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Can Virtual Observers Affect Our Behavior? Social Facilitation in Virtual Environments: A Mini-Review

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Supplementary Materials: Data, Materials [see Index of Supplementary Materials]

Abstract

The social facilitation effect describes the change in the performance of the task under the influence of the presence of observers. The effect itself consists of two components: social facilitation in simple tasks and social inhibition in complex tasks. In the context of the dynamic development of new technologies, the question of the possible influence on human behavior by virtual characters gains importance. We attempted to critically describe and summarize current research on social facilitation in order to answer the question of whether it occurs in virtual environments. We found 13 relevant studies, 3 of which demonstrated social facilitation, 4 social inhibition and 1 demonstrated the whole effect. The conclusions drawn from the analysis are ambiguous. Firstly, we identified that 12 out of 13 analyzed studies failed to show the whole effect. Secondly, we encountered several shortcomings of the summarized research that further complicated its interpretation. The shortcomings: presence of the researcher, unclear usage of "agent" and "avatar", evaluation of activation, no pilot tests of observers and no description of how their characteristics are generated, among others, are discussed. Furthermore, we investigated the effect sizes and their variability. The average effect size for social facilitation was g = 0.18, CI [-0.28; 0.64] and for social inhibition g = -0.18, CI [-0.40; 0.04]. In social facilitation, a substantial level of heterogeneity was detected. Finally, we conclude that it is still too early to provide a definite answer to the question of whether social facilitation exists in Virtual Environments. We recommend limiting evaluation activation to the lowest possible level, conducting pilot tests prior to the experiment, avoiding the presence of the researcher in the experimental room and a clear distinction of "agent" and "avatar", as measures to achieve a better quality in future research.

Keywords

social facilitation, social inhibition, audience effect, virtual environment, virtual reality

The phenomenon of social facilitation is one of the oldest effects studied in psychology (Triplett, 1898). It consists of two components that appear when the subject is performing the task in the presence of observers: the effect of facilitation in simple tasks and the effect of inhibition in complex tasks (Zajonc, 1965). According to the most popular paradigm (Zajonc & Sales, 1966), a simple task is defined as one in which the dominant response is correct as opposed to a complex task in which it becomes incorrect. Since its discovery, numerous experiments have been conducted to explore this effect. Facilitation arouses controversies from the very beginning. To date, there have been many disputes about possible explanations. Usually, explanations of the discussed effect fall into one of three categories (Bond & Titus, 1983; Guerin, 1993): drive theory (Zajonc, 1965), social comparison theories (Cottrell, Wack, Sekerak, & Rittle, 1968; Weiss & Miller, 1971) and cognitive process theories (Baron, Moore, & Sanders, 1978).

Zajonc (1965) stated that the mere presence of others increases our drive, which leads to a higher probability of generating the dominant (well-learned) response to a particular task or stimulus. It is worth noting that Zajonc understood "mere presence" broadly – as any situation in which another person observes an actor. His understanding directly excluded situations in which vicarious learning or imitation was possible. As aforementioned, the author made a distinction between simple and complex tasks, focusing on the correctness of a particular response. In his view, a simple task is the one in which the dominant response is the correct one. On the other hand, a complex task is the one in which the well-learned response would be incorrect. Therefore, the probability of a correct (dominant, well-learned) response increases in the presence of others and leads to a better performance in a simple task (social facilitation effect). However, the presence of an observer during a complex task leads to a decrease in performance (social inhibition effect).

Another explanation of the effect comes from Cottrell and associates (1968). They agreed with Zajonc (1965) about the importance of drive in the social facilitation effect explanation, but disagreed about the cause of its increase. The researchers underlined the importance of social comparison and the anticipation of the evaluation in the presence of others, which leads to an increase in drive. At the same time, this means that only the observers who are able to evaluate the subject's performance are the source of drive increase. Because of this hypothesis he proposed a narrow operationalisation of "mere presence"– as a situation in which another person is situated in the same space but is unable to even observe the actor or the task. In fact, he made confederates wear blindfolds during the study (Cottrell et al., 1968, p. 247).

Weiss and Miller (1971) expanded on that theory, adding the valence aspect of the state. The authors consider this responsive state of increased drive as aversive and name

it evaluation apprehension. Thus one can conclude that what Zajonc (1965) described as "mere presence" clearly does not fit Cottrell's understanding.

The last group of theories stress the cognitive aspect of performing. The major theory in that group is the attentional conflict theory (Baron et al., 1978). The authors focused on attentional resources, which are limited. Therefore, in a situation which demands that attention is given to two conflicting objects (the observer's reactions and the task), social facilitation will take place due to this conflict. Although the research and possible explanations are numerous, the meta-analytic approach seems to point to the most popular paradigm – Zajonc's drive theory (Bond & Titus, 1983). The research on the discussed effect cannot be classified as insignificant and limited to the academic debate. Answering the question of how the presence of others influences our behavior (in this case performance) is, in our opinion, one of the simplest and at the same time one of the most relevant questions in social psychology.

We live in an era of dynamic development of technologies, in which research using virtual reality (VR) as a research environment is numerous and still growing. VR is usually considered a technology (hardware) that uses different human-computer interfaces to create sensations that give the user a feeling of being present in the virtual world (Seth, Vance, & Oliver, 2011). In that sense, virtual reality is a technology, a group of hardware devices (e.g., goggles, monitors, trackers, etc.) that enable the user to enter and create a computerized world (Steuer, 1992). Companies can decide to transfer their training and workshops to the virtual world with the use of simulators. What is more, new paradigms focused on interaction with a computer are emerging, e.g., Computers As Social Actors (CASA), whose basic claim is that people interact with computers as if they were human (Nass, Moon, Fogg, Reeves, & Dryer, 1995).

In this context, we pose a justified question about the possibility of influencing the level of task performance through computer-generated characters. The aim of our paper is to summarize the research and underline the shortcomings that could be corrected in future studies to make them comparable and conclusive. Until now, there have been no reviews focused specifically on the aforementioned topic. Only short introductory descriptive summaries of the conducted studies are available, which are included at the beginning of the research reports as a part of the introduction to the article (e.g., Park & Catrambone, 2007). In this article we will attempt to summarize and describe the current research on social facilitation in virtual environments. Virtual environments, as Parsons (2015, p. 2) states, are the core element of the virtual reality methodology and are presented on both immersive (head-mounted displays) and non-immersive (2D computer screens) displays. Immersion is the state in which the subject finds himself to be in the environment and the ability to interact with the surroundings which provide a continuous stream of stimuli (Witmer & Singer, 1998). Computer-generated virtual environments (VE) were created in response to the demand of researchers who wanted to imitate different social situations, but lacked the resources to create a real, physical, synthetic environ-

ment (Blascovich et al., 2002). To avoid misunderstandings, we want to underline the fact that in the given paper only virtual (i.e., computer-generated) environments are used. Virtual (i.e., synthetic) environments, e.g., Milgram's (1963) experiments which utilized real, physical scenery that made participants perceive it as if it were real, are not considered here.

Research Questions, Aims and Motivation

The basic question that motivated us to write this paper was to see whether virtual observers can affect human behavior. To explore that, we decided to focus on one of the simplest forms of research based in the social influence paradigm: social facilitation. We aimed to describe, compare the research data and draw conclusions from it as well as review the methodological shortcomings of the analyzed studies.

Guerin (2010) pointed out that researchers working in the social facilitation paradigm in computers (which was before the popularization of VR technology) had not learnt from the original social facilitation research's mistakes. This is the case for part of the research discussed in the paper. We want to prevent further research from going in the same direction as previous studies by pointing out the research's inconclusiveness and shortcomings. We pointed out the faults, current results and underlined the difficulties that can be encountered by researchers dealing with the topic.

Method

The search was performed with the use of databases (Medlone, PsychInfo, PubMed, Academic Search Complete, ERIC, Google Scholar) with no date restrictions. The language was limited to English. We used the terms "virtual reality" and "virtual environment" in combination with "social facilitation", "social inhibition", "group facilitation", "audience influence", "social presence" and "social attention". Furthermore, to avoid publication bias, we tried to reach unpublished studies, which were related to the topic, via e-mails distributed among researchers who had already published research on social facilitation in VE. Unfortunately, no unpublished studies were found. Finally, only 13 experiments published in 10 papers were selected that compared the performance of humans who were alone to humans who were in the presence of virtual others in virtual environments. Subjects were regarded as "alone" if a researcher had labeled them as such, even if an experimenter had been present to observe their performance; subjects were considered to be "in the presence of virtual others" if they believed virtual characters could see them directly or indirectly or were present in the same virtual place, even if those others could not be seen. By "virtual others" we understood avatars (digital representations of other humans), agents (computer controlled characters) or non-person characters exist-

ing in virtual reality which were computer-generated, i.e., were created with design tools (software) and were not photos of real people simply transferred to the VE.

After the initial search, one hundred and three articles were chosen of which seventy-eight were excluded at the screening stage (after abstract and title analysis), because of the lack of an observer, lack of intergroup observer manipulation, lack of utilization of VR methodology (usage of either 2D or 3D display), being a technology test rather than a scientific experiment (testing VR technology against standard procedure, e.g., Babu, Suma, Hodges, & Barnes, 2011), not focusing on the influence of the virtual others, lack of empirical content or different (different than simply observing, e.g., teaching, Babu, Suma, Barnes, & Hodges, 2007) role of the virtual other. Afterwards, we performed an assessment for eligibility of full-text articles. Out of twenty-five papers that remained in our interest, three were excluded because of the lack of the "alone" condition (e.g., Anderson-Hanley, Snyder, Nimon, & Arciero, 2011). Another five did not meet the requirement of a clear performance measurement, meaning that there were no scores that we could assess in terms of clear improvement or impairment (e.g., Kappen et al., 2014 or a second study described by Hall & Henningsen, 2008). Furthermore, five articles were not analyzed, because of the observer criterion, i.e., it needs to be a computer-generated character. Therefore, in the analysis there are no studies that utilized a physically present robot (Riether, Hegel, Wrede, & Horstmann, 2012), a real person (e.g., Corston & Colman, 1996), recordings and photographs of real humans transferred to the virtual environment (Zając & Wojciszke, 2016) or simple text commands (Hayashi, 2015). Additionally, one paper was excluded because it lacked empirical content (Baylor, 2009) and another one was excluded because it reported a study already included in the analysis (Park, 2009). See Figure 1 and supplementary files for further details. It may seem that Virtual Environment research is widespread, but the majority of the texts that we found tested the performance achieved with a particular VR-based technology (e.g., Herrera et al., 2008; McArdle, Monahan, & Bertolotto, 2006) without comparing it to the control group, so one could state that these scientists were testing the VE as a tool (and at the same time an independent variable) not as an environment in which another independent variable (in our case, the presence of the observer) was tested. This may be a result of VE being relatively new. Every state-of-the-art technology needs to be thoroughly verified before being implemented in the research. We decided to use the aforementioned criteria: lack of an observer, lack of intergroup observer manipulation or lack of utilization of VR methodology (usage of either 2D or 3D display), because they enabled the inclusion of studies that tested the observer's impact on performance of the subject only and used the VE rather as an environment.

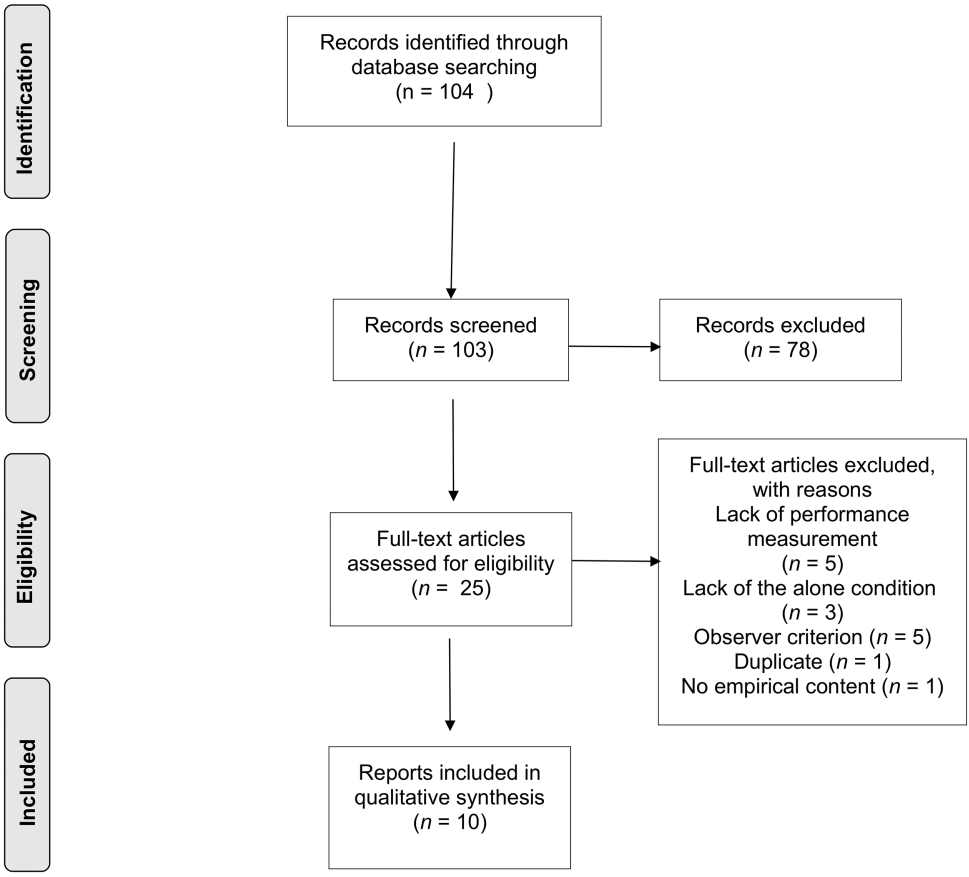

Figure 1. PRISMA 2009 flow diagram showing the selection process of relevant literature.

Results

Social Facilitation Effect

We found that only one (Park & Catrambone, 2007) out of thirteen studies was able to show the whole social facilitation effect. The authors used a series of high-level cognitive tasks frequently used in the non-virtual facilitation research, such as mazes, anagrams and modular arithmetic tasks. The observer in the study was a computer-generated character (only a head was displayed), displayed on the monitor next to the subject. The character had expressed subtle human-like behavior (breathing, blinking, etc.). The participants were told that it was an artificial intelligence (i.e., the researchers clearly suggested that the observer was an agent) that would analyze the tasks displayed on the computer screen and was not there to evaluate the performance or observe the participant. Subjects

in the virtual human condition spent more time on the completion of a complex version of the task, and less time on a simple version of the task, compared to the alone condition.

When it comes to inhibition, four out of thirteen studies suggest its existence. The oldest (Hoyt, Blascovich, & Swinth, 2003) consisted of two stages. In the first part, subjects were to master one of two (randomly assigned) recognition and categorization tasks which was followed by either completion of the same task (simple condition) or a different one (complex condition). Additionally, the authors of the experiment manipulated the perceived agency ("degree to which users believe they are in an environment with other veritable humans", Hoyt et al., 2003, p. 184) by using agents or avatars as observers. The observers were the same computer-generated characters displayed in HMD (Head-Mounted Device) in both audience conditions. There were two characters, one male and one female, which were realistically sized and displayed behavior characteristic of humans, such as blinking and small head movements. In the agent condition, the experimenter stated that the observers were fully computer-controlled and in the avatar condition the experimenter's assistants entered the room, put on the goggles (HMD) and informed the participant that they were going to join him in the virtual world as the virtual characters. The analysis showed that in the complex condition an avatar was able to produce a social inhibition effect when compared to the group that performed the task alone (and the group observed by the agent). In another study the display of the observer was manipulated (Zanbaka, Ulinski, Goolkasian, & Hodges, 2007). Eighty-five students were to assess the correctness of the math equations in the presence of a projected virtual human, a virtual human in HMD, a real person or alone. The virtual human was a woman who randomly generated behaviors like yawning, coughing or looking around. The participants assigned to one of the virtual human conditions were told that they would be observed by a computer-controlled (i.e., agent) virtual observer. The analysis of the data showed that the type of audience had no impact and all of the conditions where the observers were in some way present were able to produce a social inhibition effect in complex tasks when compared to the alone condition. Another attempt worth describing was the experiment conducted by Emmerich and Masuch (2016) in which the subjects were to play a spaceshooter game in the presence of a virtual observer (a robot displayed in the cockpit of a spaceship) or alone. Additionally, the display device varied between the conditions so the task could be completed on the ordinary monitor or HMD. Interestingly, the researchers stated that they wanted to achieve a 'mere presence' of the observer, but at the same time they implemented voice commands that were said by the robot, e.g., after the asteroid crashed or a mistake was made by the subject. Therefore, we disagree that this experiment utilized the mere presence of the observer. The participants were not told about the true nature of the observer (i.e., whether it was an agent or the avatar). The analyses revealed an inhibition effect, but only in the conditions where the participants were wearing goggles. The last of the studies describing social inhibition was that con-

ducted by Hall and Henningsen (2008). The subjects were to complete the typing task in either the presence of an animated computer icon or without it. The subjects were not told about the observer, i.e., they simply performed a task either in the presence of the icon or without it, without receiving any information about its nature (i.e., whether it was an avatar or an agent). The complexity was manipulated using real words (simple condition) and not existing ones (complex condition).

When discussing the opposite side of the effect (facilitation) the first experiment that should be mentioned is the one ran by Murray, Neumann, Moffitt, and Thomas (2016). Sixty females completed a rowing exercise in virtual reality alone, in virtual reality with an avatar companion or alone without any computer device. Interestingly, the authors led participants to believe that they were rowing with a real person via an internet connection, not only by stating that the rowers were real, but also by asking the participants to call the "team-mate" and ask him for some simple characteristics, e.g., age or gender. The observer, referred to by the authors as a "team-mate" could not be classified as a mere presence observer, because there was a co-action with the participant (for a comparison, see Table 1). The rower was paddling at approximately the same pace as the subject so we cannot exclude a possible evaluation apprehension in that case. The authors concluded that both groups that completed the task in VE outperformed the group that did not use any virtual display. Furthermore, the results show that participants who rowed in presence of the avatar reached further distances and put more effort into the task compared to those who performed it in VE alone. Another study (Khaghani Far et al., 2015) that presented results that may suggest the existence of a social facilitation effect utilized a mobile application. Thirty-seven adults were divided into two groups that were asked to use the exercise mobile app, which differed in terms of the presence of social functionalities depending on the randomly assigned condition. The participants were told that the companions were real people (i.e., avatars). The participants could interact with the companions (e.g., send them messages) so this study fails to fit Zajonc's (1965) mere presence criterion. The performance was measured by counting the number of training sessions in which the subject participated. The outcomes of the study show that the participants who worked out with social features outperformed those who worked out without those functionalities. The last two studies conducted by Pan and Hamilton (2015) aimed to test the congruency effect in combination with the influence of the virtual character. In the second experiment the authors tested the anatomical congruency effect (agent used the same arm movements as the participant) and utilized a 2x2 experimental design. Subjects were to hit the drums in a presented order, which was congruent or incongruent with the actions of either virtual character or 3D balls hitting the drums on the screen. The companion completed a similar task to the one that the subject completed, so in this case it was not a mere presence, but rather a coaction of the observer and the participant. The researchers refer to the virtual observer as an avatar, but at the same time they do not state whether participants were told that it was a human-controlled vir-

tual character or simply that it was a human-controlled virtual character (for comparison with other studies, see Table 1). The authors do not describe the nature of the observer. The results of Study 2 revealed a social facilitation effect – participants were faster with a virtual character than with the balls.

The research described above suggests the possibility of invoking a social facilitation effect in virtual environments by actors rendered by a computer in real time but the gathered data is far from conclusive. Eight of thirteen studies reported results suggesting a social facilitation effect, but it is intriguing that only one of them reported a full effect of social facilitation (in the face of a simple task) and inhibition (in the face of a difficult task). Imperfections in the designs of certain studies, which made it impossible to observe the effect in its entirety, are a possible reason. On the other hand, there were studies precisely designed to demonstrate the entire effect (e.g., Hall & Henningsen, 2008), which also failed.

The second finding regards differences in the understanding of "mere presence" between competing theories. We carefully inspected the nature of presence manipulation in order to contribute to the debate between these two understandings. As a result we found six of ten studies that matched a broad understanding of 'mere presence' that demonstrated the effect. Only one study (Murray et al., 2016) matching a narrow operationalisation of 'mere presence', albeit with a design that evoked rivalry, confirmed the facilitation effect. Additionally, some other studies (e.g., Baldwin, Branyon, Sethumadhavan, & Pak, 2015, pp. 1-3) were designed in order to exclude evaluation apprehension by direct information that stated the observer was not interested in the actor's performance. Nonetheless, the observer was focused on an actor and we found this manipulation questionable. This series of studies failed to demonstrate the facilitation effect. In the face of the scarcity of the results we find it impossible to determine whether narrowly understood mere presence (without evaluation apprehension) is also able to evoke the effect of social facilitation in the case of virtual environments.

What has to be underlined is that the aforementioned studies are the only ones in which any effect was found, while the rest failed to show it (Baldwin et al., 2015; Hayes, Ulinski, & Hodges, 2010; Pan & Hamilton, 2015). We think that such inconclusiveness and contradiction may be the result of some methodological shortcomings, which will be described below. We decided to focus on the problems specific for virtual environments only acknowledging major obstacles that have already been discussed in the former non-VR literature (e.g., Bond & Titus, 1983).

Table 1

Information About the Results, Shortcomings, Nature of the Observer and Mere Presence Operationalization of the Discussed Studies

Authors (Study)	Date	Effect	Shortcomings	MP (broad)	MP (narrow)	True nature	Info
Baldwin et al. (1)	2015	none	c	yes	no	agent	agent
Baldwin et al. (2)	2015	none	c	yes	no	agent	agent
Baldwin et al. (3)	2015	none	c	yes	no	agent	agent
Khaghani Far et al.	2015	facilitation	c, d	yes	no	avatar	avatar
Hayes et al.	2010	none	b, c	yes	no	agent	none
Murray et al.	2016	facilitation	a, b, c, d	no	yes	agent	avatar
Hoyt et al.	2003	inhibition	a, c, d	yes	no	agent	both[b]
Zanbaka et al.	2007	inhibition	c	yes	no	agent	agent
Emmerich & Masuch	2016	inhibition	c, d	yes	no	agent	none
Park & Catrambone	2007	whole effect	a, c	yes	no	agent	agent
Hall & Henningsen (1)[a]	2008	inhibition	b, c	yes	no	agent	none
Pan & Hamilton (1)	2015	none	a, b, c, d	no	no	agent	none
Pan & Hamilton (2)	2015	facilitation	a, b, c, d	no	no	agent	none

Note. Texts that consisted of reports from more than one study were listed separately for every experiment. The following shortcuts were used: a - presence of the researcher, b - unclear usage of "agent" and "avatar" c - no pilot tests, d - activating evaluation. "MP (broad)" column refers to whether the second person was performing a similar task or served as an observer (discussed in Zajonc, 1965), "yes" indicates that the virtual character served only as an observer, "no" indicates that the virtual character performed a similar task. "MP (narrow)" column refers to whether the study design (i.e., observer's behavior, position) could be interpreted by the subject as evaluative (criterion in Cottrell et al., 1968). Column "true nature" describes the true nature of the observer, i.e., whether it was controlled by a real human in real time or by a computer algorithm. Column "info" presents what the participants believed was the nature of the observer.
[a]The article contains two study reports, but one of them was excluded because of the lack of performance measurement. [b]The study incorporated two conditions. One in which participants were led to believe that the observer was an avatar and one in which they were led to believe that it was an agent.

Effect Sizes

Since mere statistical significance may be insufficient to assess the meaning of the results, we decided to analyze the studies in terms of effect sizes. Firstly, we summarized effect sizes (Part 1 of the description, Supplementary File 3) and then conducted a meta-analysis (Part 2 of the description, Supplementary File 3). The calculations revealed that the average effect size for social facilitation is $g = 0.18$ and for social inhibition is $g = 0.18$, both of which can be classified as small. These results need to be taken with a grain of salt, because of the significant level of heterogeneity detected and the small number of studies.

Discussion

Methodological Shortcomings

Presence of the Researcher

One of the major problems with experimental design in research on facilitation is that the researcher is often present in the room where the task is performed (Markus, 1978). In four of the reports no information can be found regarding whether the experimenter was present or not. As emphasized by the authors (Zanbaka et al., 2007), such a practice makes the results uninterpretable, because the presence of a researcher can induce social facilitation. When considering this we have to remember that the visibility of the observer is not necessary to elicit the effect (Bond & Titus, 1983). Therefore it cannot be said whether in each particular study the effect was triggered by avatars appearing after entering the virtual world or by people being physically present next to the participant in the real world.

Unclear Usage of "Agent" and "Avatar"

Another problem associated with the described research is that the authors of the publications use the terms avatar and agent either imprecisely, interchangeably or they do not use it at all. In seven papers discussed in this article, the term "agent" or "avatar" was used and in only three of them were they in line with a differentiating definition proposed by Hoyt et al. (2003, p. 185): "we use the term avatar to describe a graphical character that is controlled by a human being in real time. We use the term agent to refer to a graphical character that is controlled by a computer program or artificial intelligence algorithm". Despite the fact that no guidelines have been created that put on the authors a demand to use the terms as given by the researchers (Hoyt et al., 2003), we believe that accepting this kind of differentiation would make the characteristics of the observer in a given study clear to the reader. Clear application of the aforementioned terms allows researchers to differentiate experiments in which the effect is caused by contact with a bot (agent) from those in which the effects are caused by contact with another person through new technologies (avatar). This is especially important when we want to purely test the effect of virtual characters on human behavior and not people who are using avatars as the medium of influence. Of course, we have to bear in mind that the true nature of the observer can be extracted from the description of the procedure indirectly, but we think that using the terms explicitly would enhance further development of the field.

No Pilot Tests of Observers and No Description of How Their Characteristics Are Generated

As noted by the researchers (Emmerich & Masuch, 2016), one of the problems associated with virtual observers is that their characteristics are not tested in pilot studies, and instead they are directly implemented for research. Often there is also no information

about how the character was constructed, as well as how its realism was operationalized. As research (Bystrom, Barfield, & Hendrix, 1999) suggests, the level of realism can be significantly related to the subject's performance, which means that it could have an impact on the results of the studies conducted in this paradigm. In the discussed studies, there was no detailed description of how virtual characters were generated, and there were no pilot studies to check the characteristics of virtual observers. What can be found is a description of what features have been added to the computer generated witnesses. This state of affairs leads to a situation in which each time we talk about the impact of bots we discuss completely different levels of realism, and therefore also a completely different ability to influence the task performance of the subject (Bystrom et al., 1999). It is clearly impossible to implement a common standard of computer actors for all of the studies, but perhaps some common tool could be utilized in order to make actors' realism level comparable between studies - such attempts have been recently made (e.g., Co-Presence and Social Presence Scale, Poeschl & Doering, 2015).

Evaluation Activation

Another shortcoming of the analyzed studies is unintentional direct evaluation embedded in the experimental design. One of the most straightforward examples is the study of Emmerich and Masuch (2016) in which the authors implemented a robot that, after each hit of an asteroid, reminded the user that they had made a mistake. It is worth noting that when we directly inform or indicate a subject's failure, the test ceases to be a mere social facilitation study and becomes a feedback test. In six of the studies discussed in the article, we can talk about the evaluation directly. In addition, research by Rickenberg and Reeves (2000) showed that an icon that closely monitored the process of completing the task, led to a reduction in performance compared to a control group. The icon responded to the moments when the subject approached points that were critical for completion of the task. It may be tempting in the context of virtual environments to include elements of interaction between the user and virtual agents for many reasons (e.g., for maximizing a user's commitment), but it should be carefully considered during study preparation.

Other Problems

In this section we decided to list some of the shortcomings that are not unique for virtual environment-based research but may have an impact on the results. The first obstacle from this group is based on the fact that the researchers tend to ignore the basic definition of social facilitation, which consists of facilitation and inhibition that is dependent on the difficulty level of the task. In some of the studies (Khaghani Far et al., 2015; Murray et al., 2016) taken into account in this article, the tasks were not divided into simple and complex conditions. When the task difficulty is not separated into conditions, it is not possible to make any predictions about whether the effect of facilitation or the effect of inhibition in a particular experimental condition should be expected. The second

problem that belongs to this nonspecific group was clearly noted by Park and Catrambone (2007) who stated that researchers do not directly describe why and whether the given task is a simple or complex one, which is caused by the fact that many authors do not have any a priori assumptions about the structure and the difficulty of the task. This state of affairs may lead to matching hypotheses and division of groups into data.

Conclusions

Social facilitation in the Virtual Environment seems to be a complex and difficult field to explore. Only in one of the studies was the whole effect, i.e., both facilitation and inhibition, shown. In four experiments only the social inhibition effect was observed. When it comes to the social facilitation effect it was shown three times, however in two of the studies the authors did not manipulate the complexity of the task. In summary, there were only 8 out of 13 experiments that showed any part of the effect. In our opinion such results are the effect of the interference of the obstacles discussed in this article, which are: lack of pre-testing of the tasks, the characteristics of observers, lack of a priori definition or measuring only one aspect of the effect, the use of feedback or direct evaluation and the lack of precision in determining the character of the bot. Another issue is that the role of the observer can be classified in a variety of ways. Only one study matched the "narrow" definition of mere presence and ten of them complied with the "broad" one. This kind of discrepancy in the post hoc evaluations highlights the inconsistency in the observer manipulation in the research. Our main intention was to find an answer to the question of whether social facilitation/inhibition may exist in VE. Because of the current state of the research we failed to discover whether the effect exists or not, but at the same time we tried our best to summarize the research, point out the shortcomings and in that sense influence the future direction of the field.

Practical Implications for Future Research

Two important research directions should be underlined. Firstly, current research is not sufficiently focused on resolving the theoretical dispute over the role of evaluation apprehension in producing the facilitation effect. More studies designed in order to evoke the impression of being in someone else's (avatar/agent) presence while excluding the potentiality of being evaluated are needed. Secondly, there is a shortage of studies utilizing the possibility of manipulating the true nature of the observer – the majority of studies use a computer agent. It appears interesting to test whether the presence of a real person represented by an avatar (in contrast to an agent that is labelled as an avatar) could affect the results – it becomes more important with the development of VR software allowing the simultaneous presence of several people (e.g., fire-fighter team training). We think that, when planning an experiment, researchers interested in this subject should above all clearly state what kind of understanding of facilitation is being used. The requirement

for researchers should also create an a priori definition of complex and simple tasks, so that research does not become an untestable tautology (Bond & Titus, 1983). What is also worth bearing in mind is the need to test the whole effect, i.e., both facilitation and inhibition. Such uniformity would significantly facilitate comparisons between studies. In addition, main studies should be preceded by pilot studies of both tasks and characteristics of observers, and if this is not possible (e.g., due to time or financial constraints), researchers should describe the entire character generation process, use models tested in previous studies or measure the level of realism with specific tools. Furthermore, we recommend keeping the researcher out of the experimental room during task completion. If this is not possible, it is suggested that the authors should state this fact directly in the paper. It is also important to maintain precision and consistency in defining the avatar or agent bots and it is suggested to use the distinction presented by Hoyt et al. (2003). We also propose to limit the AI evaluation to the lowest level. This is necessary because of possible interference caused by additional feedback or direct evaluation.

The presented article is the first summary of a fairly young field of research, that is, social facilitation in virtual reality. The critical approach towards studies is the strength of this review. At the same time we not only critically summarized the present research, but also proposed specific solutions that might be implemented in the future. Our article is an innovative and helpful tool that can potentially lead to a definite answer to the question about the real size of the effect of social facilitation in virtual reality.

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Data Availability: Datasets for the studies are freely available (see the Supplementary Materials section).

Supplementary Materials

The following Supplementary Materials are available via the PsychArchives repository (for access see Index of Supplementary Materials below):

- Supplementary File 1 contains the list of all publications gathered in the search process (n = 103) with papers that were qualified for the full-text analysis (n = 25).
- Supplementary File 2 contains all the data used for a summary of the effect sizes.
- Supplementary File 3 contains: description of the mini meta-analysis, summary of the effect sizes, R code for the analysis and data files used in the analysis.

Index of Supplementary Materials

Sterna, R., Strojny, P., & Rębilas, K. (2019). *Supplementary materials to "Can virtual observers affect our behavior? Social facilitation in virtual environments: A mini-review"*. PsychOpen. https://doi.org/10.23668/psycharchives.2628

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Note. References marked with an asterisk indicate studies included in the meta-analysis.

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