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Fostering Team Creativity in Virtual Worlds

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Abstract

This article addresses the potential of virtual worlds as a platform for creative team collaboration. The proliferation of geographically distributed teams, striving towards innovative results, calls for ICT that support team creativity. Three-dimensional virtual worlds represent such an emergent and rapidly developing collaboration tool. A systematic literature review was conducted to reveal the affordances of virtual worlds contributing towards team creativity. The results of the literature review reveal eight proposed affordances relevant for virtual worlds to foster team level creativity. Avatars (1) allow the team members to express themselves and their insights and point out information to others. Changing the users' frame of reference (2) embraces the virtual world's potential as a context for creative action. Perceived feeling of co-presence (3) within the team members, and user's own experience of immersion (4), contributes towards engaging creative team collaboration. Multimodality (5) and rich visual information (6) facilitate communication between team members. Finally, virtual worlds allow teams to modify the collaboration environment to simulate a new kind of reality (7), and offer a selection of supporting tools (8) that can be utilized in the creative collaboration. Departures for further research efforts and insights for practitioners engaged in virtual world collaboration are presented.

1. Introduction

Creativity, in a work context, is a topic that interests both scholars and practitioners from a variety of fields and industries. Creativity and innovation are closely linked. Organizations strive to achieve competitive advantage with respect to innovation because innovation supports diversification and facilitates the organization's adaptation to the evolving market and technology environment (Gibson & Gibbs, 2006). Prior research that has focused on organizational creativity as a precondition of innovation has traditionally explored creativity on both an individual and group level (e.g., Hennessy & Amabile, 2010).

Creativity, as an individual or team activity, can be defined as the production of novel and useful ideas (Amabile, 1983). Consequently, innovation is understood as successful implementation of creative and novel ideas within an organization (Amabile, 1996). Many scholars discuss individual antecedents of creativity to be personality, skills, motivation, positive affect, expertise, and knowledge (see e.g., Sternberg, 2006). Others have investigated the environmental context or social climate to be either a facilitator or a hindrance of creativity, with differing findings (Hunter, Bedell, & Mumford, 2007; West, 2002). While the environmental context provides physical stimuli that possibly enhance individual and team creativity, the social climate includes dimensions such as goal clarity, intellectual stimulation, support for innovation and participative safety. Moving from individual creativity towards group creativity, Taggar (2002) was one of the first who posited that fluent group processes are a necessary condition of individual creativity to turn into group creativity. Meanwhile, the potential for idea generation and creativity by teams is generally higher than the potential for idea generation and creativity by individuals (Paulus, 2000).

Creative processes have become more complex in modern organizations where networks and teams are often globally distributed and functioning in separate geographic locations and time zones (e.g., Gibson & Gibbs, 2006; Ocker, 2006). In distributed team collaboration, previous research has summarized creativity-enabling factors as follows: trust, support, encouragement for creativity, freedom, challenge, goal clarity, motivation, commitment, or dedication, and sufficient resources and time (Nemiro, 2000). For globally distributed teams, brainstorming activities can be challenging because team members are no longer co-located and members lack shared physical space for ideation. However, it has been proclaimed that cultural diversity among team members, in conjunction with separate locations and individual expertise, may also enhance creativity during certain phases of the innovation process (Gibson & Gibbs, 2006; Kratzer et al., 2006). Thus, when process losses are minimized, creative activity within distributed teams can thrive.

Virtual teams can be defined as such groups of people that strive towards a common goal, are distributed across locations, and communicate with each other through the use of information and communication technology (ICT) in a varying degree (e.g., Axtell et al., 2004; Martins et al., 2004). Diversity of the team members is often pronounced in virtual teams. This diversity leads to constructive conflicts that encourage the discussion of creative ideas (Kurtzberg & Amabile, 2001). Prior research has narrowly addressed the question of virtual teams and creativity (e.g., Leendeers, van Engelen & Kratzer, 2003; Nemiro, 2002) including factors that embrace and inhibit creativity within the team setting (Merlo & Mann, 2004; Ocker, 2005). Findings from this body of research have demonstrated that creative collaboration can occur within virtual teams. Although some of the necessary conditions for innovation and insight are understood, the preconditions that are required to guarantee creativity and innovation are not yet known (Hewett, 2005).

Few studies have addressed the role of ICT tools in creative collaboration. Herrmann (2009) summarizes several design heuristics that support computer-mediated creative interaction. These heuristics include (1) potential for visualizing rich material, (2) malleability of the shared material, (3) support of convergence within evolutionary documentation, (4) smooth transitions between different modes of communication, and (5) integration of communication with work on shared material. Meanwhile, Shneiderman (2007) conceptualizes the design principles for ICT tools that support creativity as: (1) support for exploratory search, (2) rich data history, (3) processes that prime collaboration, and a (4) wide range of functionalities for users with differing needs and expertise. These design principles indicate the divergence among the suggested requirements that the creative activities address to the collaboration platform. On the other hand, support for rich and smooth collaboration and a wide range of malleable functionalities are common features discussed in both design principle classifications.

Virtual worlds (VWs) offer an interesting example of an emergent collaborative environment that conveys the potential to foster virtual team creative collaboration. Virtual worlds are defined as communication systems through which multiple interactants share the same three-dimensional digital space, despite occupying remote physical locations. Interactants can navigate the digital space, manipulate objects, and communicate with one another via avatars that are flexible and easily transformable digital self-representations in a graphic 3D form (Yee & Bailenson, 2007). Moreover, Bell (2008) clarifies that virtual worlds are synchronous but persistent communication systems that also enable asynchronous collaboration.

Virtual worlds lie at the forefront of web-based technological evolution and will become more pervasive and widely adopted over time (Riordan & O'Reilly, 2011). Virtual world technologies may not be the silver bullet (Brooks, 1987) as psychological literature informs us that creative insight cannot be commanded to happen; however, there are clear indications that it is possible to create conditions using ICT that will improve the likelihood of creative discoveries, if only through the avoidance of conditions that disrupt or conflict with creativity (Hewett, 2005).

The potential for virtual worlds to support team level creative activities and creative collaboration has received limited attention to date. However, the current body of research has somewhat addressed factors that could contribute towards team creativity in virtual worlds. We address this research gap by conducting a literature review that focuses on such *virtual world affordances* that could foster creative team collaboration in the virtual setting. Affordances are defined as environmental properties that create consequences for individual behavior (e.g., Greeno, 1994; see also Olapiriyakul & Widmeyer, 2009). By identifying these creativity-fostering affordances, we expect to shed light on the essence of the creative interaction of virtual teams. Finally, our research aims to examine the relationships between creative teamwork and virtual worlds in detail.

2. Method

To identify and address the VW affordances in a thorough manner, we conducted a systematic literature review. Tranfeld et al. (2003) emphasized the protocol of systematic literature review in providing methodologically rigorous, collective insights through a theoretical synthesis of the research field and its sub-fields. The systematic literature review protocol contributes towards transparent, high-quality and relevant reviews that are supported by documented evidence, with decent audit trail and minimized bias in the literature selection (Moustaghfir, 2009).

Following the protocol, we first constructed keywords that were related to our research topic of virtual world affordances that could foster team level creativity. The keywords were composed into search strings such as “virtual world” AND “creativity”; “virtual environment” AND “creativity”; and “virtual world” AND “innovation”. These search strings were used to execute searches in major electronic journal databases (such as EBSCO, Scopus, Science Citation Index and Social Science Citation Index). Additionally, we scanned several leading journals with respect to the topics of psychology, information systems and communication using the same search strings. We decided to include in our analysis academic papers that met the following criteria: (1) empirical articles, (2) peer-reviewed articles, and (3) articles published in academic journals or conference proceedings. We defined criteria for exclusion as certain article topics that were related to creativity in virtual worlds but not relevant to the research topic. For example, we excluded the studies that discussed the intellectual property rights (IPR) of user-generated creative content in virtual worlds. We also decided to exclude articles that described hardware based 3D virtual reality environments because these platforms and their affordances may differ significantly from the software based virtual worlds that are the focus of this paper.

The initial search yielded a total of 485 articles. The abstracts of the papers were read and the exclusion and inclusion criteria were applied to determine the paper's relevance. Those articles that met the inclusion criteria and that did not meet the exclusion criteria were collected in a database (Mendeley). The articles were scanned for backward citation and, partially, for forward citation. We were therefore able to reach the body of research that remained outside of the scope of our search strings. Relevant papers that were found during the backward and forward citation searches were added to the article database. Finally, overlapping articles were removed from the database. This procedure provided us with a total of 57 articles. Nine articles were excluded, mostly because they lacked empirical evidence. Thereafter, a total of 47 articles were used for the final review.

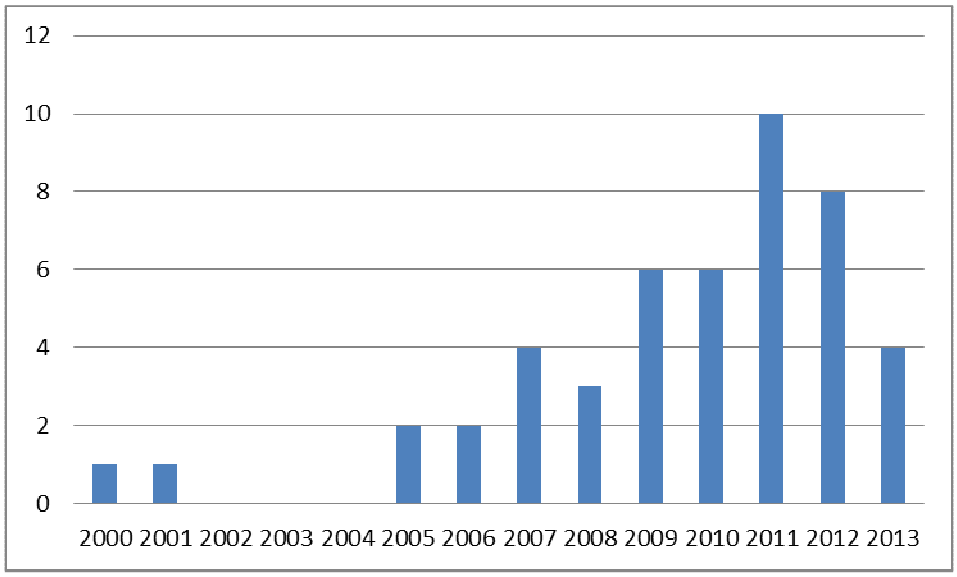

Figure 1: Amount of Publications per Year

Figures 1 and 2 describe the articles’ publication years and journals, in which the articles have been published.

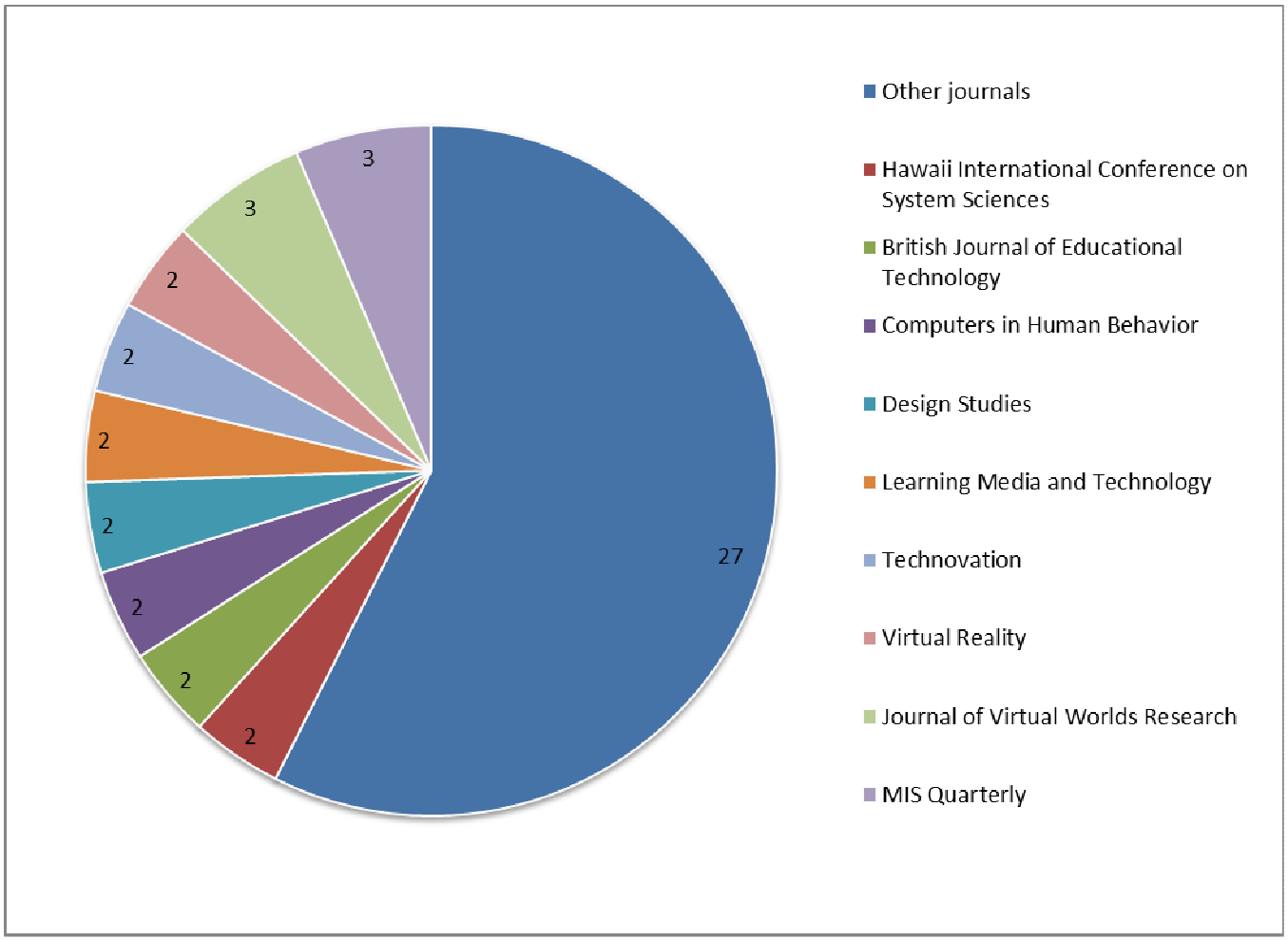

Figure 2: Publications per Journal

"Other journals" include the following journals and conference proceedings with one article from each, included in the review: 9th International Entrepreneurship Forum; Automation in Construction; Behaviour & Information Technology; Computer Graphics and Applications; Computers & Education; Creativity and Innovation Management; IEEE Internet Computing; IEEE Transactions on Professional Communication; Information; Community and Society; Innovation: Management; Policy & Practice; Innovations: Technology; Governance; Globalization; Interactive Learning Environments; International Journal of Engineering Education; Journal of Decision Systems; Journal of Information Technology in Construction; Journal of Interactive Marketing; Journal of Universal Computer Science; Library Technology Reports; Management of the Interconnected World ; On the Horizon; Organization Science; Program: Electronic Library and Information Systems; Psychology of Aesthetics; Creativity; and the Arts; Psychology of Popular Media Culture; Research Technology Management; Thinking Skills and Creativity, and Virtual Environments.

The number of reviewed articles is considered appropriate and comparable to other reviews on the topic of virtual worlds (see e.g., Kim et al., 2012; Sivunen & Hakonen, 2011; Stendal, 2012). Limited empirical studies are in existence with respect to team creativity in virtual worlds because of the emergent state of virtual worlds as an organizational collaboration tool.

Virtual world affordances related to team creativity were identified from the theoretical background and the results or discussion sections of the included articles. Articles were connected to an affordance according to factors that the following example demonstrates. Bhagwatwar and his co-authors (2013) reported a comparative experiment within which 20 teams experimented with virtual brainstorming in two virtual worlds. One of the virtual worlds was designed as a creative-priming

environment, whereas the other virtual world was designed to represent a standard office space. Bhagwatwar and the co-authors (2013) found that the creative priming environment led to an increase in the brainstorming performance of the teams. Based on the study results and discussion, we considered the virtual world's simulation capability, and the users' reported immersion, to be the most central virtual world affordances that were reported in the study. Notwithstanding, Bhagwatwar and colleagues (2013) defined virtual worlds as synchronous and persistent networks of people who are represented as avatars. The notion that users are represented as avatars was not central to the research setting, argumentation or results. Avatars were not explicitly considered as a virtual world's creativity-supporting affordance. Thus, based on that article, avatar as an affordance was not included in the results of this study.

We began the analysis of the affordances by selecting a sample of ten articles from the database. Two to four authors read each article in the sample. The sample articles resulted in an initial list of thirteen affordances. These embracing affordances were discussed together, to create a shared understanding of the list of affordances and the meaning of each affordance. Correspondingly, two authors read the remaining articles in the database and connected them to the initial affordances. After reading all articles, we reviewed the resulting list of affordances. As a result, we merged certain similar affordances and produced a final list of eight affordances.

3. Results

From the review of the 47 articles, we discovered eight proposed affordances of virtual worlds that were related to team creativity. These affordances were defined based on their potential ability to enhance team creativity in virtual worlds. The identified affordances included the following: (1) avatars as graphic self-representations, (2) changing the frame of reference, (3) co-presence, (4) immersion, (5) multimodality, (6) rich visual information, (7) simulation capabilities and (8) supporting tools for creative work. A definition for each affordance is provided in Table 1 below. A list of affordances, references, and key findings for each affordance, are depicted in Table 2.

Table 1: Affordance Definitions

Affordance	Definition
Avatars as graphic self-representations	A graphical representation of the user. The representation can be tailored to the creative task at hand. The representation also increases user's spatial awareness.
Changing the frame of reference	Enabling individuals to generate or discover novel solutions by removing constraints and changing the environment (avatars, roles, or surroundings) and viewpoints to the environment in a fundamental way.
Co-presence	User's perceived sense of presence with other avatars in the same (meaningful) place. A condition conducive to co-construction of creative concepts.
Immersion	The impression that one is participating in a realistic experience. A condition conductive to engagement and creativity.
Multimodality	The ability to combine different media (including 3D content) and knowledge sources and to use communication channel that are suitable for the

Affordance	Definition
	creative task.
Rich visual information	The potential to present content in a visually richer way, compared to traditional CSCW environments.
Simulation capabilities	The potential to rapidly change and iterate the virtual world to support the creative activities.
Supporting tools for creative work	Such integrated tools and features that allow a choice in the style of work and a suitable amount of variation in the creative expression while supporting the creative task at hand.

Our proposed affordances do not guarantee creative team performance in virtual worlds. Instead, they are suggested abilities for virtual world technology that can give rise to creativity via the mediated behaviors of team members. In the following section, we describe the essence of each proposed affordance.

Table 2: Virtual World's Affordances to Creativity

Affordance	References	Key findings
Avatars as graphic self-representations	Antonijevic (2008); Bosch-Sijtsema & Sivunen (2013); Clarke (2012); Eisenbeiss et al. (2012); de Freitas et al. (2010); Giovacchini et al. (2009); Kohler et al. (2009); Lantz (2001); Larach & Cabra (2010); Ringo (2007); Sanchez (2009); Ward & Sonneborn (2011).	With avatars, users are given an option to be something else than themselves in the real-life collaboration. Avatars offer extensive abilities to communicate verbal and non-verbal information consciously and unconsciously to other collaborators. These extended possibilities to express oneself foster creative activities and interaction.
Changing the frame of reference	Bosch-Sijtsema & Sivunen (2013); Ferguson (2011); Fuller et al. (2012); Ketelhut et al. (2010); Kohler et al. (2009); Kohler et al. (2011a); Kohler et al. (2011b); Larach & Cabra (2010); Lester & Linden (2009); Patera et al. (2008); Tampieri (2010); Ward & Sonneborn (2011).	The changing frame of reference provides user a freedom to change his/her environment. Consequently, the changing environment can be tailored to support certain creative activities. Users' actions reflect on the virtual world around the user and the user itself, embracing a transactive cycle between the user and the surrounding world.
Co-presence	Antonijevic (2008); Bosch-Sijtsema & Sivunen (2013); Chandra & Leenders (2012); Clarke (2012); Eissenbeiss et al. (2012); Fuller et al. (2012); Hendaoui et al. (2008); Kohler et al. (2009); Kohler et al. (2011a); Kohler et al. (2011b); Larach & Cabra (2010); Ondrejka (2007); Riordan & O'Reilly (2011); Vahey et al. (2011); Ward & Sonneborn (2011); Vosinakis & Koutsabasis (2013).	The sense of co-presence is also defined as a feeling of a shared space. Co-presence is embraced by immersion. The phenomenon can foster the attendees' participation to the creative interaction. Meanwhile co-presence facilitates the collaboration with others like-minded virtual world users that pursue towards similar, shared goals.

Affordance	References	Key findings
Immersion	Antonietti & Cantoia (2000); Bailenson & Yee (2005); Bhagwatwar et al. (2013); Fuller et al. (2012); Giovacchini et al. (2009); Helms et al. (2010); Hoffman & Novak (2007); Kohler et al. (2009); Kohler et al. (2011a); Kohler et al. (2011b); Koutsabasis & Vosinakis (2012); Larach & Cabra (2010); Patera et al. (2008); Peppler & Solomou (2011); Rosenman (2007); Stapleton & Hughes (2006); Suh & Lee (2005).	Immersion fosters the persistence and interest towards team's shared activities that occur in the virtual world. Immersion also nourishes the utilization of problem context in problem solving situations. The perceived sense of immersion among team members can directly contribute towards creative abilities.
Multimodality	Barrass & Barrass (2006); Berente et al. (2011); Bosch-Sijtsema & Sivunen (2013); Fuller et al. (2012); Giovacchini et al. (2009); Helms et al. (2010); Kohler et al. (2009); Koutsabasis & Vosinakis (2012); Larach & Cabra (2010); Merrick et al. (2010); Riordan & O'Reilly (2011); Suh & Lee (2005); Vosinakis & Koutsabasis (2013).	Multimodality encapsulates the virtual worlds' functionality of integrating several different communication modalities. The spatial and communicative operations allowed by multimodal communication span beyond the traditional ICT mediated collaboration. Multimodality also eliminates the communicative shortcomings that are characteristic to ICT mediated collaboration.
Rich visual information	Antonietti & Cantoia (2000); Bosch-Sijtsema & Sivunen (2013); Ferguson (2011); Fuller et al. (2012); Peppler & Solomou (2011); Rahimian & Ibrahim (2011); Ringo (2007); Riordan & O'Reilly (2011); Sanchez (2009); Ward & Sonneborn (2011).	Rich visual information assists the visualization of content, i.e. models, drawings, objects and data. Rich visual outlook can appeal virtual world users, and increase awareness and understanding of different insights, ideas and cultures.
Simulation capabilities	Bailey et al. (2011); Bhagwatwar et al. (2013); Bosch-Sijtsema & Sivunen (2013); Chandra & Leenders (2012); Eissenbeiss et al. (2012); Fuller et al. (2012); Koutsabasis & Vosinakis (2012); Merrick et al. (2010); Nambisan & Baron (2007); Ondrejka (2007); Osborne & Schiller (2009); Peppler & Solomou (2011); Rahimian & Ibrahim (2011); Riordan & O'Reilly (2011); Rosenman et al. (2007); Vosinakis & Koutsabasis (2013).	Simulation capabilities transform the virtual worlds as an ICT tool, closer to the potential of substituting reality The simulation capabilities assist the users to model new artifacts, and create an environment that simulates certain conditions in real life. Consequently, the simulation capabilities allow interacting teams to create objects that are impossible in real life and therefore help challenging some conventions and pre-assumptions.

Affordance	References	Key findings
Supporting tools for creative work	Bailenson & Yee (2007); Chandra & Leenders (2012); Clarke (2012); Jou & Wang (2013); Larach & Cabra (2010); Merrick et al. (2010); Peppler & Solomou (2011); Rahimian & Ibrahim (2011); Rosenman et al. (2007); Sanchez (2009); Vosinakis & Koutsabasis (2013).	Several supporting features and tools can be included on the virtual world to foster creativity. Examples of such include AI and artificial agents as tools that facilitate creativity and options for recording and re-playing communication which allow the team to revise their ideation and previously-used material.

3.1 Avatars as Graphic Self-representations

An avatar can be defined as a person´s digital self-representation in a graphic 3D form (Yee & Bailenson, 2007). Compared to virtual communities that do not feature avatars, avatars assist users in expressing their feelings in a more convenient and accurate manner (Eisenbeiss et al., 2012). Avatars allow users to communicate a significant amount of non-verbal social information and their identity to other collaborators (Ringo, 2007) both consciously and unconsciously (Antonijevic, 2008). For instance, avatars with a professional outlook may support global business collaboration (Bosch-Sijtsema & Sivunen, 2013).

Clarke (2012) noted that users show signs of self-projection with respect to avatars. In his experiment, attendees indicated signs of emotional attachment to the avatar, while also indicating an understanding of self-projection. Avatars are crucial for eliciting a sense of proximity (Larach & Cabra, 2007) or for providing spatial information (Benford et al., 1997). Such information encourages automatic turn-taking that facilitates discussion within a collaborating group (Lantz, 2011). Additionally, self-projection and the sense of proximity contribute to the avatar's potential to function as a self-representation of a team member in the virtual environment.

The creation process of an avatar is, arguably, one of the most attractive aspects of the virtual world user experience (Clarke, 2012). Once created, avatars can also be transformed easily and flexibly (Yee & Bailenson, 2007). While creating and modifying the avatar, virtual world users are able to create an avatar that either (1) looks like its actual user in real life, or (2) represents something totally different (Sanchez, 2009).

Connected to the notion of avatars as immersed self-representations (Clarke, 2012; de Freitas et al., 2010), the possibility for the user to *be something else other than him/herself* in an immersive collaboration environment conveys emergent potential with respect to creative team interaction. Moreover, avatars can provide a "protective shield" for the user. This protective shield can ensure that the user feels comfortable and safe while collaborating as him- or herself within the virtual environment (Bosch-Sijtsema & Sivunen, 2013). Building a psychologically safe communication climate within the virtual team is important for group creativity because it helps overcome the negative effects of distributed collaboration (such as geographic dispersion) to increase innovation (Gibson & Gibbs, 2006).

Finally, the concept of avatar-based innovation (Kohler et al., 2009; 2011a; 2011b) links avatars as user self-representations with respect to open innovation (see e.g., Chesbrough, 2003). Avatars connect company and customer knowledge to embrace mutual creative interaction and collaboration. Similarly, workshops can harness the creativity of customers and corporate representatives via avatar representations (Giovacchini et al., 2012). The aforementioned concept of avatar-based innovation and workshops that involve avatar interaction introduce practical examples of the emerging potential

conveyed by avatar-based team collaboration. Furthermore, practitioners benefit from using VWs with avatars in innovation workshops as avatars can enhance the building of a psychologically safe communication climate among workshop participants. This can, in turn, help in creating an optimal environment for distributed group creativity.

In summary, avatars contribute towards creative team interaction by allowing the team members to communicate conscious and subconscious verbal and non-verbal information to others. The team members project themselves onto a modifiable character that can make them feel comfortable and safe. This allows the user to express his or her insights in an innovative way that encourages creativity. The avatar's contribution to creativity has also been commercialized, as corporations interact with customers for avatar-based innovation.

3.2 Changing the Frame of Reference

In addition to the avatar functioning as a representation of the user in the virtual world, the virtual world itself creates a context for action and team collaboration. Virtual worlds allow users to interact directly with objects and the world rather than simply describing or displaying those objects (Fuller et al., 2012). Experimentation with different settings and configuration elements within the broad restrictions of virtual worlds creates an "infinite canvas" for the user (Larach & Cabra, 2007). The user's actions in the virtual world create a cycle of action and response that result in a transactive experience between the user and the virtual world (de Freitas et al., 2010). Therefore, virtual worlds both alter the user's frame of reference from real world to virtual world and allow users to change the world independently.

The user-generated and modifiable virtual environment may function as an engine of creation (Fuller et al., 2012). Virtual environments provide freedom for users to experiment and are therefore thought to result in unprecedented rates of innovation. However, at the same time the dynamic, synchronous and evolving nature of virtual worlds requires specific guidance with respect to the design and management of the actual process or activities that happen within those settings (Kohler et al., 2011a).

Certain studies have investigated the impact of the changing frame of reference towards creativity. Patera and her colleagues (2008) utilized virtual worlds as a method to stimulate creative writing. A changed frame of reference, i.e., in one case the virtual world representing a magic cottage, was noticed to harness the ability of elementary school students to express their creativity in a written form. Similarly, Ketelhut and co-authors (2010) describe an experiment in which middle-school students were trained in creative problem solving and scientific inquiry skills in a virtual world. The student activities included actions such as the collection and observation of data from the environment and interacting with other students or software-controlled agents. Adding to the pedagogical experiments, Tampieri (2010) used a virtual world in describing an SME from the fashion sector. The experiment participants were able to easily access and use the equipment relevant to the fashion corporation and create clothes and other fashion products. The changed frame of reference assisted the experiment participants in reflecting their personal capabilities with respect to their suitability to a profession that calls for creativity. Finally, an excursion to a virtual world was reported to contribute towards user ability in drawing new insights and connections with respect to existing work challenges (Larach & Cabra, 2007). Noteworthy, these insights highlight the emergent potential of changing the frame of reference towards virtual worlds' use practices.

Added to the activities described in the aforementioned scenarios, art can be considered moving from real life to virtual worlds (Lester & Linden, 2009). When presented with new media, individuals tend to first replicate familiar behavior onto the new media. Lester and Linden (2009) present virtual world artwork that illustrates the artist's tendency to push the boundaries of new technology. Additionally, artists are poised to make imminent new discoveries as to how virtual worlds can best be applied to deeply engage individuals. Similarly, experiences in the modeling of planned buildings in virtual worlds (Merrick et al., 2011; Rosenman et al., 2007) may foster team creativity as a result of the context-specific virtual surroundings, i.e., a changing frame of reference.

Changing the user's frame of reference alters the stimuli in the user environment. The virtual world initiates a transactive, modifiable cycle of action and response involving the user and the surrounding world (de Freitas et al., 2012). Together, these ideas highlight the potential for virtual worlds to function as contexts for creative action and collaboration. The positive impact between the changed frame of reference and the creative abilities of the virtual world user were recognized in the aforementioned empirical studies. We therefore expect the changing frame of reference caused by the virtual world to contribute to a team's potential for creativity.

3.3 Co-presence

Co-presence can be defined as a sense of "being together" with other remote team members while sharing a technology-mediated environment (Biocca, Burgoon, & Harms, 2003; Ijsselsteijn et al., 2001). Virtual worlds offer such a shared three-dimensional place, where virtual team members can interact with each other while seeing the spatial positions and movements of others. This, together with the virtual world's multimodal communication, is likely to foster a sense of co-presence among virtual world users (Barrass & Barrass, 2006; Vosinakis & Koutsabasis, 2013).

Virtual worlds can leverage the place, embodiment and simultaneous collaboration of users (Ondrejka, 2007). The shared place and context for rich real-time interaction can embrace the intensive participation of the attendees (Kohler et al., 2011b). This further contributes to a sense of co-presence among the collaborating virtual world team.

The shared place and co-presence can also contribute towards more serendipitous forms of creativity. For example, users of a virtual world can choose to enter different virtual world communities where it is possible to collaborate with other likeminded individuals and to gain inspiration from them (Riordan & O´Reilly, 2011). In these communities, the attendees might have weak social ties with each other and might not be closely acquainted in either real or virtual life. The mutual co-presence among the virtually connected users is expected to facilitate the exposure of diverse ideas and resources and ultimately result in enhanced creative abilities and greater innovation (Chandra & Leenders, 2012).

In summary, it is posited that a sense of co-presence will enhance interaction and knowledge sharing among the collaborators (Appel-Meulenbroek, 2010) of established teams and loosely coupled communities. The idea of co-presence, or collaboration in a shared space, is connected to team-level creativity (Chandra & Leenders, 2012; Kohler et al., 2011a; Kohler et al., 2011b; Ondrejka, 2007). Co-presence can contribute to a distributed team's collaboration with respect to creative tasks. We therefore identify co-presence as one of the affordances that supports team level creativity in virtual worlds.

3.4 Immersion

Immersion can be defined as the extent to which the technology is capable of delivering an inclusive, extensive environment and a vivid illusion of reality to the senses of a human participant

(Slater & Wilbur, 1997, p.3). Virtual worlds provide users with 3D digital spaces and the possibility to interact in highly graphical environments. The emerging possibility also exists for highly immersive experiences that span beyond traditional ICT collaboration tools (e.g., Koutsabasis et al., 2012; Suh & Lee, 2005). The affordance of co-presence requires the consciousness that others are sharing the same virtual space. Immersion, however, emphasizes the user's own perception of his or her surroundings. Together, the *physical* (i.e., what surrounds the user in real life), *virtual* (i.e., the virtual collaboration tool) and *imaginary* realities (i.e., the user's own perception of the environment) (Stapleton & Hughes, 2006) form a mixed reality within which the user can become deeply immersed.

This mixed reality for virtual teams can result in the immersion of distributed team members, embracing a creation of a common virtual "co-located" space. This, in turn, may enhance the perceived co-presence at the team level. Additionally, it is posited that avatars enhance the user's immersion to the virtual environment and indicate the immersion to other team members (Larach & Cabra, 2007; de Freitas et al., 2010). The immersive experience encouraged by avatars allows the user to interact within in the virtual environment in a real-life manner (Larach & Cabra, 2007).

Immersion is closely related to "telepresence", i.e., the feeling of being present in a mediated environment in time and space (Ijsselsteijn et al., 2001). This creates new possibilities for virtual product experiences. A study of co-creation in VWs (Kohler et al., 2011a) invited users to immerse themselves in the actual problem context, to explore inspirational stimuli, and to participate in different creative challenges before submitting their ideas. The study demonstrated that by describing a particular design problem concerning the VW to the users within the VW, and by achieving user immersion, the problem context was more powerful than it would have been if a simple problem description had been used.

Virtual worlds have been proven to create immersive experiences for different types of situations and tasks. In an innovation related task, user perception of a compelling experience was recognized as significant (Kohler et al., 2011b). Compelling experiences led to increased persistence and interest in further co-creation activities. Persistence and interest are considered to be an important pre-requisite for creative input and to obtain promising solutions. As a practical example, the virtual world's immersive potential can support the teaching of creative writing (Patera et al., 2008). Additionally, engagement in a virtual co-creation was found to result in higher awareness while simultaneously fostering a desire to act on the topic being discussed (Kohler et al., 2011b).

Finally, Bhagwatwar et al. (2013) demonstrated that virtual worlds can facilitate a team brainstorming process by sparking creativity and keeping members immersed while they perform the task. Parallel to Bhagwatwar and co-authors (2013) and Kohler and co-authors (2011a; 2011b), we expect that user immersion in a virtual world will significantly contribute towards a user's creative abilities. Arguably, these enhanced abilities are also reflected at the team level via the collaboration between team members who experience immersion. Therefore, we conclude that immersion is one of the virtual world's affordances towards creative teamwork. This raises implications for practitioners. For example, the user interface and platform designers should take immersion into account when developing new creativity fostering services to VWs. If immersion of the users in VWs can be fostered, their creative potential may also enhance. For example, various VW peripherals (e.g. 3D glasses) can increase users' immersion in VW, which could in turn enhance their creative potential.

3.5 Multimodality

Virtual worlds provide significantly richer communication media than traditional communication mechanisms (Bhagwatwar et al., 2013). This richness is achieved via the implementation of several

different communication modalities through simultaneous textual, auditory, visual and graphic channels (Bosch-Sijtsema & Sivunen, 2013), or via text-based chat, voice communication, graphical cues and organizational tools (Merrick et al., 2011).

Multiple simultaneous communication channels allow spatial and communicative operations that encourage creativity that is beyond the reach of traditional ICT systems. For instance, virtual world users can individually explore a three-dimensional world while simultaneously communicating with fellow team members (Riordan & O'Reilly, 2011). Although multimodality might increase the need for prudency with respect to technical difficulties (e.g., Berente et al., 2011; Ferguson et al., 2011; Ketelhut et al., 2010), multimodality contributes to creative collaboration by eliminating the communicative shortcomings of ICT-mediated collaboration, such as a lack of mutuality and reciprocity, which can then in turn enhance development of trust between the participants (Fuller et al., 2012).

Several studies with practical relevance discover that multimodality of virtual worlds is a potential affordance of creative collaboration. The auditory and visual communication channels of a virtual world have been utilized to foster musical creativity (Barrass & Barrass, 2006). The multimodality of virtual worlds has also been involved in distributed design collaboration (Merrick et al., 2011). Similarly, Vosinakis and Koutsabasis (2013) note the potential for virtual worlds to support collaborative creativity and design studio activities.

In summary, virtual worlds combine multiple communication channels with a collaboration environment that increasingly resemble real-life interaction. Compared to traditional CSCW, multimodal and synchronous communication encourages creative interaction with respect to teams. Therefore, virtual worlds can generate environments conducive to distributed collaboration and creativity.

3.6 Rich Visual Information

In addition to the multimodality of the virtual world, virtual worlds offer enhanced possibilities for the presentation of visual content (Bosch-Sijtsema & Sivunen, 2013) compared to the less rich CSCW technologies. In a survey study by Riordan and O'Reilly (2011), virtual worlds were noted to help with the visualization of models, drawings, objects and data that are more difficult to visualize when using traditional text- and audio-based media. Virtual worlds convey the potential to present data and information in unique and compelling ways.

Rahimian and Ibrahim (2011) report an experiment that monitored the differences between a traditional design environment and a 3D-immersive virtual world within a design-sketching task. They noted that 3D sketching resulted in a greater amount of detail in the sketches. In the traditional environment, the final artifact of sketching was noted to be nearer to the beginning stage, compared to the virtual sketching. Additionally, the virtual world sketching reference group had developed their ideas further than the traditional sketching group. In conclusion, virtual world technologies were capable of facilitating the condition of collaboration during the design process. Similarly, a 3D virtual tour of a painting was noticed to lead to enhanced abilities in conceptualizing the art experiment, elaborating the experiment more imaginative, contributing towards associating links to the audience's own lives, compared to viewing a corresponding two-dimensional painting (Antonietti & Cantoia, 2000). Finally, virtual worlds are considered to encourage out-of-the-box thinking among collaborators when the collaborators insist on using virtual tools for the construction process; the collaborators use their own ideas and adapt those ideas to the virtual tools that they are given (Sanchez, 2009).

As an example of practice, Ringo (2007) demonstrated the virtual world pilot at the IBM's internal Innovation Jam event. In the pilot, a virtual world appealed to individuals because of its application as a

visual and immersive collaboration tool. Highly visual and interactive applications indicate that new levels of remote collaboration can be reached. Similarly, the richness of the visual communication channels of the virtual world increases the awareness and understanding of different insights, ideas and cultures (Bosch-Sijtsema & Sivunen, 2013). In conclusion, given these results, we consider the richness of the virtual world's visual communication to be an affordance concerning creative interaction within the virtual world.

3.7 Simulation Capabilities

Simulation capabilities are aligned with the fluency and flexibility of operations in a virtual world. The possibility to create virtual objects forms a fertile ground for creative motivation within the virtual environment (Eisenbeiss et al., 2012). As a working platform of a virtual team, the simulation capabilities transfer virtual worlds closer to the substitution of the reality (Bailey, 2011). Similar to the affordance of changing the frame of reference, simulation capabilities alter the work environment from physical surroundings to a virtual environment and highlight the modifiability of the artifacts present in the virtual world.

Learning of design and innovation in the real world can be a difficult or an expensive task and the cost of the learning can even constrain the rate of innovation (Ondrejka, 2007). In virtual worlds, users can model new artifacts and, additionally, virtual worlds can be used to illustrate the real world setting in which the ideas or planned products will actually be placed (Vosinakis & Koutsabasis, 2013). Additionally, a change made by a user in the virtual world alters that world for all the other users (Merrick et al., 2011).

Virtual world users can create objects (2D or 3D) that exist in the virtual context, but the existence of these objects may be impossible in the real world. This can encourage virtual world users to identify and challenge some of our implicit conventions and taken-for-granted assumptions with respect to the real world (Riordan & O'Reilly, 2012). Similarly, the virtual world's simulation capabilities allow easier modification of objects, for example, the duplication or moving of objects (Koutsabasis & Vosinakis, 2012; Rahimian & Ibrahim, 2011). Accordingly, reverse engineering of real-life objects is possible (Riordan & O'Reilly, 2012).

As an extreme, the simulation capabilities of the virtual world allow users to create entire self-contained societies that import all the features of the human condition that exist outside the virtual world (Osborne & Schiller, 2009). Bhagwatwar and colleagues (2013) elaborate on this idea by investigating the virtual world's simulation capabilities through a creativity-primed and non-creativity primed virtual world. As a result, visual elements that are known to prime creativity in real life improved the brainstorming performance of a team operating in a virtual environment. Teams produced more unique ideas that were more original, workable and relevant in the creativity-primed environment than in the non-creativity primed environment. This finding is consistent with the premise that in a virtual world, users can create an environment for innovative experiences within virtual customer interaction (Nambisan and Baron, 2007). The potential to effect on the creative collaboration via the environment conveys a significant potential also for virtual world practitioners, such as platform and user interface developers.

In summary, virtual worlds can be used as an inexpensively modifiable learning environment for the design and investigation of new subjects (Ondrejka, 2007). This may encourage creative collaboration in unconventional methods of problem solving (Riordan & O'Reilly, 2011). As the

simulated virtual world encourages collaborators to discover emergent and original pathways to solutions, the experience conveys a possibility to foster creative interaction.

3.8 Supporting Tools for Creative Work

We consider supporting tools to be integrated tools and features that allow choices in the style of work and variation in creative expression. Without a comprehensive review, several authors have addressed tools and features that are typical for virtual worlds but scarce in traditional CSCW. However, such tools can potentially nourish creative collaboration.

For example, potential exists for artificial intelligence to push the human boundaries of a design team to include human-computer co-creativity (Merrick et al., 2011). Artificial agents have an impact on human behavior within the virtual world (Bailenson & Yee, 2007). Virtual worlds therefore offer the potential for the incorporation of artificial models of cognitive design processes to support concurrent creative collaboration. Similarly, Rahimian and Ibrahim (2011) discuss haptics that are embedded in virtual controls as a supporting tool of virtual world design operations.

Additionally, the potential for modeling objects within a design team (e.g., Vosinakis & Koutsabasis, 2013) is related to creativity, as well as the possibility of introducing the objects to other users of virtual worlds (Chandra & Leenders, 2012). Assimilating to virtual world simulation capabilities, a design team can, for instance, observe different possible solutions within the virtual world and retrieve instantaneous information concerning how the changing solutions will be reflected in the design (Rosenman et al., 2007). Finally, built-in interactive tools and in-world information services of virtual worlds could direct the users to creative interaction (Clarke, 2012; Sanchez, 2009).

We previously conceptualized virtual world's support for multimodal communication as an affordance towards team creativity. In virtual worlds, this communication can be typically recorded and archived (Peppler & Solomou, 2012). As an example of practice, team members who collaborate in a virtual world can dedicate a project room that stores the team's processed knowledge during the meetings (Bosch-Sijtsema & Sivunen, 2013). These kind of recording and archiving tools enable the persistence of the virtual space and allow the teams to utilize already existing material in their ideation. Teams can revise already discussed ideas, or use existing material to support their creativity and to explore new creative direction.

The existing body of research demonstrates the multiplicity of built-in tools and features that could support team level creativity. Applied to the direct contribution, supporting tools can have an indirect impact on team creativity. For instance, artificial agents such as avatars could facilitate creative collaboration within team members who experience co-presence, or haptics could contribute towards user-perceived immersion. Persistence of the virtual space can enhance creative collaboration over time. Different virtual world technologies offer different supporting tools for creative work, and virtual world users can even create such tools by themselves. We propose such tools as a virtual world affordance for team creativity because of the empirical evidence suggesting that tools, which are diverse and evolving in nature, support creativity.

4. Conclusions

Using the conceptualization of virtual worlds as a potential platform for virtual team creative interaction, we investigated the virtual world affordances that could support team creativity. Based on the literature review, we proposed the existence of eight such affordances. First, the literature review demonstrates that virtual worlds can function as environments for collaborative teamwork that focuses

on creative activities. Virtual worlds can be contexts for creativity. Secondly, the list of affordances reveals that certain features of virtual worlds can contribute towards team level creativity. These affordances posit virtual worlds with other platforms for distributed collaborative work.

The affordances are parallel to the existing knowledge of such design principles and features that support ICT-mediated design interaction. Multimodality, richness of communication channels, and assimilation of the communication to the transactive cycle of action and response between the user and the environment, are similar to the existing findings of CSCW oriented design heuristics (Herrmann, 2009). Meanwhile, avatar-based interaction, co-presence, and immersion foster the collaboration among users, which is suggested to prime creative interaction also when using other types of ICT tools (Shneiderman, 2007). Finally, the supporting tools, including a potential to store and retrieve results of creative interaction, are valuable in terms of creative collaboration (e.g. Hewett, 2005).

Despite peer discussion and iterative refinement of the final list of affordances, the list is still subject to interpretation. Only a small number of studies directly address the virtual world's creative potential and few provide empirical results; the proposed affordances are therefore tentative. However, our review suggests several points of departure for further research. First, the notion and existence of affordances requires investigation. The list of affordances is not comprehensive and some of the affordances are linked to one another. For instance, changing the frame of reference is related to a level of immersion. Therefore, broader concepts may exist beyond the current conceptualization of affordances. Additionally, certain conceptualized affordances could be divided into more detailed ones. Finally, as the affordances might impact on each other, there is a need to study the relationships between different affordances and their link to creativity in more detail. For instance, how does an increased sense of co-presence contribute towards team creativity in a virtual world, compared to an environment that fosters immersion and user personal experience? Or, how do different industries, cultures and technologies change the possible impact between the affordances? There are also indications of additional affordances of virtual worlds that are not yet empirically studied but that might contribute towards team-level creativity. Therefore, we welcome research efforts that target the empirical testing of the presented affordances.

Our study demonstrates the emergent potential of virtual worlds as a platform for creative collaboration. Several recommendations for practitioners can be drawn on the basis of our study. First we suggest the practitioners to utilize extensively the affordances and their potential, presented in the review. For instance, group innovation and creativity consultants and trainers can benefit from using VWs in courses and workshops, as the richness of avatar-based communication in an environment that is tailored to prime creative activities certainly fosters the team-level creative interaction. Using multiple communication channels can furthermore support this interaction. Finally the supporting tools, including potential to record and restore the meeting, or artificial intelligence that facilitates the creative interaction, convey a potential that is relevant to virtual world practitioners engaged in creative interaction. Our findings provide recommendations also for VW platform and user interface designers, who are interested in developing new VW products and services for enhancing group creativity. For example, participants' immersion could be enhanced with different VW peripherals, such as 3D glasses, which in turn can increase the creative potential of the participants.

The list of the affordances of virtual worlds to support creativity is subject to change that occurs because of technological advancement and the expanding use of virtual worlds. Significant technological advances may alter the interaction among avatars and their operations in the virtual world. Immersion and feeling of co-presence are also subject to change, while entirely new technological approaches to virtual worlds emerge. Virtual worlds are gaining more popularity as a collaboration

technology for distributed teams and organizations. In conjunction with evolving technology, it can be assumed that new industries, companies and organizations will take better advantage of the existing technology. We look forward to this development to revise our proposed list of affordances. Depending on the emerging technology and the evolving use practices, changes may be fundamental.

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