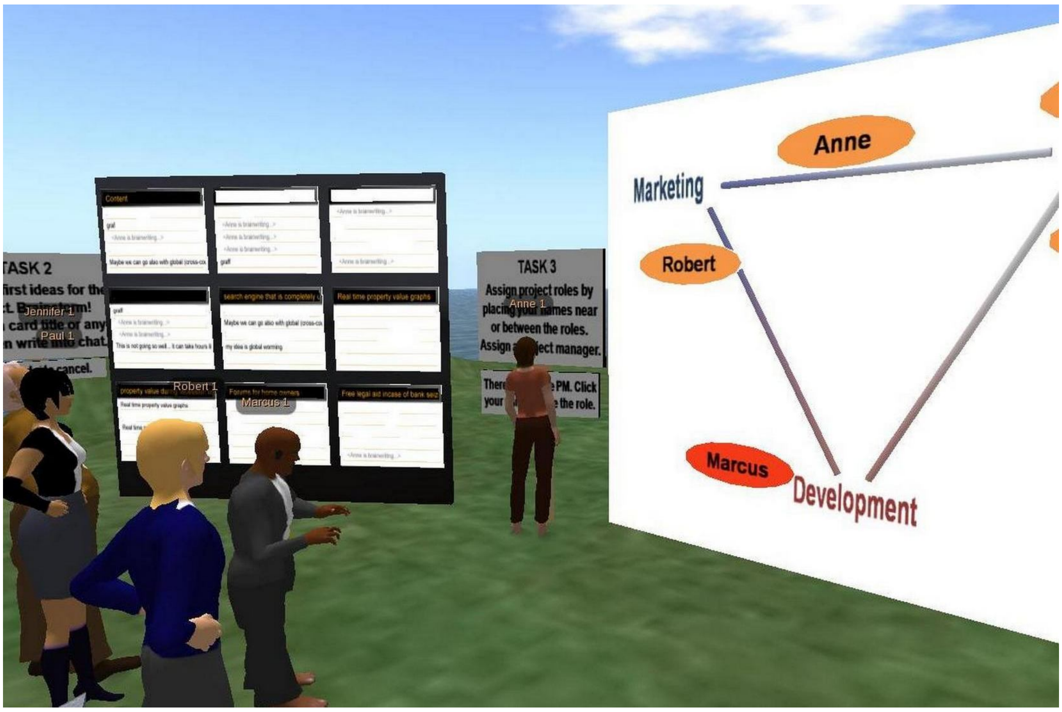

Figure 5.2. Team assigning roles using the 2D interactive board.

Condition B: Localized environment, 3D objects

In this experimental condition, the team is confined to a small area as well, using a ‘glass cube’ like in Condition A. Also the arrangement of the space for the three tasks is the same, merely the tools differ. Brief explanations of how to use the tools are written on sign posts also here. In this condition all three tasks were equipped with additional hints fixed on the sign posts.

For Task 1, a table puts 3D objects on display – personal items that describe the personas’ backgrounds (Figure 5.3). The table pops up objects associated with the persona's profile that clicks on it, as a visual, three-dimensional form of a slide presentation. The sign post says *Present yourselves to your team, one by one. Click on the table to show your personal objects.* A hint adds *The table will recognize who clicks.*

For Task 2 in this collaboration mode, the cards were modified in that they move towards the avatar who writes on it (as seen in the background in Figure 5.3), then jump back into formation. In comparison to the brainwriting cards in the control condition, this design aimed to make use of the space and make the cards more readable (and writable) to the particular writers by 'zooming' in to them. An additional advantage was believed to be the assignment of a card to one distinct avatar at a given time. The sign post says *Develop first ideas for the project. Brainstorm! Click on card title or any line, then write into chat.* A first hint adds *Write undo to cancel.* A second hint adds *The card will come closer when you click it to write.*

For Task 3, instead of the 2D interactive board, a table was provided that lets participants position flags with their owners' head shots on them within a triangular area similar to the one in Condition A. Instead of text labels, the triangle was spanned by symbolic 3D objects that depict the available roles (a megaphone for marketing, bricks for development, and a canvas for content creation). To assign the PM role a top hat – the ‘Project Manager Hat’ – had to be attached to one of the flags. This setup is shown in Figure 5.4. The sign post says *Assign project goals by placing your flags near or between the symbols. Assign a project manager.* A hint adds *Click on the PM hat to assign it to you/your flag.*

Figure 5.3. Team discussing and brainwriting in Condition B.

Figure 5.4. Team assigning roles using 3D objects in Condition B.

Condition C: Structured environment, 3D objects

This most advanced experimental condition was implemented based on the tools that were used in Condition B, but with an entirely different spatial setup: the three tasks have separate locations, cannot be seen from one another, and are connected only through a path that winds around a mountain. This design aimed at separating the tasks not only mentally but also spatially. The participants thus had to move around a whole island in the course of the meeting. Distances were short however, walking from one task to the next took about ten seconds.

In Task 1, each team member had a personal table with personal items, which were included to visually represent the team members' profiles, in order for them to present themselves in an engaging manner (Figure 5.5 shows one of the tables with the 3D objects on it – the objects were the same that were used in Condition B). Curtains hiding the items fade away whenever their respective owners write in chat. Arranging the personal items on spatially separated tables and taking the objects on other tables 'out of sight' was intended to direct the team members' attention and hence improve their focus (see Benford et al. 1994). In addition, clicking on drawers in the tables executes personalized gestures.

By including this element we aimed to offer more visual support in order to influence the memorability of profiles. The sign post says *Present yourselves to your team, describing your personal items on your personal tables.* A first hint adds *The tables tell whose objects they display.* A second hint adds *Your curtain will open when you talk.* And a third hint adds *Click on the drawers to show your personality.*

Task 2 in this condition is an area in which the nine cards are dispersed between several trees, bushes, and coves (Figure 5.6). Each card was thus placed in a different setting with a different background. This design aimed to influence the memorability of the ideas created and written on the different boards. The sign post says *Develop first ideas for the project. Brainstorm! Click on card title or any line, then write into chat.* A hint adds *Keep it short. This is brainwriting.*

Following the approach of embodied interaction, in this condition, Task 3 is done by 'voting by feet', that is the team members are asked to position their avatars in the decision-making triangle, which is scaled up to walk-in size in this condition (as shown in Figure 5.7). The avatars' proximity to symbols communicates their preferences toward or their decisions for roles. The sign post says *Assign project roles by placing your avatars next or between the symbols. Assign a project manager.* A first hint adds *Assign the roles according to your personas' profiles.* A second hint adds *There is only one PM. Click the hat to take on the role.*

Figure 5.5. A team member presenting himself using personal items and gestures.

Figure 5.6. Team discussing ideas between the brainwriting cards in a spatial setup.

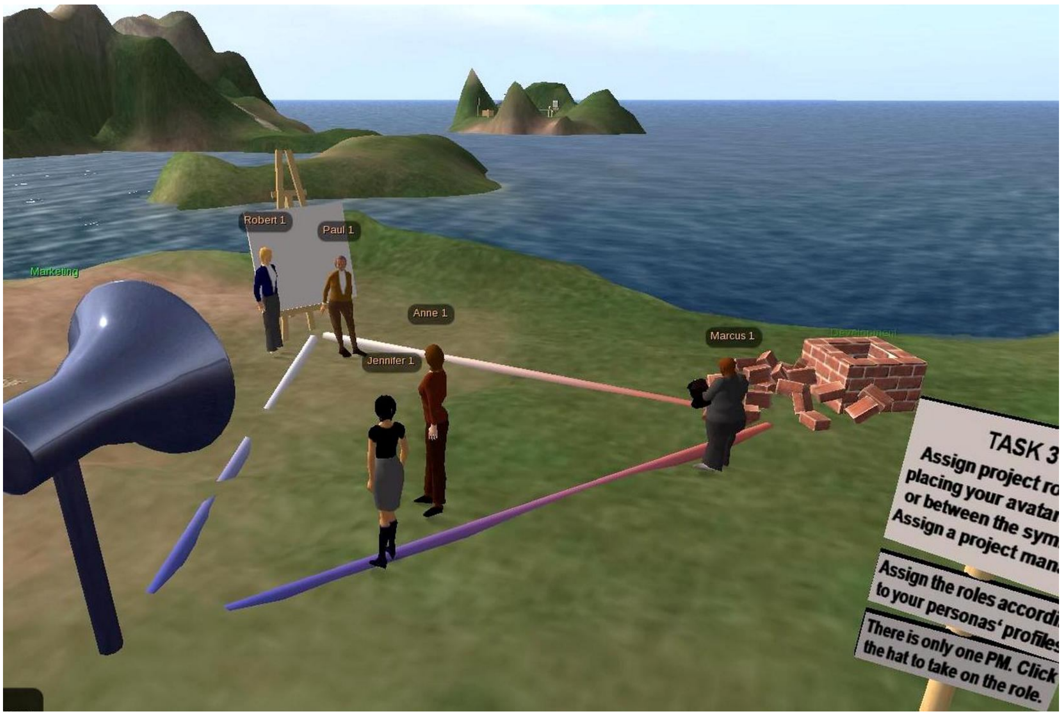

Figure 5.7. Team assigning roles 'by feet' in the role assignment triangle in Condition C.

After presenting all experimental conditions in detail it has to be noted that the implemented experiment design is not the one and only correct way of trying to answer the research question and to test the hypotheses postulated above. In fact, there are endless possibilities to design three collaboration modes for the chosen tasks that would fulfill the qualifications described in Table 5.2. This is also one of the central points in the motivation for this research: the possibilities to design and structure collaboration in a virtual world are superabundant. That is, the nature of the platform virtual world and its 3D space in part simulating the actual world has close to no limitations. Going even further, virtual world designers enjoy the freedom of being able to build structures and tools that would not be possible in the actual world, given its natural laws and physics. This freedom is at the same time an enormous challenge, the challenge to find the right approach, as well as the right degree of design.

Due to a lack of previous experiments investigating the design of virtual world collaboration in the scientific community, a design for a pioneering investigation had to be decided for. The presented design for the experiment at hand – particularly Condition C – was largely inspired by the pre-study experiment presented in Chapter 3, the results of which had been very promising and indicated that the applied approach of using embodiment and structuring the collaboration space was worth following in a more thorough investigation.

5.4. Method

5.4.1. Procedure

A questionnaire of demographic data and personality profiling had to be filled in prior to the virtual world activity (here we also measured the expertise with virtual worlds, the covariate we used in the analyses). A second questionnaire, including subjective reports and ratings, was administered right after logging out of the virtual world. After completing the second questionnaire, the participants were given a third questionnaire to test the recall (i.e., how much of the information the participants could remember). In addition, we developed a tracking module for the OpenSim platform that logs all (text) chat, avatar navigation data, and information about object interaction. The combination of such diverse objective and subjective data allows for in-depth analyses of team interaction processes and outcomes.

The research protocol and procedure was approved by the Internal Review Board (IRB) at the Palo Alto Research Center (PARC), Inc., California.

5.4.2. Participants

The experiment was conducted with 16 groups in total. Due to some incomplete questionnaires, the fully usable data set comprised N=67 participants. Participants were recruited in the United States, Switzerland, and Israel. The average age of the participants was 27.9 years. As Figure 5.8 shows, only 12% of the participants stated to be virtual world users more or less regularly, while for computer games this percentage was already 39%.

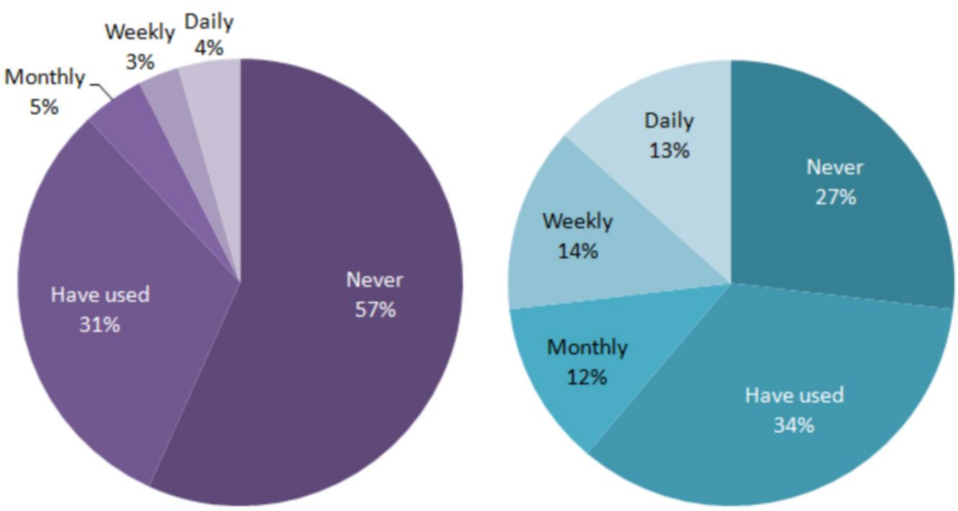

Figure 5.8. Participants' use of virtual worlds (left) and computer games (right).

5.4.3. Measures (dependent variables)

In the two post-task questionnaires (reprinted in Appendix C), we collected the following measures:

Objective task performance

We measured the retention (i.e., the participants' recall of information shared and created in the meeting) by counting the information items they remembered. For Task 1 we counted the items of the different persona profiles. For Task 2, we counted the number of generated ideas the participants recalled from the meeting. For Task 3 we measured how well the participants recalled the role assignment reached in the meeting.

Subjective task performance

In order to measure the subjective performance of the collaborating groups, we asked the participants to rate the collaboration for the three tasks separately. For Task 1 we asked if the team shared their profile information well and listened carefully, for Task 2 we asked if the brainwriting was done in an organized way and if ideas were jointly created, while for Task 3 we asked if the role assignment process was clear and effective, and whether its state was visible at all times. We used 7-point Likert scales to assess these statements.

Task evaluation

With the aim of not only getting an evaluation of the collaboration performance, but also of the collaboration tasks in the various modes, we asked participants to evaluate each of the tasks on the basis of nine attributes, rated on a 5-level scale: easy, interesting, satisfying, successful, engaging, immersive, efficient, enjoyable, and inspiring.

5.5. Results

We conducted analyses of covariance (ANCOVA). We used virtual world expertise as a covariate in order for the results to be independent from possible imbalances in virtual world proficiency among the participants. In general, we found that also first-time users quickly understood how to navigate and communicate in the OpenSim virtual world environment, especially since the experiment was setup for simple interaction (e.g., only left mouse clicks to interact with the collaboration tools); nonetheless, we deemed the inclusion of the covariate to be correct. In the following we describe the results of the different analyses. The results are graphed on the subsequent pages.

Objective task performance (retention)

We conducted ANCOVA analyses for each task separately, using the three conditions as the independent variable, retention scores as the dependent variable, and virtual world expertise as the covariate. For Task 1, the ANCOVA did not reveal any statistically significant differences between the conditions, $F(2, 61) = 1.45$, $p>.05$. For Task 2, the ANCOVA was statistically significant, $F(2, 60) = 9.73$, $p < .001$, $\eta_p^2 = .25$. A Tukey Post-hoc test showed that the difference was due to a significantly better retention score in Condition C compared to Conditions A and B (C > A, B); that is, more ideas were remembered correctly in Condition C than in the other conditions. The same pattern of result was found for Task 3 (decision-making). The ANCOVA was statistically significant, $F(2, 61) = 7.03$, $p = .002$, $\eta_p^2 = .19$. A Tukey Post-hoc test showed that retention was significantly higher in Condition C, as compared to the other conditions (C > A, B). Figure 5.9 illustrates the means and standard deviations of the retention results for tasks 2 and 3.

Subjective task performance

We conducted ANCOVA analyses for each task separately, using the three conditions as the independent variable, subjective task performance ratings as the dependent variable, and virtual world expertise as the covariate. The conditions did not significantly differ regarding subjective task performance, as measured for Task 1, $F(2, 63) = .61$, $p > .05$, and Task 3, $F(2, 63) = .29$, $p > .05$. For Task 2 the ANCOVA was statistically significant, $F(2, 63) = 6.97$, $p = .002$, $\eta_p^2 = .18$. A Tukey Post-hoc test showed that participants perceived the team's performance significantly higher in Conditions B and C than in Condition A (C, B > A). Figure 5.10 illustrates the results for the subjective task performance.

Task evaluation

We conducted ANCOVA analyses for each task separately, using the three conditions as the independent variable, task evaluation as the dependent variable, and virtual world expertise as the covariate. No statistically significant differences were found between the conditions regarding evaluation for Task 1, $F(2, 71) = .58$, $p > .05$, nor Task 3, $F(2, 71) = .60$, $p > .05$. The ANCOVA for Task 2 was statistically significant, $F(2, 71) = 4.74$, $p = .01$, $\eta_p^2 = .12$. A Tukey Post-hoc test revealed that participants rated their evaluation in Task 2 significantly more positive in Condition C compared to Condition A (C > A). Condition B did not significantly differ from A or C. Figure 5.11 shows the results for the task evaluation measurements.

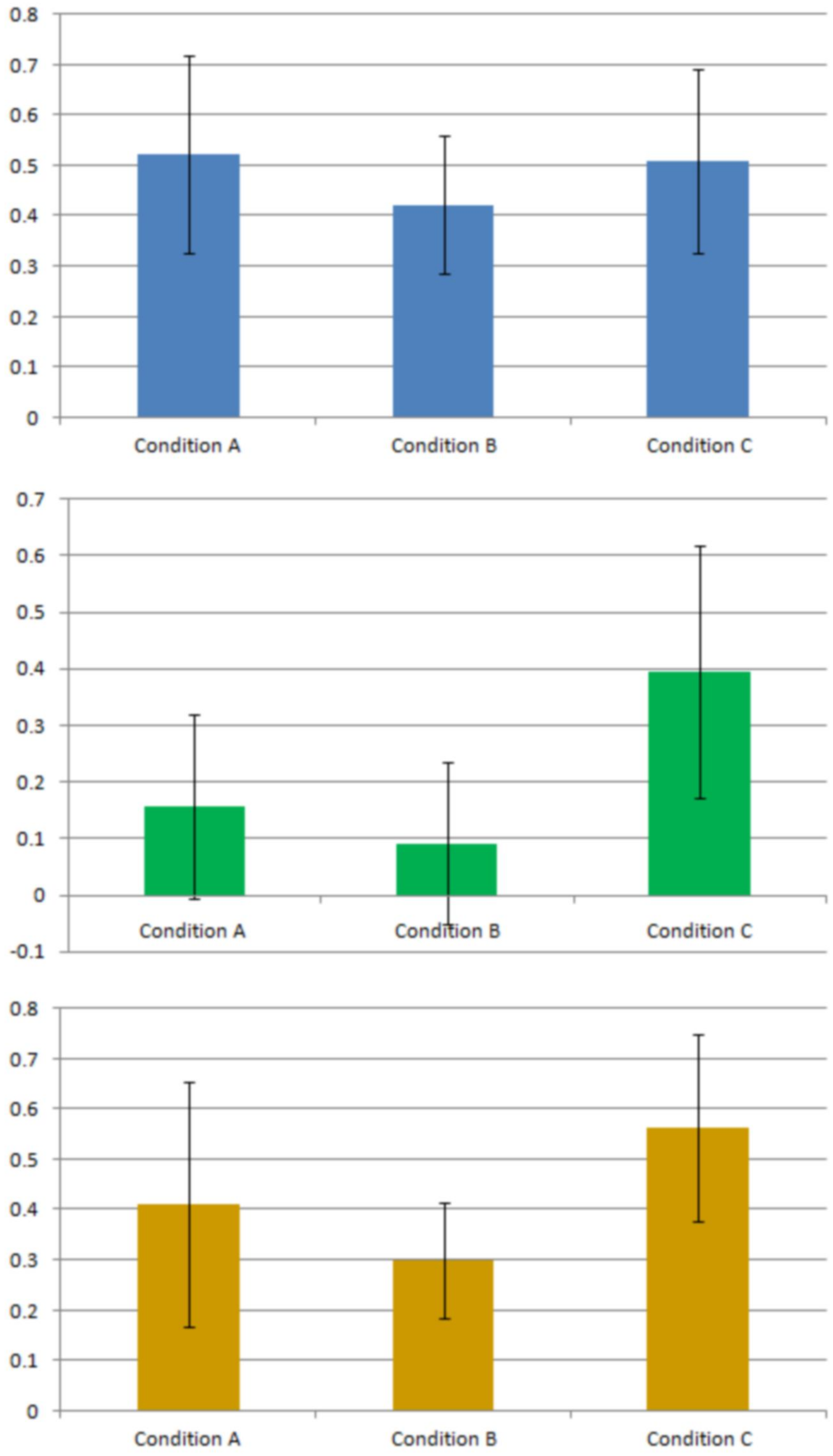

Figure 5.9. Objective task performance: means and standard deviations (top: Task 1, center: Task 2, bottom: Task 3)

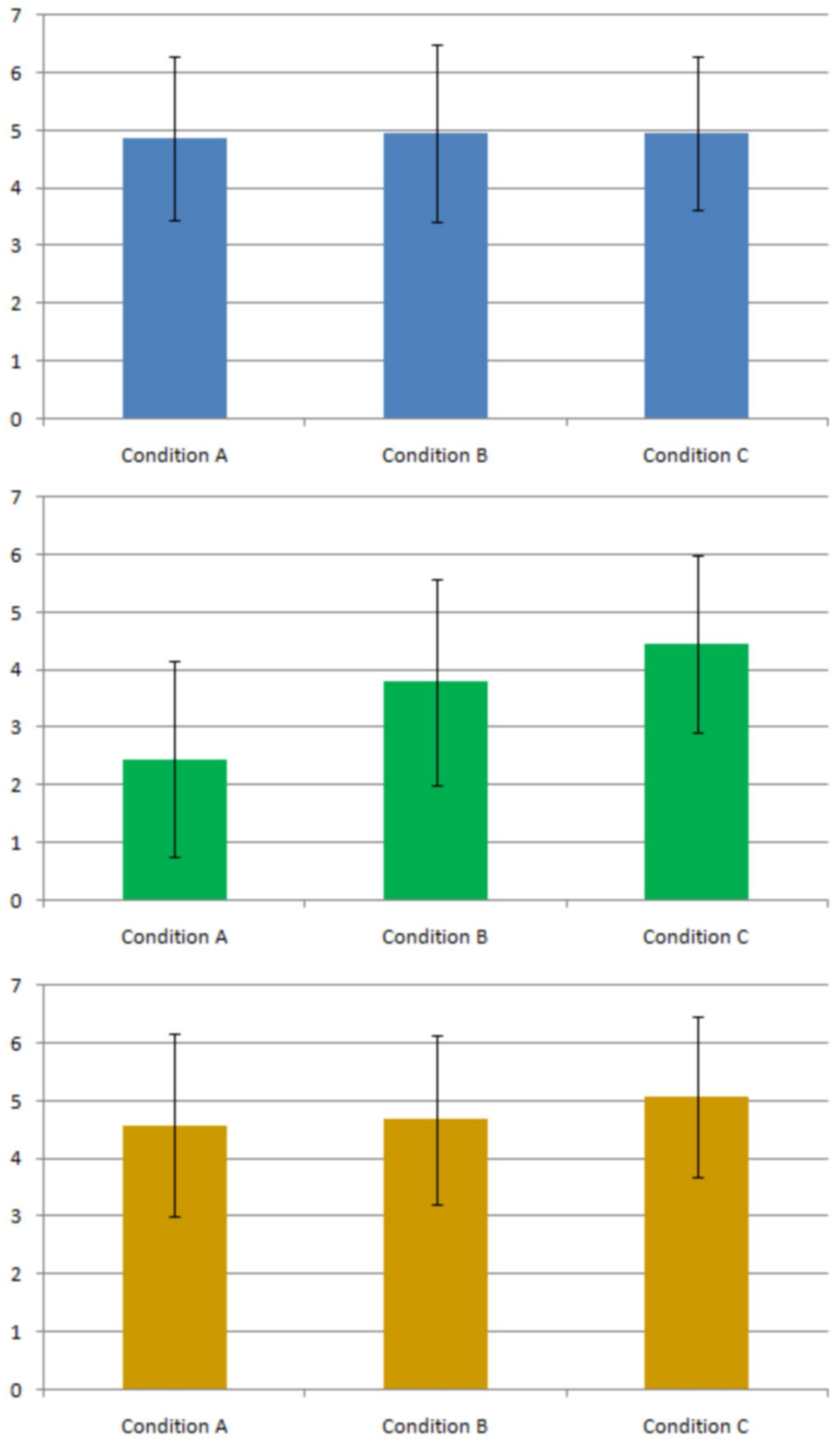

Figure 5.10. Subjective task performance: means and standard deviations for tasks 1 (top), 2 (center), and 3 (bottom).

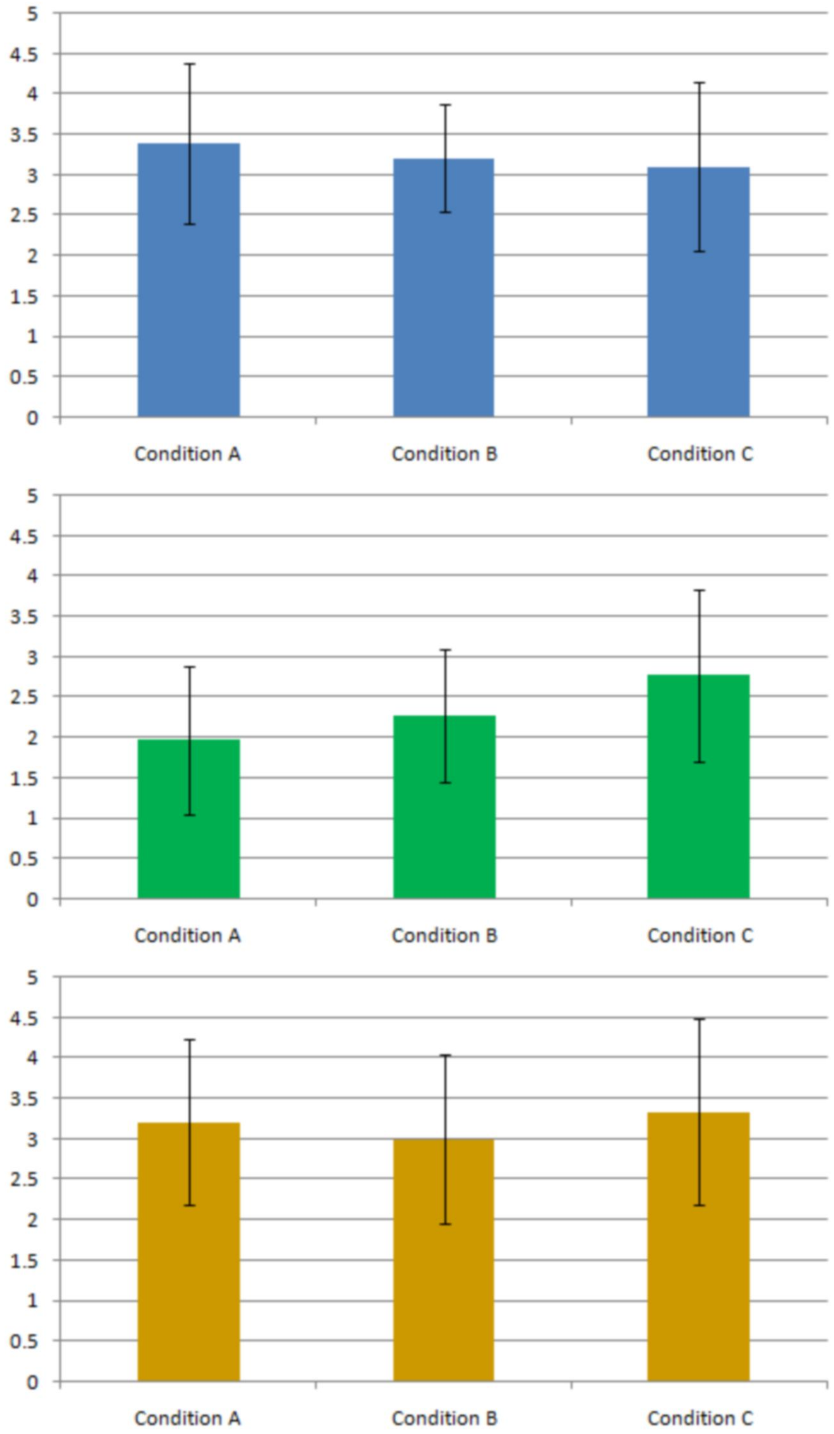

Figure 5.11. Task evaluation: means and standard deviations (top: Task 1, center: Task 2, bottom: Task 3)

5.6. Discussion

The results provide partial support for our hypotheses; they were accepted for some tasks and rejected for others. This outcome highlights the task-dependency of design evaluations. Although we attempted to manipulate the design factors (as specified for each condition) in equivalent ways, they resulted in different (objective, subjective) performance and task evaluation results.

For the brainwriting and decision-making tasks the results confirm that structuring the collaboration tasks of a meeting into separated locations can improve the memorability of the information shared and created (hypothesis H1). For the information sharing task the hypothesis was not accepted. One explanation is that this result might be due to the fact that the pre-defined information to be shared in Task 1 had no relation to the collaboration environment. In tasks 2 and 3 in contrast, all information was created in-place and was thus directly linked to the location – the *place* (cf. Harrison & Dourish 1996) – of the task. This interpretation can be understood as (1) an affirmative indication that also the effect of loci applies to virtual worlds (the positive effect on retention of the mnemonic technique had been shown, e.g. Beni & Cornoldi 1985, although never before in relation to collaboration in 3D virtual environments), and as (2) a tentative confirmation that Media Synchronicity Theory can be successfully extended to the realm of virtual worlds (regarding the planned control of focus for the promotion of synchronicity, as stated in the development of hypothesis H1).

Hypothesis H2 was accepted for Task 2: for a brainstorming task, the use of 3D objects can have a positive impact on the subjective performance of the collaboration participants. When sharing information or making decisions on the other hand, 3D objects have not significantly added to the perceived performance. This might be a weak indication that 3D objects are considered valuable in creativity tasks, which would mean a tentative confirmation of Embodied Social Presence Theory in combination with Media Richness Theory (i.e., our amendment to the posit of Embodied Social Presence Theory that stated that 3D objects increase embodiment and ultimately engagement might hold true only for tasks of higher uncertainty or ambiguity). The brainstorming task however was not equipped with symbolic 3D objects like the information sharing task in conditions B and C; the idea cards used in all conditions were merely arranged in a more spatial manner. In accordance with observations made when watching the avatars move during the meetings, the higher felt performance might be due to the fact that the team members walked back and forth between the different idea cards in order to solve the task. In combination with the discussed finding on H1 for the same task and condition, it can be inferred that a spatial separation of different tasks – or even of different elements within one task – can have a positive impact on both retention and subjective performance. This fortifies the tentative confirmations that were concluded regarding H1 above.

Hypothesis H3 was partially accepted for Task 2: the active use of avatars as a virtual embodiment had a more positive impact on the task evaluation in the spacious setup of Condition C – which, as mentioned, required constant moving around between idea cards – than in the static brainwriting board setup of Condition A. This indicates a tentative confirmation for Embodied Social Presence Theory as it was stated in the development of hypothesis H3. The 'intermediate' setup of Condition B led to an intermediate result, indicating a possible positive relationship between the level of the active use of embodiment and positive task evaluation; a possible proportional trend is visible in the center graph in Figure 5.11. At the same time, a possible anti-proportional trend is visible in the upper graph, which could be an indication that Media Richness Theory is applicable in this case: for uncertain and ambiguous tasks (like Task 2) a 'richer medium' – or in the case of the experiment: more elaborate task design – is more suitable, while for simple tasks (like Task 1) a design less rich is more suitable.

5.7. Emergent Design Guidelines

From the results of this investigation of different virtual world collaboration modes for different task types, six guidelines for successfully designing for valuable and memorable collaboration experiences emerged. These six guidelines, presented in Table 5.3., emerge out of a mix of quantitative data and qualitative observation, theories and concepts from the literature, and personal experience gathered during the entire thesis project. They emerge from implications that resulted out of the findings of the measured experiment results as well as from observations made during the conduction of the experiments, and from comments participants made after the experiment.

The first two guidelines are directly inspired from the experiment findings, and based on underlying theories used in the development of the hypotheses of the experiment.

Guideline 1 emerged from the partial acceptance of hypothesis H1 and from the discussion of results and observations regarding H2. Following Media Synchronicity Theory (Dennis & Valacich 1999) as stated in the hypothesis, structuring collaboration tasks spatially can have a positive impact on memorability, especially in tasks where knowledge is created (see previous section).

Guideline 2 emerged from the findings concerning hypothesis H3 and is based on Embodied Social Presence Theory (Mennecke et al. 2010) in combination with Media Richness Theory (Daft & Lengel 1986). Making explicit use of embodiment can have a positive impact on collaboration, especially in tasks of uncertainty or ambiguity (e.g. creativity tasks; see previous section).

Guideline 3 on the contrary came out of observation of participants during the meetings and from numerous comments from participants who stated the virtual world and the tools in it were not difficult to handle, as it took mostly one simple click on the desired objects for them to react in the desired way. Further incitement towards using simple interaction design was received in conversations with other virtual world researchers and designers. Making use of the infamous pie menu in Second Life, or any other menu for that matter, turned out to confuse people who were not used to virtual worlds or the particular virtual world viewer software. Neglecting menus and context menus, but focusing on single clicks and textual or visual responses from the object turned out to be an intuitive approach of designing the interaction in-world that also first-time virtual world users would grasp immediately.

The fourth guideline was included in this list due to the fact that the invisible artificial boundaries we created in our virtual world environment seemed to be the major cause of frustration. In the experiment's condition C, all (invisible) boundaries coincided with the water lines; participants simply accepted the fact that they cannot walk their avatars into the water. In conditions A and B on the other hand, many participants were frustrated about the invisible boundary, some tried repeatedly to overcome it forcefully by jumping and climbing. This guideline goes along the lines of Media Naturalness Theory (Kock 2004), which posits that a more natural or intuitive medium (i.e., more similar to actual world and face-to-face situations) is less alienating and thus less frustrating to its users. We can make this conjecture for the design of collaboration environments and tasks in virtual worlds. This issue regarding the boundaries issue was the stronger one of the two only causes for frustration, the other being problems with writing on the idea cards (clicking on idea cards in order to start brainwriting did not give enough feedback for some participants).

For the development of the final two guidelines, the Collaborative Dimensions Framework developed by Bresciani et al. (2008) is relevant. It is a tool for understanding how visual artifacts can facilitate collaboration in situations where knowledge is distributed among collaborating partners (cf. hidden profile situations, Stasser & Titus 1985). Following the framework, guideline 5 refers to the degree of design applied to collaboration in a virtual world. While guiding participants as to what actions they should perform and which places they should navigate in which order is likely to have a positive impact on the process and outcome of collaboration, overdoing it can reverse the effect. Similar to Dillenbourg (2002) speaking about 'over-scripting CSCL', this guideline proposes not to constrain people too much into a fixed, un-dynamic script, but to guide them to the right degree. In the collaborative dimensions framework, this guideline is captured in the modifiability dimension, which is defined as *"the degree to which the items of the visualization can be dynamically altered in response to the dynamics of the discussion"* (Bresciani et al. 2008, p. 5).

Guideline 6 emerged from observations of the difficulty participants had with the tables in Condition C and other locations with not enough space to easily approach and move around objects. Interest and participation decreased noticeably, while the frustration level increased when participants were handling situations in ‘stuffed’ places. This guideline goes in line with the clarity dimension in Bresciani et al.’s (2008) collaborative dimensions framework, which they define as the property of a visual material to be *“self-explanatory and easily understandable with reduced cognitive effort”* (p.5).

Emergent guidelines for the successful design of virtual world collaboration

1. *Structure collaboration tasks spatially to structure thoughts.*

   Dedicating separate places for separate activities can support memorizing information shared or created during collaboration meetings. Particularly valuable for knowledge creation tasks.

2. *Make active use of embodiment to engage people.*

   Making use of positioning and other avatar movements as a communication channel can improve important collaboration aspects, in particular for tasks of uncertainty or ambiguity.

3. *Use simple interaction design.*

   Designing the users interaction in a simple and intuitive way (e.g., only left clicks on objects instead of utilizing complex menus) allows users of every virtual world expertise level to participate in the collaboration.

4. *Don’t set artificial boundaries.*

   Set natural ones. Designing an island as a place for collaboration is a more natural way of restricting people’s movement than creating visible or invisible walls. It further creates a more consistent reality.

5. *Don’t overdesign.*

   Scaffolding collaboration processes is valuable for the collaboration process and outcome, but constricting people’s actions can lead to frustration.

6. *Don’t stuff.*

   Placing too many objects and other items in too little space can jam participation and bring frustration. Making use of the space to create a structured and organized place for collaboration.

Table 5.3. Six design guidelines that emerged from the research.

5.8. Conclusion

We have presented an experimental investigation of the design of collaboration in virtual worlds, focusing on two of the main distinct features of the platform, namely being embodied as avatars and having a fully-configurable space. We tested whether arranging collaboration tasks in space, using 3D objects, and making active use of virtual embodiment have a positive impact on the process and outcome of collaboration.

The results suggest that the design approach of spatially separating tasks – or elements within a task – has a positive impact on collaboration performance and satisfaction, for knowledge creation tasks. In virtual worlds, structuring tasks spatially is possible virtually without any extra effort or costs. As an overall finding of the experiment and answer to research question RQ3 it can be said that scaffolding collaboration through the design of the virtual environment and tools in it is valuable, if it is applied in the right dosage. Over-designing tools and too stringent guidance can negatively impact the collaboration process. Making active use of the virtual embodiment for navigation and communication positively influenced the participants' subjective performance in the collaboration process.

The experiment findings and the emerging guidelines provide a partial confirmation that the utilization of a structured framework as the one presented in Chapter 4 can ultimately lead to added value for collaboration. The experiment does not provide a formal evaluation or validation of the entire framework; it rather evaluates the approach of making explicit use of the distinct features of virtual worlds in the design of collaboration experiences, and of those features itself. The features of having a configurable space and being represented as avatars (as a virtual embodiment) are central underlying elements of the framework. The empirical investigation presented in this chapter thus fortifies the foundation on which the ABC Framework is built.

We have presented a set of six emergent design guidelines that resulted from the experiment results and from observations of the meetings, and were further informed from previous experiences and conversations with other virtual world researchers and designers.

The experimental design as well as the assessment of the online experiences is a potential area of improvement for research on the matter. While the experiment, in particular the design of the collaboration tasks in the different conditions, could have been approached in countless different ways, here three approaches had to be chosen. With further research in the area, different types of design approaches may emerge, then empirical investigations can be designed in a more focused manner, concentrating on narrower issues. Following the same thought for the issue of selecting what to assess in the collaboration, it can be said that with future research furthering the knowledge base in the field, components can be assessed and evaluated with more focus, increasing the rigor of the research.

The presented investigation also points to some potential disadvantages of virtual worlds, which can be amplified by simply inverting the design guidelines. These potential disadvantages would then stem from the over-designing of collaboration activities and tools, the stuffing of spaces with too many objects or people, the placing of items in an unstructured way, and the neglecting of the virtual embodiment, by merely using avatars as a visual embellishment for static interaction in virtual environments. The resulting disadvantages could include confusion and frustration with the ill-designed activities and spaces, and ultimately with the medium itself. Further research is required to look into the disadvantages of the medium itself and the possible caveats of designing collaboration experiences following the wrong approaches.

At this point we can only hypothesize how far the emerging guidelines can be transferred and applied to designing collaboration in the physical world. There is reason to believe, however, that virtual world research will ultimately be able to improve ‘real’ collaboration activities and thus entire collaboration meetings. This becomes especially evident when looking at advancements in ubiquitous computing and the trend of physical and virtual worlds merging more and more. The actual world and therefore also formerly-traditional collaboration spaces are more and more populated by digital elements. This merger requires new models and approaches of structuring collaboration. In this respect, virtual worlds are a suitable medium to look at, as they combine the actual-world features of embodiment, spatiality, and 3D objects with the digital-world features of responsive and intelligent tools, connectivity, and a number of other features CSCW systems inherit. Thus, to some extent, virtual worlds can be understood as a prototyping environment – a testbed – for collaborative work and learning how it will take place in some years from now. What we understand now from experiments and other investigations of avatar-based collaboration will inform the (re-)design of human-based collaboration in a much more digitally-augmented world, which will be reality rather soon.

Chapter 6: Conclusion

Chapter 6: Conclusion

6.1. Summary

The research presented in this doctoral dissertation has investigated collaboration in virtual worlds – in three-dimensional, online collaborative virtual environments. With the overall research goals of (a) understanding if and how virtual worlds can support collaboration and (b) providing a structure and guidelines for the design of collaborative activities for virtual worlds, the research was framed by an interdisciplinary setting, following the design science paradigm in the tradition of the Information Systems discipline. It followed a comprehensive and complementary approach, consisting of the creation of a framework as a formalization and blueprint for designing virtual world collaboration patterns, and empirical research aimed at evaluating different design approaches using distinct features of the medium virtual worlds. The research was approached by a four-step research design.

As steps one and two, two pre-studies were conducted. The first pre-study was an exploration study with the goal of understanding how teams and groups that meet in virtual worlds use the medium for their collaborative activities. This investigation included the development of a first formalization for collaboration activities in virtual worlds using a pattern-based approach, the exploration of the virtual world Second Life in order to collect existing collaboration patterns, and a review of scientific literature, websites, and blogs in order to collect ideas for innovative collaboration patterns, as well as inspiration for the ideation of novel patterns. Results of this first pre-study were the pattern-based structure for formalizing collaborative activities and a classification of 13 collaborative work and learning patterns, categorized on two axes, by their design effort and their 3D added value. As a second pre-study, a controlled experiment was conducted with the aim of getting a better understanding of the added value that virtual worlds can bring for collaboration. While the first pre-study had addressed current and potential uses of the medium, this second pre-study investigated the features of the medium itself and the added value they can bring for collaboration. We compared small groups collaborating online using pure text chat with groups collaborating in a virtual world environment we designed specifically for the three collaboration tasks. The results, although showing a high deviation, indicated that virtual worlds can have a positive impact on retention: participants that had collaborated in the virtual world on average remembered more of the information shared and created in the three tasks than those that had collaborated using pure text chat. This was true for all tested categories, namely the profile information of the five team members, and elements from the role assignment decision process. Another motivation for the further steps in the overall research was the finding that the three tasks were evaluated slightly more positively by the virtual world groups than by the text chat groups, possibly indicating a higher satisfaction for specific tasks. Due to a measured novelty effect of virtual worlds we believe the measured results to be biased in favor of text chat.

Step three in the overall research design was the development of a framework for collaboration in virtual worlds. This main conceptual step of the research was in part a continuation of the first pre-study, where a first pattern-based formalization for virtual world collaboration patterns had been developed. The developed framework is intended both as a structure and formalization for the description of virtual world collaboration patterns and as an instrument – a blueprint – for the development of innovative collaboration patterns, with a focus on the making use of the distinct features of virtual worlds (i.e., customizable embodiment, configurable environment, and user-generated content / scripting). We named this framework The Avatar-Based Collaboration Framework (ABC Framework). Its development and its component parts were described in detail in Chapter 4 of this thesis. Following the presentation of the framework, a case study was presented, from a project in which the framework came to first use.

As step four of the research, the main empirical part of the thesis, a second controlled experiment was conducted, aimed at investigating the value of different design approaches for collaboration tasks in virtual world. This experiment was both a continuation of the first experiment (the second pre-study), as the then emerged findings were investigated in a more thorough way, and a continuation of the conceptual part of the thesis (i.e., the development of the framework), as the question of *how* to best design collaboration of virtual worlds was addressed only partly by the development of a framework, regarding the *process* – the experiment regarded the *product* of the design of virtual world collaboration. While Chapter 4 and Chapter 5 can therefore be understood as presenting complement parts of the overall research, the experiment in Chapter 5 can be seen as a first part of an evaluation of the framework, by means of evaluating distinct features of the medium virtual worlds. It was designed to investigate two main distinct features in particular: virtual embodiment and configurable environment. In order to understand how these features can be best made use of for collaboration in virtual worlds, three different approaches for designing collaboration tasks were empirically compared. All in a virtual world environment, these three different collaboration modes were compared with 16 groups working on the same three collaboration tasks per condition (i.e., information sharing, brainstorming, decision-making). While the control condition was designed without the use of spatiality or 3D objects to work on the tasks, one experimental condition made use of 3D objects, the other made use of 3D objects and spatiality: tasks were spatially separated from each other, and also within tasks the participants had to move their avatars in order to solve them. The results show that making use of spatial separation of tasks and of elements within tasks can have a positive impact on retention, which was measured just as it was in the pre-study experiment. This result was statistically significant for the brainstorming and the decision-making tasks, where information was created in-place instead of brought into the virtual world for the purpose of sharing, as was the case in the information sharing task (where the data show no statistical significance). The results further indicate that the use of 3D objects in combination with spatiality can have a positive impact on the subjective performance in creativity collaboration tasks. A third finding that emerged from the experiment results is a tentative indication for a possible positive relationship between the active use of embodiment and task evaluation, which would mean that making more explicit use of avatar navigation and interaction can increase the satisfaction with the work process for the particular task.

The thesis thus produced a formal structure for the description and development of collaboration patterns for virtual worlds as well as a set of guidelines to inform the design of patterns. The guidelines, partly emerging from empirical data, can make online collaboration using virtual worlds more engaging, satisfying, and memorable. Theoretical implications of the thesis include the application and tentative confirmation or extension of several theories and concepts. The comprehensive and complementary approach provides a methodological contribution.

Research on virtual worlds is still in its infancy and this study is a broad explorative research, provides a conceptualization of collaboration in VW, a classification, vocabulary, through observation, initial testing and application of modern theories and innovative methodologies.

6.2. Originality of the Research

After summarizing the research and its results in the previous section, this section discusses the originality of the applied approach. The presented work fills a research gap in the area of the design of virtual worlds for collaboration tasks. As it was mentioned in diverse sections in this thesis, both the scientific community and the organizations using virtual worlds for collaboration and education, as well as other practitioners still are not sure what added value the medium brings to the existing forms of communication and collaboration (e.g. Bainbridge 2007, Ducheneaut et al. 2007, Kahai et al. 2008, Davis et al. 2009, Hasler et al. 2009). This work aimed at gathering first indications on how virtual worlds should be designed, in both meanings of the 'how': how the resulting collaboration patterns (i.e., environments and activities in them) should look like, and how the design process can be structured to lead to more innovative designs and ultimately higher value collaboration. With this complex dual goal alone the thesis distinguishes itself as a comprehensive work. Moreover, the approach this work followed differs from other research and from design work in the field of virtual worlds for collaboration, mainly through the following two aspects.

As a first aspect, the work laid a strong emphasis on the *consideration of the distinct features of the medium virtual worlds*. From the beginning of the planning of the research on, there was a focus on those features of virtual worlds that distinguishes the medium from other online tools and systems suitable for collaborative work or learning. With both the author and the supervisor of the thesis having a background in visual communication and a partiality for interactive systems for the support of collaboration, the medium virtual world was chosen when the topic for the thesis was discussed, due to some of the main characteristics of virtual worlds regarding their emphasis on visual cues and the possibilities of integrating visual metaphors. On another note, another reason that virtual worlds were a highly interesting and challenging topic was the timing – in 2008, the marketing hype around Second Life was bottoming out and first serious use cases as well as meaningful research was only springing up (Gartner 2008). A first principle of the work was thus to have these features that are distinct to virtual worlds singled out and to stay aware of keeping them in focus. The reason for laying such a strong emphasis on these features was the appreciation that every medium is different, and applications for each medium should be designed following different design processes and different design guidelines. Following this train of thought, and given the premise that a virtual world is fundamentally different from the actual world, collaboration in a virtual world should be designed in a different way than collaboration in the actual world is. Yet at the beginning of this work – and still now in 2012 – we can observe that virtual world environments and activities (patterns) are oftentimes either copied par for par or heavily influenced from patterns in the actual world. Serious consideration of the importance of the distinct features of virtual worlds to the design of environments and activities has been rising in the community only recently (e.g. Kapp & O'Driscoll 2010, van der Land et al. 2011).

The second aspect that distinguished the approach this thesis followed was the appreciation of *the importance of structure and formalization* in a novel and still only emerging field like virtual worlds. While many virtual world users and also researchers still seem to consider the medium as a novelty and therefore more or less neglect the central problem of designing environments and activities as either irrelevant for the matter or too complex to even try addressing, this work was based on the belief that also – or, especially – for three-dimensional environments design approaches, design processes, and design guidelines are needed.

6.3. Contributions and Implications

Following the design science paradigm and the guidelines for good design science research (Hevner et al. 2004), the contributions and implications of this work presented in this section are sorted by theoretical implications (relevant to academic rigor) and practical implications (practical relevance).

Theoretical Implications

The ABC Framework that was developed in the scope of this thesis makes a conceptual contribution by providing a foundational vocabulary for the field of virtual worlds and a classification of the elements of the medium, as well as a method for the design of collaboration patterns.

Another theoretical contribution is offered by demonstrating that making explicit use of the distinct features of the medium virtual worlds in the design of collaboration environments and activities (or, experiences) can enhance online collaboration. Due to limited statistical power however, results can only tentatively confirm and extend the several used theories and concepts by providing relevant indications based on the gathered empirical data.

The implications of the empirical findings from the conducted studies are relevant at a theoretical level by providing a first tentative empirical confirmation of Embodied Social Presence Theory (Mennecke et al. 2010). An amendment we would propose to the theory, following our research, is that Embodied Social Presence Theory may hold true especially for tasks of uncertainty or ambiguity, and should thus be considered in combination with Media Richness Theory. To our knowledge, this work presents first empirical research toward the confirmation of the theory. Insights to the application of controlled experiments for virtual worlds research can be seen as a methodological contribution.

The findings of the conducted experiments provide a positive indication that Distributed Cognition (Hutchins 1995) can be successfully extended to virtual worlds. This means that information and knowledge can be placed in the virtual world itself or in artifacts (virtual objects) in it, the environment can be structured, and the interaction among individuals as well as interaction between them and the environment can be successfully coordinated using ecological approaches. This ultimately extends a major part of the theoretical background of Computer-Supported Collaborative Learning (Dillenbourg 1999) to the medium of 3D virtual worlds, making methodologies and approaches directly applicable also there. The indications for positive effects of spatially structuring collaboration tasks in virtual worlds also imply that Media Synchronicity Theory (Dennis & Valacich 1999) can be applied to the design of collaborative virtual environments. In particular, the orchestration of synchronicity (e.g. purposefully structuring tasks in the environment in spatial arrangements in order to control the collaborators' focus of attention) has indicated to be a successful method to improve collaboration, particularly retention. These arguments also indicate that the mnemonic technique of loci (de Beni & Cornoldi 1985) may also be extended to the medium virtual worlds.

The conducted experiments further indicate that the concept of Pictorial Superiority Effect (Nelson et al. 1976) and its underlying Dual Coding Theory (Paivio 1986) can be successfully extended to the realm of 3D virtual environments, as it was shown in the context of virtual worlds. That is, also the visual cues in virtual environments seem to lead to better memorability than verbal information. On a related note, the studies in some cases also indicate that Media Richness Theory (Daft & Lengel 1986) can be applied to virtual worlds: for more ambiguous and uncertain tasks, a 'richer' task design seemed to be more suitable, while for more certain and straightforward tasks the contrary was the case.

One implication of the ABC Framework at a theoretical level is providing a basis for conceptualization and theorization on virtual worlds. Its classification and categorization of the components of virtual worlds and elements of avatar-based collaboration can serve as foundations for the development of scientific models, collaboration techniques, and design methodologies. As an example, the framework can serve as the conceptual basis for an extension of the field of Collaboration Engineering (de Vreede & Briggs 2005) to the realm of virtual worlds (as a particular type of group support system). It could also function as a basis for the development of a broader framework that could potentially encompass the entire field of Collaboration Engineering, spanning a number of different media. Such a development could be an approach to leverage the field of Collaboration Engineering.

The framework is also a novel application of Semiotics (Eco 1987) as a foundation, following others that built on the semiotic triad of syntactic, semantic, and pragmatic layers (e.g. Shanks 1999, Schmid & Lindemann 1998). The conducted empirical investigations provide an initial evaluation of parts of the ABC Framework. This mixed methods approach of development of a conceptual framework and consequentially testing parts of it can be seen as another methodological contribution.

As a last implication relevant at a theoretical, but also at a methodological level, the comprehensive approach of the thesis shall be highlighted. It connects several research fields from different disciplines, has thus resulted in having a rather broad character, and serves as a proof of concept for interdisciplinary research, shown in the context of an application area highly promising, which however is in terms of theory still in its infancy.

Practical Implications

From a practical standpoint, this research aimed at making online collaboration more engaging, satisfying, and memorable. One practical contribution of the work is a framework that serves both as a description structure and as a blueprint for the development of fruitful collaboration patterns for virtual worlds. It emphasizes the making use of the distinct features of the medium.

The other main outcome of the work is a set of six guidelines, partly derived from the empirical research conducted, partly from theories and concepts, other related work, and personal experience. The guidelines are intended to inform the design of collaboration patterns in virtual worlds, aiming for them to be more engaging, satisfying, and memorable. With these contributions, the work yields the following practical implications.

The classification developed in the pre-study exploration provides a structured overview of the possibilities of the medium virtual worlds. It shows a snapshot of the current state-of-the-art of collaboration patterns in virtual worlds and further proposes a classification method for collaboration patterns that can serve various purposes, for example to classify learning patterns according to their complexity (e.g. for assessing the suitability of collaboration patterns for certain target groups or expertise levels), or to assess the effort required to design or implement certain collaboration patterns (e.g. in order to calculate pricing for their design or implementation).

The ABC Framework can serve as a powerful tool for the description and creation of collaborative activities for virtual worlds. The structured formalization of collaboration patterns in the format of the ABC Framework that was developed in the scope of this thesis can facilitate documenting, sharing, discussing, and collaborative developing of virtual world collaboration patterns. As a formalization it provides a flexible but structured format that can serve as a basis for communication of patterns and pattern elements with the most various purposes. It is possible to assume that using this formalization as a ‘common ground’ for all kinds of communication on and around collaboration patterns could even help start the development of a formal pattern language of virtual world collaboration patterns. With a more human-centered and goal-driven design process and a stronger empirical basis, as this thesis and the ABC Framework provide it, the percentage of successful virtual world projects can be significantly increased (cf. Gartner 2008).

The results and findings of the empirical investigations conducted in the scope of this thesis project could raise awareness to the importance of design in the field of collaborative work and learning in virtual worlds. As mentioned in the previous section, many virtual world researchers and designers still do not mind design enough and at times resort to either copying actual world environments or getting heavily inspired by actual world environments and activities, although in fact designing for a fully-digital online medium that is fundamentally different from the actual world. The results of the experiments conducted in the scope of this thesis have indicated that purposeful design can make a difference. To this end, the ABC Framework provides a powerful formalization, helping make explicit use of the distinct features of virtual worlds in the creation of collaboration patterns.

The education community, which is already active in virtual worlds in high numbers, could grow stronger by making use of the tools provided as outcomes of the work at hand. This thesis, its approach, and its findings could inspire numerous researchers and educators to experiment with more innovative designs for their virtual environments and novel activities and approaches for teaching and learning. Kapp & O’Driscoll (2010) provide – besides the extensive background on learning and motivation for using virtual worlds – various examples and case studies that can perfectly be used as inspirational material, in combination with the ABC Framework. Practitioners who seek to improve aspects of working collaboratively, ranging from processes through documentation to employee engagement and satisfaction, and virtual world designers and hosts who simply want to offer more engaging experiences to their visitors or customers can directly profit from this work; the ABC Framework is readily usable: Appendix E provides a print/scan version.

As for collaborative work, the set of guidelines that emerged from the research at hand can help in designing memorable virtual experiences that lead to real added value, and thus may help render the use of virtual worlds and 3D collaborative virtual environments in general more worthwhile for corporate communication, collaborative work, and other business use cases. This in turn could increase the return-on-investment of using virtual worlds, which might ultimately improve the broader acceptance of virtual worlds as a mainstream collaboration medium.

<table>
<tr><th colspan="3">Overall research goal</th></tr>
<tr><td colspan="3">Understand if and how virtual worlds can support collaboration and provide a structure and guidelines for the design of collaborative activities</td></tr>
<tr><th colspan="3">Research questions</th></tr>
<tr><td>RQ1</td><td>RQ2</td><td>RQ3</td></tr>
<tr><td>Can virtual worlds support collaborative activities, and if so, how?</td><td>How can we support the process of designing for fruitful collaboration experiences for virtual worlds?</td><td>How should collaborative activities for virtual worlds be designed in order to best utilize the medium?</td></tr>
<tr><th colspan="3">Theoretical Implications</th></tr>
<tr><td>• Extension of Pictorial Superiority Effect & Dual Coding Theory to 3D / virtual worlds</td><td>• Vocabulary for the field of virtual worlds
• Categorization of virtual world elements as a basis for conceptualization and theorization
• Extension of the field of Collaboration Engineering to virtual worlds</td><td>• Extension of Distributed Cognition to virtual worlds
• Extension of Media Synchronicity Theory to virtual worlds
• Extension of Media Richness Theory to virtual worlds
• Initial evaluation of parts of the ABC Framework</td></tr>
<tr><td colspan="3">• Tentative confirmation of, and amendment to Embodied Social Presence Theory
• Link of several disciplines – comprehensive approach to collaboration in virtual worlds
• Methodological insights: using controlled experiments for virtual worlds research
• Mixed methods approach: conceptual framework and testing</td></tr>
<tr><th colspan="3">Practical Implications</th></tr>
<tr><td>• Overview of patterns: existing & potential
• Classification method</td><td>• Powerful tool for the creation of collaborative activities for virtual worlds</td><td>• Set of guidelines</td></tr>
</table>

Table 6.1. Overview of theoretical and practical implications of the thesis

Answering the Research Questions

After discussing and giving an overview of the contributions and implications, the three research questions of the thesis are answered concisely in the following, taking into account all of the above. Theories and concepts that were applied or extended in the research are included in brackets for each statement.

RQ1: Can virtual worlds support collaborative activities, and if so, how?

This work provides two main positive indications that virtual worlds can support collaborative activities and add value to online collaboration. First, the highly visual character of a virtual world seems to be a factor that leads to better memorability and higher retention, thus ultimately supporting collaboration (Pictorial Superiority Effect). Second, being immersed and embodied in a virtual world may lead to higher engagement in collaboration tasks, as compared to the 'disembodied' collaboration modality of simple text chat (Embodied Social Presence Theory). To answer the *how* part of the question in short, the medium virtual worlds can support collaborative activities by making explicit use of its distinct features in the design of collaboration patterns. For details on the design approach see the answer to RQ3 below.

RQ2: How can we support the process of designing for fruitful collaboration experiences for virtual worlds?

Prior to this work, there were very few structured or guided design processes or frameworks for fruitful collaboration experiences. With the development of the ABC Framework (based on Semiotics) and the initial case study we argue that its structured formalization of the components of virtual world collaboration (using a pattern-based approach) can support the design process (following the Design Science paradigm), especially due to the fact that the framework emphasizes the explicit making use of the distinct features of the medium (see answers to RQ1 and RQ3).

RQ3: How should collaborative activities for virtual worlds be designed in order to best utilize the medium?

Collaborative activities for virtual worlds should be designed following the guidelines developed in the scope of this thesis. The guidelines emerged from the experiment described in Chapter 5, other parts of the research, scientific literature, and experience of the experimenter and author. The guidelines suggest virtual world designers to (1.) structure collaboration tasks and elements spatially, which seems to be beneficial for controlling focus, and thus conducive to collaboration (Media Synchronicity Theory), to (2.) make active use of virtual embodiment to engage individuals (Embodied Social Presence Theory), to (3.) use simple interaction design in order to empower everyone to collaborate, to (4.) set natural boundaries instead of artificial ones, and to refrain from (5.) overdesigning collaboration process and (6.) stuffing the spaces.

6.4. Limitations

The arguably strongest limitation of the research is the small sample size in the empirical investigation. Due to the resulting limited statistical power, generalizations based on the results and findings of the empirical research can only be made to a certain extent. In the several discussions of the experiment results throughout the thesis this limitation was considered by concluding only indicative confirmations of hypotheses and implying only tentative extensions of theories in all the cases.

Another limitation concerning the empirical part was the fact that the experiments forced the participants to play a role, instead of being themselves in the collaboration meetings. This design was necessary out of several reasons. First, the profiles had to be the same for each single experiment run, for them to be comparable for analysis in the end; using participants' real identities and profiles would only allow to conduct case studies with different groups, no controlled experiment. Second, the avatars had to be predesigned. This was obviously connected to the first point, but also helped for streamlining purposes; having the participants design their avatars to resemble themselves would require too much effort – a separate investigation could be conducted on this one task alone.

Another arguable limitation was the use of one single virtual world platform, OpenSim. While the design of the collaboration environment for both conducted experiments was very mindful of not making use of the specific user interface of the particular viewer software used, some peculiarities of the platform can never be fully eliminated. Avatars look different on different virtual world platforms, navigation feels different, interaction works in different ways, and also text chat works and looks different. This point reflects again the early, non-standardized state virtual worlds are still in. To date, each virtual world platform is 'an island', in the sense that no communication or collaboration – let alone, navigation – between different platforms is possible yet.

As for the experiment design, a limitation to be noted could be that there might be more suitable approaches that could have been taken in the design and development of the different collaboration modes. Implementing one condition using 2D objects and making just little use of the spatiality inherent to the world, one condition making explicit use of 3D objects, avatars, and the world's spatiality, as well as one intermediate condition, bridging the two former conditions, can be done in an infinite number of different ways. The ways pursued in the implementation of the conducted experiment presented in this thesis is merely one possible way. A whole series of experiments could compare various implementations for each collaboration mode by itself. The possibilities virtual worlds offer with respect to designing and implementing designs are of unseen extent – which was one main motivation for this research, and will be one for future research.

As a last limitation to mention here the scope of the entire research has to be noted. The work being 'only' a doctoral thesis, its leeway had to be confined somewhere. In a larger-scale research project, the two directions that the thesis took (i.e., addressing both process and outcome of the design of collaboration in virtual worlds) could have been explored more thoroughly. This point is also the reason for the fact that a choice had to be made after the development of the ABC Framework regarding the continuation of the research; it could have either been the initiation of a formal validation of the framework or the experimental investigation of design approaches for virtual world collaboration tasks. The choice was made for the latter. The former had to be moved to the section of future research, and is described below.

Also, as a result of having to confine the research in order for it not to exceed the scope of a doctoral thesis project too much, not all data gathered in the experiment described in Chapter 5 could be analyzed. In addition to the analyzed data described in this work, we collected data about every move and action of all avatars in all experiment runs. This includes navigation data (3D position), orientation data (2D rotation), interaction data (clicks on objects), and data on the use of the brainstorming boards (entered text).

6.5. Future Research and Outlook

This interdisciplinary work connects several academic disciplines and research areas. As a first research project addressing both the formalization of the design process and the investigation of valuable approaches and design aspects of the collaboration experience to ultimately design for, it opens up various research directions. In general, future research in this area should look into conducting larger-scale empirical investigations in order to conclude statistically valid generalizations.

One direct step of future work would be the mentioned formal validation of the ABC Framework with independent participants. This should be done in a bit-by-bit fashion, concentrating only on a limited set of elements each time. As a first step, test subjects could be asked to look at a virtual world collaboration environment – or, at a collaboration meeting – and to then describe it in the formalization of the framework. While the initiation of such a formal validation was considered to directly follow the development of the framework in the scope of the thesis at hand, the controlled experiment presented in Chapter 5 was favored, as one main goal of the thesis was to address both the process and the product of the design of collaboration experiences in virtual worlds. The experiment so evaluated first distinct features of the medium virtual worlds, thus a part of the base of the ABC Framework.

Another step would be to further develop the framework itself, either before or through its empirical investigation and validation. Here, the distinction between learning patterns and patterns of collaborative work should be investigated more thoroughly. The framework could be modified in order to be more flexible for the three different application areas (i.e., work, learn, and play), for this purpose it could potentially be redesigned with exchangeable elements in the dramaturgy layer, which could be selected depending on the goals and contexts of the pattern. This way, the relationship between the dramaturgy and goal/context layers could be redeveloped.

Taking this idea further, as a formalization and a structured development tool for collaboration patterns, the Avatar-Based Collaboration Framework can potentially be transferred to other media, in other words, transformed into a framework for collaboration in other digitally-augmented environments. Examples for such environments would be ubiquitous computing (UbiComp, the actual world populated with many interactive or responsive devices), augmented reality (AR, the actual world superimposed with digital, mostly visual and auditory, information), and office environments equipped with big interactive walls or projection screens. Transformed to such other digitally-augmented environments, the infrastructure layer of the ABC Framework would be replaced with a layer representing the distinct features and main structural elements of the destination media. Such an evolving framework could in the longer run grow more generic and offer a pool of interchangeable infrastructure layers, for the use in different environments. The dramaturgy and context/goal layers could remain as they are (besides the integral improvements that come with the design-science research cycle, see section 4.10). The framework developed in this presented thesis could thus become the basis for a very versatile standard tool and format for the design collaboration.

Further empirical investigations of design approaches and use as well as effects of distinct virtual world features should be conducted. Such investigations can be conducted either as direct, or as more indirect continuations of the experiment that was presented in Chapter 5.

Similarly, the investigation of the added value of virtual worlds that was started with the experiments presented in Chapter 3 can be pursued, for example by comparing collaboration in a virtual world environment to collaboration using video chat, or to collaboration in a face-to-face setting.

Whether or not the medium of virtual worlds as it is now will prevail and further develop into a mainstream collaboration platform is yet undecided. Surely, it will take a great number of further investigations in order to generically answer to the rather broad research questions that were first approached in this thesis. This future research will also give more insights into the disadvantages of virtual worlds, which in this thesis could only be marginally addressed.

Appendix

Appendix A: Persona Profiles used in the Experiments

Online Collaboration

Instruction

Situation

A group of five professionals with different backgrounds meet for the first time – online. The goal of this meeting is to get to know each other and form the project team for the development of a website that illustrates the financial crisis to non-experts. You impersonate one of the five professionals (find the characterization of your persona below).

Meeting

Steps that need to be followed in the meeting are:

1) present yourself (i.e. your persona) to your team members, as detailed as possible – **5 mins**
2) agree on the scope of the project (briefly discuss the meaning of the goals) – **5 mins**
3) discuss and assign project roles to individuals based on their profile and skills – **5 mins**

The project roles are:

- content (and graphical design)
- development (website creation)
- marketing (public relations)
- project management

A person can have more than one role, and it is possible to have more persons for one role. Only project management should be assigned to exactly one person.

Your profile

Name	Anne
Gender	F
Age	45
Occupation	economist
Experience/ History	banker, marketer, entrepreneur
Hobbies	motivational trainer

Online Collaboration

Instruction

Situation

A group of five professionals with different backgrounds meet for the first time – online. The goal of this meeting is to get to know each other and form the project team for the development of a website that illustrates the financial crisis to non-experts. You impersonate one of the five professionals (find the characterization of your persona below).

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3) discuss and assign project roles to individuals based on their profile and skills – **5 mins**

The project roles are:

- content (and graphical design)
- development (website creation)
- marketing (public relations)
- project management

A person can have more than one role, and it is possible to have more persons for one role. Only project management should be assigned to exactly one person.

Your profile

Name	Robert
Gender	m
Age	23
Occupation	economist
Experience/ History	master thesis on mortgages
Hobbies	tennis

Online Collaboration

Instruction

Situation

A group of five professionals with different backgrounds meet for the first time – online. The goal of this meeting is to get to know each other and form the project team for the development of a website that illustrates the financial crisis to non-experts. You impersonate one of the five professionals (find the characterization of your persona below).

Meeting

Steps that need to be followed in the meeting are:

1) present yourself (i.e. your persona) to your team members, as detailed as possible – **5 mins**
2) agree on the scope of the project (briefly discuss the meaning of the goals) – **5 mins**
3) discuss and assign project roles to individuals based on their profile and skills – **5 mins**

The project roles are:

- content (and graphical design)
- development (website creation)
- marketing (public relations)
- project management

A person can have more than one role, and it is possible to have more persons for one role. Only project management should be assigned to exactly one person.

Your profile

Name	Marcus
Gender	m
Age	38
Occupation	communications
Experience/ History	marketing, web development
Hobbies	active as kick boxer in the past, now maintaining an internet portal about kick boxing

Online Collaboration

Instruction

Situation

A group of five professionals with different backgrounds meet for the first time – online. The goal of this meeting is to get to know each other and form the project team for the development of a website that illustrates the financial crisis to non-experts. You impersonate one of the five professionals (find the characterization of your persona below).

Meeting

Steps that need to be followed in the meeting are:

1) present yourself (i.e. your persona) to your team members, as detailed as possible – **5 mins**
2) agree on the scope of the project (briefly discuss the meaning of the goals) – **5 mins**
3) discuss and assign project roles to individuals based on their profile and skills – **5 mins**

The project roles are:

- content (and graphical design)
- development (website creation)
- marketing (public relations)
- project management

A person can have more than one role, and it is possible to have more persons for one role. Only project management should be assigned to exactly one person.

Your profile

Name	Paul
Gender	m
Age	59
Occupation	economist
Experience/ History	teacher, book editor
Hobbies	story writing, storytelling, public readings

Online Collaboration

Instruction

Situation

A group of five professionals with different backgrounds meet for the first time – online. The goal of this meeting is to get to know each other and form the project team for the development of a website that illustrates the financial crisis to non-experts. You impersonate one of the five professionals (find the characterization of your persona below).

Meeting

Steps that need to be followed in the meeting are:

1) present yourself (i.e. your persona) to your team members, as detailed as possible – **5 mins**
2) agree on the scope of the project (briefly discuss the meaning of the goals) – **5 mins**
3) discuss and assign project roles to individuals based on their profile and skills – **5 mins**

The project roles are:

- content (and graphical design)
- development (website creation)
- marketing (public relations)
- project management

A person can have more than one role, and it is possible to have more persons for one role. Only project management should be assigned to exactly one person.

Your profile

Name	Jennifer
Gender	F
Age	28
Occupation	communications consultant
Experience/ History	journalism
Hobbies	yoga, dancing

Appendix B: Questionnaires from Experimental Comparison Virtual World and Text Chat

Pre-Experiment Questionnaire

Online Collaboration

Questionnaire 1 of 2

Lugano, April 2009

Real Name ______________________________________

Assigned Name __________________________________

Please provide some personal information:

Mother tongue: ❑ Italian ❑ French ❑ German ❑ English ❑ Other: ______________

Age: _______

Gender: ❑ female ❑ male

Please answer the following statements making a cross on the response that best matches your feelings toward the statement.
Your personal information and all your answers will be kept confidential.

I have worked in teams before: ❑ yes ❑ no

I use text chat…

never			*sometimes*			*very often*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I use 3D virtual worlds or play 3D video/computer games...

never			*sometimes*			*very often*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Please turn over the questionnaire and put it aside, but leave it on your desk.

Now proceed with the next sheet – read the instructions for the activity.

First Post-Experiment Questionnaire

Online Collaboration

Questionnaire 2 of 2

Lugano, April 2009

Real Name ______________________________________

Assigned Name __________________________________

In this experiment I used: ❑ Virtual World ❑ Text Chat

Please answer to the following statements making a cross on the response that best matches your feelings toward the statement. There are no right or wrong answers. Your answers will be kept confidential.

I feel satisfied with the way in which the project team meeting was conducted.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I feel satisfied with the overall results of the meeting.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I was able to present my persona and his/her profile to my team mates in a memorable way.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

My team mates presented their personas in a way that I can remember them, also after the meeting.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

When talking about the project, me and my team mates quickly came to a common understanding.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Me and my team mates came to a common understanding.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Assigning the roles was straightforward and understandable for all team members.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

The final role assignment makes sense.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I felt comfortable using this media for this collaboration meeting.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I would use this mode of collaboration again.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Why / why not? ____

We were often distracted from the main tasks by off-topic conversation or actions.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

There were personal conflicts among some of the people of the group during the meeting.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

There were communication difficulties because of the language or for other reasons.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

I feel I performed well in the meeting.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Why / why not? ____

I felt that my team members collaborated well.

strongly disagree			*neutral*			*strongly agree*
1❑	2❑	3❑	4❑	5❑	6❑	7❑

Why / why not? ____

Please turn over the questionnaire and hand it in, together with the other sheets.

Thank you very much for your participation!

Second Post-Experiment Questionnaire

Online Collaboration

Questionnaire 3 of 2

Lugano, April 2009

Real Name ______________________________

Assigned Name ______________________________

Please try to remember your team members. Fill in the following table with the data you can recall. For points you can not remember, try to guess (don't enter your own persona's profile here).

Name				
Gender				
Age				
Occupation				
Experience/ History				
Hobbies				

Now try to remember the role assignment you agreed on with your team and mark it (with **X**'s) in the appropriate cells. You can use bigger **X**'s for emphasis. Please fill in the names first.

Name					
Project Management					
Content					
Development					
Marketing					

Well done! This was the final questionnaire.

Please leave all your questionnaires on your desk.

Thank you very much for your participation – again!

Appendix C: Questionnaires from Virtual World Collaboration Experiment

Pre-Experiment Questionnaire

Virtual World Collaboration: Pre-Study Survey

Intro

0%

Before we start with the virtual world collaboration tasks, we would like to ask you some questions about yourself.

The information that you provide in this survey will be kept confidential. We will only evaluate it in the context of this research project. All answers are collected anonymously so that no individual can be identified in the data. If you have any questions during the study, don't hesitate to ask the experimenter.

Thank you very much for your participation!

Please enter your participation number:

The number is printed on your instruction sheet.

Virtual World Collaboration: Pre-Study Survey

Personal information

20%

Age:

Sex:

- male
- female

Nationality:

First language:

Virtual World Collaboration: Pre-Study Survey

Computer experience

40%

On average, how much time do you spend at the computer per week?

Please estimate the time per week in hours.

[ ]

How often do you use virtual worlds (like Second Life)?

- ○ every day
- ○ at least once a week
- ○ at least once a month
- ○ I have used virtual worlds only once or few times.
- ○ I do not use virtual worlds.

How often do you play computer or video games?

- ○ every day
- ○ at least once a week
- ○ at least once a month
- ○ I have played computer/video games only once or few times.
- ○ I do not play computer/video games.

How many avatars or game characters do you have in total?

[ ]

Virtual World Collaboration: Pre-Study Survey

Virtual team and leadership experience

60%

How often have you worked or learned in a virtual team (a team consisting of members who work at different locations)?

- ○ never
- ○ occasionally
- ○ often

Have you ever led a work team in a formal leadership position?

- ○ never
- ○ occasionally
- ○ often

Virtual World Collaboration: Pre-Study Survey

Personality

80%

How do you perceive yourself regarding the following attributes?

Try to describe yourself as accurately as possible. Describe yourself on the following scales as you see yourself at the present time, not as you wish to be in the future. Describe yourself as you are generally or typically, as compared with other persons you know of the same sex and of roughly your same age.

silent	talkative
unassertive	assertive
unadventurous	adventurous
unenergetic	energetic
timid	bold
unkind	kind
uncooperative	cooperative
selfish	unselfish
distrustful	trustful
stingy	generous
disorganized	organized
irresponsible	responsible
impractical	practical
careless	thorough
lazy	hardworking
relaxed	tense
at ease	nervous
stable	unstable
contented	discontented
unemotional	emotional
unimaginative	imaginative
uncreative	creative
uninquisitive	curious
unreflective	reflective
unsophisticated	sophisticated

Virtual World Collaboration: Pre-Study Survey

Thank You!

100%

Thank you for taking this survey!

Please wait for further instructions from the experimenter.

First Post-Experiment Questionnaire

Virtual World Collaboration: Post-Study Survey

Intro

10%

We would like to ask you some questions about your opinion on the use of virtual worlds for remote collaboration, and how you experienced the virtual environment, group dynamics, and collaborative tasks in this study.

The information that you provide in this survey will be kept confidential. We will only evaluate it in the context of this research project. All answers are collected anonymously so that no individual can be identified in the data. If you have any questions about this survey, don't hesitate to ask the experimenter.

Thank you very much for your participation!

Please enter your participation number:

The number is printed on your instruction sheet.

00112201

Virtual World Collaboration: Post-Study Survey

Virtual (world) environment

10%

Did you feel comfortable using a 3D virtual world for this collaboration meeting?

○	○	○	○	○
very uncomfortable	rather uncomfortable	neutral	rather comfortable	very comfortable

Were the setup of the environment and the tools in it useful to effectively support and foster the collaboration?

○	○	○	○	○
very useless	rather useless	undecided	rather useful	very useful

Was it generally clear to you what you were supposed to do or where you were supposed to go?

○	○	○	○	○
very unclear	rather unclear	undecided	rather clear	very clear

Virtual World Collaboration: Post-Study Survey

Avatar embodiment

20%

Please indicate how much you agree or disagree to the following statements regarding the use of avatars and to what extent they contribute to the teamwork success.

	strongly disagree	quite disagree	slightly disagree	neither agree nor disagree	slightly agree	quite agree	strongly agree
The appearance of avatars is relevant to the teamwork success.							
Displaying nonverbal behavior (such as gestures and facial expressions) through avatars improves team communication.							
Interacting with 3D objects in a virtual world can improve team collaboration.							
A shared virtual environment creates a sense of presence ("the feeling of being there together in the same room").							

Virtual World Collaboration: Post-Study Survey

Task evaluation

30%

Please rate each of the tasks that you just completed with your team on the following attributes.

Assign more stars the better you rate a task on the attributes below.

Example:
If you found task 1 very easy, select all 5 stars (*******).
If you found task 1 not easy at all, select only 1 star (*).
If the difficulty level of task 1 was somewhere in-between, choose the corresponding number of stars (between 2 and 4).

	Task 1 (Presentation)	Task 2 (Brainwriting)	Task 3 (Role Assignment)
easy			
interesting			
satisfying			
successful			
engaging			
immersive			
efficient			
enjoyable			
inspiring			

Virtual World Collaboration: Post-Study Survey

Subjective Performance

40%

Please indicate how much you agree or disagree to the following statements about your team's performance in TASK 1 (presentation task).

	strongly disagree	quite disagree	slightly disagree	neither	slightly agree	quite agree	strongly agree
The team members shared information and listened carefully to each other.	○	○	○	○	○	○	○
The team members presented their personas clearly and effectively.	○	○	○	○	○	○	○

Please indicate how much you agree or disagree to the following statements about your team's performance in TASK 2 (brainstorming task).

	strongly disagree	quite disagree	slightly disagree	neither	slightly agree	quite agree	strongly agree
The team summarized and organized their ideas.	○	○	○	○	○	○	○
The team members built on each others' ideas.	○	○	○	○	○	○	○

Please indicate how much you agree or disagree to the following statements about your team's performance in TASK 3 (role assignment task).

	strongly disagree	quite disagree	slightly disagree	neither	slightly agree	quite agree	strongly agree
The team members communicated clearly and effectively.	○	○	○	○	○	○	○
The quality and problems of the current state of role assignment were easily visible at any given time.	○	○	○	○	○	○	○

Virtual World Collaboration: Post-Study Survey

Work satisfaction

50%

How satisfied or dissatisfied are you with the quality of the solutions (or outcomes) which you and your team members reached?

	1	2	3	4	5	6	7	
very dissatisfied	○	○	○	○	○	○	○	very satisfied

Please answer the following questions on a scale from "not at all" to "very much".

	(1) not at all	(2)	(3)	(4)	(5)	(6)	(7) very much
To what extent does the final solution (or outcome) of each task reflect your inputs?	○	○	○	○	○	○	○
To what extent do you feel committed to the solutions (or outcomes)?	○	○	○	○	○	○	○
To what extent are you confident that your solutions (or outcomes) are optimal?	○	○	○	○	○	○	○
To what extent do you feel personally responsible for the solutions (or outcomes) which you and your team members reached?	○	○	○	○	○	○	○

How would you describe the problem solving (or negotiation) process you and your team members used in the collaboration?

efficient	○	○	○	○	○	○	○	inefficient
uncoordinated	○	○	○	○	○	○	○	coordinated
fair	○	○	○	○	○	○	○	unfair
understandable	○	○	○	○	○	○	○	confusing
dissatisfying	○	○	○	○	○	○	○	satisfying

Virtual World Collaboration: Post-Study Survey

Perceived Group Cohesion

60%

Please indicate how much you agree or disagree to the following statements.

	strongly disagree	quite disagree	slightly disagree	neither	slightly agree	quite agree	strongly agree
I felt that I belong to this group.	○	○	○	○	○	○	○
I was happy to be part of this group.	○	○	○	○	○	○	○
I saw myself as part of this group.	○	○	○	○	○	○	○
This group was one of the best anywhere.	○	○	○	○	○	○	○
I felt that I am a member of this group.	○	○	○	○	○	○	○
I was content to be part of this group.	○	○	○	○	○	○	○

Virtual World Collaboration: Post-Study Survey

Emergent leadership

70%

Please indicate which of the following team members (if any) have taken over a leadership role in your group work. You can select one or multiple team members including yourself. If nobody has taken over a leadership role in your teamwork, please select "nobody".

Note: The person(s) who emerged as a leader does not necessarily need to be the same person(s) who has been assigned to the project manager role in task 3!

- ☐ Anne
- ☐ Jennifer
- ☐ Marcus
- ☐ Paul
- ☐ Robert
- ☐ nobody

Virtual World Collaboration: Post-Study Survey

Perceived Similarity

80%

Please indicate how different or similar you perceived your team members to yourself based on their behavior in the collaboration tasks.

Note: For administrative reasons you will also find your own avatar name on this list. The ratings that you provide for yourself will of course not be considered.

	I strongly disagree	I quite disagree	I slightly disagree	I neither disagree or agree	I slightly agree	I quite agree	I strongly agree
Anne is very similar to me.	○	○	○	○	○	○	○
Jennifer is very similar to me.	○	○	○	○	○	○	○
Marcus is very similar to me.	○	○	○	○	○	○	○
Paul is very similar to me.	○	○	○	○	○	○	○
Robert is very similar to me.	○	○	○	○	○	○	○

Virtual World Collaboration: Post-Study Survey

General questions

90%

Did you find out which person was behind which avatar?

- (•) No
- ( ) Yes

If you answered "Yes" to the question above, please specify which person you think was behind which avatar and at what time during the collaboration you found it out. (If you don't know the person's name, describe where he/she was sitting)

Did you take notes during the collaboration tasks?

- ( ) Yes
- ( ) No

Did you have technical difficulties in participating in this study?

- ( ) Yes
- ( ) No

Did anything hinder you from being able to contribute to the collaboration tasks?

- ( ) Yes
- ( ) No

Do you have any questions or comments about the Virtual World Collaboration study?

Virtual World Collaboration: Post-Study Survey

Thank You!

100%

Thank you for taking this survey!

Please wait for further instructions from the experimenter.

Second Post-Experiment Questionnaire

Virtual World Collaboration Post-Post-Study Survey

Intro

0%

We apologize not having advertised this third questionnaire, doing so would have tempered with the results.

The information that you provide in this survey will be kept confidential. We will only evaluate it in the context of this research project. All answers are collected anonymously so that no individual can be identified in the data. If you have any questions during the study, don't hesitate to ask the experimenter.

Please enter your participation number:

The number is printed on your instruction sheet.

Virtual World Collaboration Post-Post-Study Survey

Recall of team members' profiles

25%

Please try to remember your team members. Fill in the following table with the information about them you can recall. For points you can not remember, try to guess. (Don't enter your own persona's profile here).

	Name	Sex (f/m)	Age	Occupation	Experience/History	Hobbies
Team Member						
Team Member						
Team Member						
Team Member						

Virtual World Collaboration Post-Post-Study Survey

Recall of final role assignment

50%

Now try to remember the role assignment you agreed on with your team and mark it (writing x) in the appropriate cells. You can use bigger X for emphasis. Please fill in the names in the top row first, including your own persona.

	Member	Member	Member	Member	Member
NAME					
Content					
Development					
Marketing					
Project Management (PM)					

Virtual World Collaboration Post-Post-Study Survey

Recall of brainstorming outcomes

75%

Last but not least, please try to remember the ideas you developed in your team during the brainstorming task. Fill in the lines with the titles and points you remember from the cards. Formatting is not important.

Card 1

Card 2

Card 3

Card 4

Card 5

Card 6

Card 7

Card 8

Card 9

Virtual World Collaboration Post-Post-Study Survey

Thank You!

100%

Now this was the very last questionnaire.

Thank you again for your participation!

Appendix D: Example Collaboration Patterns in the Structure of the ABC Framework

Anticipate Robot Behavior (+ Robot Pantomime / Role Play)

Goal/Context

Collaborate				Learn						Play				
Share	Decide	Design/ Create		Memorize/ Recall	Compre-hend	Apply	Analyze	Synthesize	Evaluate	Enjoy	Challenge	Socialize	Distract	
						Sketch, draw, dramatize		Hypotesize						

Dramaturgy

Who	PARTICIPANTS • Team of 4-5 students	ACTORS	ROLES	RELATIONS
Where	LOCATION Team arena	SETTING Screens with robot designs along a path, with one whiteboard each	ATMOSPHERE	
When	DATE	TIMING		
What	AGENDA I. Discussion of case II. Cartoon development	STEPS / MACRO-ACTIONS 1. Student team gets a robot design (or walks to a board displaying it) 2. They discuss and take notes of how the robot would behave in a given situation (eg. on the provided sticky notes board) 3. They stage a short performance for one or more members of the team to deliver to the tutor at the next tutor meeting 4. The tutor assesses the performance and gives feedback 5. [Repeat 1-4] for more robots	RULES	

Infrastructure

Communicative Actions		Navigation			Object-Related Actions		
Verbal	Non-verbal	Walk	Fly / Swim	Teleport	Select	Create / Insert	Transform
• Discuss the robot design		• Simulate robot behavior					• (move the obstacles to demonstrate movement?)

Static Objects		Automated Objects			Interactive Objects		
Fixed	Portable	Update State	Execute Animation	Follow Behavior	Input/Output	Tools, Instruments	Vehicles
• Designs of robots (on screens?) • Obstacles			• (Robot design and whiteboards move away after work on them is finished?)			• Whiteboard with several frames cartoon → • Also noteboard?	

Experience Situatedness

Goal/Context

Collaborate				Learn						Play				
Share	Decide	Design/ Create		Memorize/ Recall	Compre-hend	Apply	Analyze	Synthesize	Evaluate	Enjoy	Challenge	Socialize	Distract	
Describe experiences							Compare							

Dramaturgy

Who	PARTICIPANTS • Team of 4-5 students	ACTORS	ROLES • One subgroup rides on robot, the other watches from outside • Then the roles switch	RELATIONS
Where	LOCATION Team arena	SETTING - Vast arena/stage for the robot to navigate and show some typical and impressing behavior - Spots to watch from outside	ATMOSPHERE Colosseum feeling?	
When	DATE 2010-11-04	TIMING 10 mins per robot?		
What	AGENDA I. Experience robot behavior situated or not II. Share and discuss III. Have other experience IV. Share and discuss again	STEPS / MACRO-ACTIONS 1. One subgroup mounts the robot, the other one stays outside to watch 2. Robot behaves, with one subgroup in it → subgroups get different experiences 3. The students share their experiences and discuss 4. The subgroups switch (stay out / ride) 5. After the second round the students meet again to discuss and refine their notes 6. [Repeat 1-5] for more robots 7. Write a comparison, back in UNIworld	RULES	

Infrastructure

Communicative Actions		Navigation			Object-Related Actions		
Verbal	Non-verbal	Walk	Fly / Swim	Teleport	Select	Create / Insert	Transform
• Share experience, discuss differences	• Express emotions while sharing their experiences • Turn towards focus of attention		• (Fly up to view robot's performance from viewing plaform or from air?)				

Static Objects		Automated Objects			Interactive Objects		
Fixed	Portable	Update State	Execute Animation	Follow Behavior	Input/Output	Tools, Instruments	Vehicles
• Viewing platform • Obstacle course			• Mountable robot (see on right)		• Board to take notes?		• Mountable robot with space for up to 3 students to ride with it

Which Robot am I?

Goal/Context

Collaborate				Learn						Play				
Share	Decide	Design/ Create		Memorize/ Recall	Compre-hend	Apply	Analyze	Synthesize	Evaluate	Enjoy	Challenge	Socialize	Distract	
	Agree on an answer				Match, explain		Identify, differentiate							

Dramaturgy

Who	PARTICIPANTS • Team of 5 students	ACTORS	ROLES	RELATIONS
Where	LOCATION	SETTING Robot acting arena: course with obstacles , on which robots perform / show their behavior Robot selection area: a place (circle arc?) where robots stand ‚in line' to be selected by the team	ATMOSPHERE Automated world. Robots feel when you are about to select them and come closer (reacting to proximity) // Confrontation	
When	DATE	TIMING		
What	AGENDA	STEPS / MACRO-ACTIONS 1. Cloaked robot performs in acting arena 2. Students discuss and make a choice positioning themselves between the robots in the selection area → robots move towards student team, one of them is selected 3. Behaving cloaked robot from acting arena and the selected one meet decloak → either unite or not 4. [Repeat 1-3] for more robots	RULES →	

Infrastructure

Communicative Actions		Navigation			Object-Related Actions		
Verbal	Non-verbal	Walk	Fly / Swim	Teleport	Select	Create / Insert	Transform
• Discuss		• Students get closer to robots to make them feel proximity and come closer					

Static Objects		Automated Objects			Interactive Objects		
Fixed	Portable	Update State	Execute Animation	Follow Behavior	Input/Output	Tools, Instruments	Vehicles
• Robots for the students to make their choice („1, 2, oder 3“)			• Robots that execute their typical behavior	• Robots come closer when approached			

Appendix E: The Avatar-Based Collaboration Framework – Blueprint

Goal/Context

Collaborate				Learn						Play				
Share	Decide	Design/ Create		Memorize/ Recall	Compre-hend	Apply	Analyze	Synthesize	Evaluate	Enjoy	Challenge	Socialize	Distract	

Dramaturgy

Who	PARTICIPANTS	ACTORS	ROLES	RELATIONS
Where	LOCATION	SETTING	ATMOSPHERE	
When	DATE	TIMING		
What	AGENDA	STEPS / MACRO-ACTIONS	RULES	

Infrastructure

Communicative Actions		Navigation			Object-Related Actions		
Verbal	Non-verbal	Walk	Fly / Swim	Teleport	Select	Create / Insert	Transform

Static Objects		Automated Objects			Interactive Objects		
Fixed	Portable	Update State	Execute Animation	Follow Behavior	Input/Output	Tools, Instruments	Vehicles

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