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Modelling the Metaverse: A Theoretical Model of Effective Team Collaboration in 3D Virtual Environments

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Abstract

In this paper, a theoretical model of effective team collaboration in 3D virtual environments is presented. The aim of this model is to enhance our understanding of the capabilities exerting influence on effective 3D virtual team collaboration. The model identifies a number of specific capabilities of 3D virtual worlds that can contribute to this team effectiveness. Compared to "traditional" computer-mediated collaboration technologies, 3D virtual environments support team collaboration primarily through (a) the shared virtual environment, and (b) avatar-based interaction. Through the shared virtual environment, users experience higher levels of presence (a feeling of actually "being there"), realism and interactivity. These capabilities increase the users' level of information processing. Avatar-based interaction induces greater feelings of social presence (being with others) and control over self-presentation (how one wants to be perceived by others), thus increasing the level of communication support in the 3D environment. Through greater levels of information and communication support, a higher level of shared understanding is reached, which in turn positively influences team performance. Our paper concludes by presenting several propositions which allow further empirical testing, implications for research and practice, and suggestions for future research. The insights obtained from this paper can help developers of these virtual worlds to design standards for the capabilities that influence effective team collaboration in 3D virtual environments.

1. Introduction

Increasing competition, globalization of markets, and the rampant geographical dispersion of organizations make it more and more important for organizations to enable team collaboration regardless of time and place (Lipnack & Stamps, 2000; Lurey & Raisinghani, 2001; Maznevski & Chudoba, 2000). With the advent of worldwide connectivity through the Internet and the advancement of digital technologies, the use of virtual teams, due to their feasibility and cost-effectiveness, is becoming commonplace in organizations (Martins, Gibson & Maynard, 2004). Virtual teams are teams that work together on a common task, independent from geographical, temporal and relational boundaries, supported by information and communication technologies (Lipnack & Stamps, 2000). Up until now, most scholars investigating virtual teams have focused on text- and data-based technologies, such as group support systems, that allow teams to work together virtually (Zigurs & Buckland, 1998). With the rise of three-dimensional (3D) virtual environments, however, it seems that richer forms of collaboration in virtual teams can be supported. Thus far, however, there is no systematic analysis of how these environments can contribute to improved collaboration in virtual teams. To fill this gap, this paper develops a theoretical model to explain how three-dimensional virtual environments may support virtual team collaboration.

3D virtual environments might offer unique opportunities for virtual collaboration. 3D virtual environments are defined as "online electronic environments that visually mimic complex physical spaces, where people can interact with each other and with virtual objects, and communicate via avatars - a digital representation of themselves" (Bainbridge, 2007, p. 472). The potential of such a rich and engaging medium for knowledge sharing and virtual collaboration has been recognized by both practitioners (e.g. IBM) and academics (Wilson, 2009). Academics have started to examine, for instance, how virtual doctor-patient consultations might benefit from the aspect that 3D virtual worlds resemble face-to-face communication in a way that no other medium has ever done before (Bainbridge, 2007; Maged, Lee, & Steve, 2007).

Despite this increasing attention paid to 3D virtual environments in the literature, less attention has been paid to how the unique capabilities of 3D virtual environments might affect virtual team collaboration (Konsynski, 2007; Kahai, Carroll, & Jestice, 2007; Roche, 2007). For effective team collaboration, two types of communication tasks need to be performed (Dennis et al., 2008). First, information about the task at hand needs to be transmitted and processed by individual members of the group, a process called *information support.* Second, group members need to communicate socially-related information and need to reach a common understanding based on the individually-processed information, which is called *communication support*. To date, there is no theoretical model of 3D virtual environment that takes into account the unique media capabilities of 3D virtual environments for supporting these two processes. Existing frameworks of virtual worlds are generally too broad to be applied to virtual team collaboration, as they include a wide range of characteristics of which only some are relevant in this context (Messinger et al., 2009).

Therefore, the purpose of this paper is to present a theoretical model specifically focused on the effectiveness of 3D virtual team collaboration. For practice, this paper is relevant for developers of 3D virtual worlds, as they can use the insights derived from this framework in order to design standards for the capabilities that influence team collaboration in 3D virtual environments. In building our theoretical framework, we use insights from media synchronicity theory (Dennis et al, 2008), theories on CMC (Short et al., 1976; Walther, 1996) and group decision support literature (DeSanctis & Galuppe, 1987). Our central assumption is that characteristics of 3D virtual environments support both information and communication processes (Dennis et al., 2008). That is, 3D virtual environments support information processes because 3D virtual environments allow the ability to manipulate and present information that is relevant for forming mental models of a certain situation (Rosenhead, 1989). Communication processes are supported because 3D virtual environments allow for rapid and rich communication and the strategic manipulation of avatars, giving great control over common information that is transmitted. This will help teams in reaching a shared understanding and mutual agreement. These two processes, in turn, are likely to enhance effective team collaboration. In Figure 1, our theoretical model is presented which shows the components that we argue are fundamental in exerting influence on effective team collaboration (i.e., collaboration through which the team achieves its purposes) via 3D virtual environments.

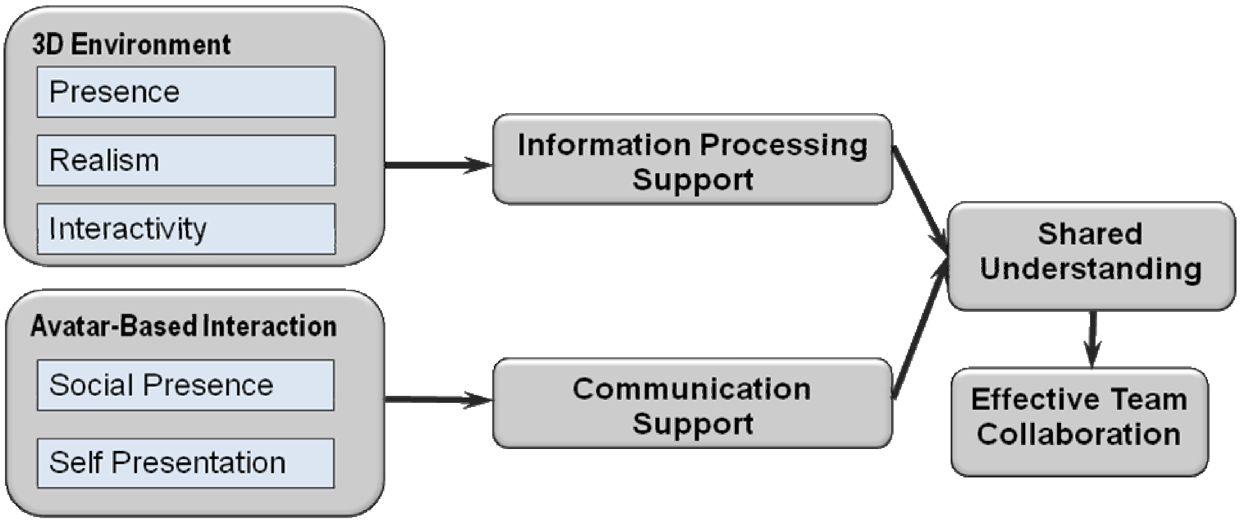

Figure 1: Theoretical model depicting how capabilities of 3D virtual environments affect information processing and communication processes, leading to shared understanding

2. Capabilities of 3D virtual environments to support team collaboration

Compared to traditional technologies that support team collaboration and decision making, the specific capabilities that 3D environments provide, result from two unique characteristics derived from these environments that might support team collaboration (Davis et al., 2009): (1) the 3D environment in which participants are immersed, and (2) the avatar-based interaction through which all communication in 3D virtual environments takes place. In Table 1 (p. 6) the five capabilities that are offered through these two characteristics are presented in comparison to traditional collaboration technologies. This is further explained below.

2.1 3D virtual environments

The first characteristic of 3D virtual environments that might support team collaboration is the 3D environment itself. A 3D environment offers many visual cues: the environment can be a city, a street, a building, a meeting or conference room, an airport, a tropical island – whatever the preferred design is. Virtual worlds also offer the possibility to integrate different applications into the interaction – for instance, a video can be shown on a screen in a virtual room, a Power Point presentation can be displayed, and so forth. Moreover, 3D virtual environments offer the ability to manipulate the 3D design for task relevant purposes. For instance, in the context of spatial planning issues, the medium allows users to virtually walk through a hotel lobby or sushi bar, which has yet to be constructed in real life, and to personally experience the final result.

Figure 2: The lobby of a Starwood hotel in Second Life (Jana, 2006)

According to Suh and Lee (2005), the shared environment in 3D virtual environment offers three capabilities that could affect team collaboration: presence, realism, and interactivity.

Presence. First, 3D virtual environments offer a greater degree of 'presence' than traditional technologies (e.g. Instant Messaging and email) that support team collaboration. According to Witmer & Singer (1998), presence consists of both *immersion* and *involvement*. Immersion is the extent to which one feels perceptually surrounded in the virtual environment rather than ones physical surroundings (Banos et al., 2004; Guadagno et al., 2007; Witmer and Singer, 1998). Involvement relates to "focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events in the environment" (Witmer & Singer, p. 227). 3D virtual environments could stimulate immersion because they offer a higher level of stimuli and experiences than other, less rich environments, leading to a stronger feeling of being immersed in the environment. Moreover, 3D virtual environment may stimulate involvement because participants are attentive to relevant visual cues the environment offers that might help them process information (Grigorovici, 2003; Scaife & Rogers, 2001).

Realism. Second, realism is the extent to which one believes the virtual environment is real (Davis et al., 2009). Davis et al. (2009) argue that representation and rendering are important technological capabilities of 3D virtual worlds, both of which refer to the process of creating life-like images on screen as well as to how realistically objects are represented in the three-dimensional space. For instance, in a virtual environment one can navigate through the environment to virtually experience physical locations that do not (yet) exist in real life, for example a virtual representation of an architectural design. Compared to 2D representations, 3D virtual environments offer more cues and provide a higher degree of reality, which might positively affect information processing (Daft et al., 1986; Scaife et al., 2001).

Interactivity. Third, 3D virtual worlds offer a higher level of interactivity than many traditional collaboration technologies. Interactivity refers to the capability to move and navigate through a virtual environment in contrast to examining static 2D or 3D images the environment (Bishop et al., 2001), and the ability to interact with and control the environment in real time (Fox et al., 2009). For example, 3D virtual environments such as Teleplace allow people to give presentations in and interact with the environment by using tools such as a shared whiteboard and a shared presentation space. Second Life also offers a basic scripting language which allows one to program interactions with the environment (Wirth et al., *in press*). Because 3D virtual environments are highly interactive, users are active rather than passive in their engagement with the information, which may lead to more effective information processing (Pimentel et al., 1994).

In conclusion, these arguments lead to the following proposition:

P1. Compared to traditional collaboration technologies such as Instant Messaging, email and group decision support systems, virtual team members will experience higher levels of (a) presence, (b) realism and (c) interactivity in a 3D virtual environment.

2.2 Avatar-based interaction

The second characteristic of 3D virtual environments that provides capabilities that might support team collaboration is the avatar-based interaction through which all communication takes place. In 3D virtual environments, people are represented by avatars, virtual representations of themselves in a variety of forms (Yee, Bailenson, Urbanek, Chang, & Merget, 2007). Based on Yee et al. (2007), we define avatars as "a digital representation of one's identity." Avatar-based interaction is a rich form of interaction in which team members can use a variety of cues to communicate, such as text-based chat, audio, pre-recorded animations (e.g., dance moves, gestures). Moreover, most virtual environments allow participants to create and adapt their own avatar. This also allows team members to add cues to their communication, such as clothing style and physical appearance. Two capabilities related to avatar-based interaction may especially support team collaboration in virtual environments: social presence and control over self presentation through the ability to manipulate avatars. These two capabilities are discussed below.

Social presence. Social presence is generally defined as the awareness of being present with others in a mediated environment combined with a certain degree of attention to the other's intentional, cognitive, or affective states (Biocca & Harms, 2002; Green & Taber, 1980). Avatar-based interaction offers a wide array of symbol sets: it is synchronous, uses text or voice interaction, and offers more cues than text-based interaction, such as gestures, avatar appearance and avatar behavior. These cue-rich forms of interaction could enhance social presence (Short et al., 1976). Moreover, people in virtual worlds also experience co-presence because they feel they are in a world together (Biocca et al., 2002). Combining the feeling of being together with possibilities for rich interaction, social presence thus relates to the extent to which participants feel that the team members who are interacting within the 3D virtual environment are really present in that environment.

Self-presentation. 3D virtual environments offer great control over the appearance of one's avatar. Self-presentation is an important social process in everyday life (Goffman, 1959; Leary, 1995).

However, in real life there are physical boundaries that limit one's ability for strategic self-presentation. Online, these boundaries exist to a lesser extent. People have more freedom to present themselves the way they would like to (Ellison et al., 2007). These opportunities for strategic self-presentation also exist in 3D virtual environments through the manipulation of avatars. For instance, avatars can be manipulated to look like real-life representations of the participants, or, conversely, to be made anonymous and similar to other team members' avatars. Choices made with regard to avatar manipulation will affect the level of identification (with the avatar, and/or with the team), group dynamics and collaboration within the team. Thus, the increased possibilities offered for self-presentation in 3D virtual environments through avatar manipulation is an important capability in terms of team collaboration effectiveness. In Table 1 below, a comparison of different media on all of the five capabilities is presented.

Table 1. Comparison of Selected Media and their Capabilities

	Presence	Realism	Interactivity	Social Presence	Self Presentation
3D virtual worlds	High	High	High	High	High
Video conference	Medium-High	High	Medium	Medium-High	Medium
Instant Messaging	Medium	Medium-Low	Medium	Medium	Medium-High
Telephone Conference	Medium-Low	Low	Medium-Low	Medium-Low	Low
Email	Low	Low	Low	Low	Low

Together, these arguments lead to the following proposition:

P2. Compared to traditional collaboration technologies, virtual team members will experience higher levels of (a) social presence and (b) control over their self-presentation in a 3D virtual environment.

3. Information processing and communication support in 3D virtual environments

We propose that the above capabilities of 3D virtual environments could support team collaboration. To identify the processes through which the capabilities of 3D virtual environments support effective team collaboration, we first turn to the literature on group support systems. Group support systems are "A set of communication, structuring and information processing tools that are designed to work together to support the accomplishment of group tasks" (Zigurs & Buckland, 1998: 319). Research generally distinguishes three ways in which group support systems could facilitate team collaboration:

- Communication support: the support of group members' capabilities to communicate with each other,

- Information processing: the support of group members' capabilities to gather, share and process information
- Process structuring, support of the process by which group members interact, such as agenda setting, facilitation and creating records (Zigurs & Buckland, 1998, p.319, Desanctis & Galuppe, 1987).

The specific capabilities of 3D virtual environments are likely to support primarily both communication and information processing. Specifically, the presence, realism, and interactivity that a 3D virtual environment offers, aid information processing for tasks that require visual and spatial components. Avatar manipulation and social presence offered by avatar-based interaction will provide communication support. Thus, our general assumption is that, compared to traditional collaboration technologies, the specific capabilities of a 3D virtual environment will imply that such an environment offers higher levels of information processing and communication support.

3.1 Information processing capabilities

We will now elaborate on why the capabilities presence, realism and interactivity experienced in 3D virtual environments will lead to greater information processing.

First, presence may increase information processing because team members feel immersed and involved in the 3D environment. For example, when team members are actually present in the environment, they may feel more immersed and involved in the decision task about a spatial planning issue (Schouten et al., 2010; Grigorovici, 2003; Scaife & Rogers, 2001). As such, they are more devoted to giving *attention* to the source of information, which is the primary perquisite to how thoroughly information is processed (Lamme, 2004; Ledoux, 1998).

Second, realism could support information processing because the more one experiences the 3D virtual environment as being real, the better one is able to make visualizations and understand the desired outcome of a team task (Baker et al., 2009). Visualization aids (e.g. 3D representations of buildings, charts, images) are extremely powerful in simplifying complex issues and tend to minimize the chance of having divergent interpretations by group members (Rosenhead, 1989). Thus, the higher degrees of realism experienced in a virtual environment are positively related to depth and effectiveness in information processing (Grigorovici, 2003; Scaife & Rogers, 2001).

Thirdly, the interactivity offered by 3D virtual environments might stimulate information processing because the environment is perceived as more natural than 2D representations (Zhou et al., 2007; Tavanti & Lind, 2001). Scholars found that dynamic, moving cues resulted in more attention than static cues (Cheal & Chastain, 1998) and that interaction attributes, such as movement can be more easily detected and processed (Khakimdjanova & Park, 2005). Because 3D virtual environments are highly interactive, users are active rather than passive in their engagement with the information, which could lead to more effective information processing (Pimentel et al., 1994).

Together, these arguments lead to the following proposition:

P3: The higher levels of (a) presence, (b) realism and (c) interactivity experienced in a 3D virtual world relative to traditional collaboration technologies will lead to a higher level of information processing in these environments.

3.2 Communication support

Avatar-based interaction in a 3D virtual environment can offer communication support to teams working together on a task, for the following reasons:

First, social presence offers communication support because it enhances the social-relational processes needed for effective team collaboration. Avatar-based interaction in virtual worlds offers immediate feedback, multiple cues to be transmitted simultaneously, and a wide range of symbol sets to communicate. Therefore, avatar-based interaction is a rich form of interaction, which is a prerequisite for establishing interpersonal relationships (Short et al., 1976). For example, Ducheneaut et al. (2006) conducted a longitudinal study on the social dynamics within the 3D virtual game *World of Warcraft* (WoW). Their research revealed that social presence, the "realness" of interacting with other people in the virtual environment in WoW, was the main attraction for most players to the game.

Second, self presentation through avatar manipulation may be strategically employed by teams to maximize team collaboration and team outcomes. In order for teams to be willing to collaborate and to share information needed to complete a task, team members need to feel as if they are part of their team (Sassenberg 2002, Tajfel et al., 1972). Manipulating avatars' appearance, by for instance giving team members avatars that look similar to each other, may lead to this form of belonging (Brewer, 1979; Oakes & Turner, 1980). It may also lead to more equal participation in a virtual project (Postmes, Spears, Sakhel, & de Groot, 2001; Straus, Miles, & Levesque, 2001) and result in more original solutions in a team task (Connolly, Jessup, & Valacich, 1990). Bailenson & Beall (2006) *morphed* (digitally manipulated) a team manager's avatar face in order to represent equally a division of his three team members *real-life* facial features. Their research showed that this resulted in the manager being perceived as more sympathetic and credible (Bailenson & Beall, 2006). Based on Walther's (1996) hyperpersonal theory, the combination of higher social presence and increased control over self presentation in 3D environments could lead to hyperpersonal effects, creating increased social attraction among team members. Therefore, we argue that the strategic manipulation of avatars offers communication support.

P4. The higher levels of (a) social presence and (b) self presentation experienced in a 3D virtual world relative to traditional collaboration technologies will lead to a higher level of communication support in these environments.

4. Information processing and communication support, shared understanding and effective team collaboration in 3D virtual environments

According to Dennis et al. (2008), both information processing support (conveyance) and communication support (convergence) are necessary in order for a team to reach a shared understanding. Shared understanding refers to reaching a common understanding of a task or problem, an understanding of each other's viewpoints (Weick, 1985), and an overlap in possible solutions (cf Hinds & Weisband, 2003; Swaab et al., 2002). Information processing is necessary for shared understanding as task-related information needs to be shared and processed in order for each team member to create an individual understanding of a task. Achieving an individual understanding of task-related information is the first step to reaching a shared understanding (Corning, 1986; Weldon & Bellinger, 1997). Communication support contributes to shared understanding since the outcomes of the conveyance processes (i.e., the individual understanding) need to be shared and communicated in order to reach a common understanding e (Dennis et al, 20008). Moreover, Driskell et al. (2003) stress that in order for teams to collaborate successfully team members do not only need to perform well on task-related functions, but they must also work well together socially as a team. Therefore, communication support also entails the social-relational aspects of team collaboration (Buss & Kenrick, 1998). In sum, in order to reach shared understanding, information processing and communication support is necessary because teams must (a) share task-related information in order to form an individual understanding of a team task, and (b) share and discuss the outcomes of this individual process in order to reach a common understanding.

Therefore, we offer the following proposition:

P5. The higher levels of a) information processing and b) communication support experienced in a 3D virtual world relative to traditional collaboration technologies will lead to a higher level of shared understanding in these environments.

4.1 Shared understanding and effective team collaboration

Shared understanding, in turn, is considered to be a prerequisite for effective team collaboration (Matthieu et al., 2000; Swaab et al., 2002; Thompson & Fine, 1999; Tindale & Kameda, 2000). Group members are likely to process any information about the task at hand from a shared viewpoint, which facilitates task performance, especially in decision making and negotiation tasks (Swaab et al., 2002; Thompson & Fine, 1999; Tindale & Kameda, 2000). Furthermore, shared understanding is an important prerequisite for positive group outcomes such as cohesion and other task performance measures (Mohammed & Ringseis, 2001).

The concept of effective team collaboration can be broken down into two major constructs: performance and satisfaction (Gladstein, 1984; Lin et al., 2008; Lurey & Raisinghani, 2001; McGrath, 1984). Performance is the actual outcome that is generated by the collaboration process, an output measure that rationally and objectively measures whether earlier defined goals have been achieved. For instance, when outcome refers to *productivity level,* it can be measured objectively by the sheer quantity of products a team has produced. Alternatively, when outcome refers to the *decision* a team has made as result of collaborating, performance, it is measured in a more subjective way (e.g. by asking a manager or customer to rate the quality of the decision (Galegher & Kraut, 1990).

Satisfaction refers to how team members themselves have experienced the process of collaboration (Lin et al., 2008). Satisfaction is viewed as a more emotional, subjective measure that reflects how the team members have experienced the process of collaboration. Satisfaction is strongly related to performance (Kirkman, Rosen, Tesluk, & Gibson, 2004; Montoya-Weiss, Massey, & Song, 2001). Satisfaction, however, is a subjective construct and captures the perceptions of the individual team members. Campion, Medsker, and Higgs (1993) demonstrated that satisfaction is a valid predictor of the team's effectiveness in terms of performance, since team members are central to the task, and thus subsequently directly influence the team's productivity. All in all, we expect shared understanding to be positively related to the components that together determine effective team collaboration.

Thus, our final proposition is:

P6. The higher level of shared understanding in a 3D virtual world relative to traditional collaboration technologies will lead to a higher level of team collaboration effectiveness in these environments.

5. Conclusion and future directions

In the previous section, we have presented our argumentation to support a theoretical model of effective team collaboration in 3D virtual environments. This argumentation leads us to expect that, compared to "traditional" collaboration technologies 3D virtual environments have a number of specific capabilities that could very well enhance the effectiveness of collaboration within virtual teams. The two main characteristics of virtual environments that support team collaboration are (a) the shared virtual environment, and (b) avatar-based interaction. The shared environment offers capabilities that support information processing during team collaboration. An increased presence in the environment leads to immersion in the world and involvement in the task, leading to more depth in information processing. The higher degree of realism and interactivity offered by the 3D environment also aids information processing when a task consists of visual or spatial components.

Avatar-based interaction offers capabilities that foster communication support in team collaboration. The social presence offered by avatar-based interaction enhances the feeling of being together and creates a willingness to share information and to cooperate. Moreover, the ability to control self presentation through the manipulation of avatars might even increase communication support because, based on what the task requires, individual differences in a team can be accentuated or attenuated, which in turn allows for different forms of group attachment. More specifically, when avatars are homogeneous this could lead to common information being inflated, resulting in increased feelings of belonging to a group (Walther, 1996, Postmes et al., 1998). Both information processing and communication support can lead to a shared understanding which, in turn, results in effective team collaboration in terms of performance and satisfaction.

5.1 Contribution to research

Our model provides a theoretical basis for conducting empirical research on the potential of 3D virtual environments for team collaboration. Up until now, no research papers have provided a theoretical framework which could be empirically tested related to team collaboration in virtual worlds. Other frameworks of virtual worlds are generally too broad to be applied to online collaboration, including a plethora of virtual world characteristics that may or may not be relevant in certain circumstances (Messinger et al., 2009). Based on our model, we can specifically argue under which circumstances the capabilities of virtual worlds will lead to effective collaboration.

This article contributes to theory by building upon earlier models of computer mediated collaborative work, and media synchronicity theory in particular. We specifically show the capabilities that are offered by virtual worlds and how they can support either information processing (conveyance) or communication (convergence) processes. For example, when a task requires a common focus, it may be best to make all avatars look similar, as this draws attention to group commonalities, and will yield the best outcomes. On the other hand, if individual input is required for a task, it might be best to create avatars which are different from one another and resemble real life persona. Future research can empirically test the propositions of our model, which will lead to further understanding and development of both this theory, and the theory of media synchronicity in a virtual world context.

5.2 Implications for practice

This paper identified the capabilities that influence effective team collaboration in 3D virtual environments. Based on the insights obtained from this paper, developers of virtual worlds can design standards for these capabilities to improve 3D virtual team collaboration. This could change long-accepted ways of working and interacting, and change how task-information is understood and how people socially interact with each other. As often is the case with new technology in its infancy stages, the question remains how the technology will eventually be used (DeSanctis & Poole, 1994). We believe that metaverse developers should think creatively about how the unique media capabilities of 3D virtual environments can be used for interaction, knowledge sharing and collaboration, rather than continuing to seek the simulation of face-to-face interaction across distributed sites and contexts. The challenge in understanding 3D virtual environments' potential for practice is to grasp what is different in terms of capabilities as well as their relationships to the foundational theories that have guided our thinking about virtual teams in the past.

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