Virtual Collaboration

van der Land, S.F.

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General Discussion

The four studies of this dissertation have all concentrated on 3D virtual environments' potential for effective team collaboration and group decision making. The first study was an exploratory study (Chapter 2), the second study was a conceptual study (Chapter 3), the third study was an experimental study investigating information processing (Chapter 4) and the fourth study was a multi-method study investigating communication support (Chapter 5). All four studies have contributed to answer our overarching research question: *"How can 3D virtual environments be employed to enhance effective team collaboration?"* In the following pages, I will summarize the main findings for each chapter. These findings are presented in Table 6.1, and afterwards an answer to this dissertation's main research question will be provided. Subsequently, the implications to theory and practice are discussed. Next, an elaboration will be given of these studies' limitations and directions for further research will be offered. This particular chapter will end with a discussion in which several future scenarios are depicted for collaborative 3D virtual environments to support team processes.

Chapter 2

In Chapter 2, several exploratory studies are discussed which aimed to investigate Second Life's potential use as a platform for facilitating information processing and communication support (referred to as the "pedagogical potential" in this chapter). The findings showed that there are three aspects which seem to be of particular relevance for conducting further research on the potential of 3D virtual worlds. First, in our preliminary research we found that participants experienced *equality of participation*. In our study, we found that although the participants formed part of a rather diverse community of learners which consisted of four different parties (VU University Amsterdam, ABN Amro, the Disabled Sports Foundation, and the Red Cross), they reported that they felt as if they had been treated as equals and that they had not experienced any feelings of hierarchy. A capability of virtual environments that could perhaps be responsible for this equality is the fact that all of the participants were represented by avatars, and these avatars did not display any social status cues (Walter, 1995). Prior research has emphasized that when participation is based on equality, active participation is stimulated, which in turn has a beneficial effect on information processing and communication (Hiltz et al., 2001). Secondly, the "gamelike" experience of *Second Life* induced feelings of *involvement*. For instance, the participants who participated in a wheelchair race in Second Life that had been initiated by the Disabled Sports Foundation were able to experience how it must "feel" to be disabled. In prior research, this feeling of involvement in a 3D virtual environment has been related to enhanced information processing and learning (Grigorovici, 2003; Scaife & Rogers, 2001). Thirdly, our findings indicate that one of the

most promising capabilities of 3D virtual environments may very well be the ability to offer 3D *simulations*. Simulations have been widely recognized as an efficient and effective tool for learning and processing complex information (Parush, Hamm, & Shtub, 2002; Wagner, 2008). Based on our observations and experiences, we have proposed a research agenda which can be used to research the influence of 3D virtual environments' potential for team collaboration further. These capabilities, *equality of participation, involvement* and *simulations,* provided the input for the definite formulation of sub-research questions in the following chapters.

Chapter 3

The aim of Chapter 3 was as follows: a) to systematically review the literature on what capabilities influence effective team collaboration and group decision making in 3D virtual environments, b) to integrate these insights into a theoretical model, and c) to offer propositions that enable further empirical testing. In building our theoretical model, we used insights from media synchronicity theory (Dennis, Fuller, & Valacich, 2008), social psychological group research (Chang & Bordia, 2001; Hinsz, Tindale, & Vollrath, 1997), computer-mediated communication (Walther & Parks, 2002) and group decision support literature (DeSanctis & Gallupe, 1987). Our central finding and assumption is that, compared to traditional technologies, 3D virtual environments provide two unique characteristics that could support effective team collaboration: 1) the 3D virtual environment in which participants are immersed, and 2) the avatar-based interaction through which communication in 3D virtual environments takes place (Van der Land, Schouten, Van den Hooff, & Feldberg, 2011). These unique characteristics offer different capabilities that can support either information processing or communication via two distinct routes. In particular, the 3D virtual environment supports information processing because it creates the ability to manipulate and present information in a relevant way in order to increase *individual understanding* of task-related information. Communication processes are supported by the strategic manipulation of avatars, which gives greater control over the social-relational aspects of team collaboration. Both information processing and communication support are prerequisites for shared understanding which, in turn, result in effective team collaboration in terms of performance and satisfaction. This study contributes to theory as it is one of the first studies to provide a theoretical framework that can be related to team collaboration in 3D virtual environments. The findings and propositions of this framework can be used as a stepping stone for future empirical testing.

Chapter 4

In Chapter 4, we investigated the information processing capabilities of 3D virtual environments. An experiment was conducted in an effort to investigate whether 3D virtual environments can help the decision making process in dispersed situations.

Based on *cognitive fit theory* and *cognitive load theory* (van Merriënboer & Sweller, 2005; Vessey, 1991), hypotheses were formulated which aimed to answer the following research question: "How does visual representation of information in 3D virtual environments support both individual and shared understanding, and consequently contribute to group decision making?" In teams of three, participants were asked to make a decision regarding an apartment choice task. The visual representation of the apartments was manipulated, so that there were three conditions. In the first condition teams could navigate through a 3D virtual simulation of the different apartments from a first-person perspective in such a way that they felt as if it was a real life experience. In the second condition, teams were provided with a 2D floor-plan of the apartments. Whereas in the third and last condition, the teams had a bird's-eye view of the apartments and were able to view pictures of the apartments from different angles (the 3D static condition).

The results of this experiment were quite surprising. Contrary to what was expected, the 3D static condition better supported the group decision making process than the immersive 3D virtual environment and the 2D floor plan condition. Our findings indicated that, in line with the *cognitive load theory,* both the 2D and the 3D virtual environment conditions were experienced as being highly cognitively taxing with regard to the task of making a group decision. Cognitively taxing refers to that a high amount of cognitive input was required to be able to effectively process information and negotiate different solutions in order to reach a group decision in these environments (Schrader & Bastiaens, 2011). The 2D condition was taxing due to the leanness of information provided by the 2D floor plan, which may have resulted in more uncertainty regarding the task-information. The 3D virtual environment was taxing due to the overload of detailed information, the extra cues and the stimuli that a rich environment offers, thus distracting from the group decision making process. In contrast, teams in the third condition, the 3D static condition, experienced the least amount of cognitive load of all the conditions, perhaps because it may have offered an optimum balance between overview and detail information. In this condition, shared understanding (the extent to which the teams were on a par with each other) was also higher than in the 3D virtual environment condition and the 2D condition.

However, the 3D virtual environment was found to effectively support the *individual understanding* of the apartments to a greater extent than the 2D visual representation, which was in line with *cognitive fit theory*. The results showed that the mechanisms behind this increased individual understanding are 3D virtual environments' capabilities of *realism* and *interactivity*. The findings of this chapter suggest that 3D virtual environments may best be employed selectively during the different phases of the group decision process. In particular, 3D virtual environments could support the

individual decision making process because the information rich environment enables individuals to make a thorough decision. However, when much team interaction is required, a 3D virtual environment may hamper the group decision making process because the environment provides too much distracting information which impedes team communication. This chapter contributes to our understanding of virtual team collaboration as it indicates which tasks and what type of information presentation regarding these tasks are most conducive in 3D virtual environments.

Chapter 5

In Chapter 5, a multi-method study was conducted to investigate whether the appearance of avatars can enhance group decision making in virtual teams. Based on two contrasting frameworks, (a) the social identity model of deindividuation effects (SIDE, Postmes, Spears, & Lea, 1998) and (b) self-identification (Bailenson, Blascovich, & Guadagno, 2008), hypotheses were formulated to answer the following research question: "How do similarity and self-identity in avatar representations influence team performance in virtual teams?" In three-person groups, participants were asked to solve a "murder mystery" similar to the hidden profile task employed by Stasser and Stewart (1992). The visual representation of avatars was manipulated, so that there were four conditions which combined different levels of similarity and self-identity. The first condition, "the morphed team avatar", combined both a high level of team similarity and self-identity in the facial characteristics of the team members, and it was created by using morphing techniques. In the second condition, participants were represented by their photographs, combining both a high level of self-identity, but a low level of team similarity. The third and fourth conditions were both low in self-identity, and represented either similar or dissimilar cartoon figures which had been derived from prior research (Lee, 2004).

It was found that the teams which communicated via a "morphed team avatar", an avatar whose appearance combined both high team similarity and self-identity, were better able to find the correct solution in the group decision making task and that they liked each other more. In contrast, the low team similarity, high self-identity condition in which participants were represented by a photograph of themselves (which resembles current Instant Messaging practice), performed the worst. For the other two conditions, which represented team similar or dissimilar cartoon figures, no significant differences were found in performance, social liking or group identity. Secondly, the content analysis that was made of the conversations between team members showed that teams in the morph condition are significantly more committed to the task, than the team members in the other three conditions. These findings suggest that for team tasks in which a common focus is important, a morphed avatar that represents both a high degree of self-identity and similarity of team members, is

beneficial. This chapter contributes to our understanding of virtual team collaboration as it attempts to unravel the mechanisms which are responsible for achieving effective avatar representations in virtual team collaboration.

This Dissertation's Central Research Question

The purpose of this dissertation was to answer the following central research question "*How can 3D virtual environments be employed to enhance effective team collaboration?"* Based on the insights derived from the various studies, the findings of this dissertation show that effective team collaboration in 3D virtual environments depends on two different processes.

The first process refers to 3D virtual environments' ability to support information processing. Our findings show that when 3D virtual environments are employed as a visual simulation tool for tasks of which the related information is visually complex (e.g., an apartment choice task), a rich immersive 3D virtual environment fails to sufficiently support group decision making processes. The results show that the amount of cognitive input required to effectively process the relevant information and negotiate different solutions to reach a group decision in these environments is experienced as being cognitively taxing. In contrast, the 3D virtual environment was found to effectively support individual understanding of the apartments to a greater extent than the simple and lean 2D representation. Thus, 3D virtual environments are particularly conducive for visual information tasks that require individual understanding.

The second process refers to 3D virtual environments' ability to support communication processes. Our findings show that the ability of 3D virtual environments to alter avatars' self-presentation, positively affects team collaboration. The results show that when team members communicated via a team avatar that had been 'morphed', an avatar that increased the similarity of the team members' facial characteristics, the team performance and team commitment was greater than in the other conditions. Thus, particularly for tasks that require a positive first impression among dispersed team members, "morphing" the appearance of team members' avatar can enhance effective team collaboration. To conclude, this dissertation's studies show that 3D virtual environments may best be employed selectively, during different phases of the virtual team collaboration process.

Table 6.1 Overview of the main findings of this dissertation's studies

Study	Research Question/Aim	Method
Study 1: Exploratory (Chapter 2)	To explore the collaborative benefits for an organization to be present in Second Life.	Qualitative
Study 2: Conceptual (Chapter 3)	To present a conceptual model specifically focused on the effectiveness of 3D virtual team collaboration	Literature Review
Study 3: Experimental (Chapter 4)	How do visual representation of information in 3D virtual environments support both individual and shared understanding, and consequently contributes to group decision making?	Experiment
Study 4: Multi-method (Chapter 5)	How do similarity and self-identity in avatar representations influence team performance in virtual teams?	Multi-Method

Theoretical Contributions

The previous section discussed the main findings of the four studies in this dissertation regarding 3D virtual environments' potential for effective team collaboration. In this section, the broader theoretical implications of this dissertation's findings are discussed. This dissertation is one of the first to establish and empirically test a theoretical framework of effective team collaboration and group decision making in the context of 3D virtual environments. To date, most theoretical frameworks for effective team collaboration are generally too broad to be applied to the context of 3D virtual team collaboration because they have not been designed with the specific capabilities of

Data Source	Key Findings
- Exploratory studies	- Three aspects seem of particular relevance for further research: 1) *equality of participation* 2) *involvement* and 3) *simulations*. A research agenda is proposed to further research the influence of 3D virtual environments' potential for team collaboration.
- Existing literature	- 3D virtual environments can support two processes vital to effective team collaboration: 1) information processing support through the manipulation of visual information presentation. 2) communication support through the manipulation of avatar appearances
- Self-report	- As proposed by *cognitive fit theory*, our results indicate that 3D virtual environments are indeed more effective in supporting individual understanding than 2D information presentations - In line with *cognitive load theory*, the static presentation of 3D information turns out to be more effective in supporting shared understanding and group decision making than an immersive 3D virtual environment.
- Experiment - Content analysis of logged chat conversations	- Results of the experiment confirm that teams in which the avatar appearance combined both a high degree of group similarity and self-identification, represented by a morphed team avatar, performed best on the task and liked each other more. - Content analysis of the conversations between team members shows that participants in the morph condition are significantly more committed to the task than those team members who used avatars which did not correspond to themselves as well as the team.

3D virtual environments in mind (Messinger, et al., 2009). An important theoretical point of departure in forming this dissertation's theoretical framework was media synchronicity theory (MST) (Dennis et al., 2007). In the four different studies of this dissertation, the MST framework was further developed by extending its premises with insights from different streams of existing literature (Chapter 3), cognitive fit and cognitive load theory (Chapter 4), and SIDE and self-identity theory (Chapter 5), in order to test the hypotheses of our research questions. Based on the results, the theoretical findings of this dissertation are embedded in a final theoretical framework, which is presented in Figure 6.1.

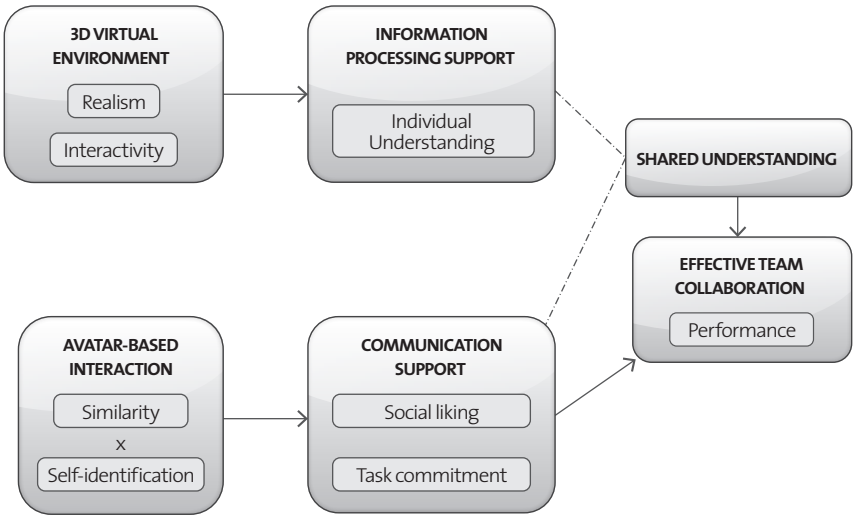

Figure 6.1 Final Theoretical Framework

Information Processing Support and Effective Virtual Team Collaboration

The dissertation's research has shown that the 3D virtual environment's capability *presence* was not a significant predictor of the individual understanding regarding the task information. Our findings show that *realism* and *interactivity* were more beneficial in enhancing individual understanding than the mere feeling of being *present* in a 3D virtual environment. Although this finding conflicts with prior research (Grigorovici, 2003; Scaife & Rogers, 2001), it nevertheless provides initial support to a more recent theory, namely Virtual Space and Place theory (Saunders et al., 2011). This theory argues and provides a tentative empirical test that shows that *interactivity* with a virtual object in 3D virtual environment stimulates *presence*. This interactive experience can even occur without an avatar, and it is crucial to the understanding of the virtual object (Saunders et al., 2011). Thus, this study contributes to Virtual Space and Place Theory and the recognition that the concept of *interactivity* with virtual objects is of crucial importance in the understanding of these virtual objects.

This dissertation's findings also have implications for the proposed relationship between individual and shared understanding, which is central to MST. Based on MST and cognitive-informational theories (Weldon & Bellinger, 1997; Dennis et al., 2008), it was assumed that the capabilities of a 3D virtual environment would support individual understanding via information processing, which in turn would lead to an enhanced shared understanding (Weick, 1985). However, in Chapter 4, it was found

that there was no significant relationship between individual understanding and shared understanding in the context of 3D virtual environments. In other words, the theoretical idea that the sum of the individual members' understanding evidently positively affects shared understanding was not supported by the empirical findings of this dissertation. Therefore, in Figure 6.1, a dotted line is displayed between the variables of individual understanding and shared understanding. The implications of these findings may be interpreted in such a way that one might conclude that individual understanding of task-related information may not necessarily be a prerequisite to achieve shared understanding. A possible explanation for this may be that reaching shared understanding is more of an iterative group process and that social factors come in to play when creating a shared understanding (Driskell et al., 2003).

Communication Support and Effective Virtual Team Collaboration

Due to the accumulation of insight regarding *shared understanding* in Chapter 4, it was decided that shared understanding would not be the focus of the fourth and last study in this dissertation. Instead, the focus of this last study was directly aimed at the dependent variable *effective team collaboration*. A closer reading of the literature showed that a more substantial contribution could be made to the literature if this dissertation would build on prior work of Bailenson et al. (2006) and Lee (2004), by placing it in the context of effective virtual team collaboration and the role of avatar self-representation. For the final theoretical framework in Figure 6.1, this implied that the initial concepts of avatar self-based interaction *´social presence'* and *'self-presentation'* as presented in the model of Chapter 3, were specified by the concepts *similarity* and *self-identity*.

The empirical findings of this dissertation show that the mechanisms studied concerning *similarity* and *self-identity* of avatar's appearances, can contribute to a greater virtual team performance. More specifically, this dissertation is one of the first to show in a virtual team context, that the strategic manipulation of an avatar's self-presentation via the novel technique of "morphing" increases social liking among team members. Morphing techniques enable one's avatar's facial characteristics to become similar to the other avatars, while at the same time an optimal balance in self-identity of the user is maintained. Particularly regarding the communication between team members, the content analysis results showed that when team members were visually presented as "morphed team avatars", they expressed greater task commitment in their communicative behaviors. In turn, a greater team performance was achieved when these mechanisms of self-identity and similarity were optimally utilized, than when avatars were represented to be dissimilar and cartoon figures. These findings theoretically complement prior studies, drawing upon

SIDE, which focused on the appearance of cartoon figures (Kim, 2009; Lee, 2004), with the dimension of *self-identity,* in which one's physical appearance is represented.

The empirical findings of this dissertation imply that for the social identity model of deindividuation effects (SIDE), under different methodological circumstances the impact of avatar representation on social interaction between team members may not occur. SIDE proposes that under the conditions of visual anonymity (e.g. absence of visual cues in CMC), the visual similarity of avatars can diminish the focus that people have on their individual differences, and increase the salience of their group membership. In prior SIDE-based studies, the participants would, for instance, typically have to determine whether or not to trust the other participant by basing this on only a minimal number of cues (e.g. similarity of a cartoon figure), and under great time pressure. In such circumstances, it is perhaps more likely that the ample cues which breed familiarity have been magnified. This dissertation's research anticipated Kim's (2011) call to make future SIDE-based studies less experimental and to allow natural interaction, thus not pre-programmed via the computer. In contrast to these prior SIDE-based studies, the empirical findings of this dissertation showed no differences between the conditions in group identity and trust, which may imply that when natural discussions occur between the actual participants, the effect of stereotyping regarding the available social cues is reduced.

Implications for Effective Virtual Team Collaboration

In the introduction chapter of this dissertation, I wrote that the idea of *virtuality* has always seduced thinkers, writers, designers and others, and that maybe one day we could accomplish via a computer in a virtual world what we have historically done physically, allowing us to part with the physical. But more than half a century of research on organizational communication and information systems has shown that there are many challenges that still must be overcome in order for this idea to become reality (Contractor, Monge, & Leonardi, 2011; Jarvenpaa & Leidner, 1998; Thompson & Bates, 1957).

From a historical perspective, most group researchers initially agreed that effective team collaboration is inextricably intertwined with the nature of the tasks being performed (Gladstein, 1984; McGrath, 1984; Rousseau, Aubé, & Savoie, 2006; Straus, 1999). However, studies on task-technology fit have not yielded consistent results regarding the effects on task performance (Daft, Lengel, & Trevino, 1987; Mennecke, Valacich, & Wheeler, 2000; Straus & McGrath, 1994). Therefore, MST (Dennis, et al., 2008) proposed that the concept of fit should be rethought, and suggested that the success of any given task that requires team collaboration (e.g. decision making), is determined by shared understanding, which is influenced by either convergence or

conveyance processes. This dissertation contributes to MST on effective virtual collaboration, by acknowledging both information and communication support processes, and by adding empirical proof for the notion that effective collaboration consists of different "task" phases. For instance, this dissertation showed that the individual phase of understanding the task may benefit from the richness of 3D virtual environments' representation of information. However, when negotiating with team members forms a relevant phase of the task, a medium which supports communication processes is more appropriate for this specific phase of the collaborative task.

Moreover, this dissertation shows that the "shared understanding" seemed to be of less importance to effective team collaboration in 3D virtual environments than it was initially hypothesized. In Chapter 4, we showed that 3D representations stimulate individual understanding of a task, but it did not stimulate shared understanding. When groups needed to make a shared decision, the extra visual cues and stimuli that a rich 3D virtual environment offers seem to cause a cognitive overload among the team members. For group decision tasks, the rich 3D virtual environment seemed to impair the communication processes of discussing preprocessed information with team members. In other words, the multitude of visual cues in the 3D virtual environment hindered, rather than helped the establishment of shared understanding. A leaner environment, such as the 3D static environment provided a more optimal balance in presenting information and enhanced the decision making process in such group tasks.

However, the study in Chapter 5 showed that the strategic manipulation of avatars in a decision task led to increased team performance. Although shared understanding was not measured directly, significant differences were found in the decision making strategies between the conditions. More specifically, the teams in the morphed avatar condition exerted more strategic remarks and they made more motivating comments than the teams in the other three conditions did. Therefore, this clearly demonstrates that these teams were better able to exchange information and share their perceptions regarding the task at hand, which is considered as creating shared understanding (Dennis, et al., 2008; Swaab, Postmes, Neijens, Kiers, & Dumay, 2002). This ultimately led to increased performance. Therefore, in Figure 6.1, a dotted line is displayed between the variables of communication support and shared understanding. Moreover, a recent study by Schouten, Van den Hoof & Feldberg (2010) also showed that avatar-based interaction in a shared environment increased the shared understanding in a decision making task, which in turn, subsequently led to increased performance.

Thus, this dissertation's studies show that 3D virtual environments may best be employed selectively, during different phases of the virtual team collaboration process. It appears that individual and shared understanding are two different processes, each of which

may be supported by different technologies. A rich 3D environment can indeed help to process information in order to create an individual understanding of a task. However, a too rich environment distracts from the group process and therefore hampers the development of shared understanding and ultimately, team performance. The capability of 3D virtual environments to manipulate avatar-based interaction, on the other hand, does to a certain extent seem to stimulate shared understanding. Therefore, it can be concluded that the 3D presenting of information may best be employed in an individual information processing phase of a team task, whereas avatar-based interaction in a leaner environment may better support the communication phase of a team task.

Practical implications

This dissertation has several practical implications for organizations regarding the potential contribution of 3D virtual environments for virtual team collaboration and decision making, which will be further elaborated below.

First, the empirical findings of this dissertation indicate that 3D virtual environments might be particularly useful for visually complex tasks (e.g. simulations). For such tasks, the main implications in using a 3D simulation is to help visualize and enhance individual understanding of the physical end results of, for instance, the design of a hotel. Used in such a manner, a 3D virtual space can help to provide a better understanding of how this hotel would appear in the physical world. Applied in a different context, if for instance, an architect seeks to convince a client of the end results of a rather radical design solution for his/her home (e.g. sacrificing a bedroom to create a kitchen), the architect will be more likely to do so by using a 3D virtual world representation. When a person can virtually navigate through this new kitchen, and see and "feel" how this positively affects the dimensions in his/her own home, the personal experience will be greater, leading to a greater impact on the person's understanding of the design solution. When translating this into concrete design guidelines for practitioners, it is imperative to comprehend that the features implemented in the design should directly aim at enhancing the participants' understanding. Evidently, this may improve individual understanding and enhance decision making.

Secondly, our results from Chapter 4 show that in regard to the use of technology for collaborative purposes, there is no "one size fits all-model". For different phases of a group decision making process, different technologies seem most conducive. For instance, for tasks in which immediate feedback and negotiation with different team members (such as deciding on an apartment together) is required, a leaner medium that supports these communication processes is of more importance than in a rich 3D

immersive environment. Ideally, for such tasks a medium that provides an optimal balance between overview and detailed information is provided, which reduces a team member's tendency to feel cognitively overloaded (Birnholtz, Ranjan, & Balakrishnan, 2010). As a general rule of thumb, I would recommend practitioners to carefully analyze the specific characteristics of the task, in order to determine whether (or not) to use 3D virtual worlds for collaborative purposes.

Thirdly, platform developers of 3D virtual environments may translate the findings of this dissertation into future applications which are aimed at supporting effective team collaboration. For instance, developers may implement "morphing" functionalities into their future collaborative software. Based on the empirical findings of Chapter 5, particularly in tasks that require a positive first impression, "morphing" the appearance of team members' avatar could perhaps contribute to effective team collaboration. The theoretical implications of this dissertation's finding on the impact of avatar appearance may, albeit with certain caution, transfer to other tasks and media such as Skype or LinkedIn (Bailenson, Yee, Merget, & Schroeder, 2006). For instance, for a negotiation task, in which a positive first impression is necessary, morphing your Instant Messenger profile picture with the other negotiator's Instant Messenger profile picture may increase the chance of a favorable outcome for you in the negotiation, due to the other negotiator's recognition of similarity in combination with self-identification. Moreover, in tasks in which participants are unfamiliar with each other (e.g. an avatar-based job interview, see Behrend et al., 2012), morphing your avatar's face with the face of the other interviewer may function as a "social glue", due to the interviewer's recognition of facial similarity in combination with self-identification. This is in keeping with research conducted by Bailenson et al. (2008) which found that in the context of influencing voting preference for a political candidate, a person is more likely to express his/her positive preference towards a political candidate when that person's picture is subtly morphed into the picture of a political candidate. Thus, particularly for tasks that require a positive first impression, "morphing" the appearance of the team members' avatars may contribute to effective team collaboration. Of course, it is important to note that generating a strong first impression may not be relevant for all tasks. Some tasks may require the establishment of more long-term collaboration, which might influence the effects of these "morphing" mechanisms.

Limitations and Future Research

As is the case in every study, there are several limitations to this dissertation's studies. The main limitations of this dissertation are the use of experiments as a methodology and students as a convenience sample.

For the purpose of empirical testing, we selected and thus isolated the two different routes and their mechanism of processing task-related information and communicating processes via an avatar. In doing so, we could objectively measure whether our manipulation of either the 3D virtual environment or avatar based-interaction attained its hypothesized effects. However, a potential disadvantage from this isolation is that the interaction between these two processes could not be studied. Therefore, a possible starting point for future research would be to employ a socio-materiality perspective on effective virtual team collaboration (Orlikowski, 2010). A social-materiality perspective envisions that the effects that an intervention or a medium have on the behavior of individuals is not a causal relationship, but a continuous process. This perspective strongly advocates against treating technology as an exogenous force. Future research that builds on this social-materiality perspective should study a medium's *affordances* as a way "to explain the increasingly symbiotic relationship between IT and organizations" (Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007, p. 752). In order to study these affordances, social-materiality states that existing theories fall short and calls for ethnographic research approaches that allow new theory development. However, one might also question whether 3D virtual environments nowadays actually are "socially embedded" in practice. An example of a "more socially embedded" medium could be for instance, a smart phone, since this medium is used in a more symbiotic way. Nevertheless, a social-materialistic research perspective may shed light and unravel insights that cannot be found through experimental testing alone.

Secondly, college students were used as a convenience sample. Although the participants were students of Business Administration, they do not fully represent the professionals that are currently using virtual environments for dispersed work. Moreover, the results of this dissertation may not hold outside of the lab, due to the susceptibility to extraneous "uncontrolled" variables in real-life settings (Parikh et al., 2001). Therefore, researchers should be cautious when generalizing our findings and applying them to practice. However, given that this research selected and isolated certain constructs for the purpose of empirical testing, this dissertation focused more on understanding the factors involved in team collaboration than on generalizability. Future research is encouraged in which different samples are used, such as professionals (instead of students), different tasks, and the use of 3D virtual environments in real-life settings on effective virtual team collaboration should also be investigated.

Thirdly, to answer this dissertation's research questions, an experimental methodology was chosen, and as a result, the two different routes were isolated for the purpose of experimental testing. However, one could imagine that these two routes may not be completely unrelated. Studies on group research have begun to argue that cognitive-

informational and social-relational influence cannot be seen as separate, but that they represent different aspects of the same process (Swaab, Postmes, van Beest, & Spears, 2007; Turner, 1991). For instance, in the context of this dissertation's research, it could be that the cognitive process of sharing the same point of view or preference regarding the choice of an apartment (Chapter 4), may be the basis upon which the team members begin to develop feelings of commitment. While conversely, if team members are committed to one another such as expressed in Chapter 5, one could infer that there is a basis from which people can begin to understand each other's views, which may, in turn, provide a basis for shared understanding. Despite such theoretical reasons which assume that cognitive-informational and social-relational influences might be related, empirical evidence is still scarce. It remains questionable, if, and how cognition and commitment are related. Therefore, further research is encouraged to investigate the relationship and integration between these two routes.

Potential Future Scenarios for Collaborative 3D Virtual Environments

After having discussed this dissertation's work on 3D virtual environments' potential for team collaboration, where do we go from here? If I were to speculate about the future of 3D virtual worlds and their consequences regarding future ways of virtual team collaboration (with the risk of being accused of "science fiction"), it can be noticed that two aspects of 3D virtual environments have in the meantime become part of more mainstream applications. Over the four-year span of this dissertation, these two aspects of 3D virtual environments may have survived the rise and fall of 3D virtual environments.

First, a clear example of this is the increasing use of 3D visualizations (Lee, Li & Edwards, 2012; Morrisson & Skjulstadt, 2010; Li et al., 2008). As indicated in Chapter 4, a wide array of companies, ranging from Philips to IKEA to real estate agencies, are using 3D visualizations of their products as a popular tool to help people visualize the end result of how their products will appear in their homes, or how stunning a real estate property will look after investing an X-amount of money for renovating it. An example of how 3D visualizations are being used in a work-related collaborative context is the case of Yuansantze Flood Diversion Works Project, in which a 3D virtual environment was used as a visualization tool to improve public participation and communication between stakeholders (Lai et al, 2011). Moreover, in the medical field, highly realistic 3D simulations of an emergency room are currently being used for distributed virtual training purposes (Krange, Moen, Ludvigsen, 2012). I expect that as using and creating 3D visualizations will become more mainstream and user-friendly, that certain aspects of 3D visualizations (e.g. simulations to increase individual understanding) will gradually transfer to the realm of virtual team collaboration.

A second prominent aspect is avatar representation. In today's world, the use of an avatar (e.g. a picture) to represent oneself on social network sites such as LinkedIN, Facebook or VoIP services such as Skype has become widespread (Ellison, Heino, & Gibbs, 2006; Ong, et al., 2011). This number of avatar usage is even greater in game-like settings such as *World of Warcraft, Habbo-hotel,* and the *Wii* (Ducheneaut, Wen, Yee & Wadley, 2009; Lanningham-Foster, et al., 2009). One reason for the popularity of avatar-based interaction is that some people do not always want to be confronted with their "real selves" in the virtual realm. For instance, studies on the 3D virtual environments show that most avatars are a younger, skinnier and a more attractive version of peoples' real selves and that they are their *ideal self* so to speak (Dunn & Guadagno, 2012; Ducheneaut et al., 2009; Heider, 2009; Turkle, 1994). Next, another advantage of avatar usage is that it could serve as a mask, helping the shy. Research has shown that in the virtual realm under conditions of "relative anonymity" people feel more comfortable disclosing personal things they would otherwise feel hesitant saying in a face-to-face setting (Antheunis, Schouten, Valkenburg & Peter, 2012). When translating this to the context of collaborative virtual environments, it could be argued that in order to improve task performance, people should have the ability to pick an avatar that resembles their perception of self (Kil-Soo, Hongki, & Eung Kyo, 2011; Cui et al. 2009; Galanxhi and Nah 2007). All in all, I expect that as avatar-based interaction will become more and more an integral part of our everyday communication, this will gradually transfer to the realm of virtual team collaboration.

The success of future application of 3D virtual environments for virtual team collaboration may also depend on whether these environments are able to discard the so-called "horseless-carriage syndrome". When the first automobiles emerged, they resembled horseless carriages. The design of these automobiles reflected the lens of a paradigm that had been dominant for centuries, and thus resembled a vehicle similar to the horse and carriage, but then without the horse, and it even included a special place for the horse whip. The dominant paradigm regarding most of the current work on 3D virtual environments' potential (including some of our own) focuses on translating traditional face-to-face tasks (e.g. participating in a lecture) to a "realistic" 3D virtual environment setting. I believe that there may be a future for collaborative 3D virtual environments, but that it will require a shift away from using traditional virtual team work as a frame of reference, towards innovatively applying 3D virtual environments in practice. To conclude, the main challenge for future researchers and developers of 3D virtual environments will be to try and imagine how the unique affordances of 3D virtual environments can be applied in ways that are not limited by the existing paradigms, but ways that transcend the boundaries of what is possible in the physical world in terms of presenting task-related and social information.