A Social Network Approach for Investigating Social Influences on Effective Use: Demonstration in Virtual Reality Collaboration

Jennifer Fromm
University of Duisburg-Essen, fromm@connected-organization.de

Laura Tölle
Paderborn University, laura.toelle@upb.de

Elena Slawinski
University of Duisburg-Essen, elena.slawinski@stud.uni-due.de

Milad Mirbabaie
Paderborn University, milad.mirbabaie@uni-bamberg.de

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Laura Tölle
Paderborn University
Warburger Str. 100
33098 Paderborn, Germany
laura.toelle@upb.de

Elena Slawinski
University of Duisburg-Essen
Forsthausweg 2
47057 Duisburg, Germany
elena.slawinski@stud.uni-due.de

Jennifer Fromm
University of Duisburg-Essen
Forsthausweg 2
47057 Duisburg, Germany
jennifer.fromm@uni-due.de

Milad Mirbabaie
University of Bamberg
Bamberg, Germany
milad.mirbabaie@uni-bamberg.de

Abstract

Merely using new collaboration technologies does not necessarily result in the desired benefits, which is why it is important to understand what constitutes effective use behavior. In information systems research, the affordance network approach has been developed as a methodological approach to investigate effective use behavior. The approach has already been applied to understand the effective use of electronic medical record systems and fitness wearables; however, it neglects how social influences foster or hinder effective use behavior in collaborative settings. Therefore, we supplemented the affordance network approach for collaborative contexts by using social network methods. We demonstrate our approach based on two university courses in which students carried out group work within the collaborative VR application Spatial. Thereby, we contribute a methodological approach that enables researchers to identify influential users who encourage their team members to actualize affordances leading to goal achievement.

Keywords: Effective Use, Affordance Network Approach, Virtual Reality, Collaboration, Social Network Analysis

Introduction

In contemporary times, collaborative settings are no longer exclusively carried out co-presently, but are increasingly enriched by digital technologies - a shift that has become particularly evident during the COVID-19 pandemic (Mitchell, 2021). For instance, Larvol, a leading provider of data and intelligence solutions, conducted all its team collaboration activities exclusively in virtual reality (VR) and augmented reality throughout 2021 (Fraser, 2021). Additionally, the global market for this technology is expected to reach $69.6 billion by 2028, with an average annual growth rate of 18% from 2021 to 2028 (Grand View Research, 2021). The technology offers distinct characteristics, namely immersion, interactivity, and presence, whereby the high degree of immersion in particular drives users' intention to collaborate (Mütterlein et al., 2018).

With respect to collaboration technologies, social influences are an important factor to consider as they have been found to predict the actual use of collaboration systems (Olschewski et al., 2013). However, simply using collaborative technology is not sufficient to achieve the desired collaboration goals (Seddon, 1997). Instead, information system (IS) research emphasizes the importance of effective use in achieving usage goals (Burton-Jones & Grange, 2013). Burton-Jones and Volkoff (2017) proposed the affordance network approach as a means to examine effective use, which visualizes effective use as a network of realized action potentials (so-called affordance actualizations) and their associated immediate outcomes. This approach is suitable to identify a sequence of affordance actualizations that are critical to achieve desired outcomes. However, the affordance network approach does not consider that specific users might encourage or hinder their team members at effective affordance actualization, thus providing an incomplete picture of effective use behavior in collaborative settings. Furthermore, the sequential nature of the affordance network approach does not reflect the reality of affordance actualizations in collaborative settings, as multiple users may actualize several affordances simultaneously or jointly. As a result, the affordance network approach is less suited for investigating effective use of collaboration technologies such as collaborative VR systems. As stated by Eckhardt et al. (2010), research still lacks a sufficient investigation of the influence of social environments on technology usage. Olschewski et al. (2013) find in a pretest of the Technology Acceptance Model for Collaboration Technology, that social influence is an important factor in collaboration technology adoption, since collaboration technologies are designed to be used jointly with other members and not individually (Brown et al., 2010). Following the work by Blascovich (2002), we seek to understand how social influence effects facilitate immersive virtual environments. Hence, our research goal was to supplement the affordance network approach for collaborative contexts using a social network approach. Thus, we ask the following research question:

RQ: *How can the affordance network approach be advanced to investigate effective use behavior in collaborative settings?*

By answering this research question, we contribute to effective use theory by extending the affordance network approach for collaboration technologies enabling IS researchers to investigate the social influence of fellow users on effective use behavior more thoroughly. We demonstrate our approach based on two university courses in which students carried out group work within the collaborative VR application *Spatial*[1] over the course of six weeks. In total, we conducted 28 interviews at two points in time and twelve observations of their collaborative work in Spatial. The data was analyzed using qualitative content analysis and social network analysis to identify social influences on the actualization of affordances.

In the next section, we summarize the theoretical background on collaborative VR, social influences, effective use, and the affordance network approach. Afterward, we describe our data collection and how we developed the rules for creating a social network that visualizes effective use behavior in collaborative settings. Following that, we report the results of our analysis. We conclude by discussing the strengths and limitations of the affordance network approach and our social network approach, addressing the limitations of our study, and proposing areas for future research.

Background

Collaborative Virtual Reality

Collaboration can be defined as "*an evolving process whereby two or more social entities actively and reciprocally engage in joint activities aimed at achieving at least one shared goal*" (Bedwell et al., 2012, p. 3). Nowadays, in times of constant digitalization, group work is often conducted through collaborative technologies. An early definition of collaboration technology was made by Ellis et al. (1991), who describe it as "*computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment*" (p. 40). Collaborative technology can help save time and costs and improves the flow of communication (Bafoutsou & Mentzas, 2002). As an inherently immersive and interactive technology, VR can foster collaborative group work (Mütterlein et al., 2018).

VR can be defined as an "*immersive technology to simulate interactive virtual environments or virtual worlds with which users become subjectively involved and in which they feel physically present*"

[1] https://spatial.io/

(Wohlgenannt et al., 2020, p. 457). The technology is characterized by three distinct characteristics, namely a high degree of presence, interactivity, and immersion (Mütterlein, 2018). According to Sanchez-Vives and Slater (2005), presence refers to the feeling of being in a certain (virtual) place without actually being there physically. Interactivity is the extent to which users can manipulate their virtual environment (Steuer, 1992). While the understanding of presence and interactivity in VR research is mostly the same, immersion can be viewed from both a psychological and a technological perspective (Mütterlein, 2018). Psychologically, immersion can be seen as a feeling of being completely absorbed in a virtual world (McMahan, 2003). Alternatively, the degree of immersion can be described by the technological capabilities of the VR system, such as the number of sensors (Sanchez-Vives & Slater, 2005). We follow the understanding of Mütterlein (2018), who sees immersion as a psychological experience based on the technological components.

Presence, interactivity, and immersion have a positive impact on collaborative group work. For example, when users experience a feeling of presence in a shared space, participation is likely to increase in a collaborative setting (Chandra & Leenders, 2012). The ability to share and manipulate objects or files in VR (i.e., interactivity) stimulates remote collaboration, providing a more interactive communication (Leung & Chen, 2003). Immersion promotes cooperation awareness by helping users to keep their focus, creating problem-solving situations, and simulating personal collaboration (Zheng et al., 2018). Moreover, it ensures less distraction from environmental stimuli through an increased focus on current activities in the virtual world (Bhagwatwar et al., 2013). Furthermore, VR has been found to increase motivation and engagement in collaborative learning contexts (Majchrzak et al., 2022). Also, VR is already used in companies to collaborate across borders; for example, the German automotive manufacturer Audi uses the technology in the design process of its cars to avoid expensive prototypes and business trips (Audi Media Center, 2020). Other large companies, such as Larvol, Mattel, Pfizer, and Nestlé, use the collaborative VR platform Spatial to conduct virtual team meetings (Fraser, 2021; Horwitz, 2020).

Social Influence in Collaborative Settings

Collaborative group work is subject to social influences. This concept takes on an important role in the field of collaboration technology due to the social characteristics of collaborative systems (Olschewski et al., 2013). According to French and Raven (1959), social influence is the change in an individual's behavior that results from interaction with another individual or a group. This influence cannot only lead to positive behavioral changes but can also cause negative effects. Already early studies emphasized the importance of social influences on IS use, such as Boudreau & Robey (2005), who report a case study of an enterprise resource planning system after its implementation in a large government agency. The authors elucidate changes in enactments with the theory of improvised learning, explained by social influence from project leaders and peers. Pinnsoneault et al. (1999) investigate electronic brainstorming in an effort to find conditions of using these systems more productively. Nunamaker et al. (1991) provide one of the first studies to examine same-time/same-place and same-time/different-place electronic meeting systems and find that the use of this technology can significantly improve group processes and outcomes depending on the specific situation. In co-present collaboration, a positive influence can take place in the form of social interdependence, where individuals not only want to maximize their own productivity but also the productivity of other group members to achieve common goals (Kelley & Thibaut, 1978). Superior influence is another factor that can lead to a positive behavioral change in a collaborative setting (Brown et al., 2010). Superiors are seen as a key factor of social influence because a person is more likely to use a system when their superior believes they should do so (Brown et al., 2010).

Social influences that result in negative effects include, for example, social loafing, which is described as the tendency for individuals to show less effort when working with others than when working alone (Latané et al., 1979), which can lead to passivity and free riding (Roberts & McInnerney, 2007). This is more likely in settings with a high degree of anonymity as performance, contributions, and accountability cannot be assigned clearly to a certain group member (Shepperd, 1993). Social influences in VR have been investigated only to a limited extent; for example, Blascovich (2002) found that the presence of other users has an influencing effect in immersive VR environments. Furthermore, Fromm et al. (2020) revealed that the affordances and constraints of social VR apps can lead to negative group effects during VR brainstorming sessions.

Effective Use and the Affordance Network Approach

Simply using an innovative technology such as VR is insufficient for achieving user goals (Seddon, 1997). According to Burton-Jones and Grange (2013), effective use is a necessary condition defined as "*using a system in a way that helps attain the goals for using the system*" (p. 632). To examine effective use, Burton-Jones and Volkoff (2017) proposed the affordance network approach, which describes effective use as "*an interrelated set of potential individual actions, and the associated immediate outcomes*" (Burton-Jones & Volkoff, 2017, p. 469). In other words, it is a network of affordances, affordance actualizations, and immediate outcomes.

The concept of affordances was initially introduced by the ecological psychologist James Gibson (1979), who found that animals do not perceive the physical properties of their environment first but rather directly notice their potentials for action. He defined affordances as "*what [the environment] offers [...], what it provides or furnishes, either for good or ill*" (Gibson, 1979, p. 127). In the IS field, Markus and Silver (2008) proposed the concept of functional affordances, which are defined as "*possibilities for goal-oriented action afforded to specified user groups by technical objects*" (p. 622). Affordance actualization, the realization of such possibilities for action, is associated with immediate outcomes (Strong et al., 2014). Effective use of a technology occurs when successful affordance actualization leads to the achievement of desired outcomes (Burton-Jones & Volkoff, 2017). The affordance network approach has also been applied to study the effective use of technologies like e-health systems, social media, and wearable devices (Burton-Jones & Volkoff, 2017; Jayarathna et al., 2020; Abouzahra & Ghasemaghaei, 2021). The study by Abouzahra and Ghasemaghaei (2021) on wearable devices is particularly relevant to our research, as it found that social influence positively impacted affordance actualization (e.g., the friends of fitness wearable users have motivated them to actualize affordances). In this study, social influence was visualized as a dimension of effective affordance actualization as demonstrated in Figure 1.

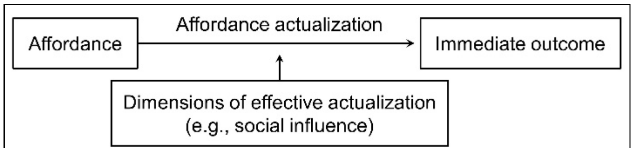

Figure 1. Affordance Network Approach

While the study highlights the importance of social influences regarding effective use behavior (Abouzahra & Ghasemaghaei, 2021), the affordance network approach does not allow to identify users that exert a particularly strong influence on the effective use behavior of their team members. Consequently, the affordance network approach only provides a superficial understanding of social influences and may not be the most appropriate method to investigate the effective use of collaboration systems. To overcome this limitation, we propose utilizing a social network approach that enables the visualization of social connections among team members.

Methods

To investigate social influences on effective use behavior, we collected qualitative data during two university courses using a collaborative learning approach. In both courses, we conducted two series of interviews with the participants focusing on perceived affordances and social influences. Furthermore, we observed their collaborative VR learning sessions focusing on actualized affordances and observable social influences. The interviews were analyzed with a qualitative content analysis (Mayring, 2015), and the resulting category system served as the basis for the analysis of the observations. To identify users who exerted a strong social influence on the affordance actualization of other users, we created multidimensional networks based on the observation data (Contractor et al., 2011). Finally, the analysis of two different collaborative VR learning settings allowed us to compare the results and confirm our findings. Figure 2 visualizes our research process.

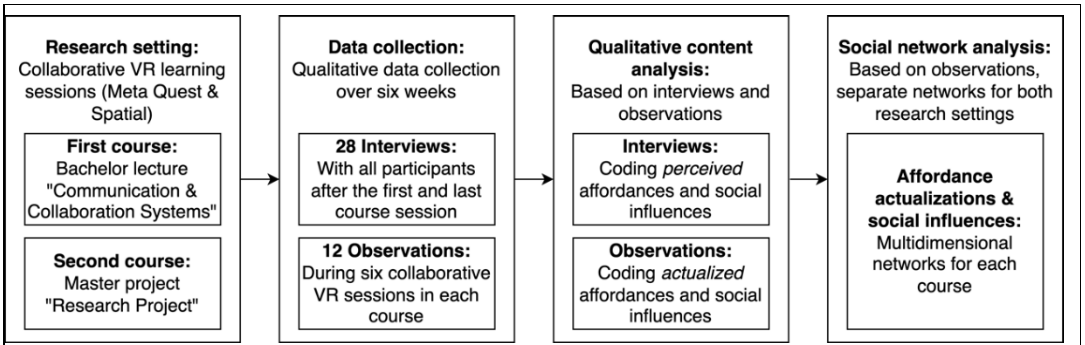

Figure 2. Overview about the Research Process

Research Setting

We collected data during two different courses that took place as part of a cognitive and media science study program consisting of information systems, computer science, and psychology courses at a German university. In both courses, the students received the stand-alone VR headset Meta Quest for mandatory usage from their homes and met once per week in the collaborative VR application Spatial. The headset was used for the lecture, for group work and for presentation and brainstorming sessions. Overall, the students used Spatial for six consecutive weeks allowing us to collect data over a longer timeframe. The application enabled the participants to create different spaces and switch between virtual environments. Within a space, users could move via teleportation. By uploading a selfie, users were able to create a realistic avatar allowing them to communicate via audio, gestures, and reactions. Users were able to upload local files (e.g., presentation slides, documents) or search the web for 3D objects and images to be placed in the virtual environment. Each space included a virtual whiteboard to arrange sticky notes that could be labelled via a virtual keyboard, the scribble feature, or voice input. The Meta Quest provided a built-in screenshot feature.

The first course was a lecture titled Communication & Collaboration Systems and was part of the bachelor's program. The lecture took place during the winter term 2020/21 and overall, one lecturer and nine students participated. The goal of the lecture was to increase the students' understanding for the challenges and success factors related to the introduction of communication and collaboration systems in enterprises. During the lecture, the students applied technology adoption, spread of innovation, and media selection theories to develop strategies for the introduction of new technologies. Before each course unit, the students were asked to read scientific articles about the course topics at home. During the VR course, the students applied their theoretical knowledge by solving three tasks provided by the lecturer through discussion and group work. Since the lecturer was part of the author team, she tried to exert as little influence on the students' affordance actualization process as possible. She presented the tasks to the students and answered questions but did not actively suggest how or for which purposes to use specific features.

The study included a sample of 2/3 female and 1/3 male participants, aged between 20 and 31 years ($M = 23.7$ years). All but one student had prior experience with VR, with half reporting low experience levels and the other half reporting high experience levels. Students had encountered VR through work or study programs, participation in other scientific studies involving VR app tests, and gaming in their free time. Table 1 provides an overview about the participants of the first course.

The second course was a student project titled Research Project and was part of the master's program. The project took place during the winter term 2021/22 and overall, one lecturer and four students participated. The goal of the project was to learn scientific working and academic writing. The main objective was for the students to plan and conduct a survey on social VR experiences and create prototypical social VR experiences while also summarizing their research in a scientific paper. The students used the VR environment to update each other on their progress, distribute tasks, plan their survey, and design concepts for the implementation task. Other tasks such as conducting the survey, implementing the prototypes, and writing the paper took place outside of the VR environment. The lecturer was not part of the author team, and therefore did not deliberately try to limit his social influence on the students. Compared to the lecturer in the first course, he encouraged the students more to experiment with all features provided by Spatial.

User	Age	Gender	Educational Level	VR Expe-rience	Type of Experience
L01	27	Female	Research associate and PhD student	High	Work and study program
S01	22	Female	Bachelor's program, fifth semester	Low	Study participation
S02	20	Female	Bachelor's program, fifth semester	Low	Gaming
S03	31	Female	Bachelor's program, fifth semester	High	Gaming
S04	23	Female	Bachelor's program, eleventh semester	Low	Gaming
S05	22	Male	Bachelor's program, fifth semester	High	Work and study program
S06	27	Male	Bachelor's program, eleventh semester	High	Gaming
S07	24	Male	Bachelor's program, sixth semester	Low	Study participation
S08	24	Female	Bachelor's program, eleventh semester	High	Work and study program
S09	21	Female	Bachelor's program, fifth semester	None	None

Table 1. Overview about the Participants of the First Course

The sample consisted of five males who were between 24 and 32 years old (*M* = 29 years). One student reported no previous experience with VR, while two students had a little experience, and one student had a lot of experience. The students with experience got in contact with the technology through gaming in their free time, the participation in other scientific studies involving VR app tests, their work, or study program. Table 2 offers an overview about the participants of the second course.

User	Age	Gender	Educational Level	VR Experience	Type of Experience
L01	32	Male	Research associate and PhD student	High	Work and study program
S01	30	Male	Master’s program, second semester	Low	Gaming and study participation
S02	25	Male	Master’s program, fifth semester	High	Study program and study participation
S03	24	Male	Master’s program, third semester	Low	Gaming
S04	24	Male	Master’s program, fifth semester	None	None

Table 2. Overview about the Participants of the Second Course

Data Collection

We decided to use a semi-structured interview series to get insight into the participants’ perceived characteristics of the setting (Myers & Newman, 2007). Interviews are a common method to identify affordances (Volkoff & Strong, 2013; Fromm et al., 2020). We interviewed all participants after their first VR session, except for the lecturer of the first course who was part of the author team. Additionally, we observed their collaborative VR sessions over six weeks. After the observations, we carried out a second round of interviews to verify our interpretation of the observations with the interviewees and enrich our interview data from the first round since the participants perceived further affordances due to their increasing experience with Spatial. According to Denzin (1970), method triangulation allows the strengths of different methods to complement each other. While interviews provided insight into the subjective experience of the participants, observations allowed us to capture actual behavior in the VR environment. To structure the interviews, we created an interview guide based on concepts derived from the literature. In the beginning, we asked introductory questions about the participants’ previous VR and collaboration experience. The main part of the interviews focused on perceived affordances (Markus & Silver, 2008) and perceived social influences (French & Raven, 1959). In the concluding part, we asked about their final thoughts on the effective use (Burton-Jones & Grange, 2013) of VR for collaborative learning. Table 3 provides example questions for each concept. Both interviews lasted sixty minutes on average.

Concepts	Sample Questions
Introductory part: Sociodemographic, previous VR and collaboration experience	What previous experience have you already had with VR? (self-developed)
Main part I: Perceived affordances (Markus & Silver, 2008)	Which actions did VR enable you to reach your goals? (Volkoff & Strong, 2013)
Main part II: Perceived social influence (French & Raven, 1959)	How have you been influenced by others while using VR? How would you describe your own role during the collaborative VR sessions? (self-developed)
Concluding part: Effective use (Burton-Jones & Grange, 2013)	What would you call effective use of VR? (Burton-Jones & Volkoff, 2017)

Table 3. Interview Topics and Example Questions

In addition, we conducted observations for all twelve sessions with passive participation by an alternating member of the research team in collaborative VR learning sessions via the web browser application Spatial (Spradley, 2016). We recorded the sessions using the screen capture tool OBS-Studio[2] and wrote an observation protocol for every session. The protocol included observations about the actualized affordances (Strong et al., 2014) and social influences (French & Raven, 1959). Furthermore, we monitored technical problems, which were mentioned as an additional factor influencing effective use (Burton-Jones & Grange, 2013) in the first round of interviews. Taken together, our data consisted of 28 interview transcripts and twelve observation protocols. To ensure a smooth transition into the data analysis, the interviews were transcribed literally (Kuckartz & Rädiker, 2019).

Qualitative Content Analysis

After the data collection phase, we conducted a qualitative content analysis using a combination of deductive category assignment and inductive category formation (Mayring, 2014). First, we deductively derived the following main categories based on our research question and the existing literature: perceived affordances (Markus & Silver, 2008) and social influences (French & Raven, 1959). Second, we inductively built subcategories based on the interview transcripts. Third, we applied the resulting category system from the interview data for the categorization of the observations. We analyzed which of the perceived affordances mentioned by the interviewees were indeed actualized and then summarized these under the main category actualized affordances (Strong et al., 2014). Likewise, we analyzed observable instances of the social influences perceived by the interviewees (French & Raven, 1959).

According to Mayring (2014), we developed a coding guide to ensure that the text sequences were assigned consistently by the two independent coders and to avoid delimitation problems between the categories. The coding guide contained category labels, category descriptions, and anchor examples. As recommended by Mayring (2014), the two coders discussed their coding and agreed on a revision of the category system and coding guide after coding 30% and 50% of the material. After each revision, the transcripts were coded from scratch using the revised category system. The final category system was given to a third coder, who coded a third of the material again, allowing us to assess the intercoder reliability (Kuckartz & Rädiker, 2019). We calculated the kappa-coefficient according to Brennan and Prediger (1981) and received a relative agreement of 83.88%, which is classified as almost perfect, according to Landis and Koch (1977). The final coding guide can be found in Table 4.

[2] https://obsproject.com/

	Category	Description	Anchor Example
Affordances	Inter-activity	Users can (1) communicate with each other via audio and avatar gestures and (2) manipulate the size, color, and position of sticky notes and 3D objects.	“S04 presents the results; meanwhile, S06 and S08 adjust the content on the whiteboard a bit more by moving individual sticky notes around” (Course 1, Observation 5).
	Naviga-bility	Users can move through the virtual environment via teleportation.	“S06 moves around in the virtual space” (Course 1, Observation 1).
	Content generation	Users can (1) generate content by labeling sticky notes and (2) create 3D freehand drawings with the scribble feature.	“Students use sticky notes as headings to divide the whiteboard into sections” (Course 1, Observation 5).
	Multi-modality	Users can (1) search the Internet for images and 3D objects, (2) upload local files (e.g., images, slides, documents), and (3) combine them with sticky notes and scribbles.	“Students use the search function to look for 3D objects and images; they combine these on the whiteboard” (Course 1, Observation 5).
Social Influences	Help request	A user asks a specific other user or the whole group for help with affordance actualization.	“S09 asks in the round if it is possible to change the color of sticky notes” (Course 1, Observation 1).
	Assistance	A user provides another user with assistance regarding the actualization of affordances.	“S07 reduces the size of a sticky note for S03 because her controller battery is empty” (Course 1, Observation 5).
	Encoura-gement	A user encourages others to actualize specific affordances or suggests specific features that could be used for actualization.	“After S09's comment, the others (S03, S02, S01) change the color of their notes” (Course 1, Observation 1).

Table 4. Coding Guide

Social Network Analysis

The coding performed during the qualitative content analysis served as a basis for the social network analysis. The goal of the social network analysis was to identify users who were highly active in affordance actualization and exerted a strong social influence on the affordance actualization of other users. For the visualization of the networks, we created an input file for each course specifying the types of nodes and the relationships between them. We created the input files based on the actualized affordances and social influences (i.e., help request, assistance, and encouragement) coded in the observation protocols because the interviews reflected perceptions and not actual behavior. The interviews, however, were important to ensure that the coding of the observations reflected the perceptions of the participants. In the input files, we defined two types of nodes (i.e., users and features) and four types of relationships that could exist between these nodes: (1) affordance actualization between a user and a feature node, (2) a help request regarding affordance actualization from a user to another user, (3) assistance with affordance actualization provided by one user to another user, and (4) encouragement to actualize an affordance voiced from one user to another user. Table 5 visualizes the structure of our input files.

Source node	Target node	Edge label	Weight
User 1-5	Feature	Specific actualized affordance	Quantity of actualizations
User 1-5	User 1-5	Specific social influence	Quantity of influences

Table 5. Structure of the Social Network Input Files

After the input files were imported into the network visualization tool Gephi[3], we created multidimensional networks for both courses (Contractor et al., 2011) consisting of two types of nodes (i.e., features, users) and edges (i.e., affordance actualizations, social influences). The types of nodes and edges can be distinguished based on their color (i.e., bright gray, dark gray). The thickness of the edges was adjusted based on their weight (i.e., quantity of affordance actualizations and social influences). Since Gephi does not allow for edge-bending to make parallel edges visually distinguishable from single edges, we summarized all affordance actualizations occurring between a specific user and feature node as well as all social influences occurring between two specific user nodes. For example, if two different social influences (e.g., assistance and encouragement) occurred between two given users, we summarized these as one edge with the edge weight referring to the quantity of both social influences in sum.

For each course, we created two multidimensional networks: Whereas the node size in the first network was adjusted based on their weighted in-degree, the node size in the second network was adjusted based on their weighted out-degree. According to Barabasi and Bonabeau (2003), the weighted in-degree of a node represents the sum of the weights of incoming edges, while the weighted out-degree is calculated by summing the weights of outgoing edges. Thus, the first network emphasizes the features that were used particularly often for affordance actualization and users who were frequently influenced by others (i.e., by receiving assistance with affordance actualization or being encouraged to actualize affordances). The second network highlights users who were particularly active in terms of affordance actualization and exerting social influence on the effective use behavior of their team members. Figure 3 summarizes the characteristics of the network graph.

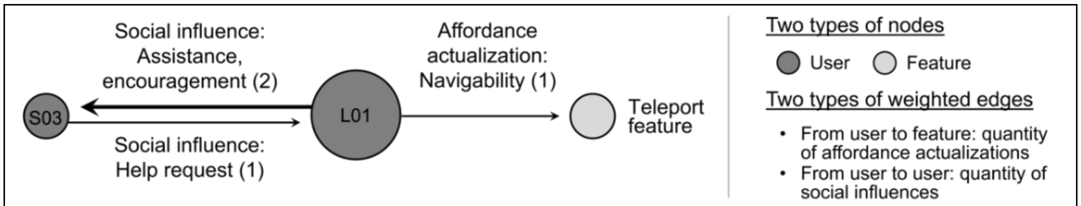

Figure 3. Characteristics of the Network Graph

Findings

Figure 4 provides a comparison of the social network graphs for both courses with an adjusted node size based on the in-degree, while Figure 5 compares the network graphs of both courses focusing on the weighted out-degree. In total, the network graphs for the first course include nine user nodes, nine feature nodes, and 102 edges. 65 of these edges refer to affordance actualizations and 37 edges refer to social influences. With five user nodes, nine feature nodes, and 45 edges, the network graphs for the second course include fewer interactions because of the smaller number of participants. 35 of these edges refer to affordance actualizations and ten edges refer to social influences.

When looking at the weighted in-degrees of the feature nodes in Figure 4 and considering the different course sizes, the students in both courses frequently used the audio (277 vs. 271), sticky note (199 vs. 78), whiteboard (102 vs. 90), and teleportation (100 vs. 178) features to actualize affordances. Compared to the students in the first course, the students in the second course additionally used the avatar (8 vs. 109), 3D object (14 vs. 55), and scribble (1 vs. 19) features more often for affordance actualization.

In both courses, the participants used the features provided by Spatial to actualize the affordances of interactivity, navigability, content generation, and multimodality. The interactivity affordance was most frequently actualized in both courses by using the audio feature to discuss ideas during group work and present the results afterward. In actualizing the interactivity affordance, the participants of the second course made use of the avatar feature more often, "for example, by waving to say hello or goodbye. And for example, when someone gives a presentation, you usually bang on the table at university. Instead, you can just clap in VR. If someone has done something very well or something" (Course 2, S04, Interview 2). In both courses, the interactivity affordance was also actualized to manipulate elements in the VR

[3] https://gephi.org/

environment, “for example, if you upload slides as a PDF, you can make them smaller or bigger, slap them anywhere you want in VR. You're super flexible” (Course 2, S01, Interview 2).

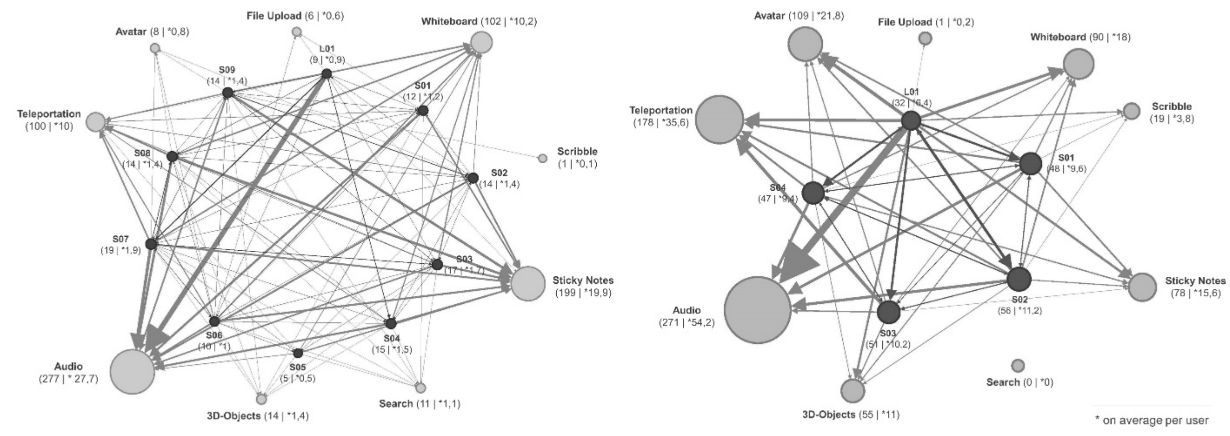

Figure 4. Network Graphs Focusing on Differences in the Weighted In-degree

The teleport feature was frequently used in both courses to actualize the navigability affordance, for example, a student explained: “I may have positioned myself in a special way to show others ‘Okay, I'm looking at this document right now or I'm looking at this person right now’. To recreate that as in a real interaction. For example, standing in a circle around a person who is talking or positioning yourself in front of a whiteboard” (Course 2, S02, Interview 2). Since a larger number of participants took part in the first course, the navigability affordance was also actualized to split up in breakout rooms: “This enables us not to disturb each other and each group can separate its results from the results of the other groups” (Course 1, S03, Interview 1).

In both courses, the participants often used the sticky note feature to actualize the content generation affordance, as one student explains: “I think the sticky notes are essential, of course, that you can always write something down, that you can remember something, that you can pin it down, I think that's very important” (Course 1, S02, Interview 1). However, the participants in the second course raised the issue that “you can kind of take notes in VR, but it just takes an extremely long time” (Course 2, S02, Interview 2). For this reason, they used the scribble feature more often to actualize the content generation affordance compared to the participants of the first course.

The multimodality affordance was only actualized seldomly in both courses, mainly because the participants did not see an added value of combining their content with the available, rather playful 3D objects (e.g., cats, dogs, cakes). However, in the first course, the 3D objects were used “to make our opinion clear. That is, when we voted for something, we simply put a cat object on a sticky note” (Course 1, S04, Interview 1). Furthermore, a student explained that “you can always use objects like arrows or something like that to clarify relationships between concepts. Sometimes it takes me a little longer to get it right, but it's good for representing processes and models” (Course 1, S09, Interview 1). In the second course, the participants actualized the multimodality affordance by combining sticky notes with uploaded PDF files: “You can also set annotations with sticky notes. So, for example, if I drag a file onto the whiteboard in Spatial and then present it, I can put the sticky notes directly on it and make my annotations. Like comments in Google Drive” (Course 2, S02, Interview 2).

The network graphs focusing on the weighted out-degrees in Figure 5 highlight users who were particularly active in terms of affordance actualization and exerting social influences. In the first course, the most active users were the students S07 (132), S08 (111), S09 (100), and the lecturer L01 (108). In general, the difference between the least active user S05 (33) and the most active user S07 (132) in the first course is not as significant as in the second course. In the second course, the lecturer L01 was by far the most active user with a weighted out-degree of 481, while the student nodes had much lower and relatively similar out-degree values (ranging from 101 to 163).

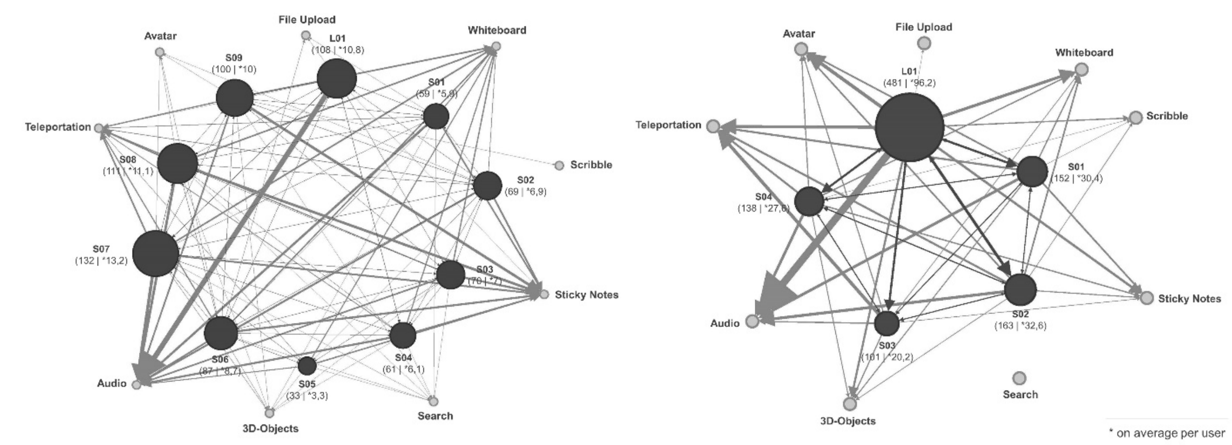

Figure 5. Network Graphs Focusing on Differences in the Weighted Out-degree

In order to obtain a better overview on the social influences, the influences of the second course are displayed in detail in Table 6. The influences are divided into request, assistance, and encouragement, and are separated by a slash. For example, L01 performed 3 requests, 4 assists, and 23 encouragements on S01.

	Recipient					Sum out-degree
Sender	L01	S01	S02	S03	S04	
L01	-	3/4/23	4/10/28	4/5/21	3/4/21	14/23/93 (in total: 130)
S01	4/2/0	-	5/1/0	5/1/0	5/1/0	19/5/0 (in total: 24)
S02	9/4/0	8/0/0	-	8/0/0	8/0/2	33/4/2 (in total: 39)
S03	1/2/0	2/0/0	2/1/0	-	2/1/0	7/4/0 (in total: 11)
S04	4/6/0	4/4/0	4/1/0	4/3/0	-	16/14/0 (in total: 30)
Sum in-degree	18/14/0 (in total: 32)	17/8/23 (in total: 48)	15/13/28 (in total: 56)	21/9/21 (in total: 51)	18/6/23 (in total: 47)	-

Table 6. Counted Social Influences Divided into Requests/Assistances/Encouragements

These differences underline that the lecturer in the first course intentionally refrained from exerting too much influence on the students' use of Spatial. She allowed them to explore the features of the platform on their own and only provided assistance when directly asked to do so. Consequently, the students collaborated and supported each other, leading to a shared understanding of the technology. As one student from the first course noted in an interview, “We all supported each other. In the end, we were all on a common denominator. Because we helped each other, experienced this technology together and then actually used it. We all helped each other in the process” (Course 1, S06, Interview 1). In contrast, the lecturer in the second course (who was not part of the author team) felt that his students were not able to recognize the affordances of VR on their own, which is why he tried to actively encourage them to do so: “I don't know if it's some kind of inhibition or laziness that unfortunately prevents the participants of the course from really letting loose and trying things out. I'm already trying to get people going, but I can see that the other participants don't really realize yet what this VR platform could actually be helpful for” (Course 2, L01, Interview 1). The lecturer assumed the missing maturity of VR features to be a reason for the students’ restraint with affordance actualization, explaining that “it is cumbersome to take notes in Spatial. You can also type or draw in VR. It's just not mature, yet. I can understand when students say, ‘I'll just take off my glasses for a moment and write something down on a piece of paper’. But unfortunately, we don't have the information in VR then” (Course 2, L01, Interview 1). That is why he deliberately encouraged the students to actualize affordances such as content generation: “Every time I get up and start making a sticky note, I'm already doing it in hopes that they'll see that they can do it too. That is already an attempt by me to influence" (Course 2, L01, Interview 1).

As an explanation for the large social influence of the lecturer, a student suggested that it "probably also plays a role that he is the one who leads the course and when he says something, it is more important for me than when others say something" (Course 2, S02, Interview 1). Another student found it convenient that they could ask the already VR experienced lecturer L01 for help at any time, for example, S01 stated that "if L01 couldn't explain to me how things work from a technical point of view, then I would have to use learning by doing and that would take a lot more time, so that was of course very pleasant that L01 already had a certain expertise" (Course 2, S01, Interview 1). Although the lecturer had the largest social influence, one student mentioned that they also "helped each other. For example, one had problems moving and I just said, 'You can teleport' and explained how to do it" (Course 2, S03, Interview 1). Nevertheless, the students confirmed that the social influence among them as peers was less strong compared to the influence of the lecturer because "L01 has always encouraged us that we should use certain features. That we should create some scribbles, that we should make some notes. He encouraged us to interact. So, among ourselves, I would say, it wasn't so mega strong that we brought each other to do something. I somehow have the feeling that the others don't really want to use the features either. There were just situations where the necessity of the situation somehow required it. For example, if someone uploaded a document and it had to be moved, scaled, or pinned, someone who could already do that did it" (Course 2, S02, Interview 2).

The interviewees also hinted to negative social influences, which in turn affected others. For example, a student explains that he "found it negative at times that L01 and S03 created some 3D objects while the rest of us were still in the middle of a conversation. I found that very distracting" (Course 2, S02, Interview 2). Another student stated that "there's also a lot of potential to play with objects or to make objects so big that nobody can see anything anymore. You can do things that disrupt the others, where you really can't work effectively anymore. But of course, those tend to be things that happen unintentionally. But it's definitely possible" (Course 1, S06, Interview 1). Hence, these actions can also be termed inappropriate affordance actualizations.

Furthermore, the interviews revealed that not only social influences, but also technical issues hindered them at affordance actualization. For example, a student mentioned that he "had a connection error once in a while, so I was kicked out for a few minutes" (Course 1, S05, Interview 1). Also, "the interaction with objects in the VR environment is difficult. Whether it's files or documents or 3D objects. That often doesn't work the way you want it to. It's also a bit of a problem that you can't see who's doing what. So, we often had two people trying to place a document somewhere else at the same time and then of course getting in each other's way" (Course 2, S02, Interview 2).

Discussion

The main components of the affordance network approach are affordance-outcome units consisting of affordances, affordance actualizations, and associated outcomes (Burton-Jones & Volkoff, 2017). In comparison, our social network approach includes two types of nodes (i.e., technology features and users) and two types of edges (i.e., affordance actualizations and social influences). While the affordance network approach emphasizes the links between affordances and outcomes that contribute to goal achievement (Burton-Jones & Volkoff, 2017), our approach does not include the outcomes of affordance actualization. The included affordances in our study align with the affordances that were found to contribute to the achievement of collaborative learning goals in previous research (Jayarathna et al., 2020). Instead of outcomes, our social network approach highlights the relational nature of affordances (Strong et al., 2014). Affordance actualizations are visualized as edges between technology features and users, emphasizing that, for example, one user could actualize the information generation affordance using the sticky note feature, while another user could actualize the same affordance using the scribble feature.

Furthermore, the affordance network approach visualizes effective use behavior as sequences of affordance actualizations (Burton-Jones & Volkoff, 2017). For example, first, the inputting affordance needs to be actualized—the outcome enables the accessing affordance; second, the accessing affordance needs to be actualized—the outcome enables the decision-making affordance, and so on. The affordance network approach seems to be well suited for systems that are used by individuals; however, in collaborative settings, users typically actualize several affordances at the same time, which results in several outcomes simultaneously (e.g., the information generation and capturing affordance is actualized while the users also actualize the verbal information exchange affordance at the same time). Visualizing affordance actualizations as a sequence for collaborative settings would be a difficult endeavor, making our approach more suitable for this context.

In their research article on effective use, Burton-Jones and Grange (2013) highlighted the importance of context and showed that influencing factors (i.e., people, systems, tasks, and organizational factors) could increase or reduce the level of effective use. Related to this, other researchers identified influencing factors such as those related to the effective use of hospital IS (Weeger et al., 2014) and big data (Surbakti et al., 2020). Among the influencing people factors, the authors also identified social influences such as top manager support (Surbakti et al., 2020). However, despite their importance, these influencing factors do not represent a component of the affordance network approach (Burton-Jones & Volkoff, 2017). We argue that social influence cannot be ignored, especially in collaborative use contexts. Therefore, our social network approach visualizes positive social influences that encourage others to actualize affordances contributing to goal achievement (i.e., help requests, assistance, encouragement). Furthermore, the interviews suggest the high distraction potential of VR as a cause for negative social influences. Thereby, we also extend the scarce body of research on social influences in VR settings (Blascovich, 2002; Fromm et al., 2020). Our results confirm that the presence of other users has an influence on user behavior in immersive settings (Blascovich, 2002).

In comparison to another study that applied the affordance network approach and identified social influences (Abouzahra & Ghasemaghaei, 2021), our social network approach allows to identify specific users who exert a particularly high social influence on other users. For example, Abouzahra and Ghasemaghaei (2021) found that friends motivated senior wearable users to actualize affordances related to the goals of activity monitoring which aligns with the social influence called encouragement we found in our study. However, by calculating the weighted out-degree, we were able to identify the lecturer L01 as a particularly influential user in the second course when it comes to assisting other users in their effective use behavior. With activated edge labels, further insights can be gained, such as the fact that most help requests in the second course originated from the student S02. However, in a social network, there can only be one edge between two nodes, which is why all affordance actualizations by a specific user that are related to the same feature and all social influences that occurred between two specific users are summarized in one edge. In this regard, the affordance network approach provides a clearer distinction between affordance actualizations as each affordance is visualized as part of a separate affordance-outcome unit (Burton-Jones & Volkoff, 2017).

Related to different user behaviors, our social network approach offers insights into the affordance actualizations and social influences related to each user, while the affordance network approach only distinguishes between user roles (e.g., front line staff vs. managers) who actualize different affordances (Burton-Jones & Volkoff, 2017). In this regard, our approach offers more detail; however, with too many edges, a social network quickly becomes cluttered. Therefore, we consider our approach more suitable for investigating effective use behavior on the team level, while the affordance network approach might be more suited for studies on the individual or organizational level. In conclusion, both approaches have their strengths and limitations, and thus we propose to view them as complementary to each other.

Theoretical Contribution and Practical Implications

The theoretical contribution of our research is advancing the affordance network approach (Burton-Jones & Volkoff, 2017) for the investigation of effective use behavior in collaborative settings. We propose a social network approach, which enables researchers to visualize and measure the social influence of individual users on the effective affordance actualization of their team members. In this paper, we describe the rules for the social network production so that IS researchers can use our methodological approach in future research. Furthermore, we have demonstrated our approach in two collaborative VR settings and thereby extend the research on social influences in VR (Blascovich, 2002; Fromm et al., 2020).

In practice, our social network approach can be used to evaluate team composition in collaborative settings. Our approach allows the identification of key users who can help fostering effective use behavior in teams, such as by stimulating the use of specific features, assisting their team members, or encouraging others to actualize affordances that lead to desirable outcomes. In the future, our approach could also be used to identify team members who hinder others at affordance actualization through distracting behavior. If the social network includes many help requests, this could be an indicator that more training is required to use a given technology effectively. Furthermore, we found that not only social influence but also technical issues play an important role for the effective use of collaborative VR apps. We frequently observed that writing sticky notes was cumbersome or that disconnects disrupted the collaboration. This indicates that collaborative VR apps still need further development with regard to stability and smooth interactions with objects in the environment.

Conclusion

We explored social influences on effective use behavior in a collaborative VR setting. Therefore, we conducted two rounds of interviews with the participants of two collaborative learning courses at a German university and observations of their meetings in Spatial over the course of six weeks. We analyzed the data using a combination of qualitative content analysis and social network analysis. Our main contribution to IS research is advancing the affordance network approach (Burton-Jones & Volkoff, 2017), which allowed us to examine social influences in collaborative VR settings and their implications on effective use behavior.

Our study has some limitations that point to avenues for future research. The small sample size limits the generalizability of our findings; however, we tried to diminish this limitation by comparing two collaborative VR courses. Network size might also have a substantial effect on the exertion of social influences and the development of social norms. Other external factors and their effects can be investigated in future research, such as the participants' ability to collaborate, their attitude towards VR and their general openness to (new) technologies. Future work is encouraged to explore different contexts, such as workplace situations. The students who participated in our study were probably motivated by the link between their performance and their course grades. In different contexts, such as a workplace scenario, the underlying external motivations might differ, for example financial incentives or the fear of job loss, affecting the level of effort and dedication concerning the use of VR.

In addition, generalizability is reduced due to the characteristics of the instructor, who affects the social influence among peers. In future studies, one could focus on settings where the students have sufficient knowledge on the technology and the platform, which might reduce the amount of lecturer intervention. To reduce the bias of superior influence, future work can focus on settings without a lecturer or the extent to which the supervisor intervenes can be adjusted, paving the way for the investigation of a comparison of effects on effective use. Gaining further insights into the relationship between social influence and effective use behavior and explaining possible changes over time that might arise due to increasing experience or decreased interpersonal distance is another possible field of interest.

Furthermore, some affordance actualizations were more difficult to observe, for example the actualization of multimodality using the search in the web browser, because they are not visualized in the VR environment but rather inside the VR glasses of the individual participants. Consequently, our observed quantities of affordance actualizations can differ from the actual affordance actualizations.

Disentangling the individual effects of a specific social influence concerning its associated affordance outcome might provide promising in-depth insights. Also displaying the social influences and the affordance actualizations separately might be beneficial in certain contexts. We further recommend visualizing each social influence in an individual network graph. Since Gephi does not allow visually distinguishing parallel edges from single edges, different affordance actualizations related to the same features and social influences between the same two users needed to be summarized in a single edge.

An additional value could be delivered by a closer look at the disadvantages of using VR for collaborative work, such as the cost and time involved. Future research may draw attention to this and its implications.

In conclusion, we extended effective use research in collaborative settings by proposing a methodological approach integrating social influences. Future research could focus on prolonged and repeated usage. A larger and more diverse sample as well as a longitudinal study would enable testing for clustering effects.

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