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Virtual social support buffers stress response: An experimental comparison of real-life and virtual support prior to a social stressor

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ABSTRACT

Background and objectives: Face-to-face and text-based social support have been shown to attenuate stress responses in past studies. Yet as social interactions increasingly take place online by means of virtual humans, our objective was to examine whether different forms of social support (virtual vs. real) prior to the Trier Social Stress Test (TSST) would also decrease stress. Additionally, the effect on subsequent real-life social behaviors (helping and approach) was evaluated while controlling for affective states and social presence.

Methods: 56 participants were either supported by an avatar, an agent, a real human or received no support before completing the TSST and two subsequent social behavior tasks (pen task and seating task).

Results: Results show no difference in agency regarding social presence. Yet, participants with agent support and no support had significantly higher heart rates during the TSST and reported to be more worried. Also, they were more irritated and showed significantly slower helping reactions (picking up pens).

Limitations: A limitation to this study is that only emotional verbal and non-verbal support were provided by a stranger. Different forms of support as well as a different source (i.e., a friend) may have a more pronounced effect on stress buffering.

Conclusions: Virtual social support is as effective as face-to-face support in terms of stress buffering, as long as the recipient has the impression that it is provided by another human (via an avatar). This has wide ranging implications not only for health-related application in prevention and treatment but also for further research.

1. Introduction

In light of its negative impact on a multiplicity of health factors including anxiety disorders, depression and obsessive compulsive disorders (Chrousos, 2009; Dishman et al., 2009) as well as somatic illnesses like cardiovascular diseases, obesity and immune dysfunction (Glaser & Kiecolt-Glaser, 2005; Kemp, Quintana, Felmingham, Matthews, & Jelinek, 2012), social stress has become a key subject in health related research. In general, two types of social stressors are distinguished in literature: interpersonal stressors and social-evaluative threats (Dickerson & Kemeny, 2004). While the first one comprises different forms of social rejection or ostracism (i.e., being excluded or ignored), the latter describes experiences frequently made in performance or vocational contexts where one may be potentially exposed to negative evaluations by peers (e.g., during an oral presentation). Past studies (e.g., Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004) have shown that the stress response especially to social evaluative stressors is large, particularly if they are perceived as out of one's control (see also Rosenbaum et al., 2018 for a successful induction of rumination).

Apart from its negative influence on mental and physical health (Pearlin, 1999), social stress has also been reported to have a profound

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impact on social behaviors (von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs, 2012). Social behaviors cover a variety of actions such as avoidance and approach tendencies (e.g., proxemics) as well as prosocial behaviors (e.g., helping; Batson & Powell, 2003). In stressful situations, social behaviors are thought to be shaped by one of two evolutionary mechanisms, the fight-or-flight response or the tend-and-befriend strategy (Taylor et al., 2000). While the former is related to avoidance and approach tendencies and is, thus, characterized by an increase in aggressive or anxious behavior (Steinbeis, Engert, Linz, & Singer, 2015), the latter includes affiliative actions like helping and cooperating.

Previous data suggests that humans are likely to befriend others and intensify their prosocial behaviors when exposed to social stress (Carter-Sowell, Chen, & Williams, 2008; von Dawans et al., 2012). This increased social affiliation may be interpreted as an attempt to reconnect with a group or to achieve mutual protection. However, empirical evidence is still far from conclusive: In contrast to the reported increase in affiliative behaviors, some researchers (Twenge & Baumeister, 2005; Twenge, Baumeister, DeWall, Ciarocco, & Bartels, 2007) have also found significant reductions in prosocial tendencies following stress. Thus, other than attempting to achieve improved group protection, reducing affiliative behaviors may also serve as a means to regain control and recognition as an individual.

Apart from the need for further debunk the impact of social stress on social behaviors, the question of whether there are protective factors which may possibly buffer stress reactions is of paramount interest, especially when considering prevention and treatment of stress related disorders. Here, social integration and social support have been suggested to have particularly beneficial consequences both in acutely stressful situations and in the long term (Ditzen & Heinrichs, 2014).

1.1. Social support and stress

Social support constitutes a multifaceted concept, which is conceptually defined along the lines of whether support is received or perceived (Ditzen & Heinrichs, 2014). While received support involves an evident act of assistance, perceived support refers to the expectation of getting help. As this expectation remains largely stable over time, perceived social support has been considered a trait (Sarason, Sarason, & Shearin, 1986). Furthermore, different types of support are distinguished, i.e., whether it is instrumental (practical guidance) or emotional (verbal encouragement) (Ditzen & Heinrichs, 2014). Current studies suggest that – in contrast to social isolation which is regarded a risk factor – social support may act as a protective factor regarding the development of mental disorders such as depression, anxiety disorders and suicidal ideation (e.g., Dworkin, Ullman, Stappenbeck, Brill, & Kaysen, 2018; Fredrick, Demaray, Malecki, & Dorio, 2018). Similarly, novel data shows that social support is negatively associated with post-traumatic cognitions and the occurrence of post-traumatic stress disorder (PTSD) symptoms (Woodward et al., 2015).

In the related literature, two models have emerged which describe the effects of social support on health outcomes. According to the *Buffering Model*, social support constitutes a stress buffer as negative effects of stress are expected to be reduced if the provided supportive resources are "responsive to the needs elicited by stressful events" (Cohen & Wills, 1985, p. 310). Hence, social support is expected to protect the individual against the detrimental consequences of stress over time. Another approach is the so-called *Main Effects Model*, which, in contrast to the buffering hypothesis, states that social support exerts a direct positive influence on health factors irrespective of the existence of stressors (Ditzen & Heinrichs, 2014). Past data is generally in favor of the buffering hypothesis: In previous experimental studies, receiving social support (e.g., from a friend or a stranger) prior to being exposed to an acute social-evaluative stressor (i.e., the Trier Social Stress Test, TSST; Kirschbaum, Pirke, & Hellhammer, 1993) led to attenuated physiological stress reactivity (cortisol response and cardiovascular activity) as well as to a reduction of self-reported anxiety (Ditzen et al., 2008; Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003).

Traditionally, experimentally manipulated social support has been provided via text-based messages or face-to-face by either a known person or a stranger. Yet, in light of increasing online social interactions via social networks (e.g., Facebook), social online games (e.g., Massively Multiplayer Online Role Playing Games, MMORPGs) or in the context of treatment and therapy (c.f., Gorini, Gaggioli, Vigna, & Riva, 2008), digital social support in the form of virtual humans gains even more significance. Accordingly, studies show that most people play MMORPGs for social reasons (Yee, 2006) and results suggest beneficial effects of online social support on depressive symptoms (Dupuis & Ramsey, 2011) and well-being (Indian & Grieve, 2014).

1.2. Avatar and agent based social support

Specific to online social interaction is the fact that – known or unbeknownst to the user – virtual interaction partners may be controlled by a friend, a stranger or even a computer (Kothgassner et al., 2017). Generally, two types of virtual humans are distinguished in terms of their agency, that is whether the user has the impression that s/he is interacting with a computer controlled entity (an agent) or a human controlled virtual other (an avatar). Hence, in this context, the construct of agency incorporates a person's perception or belief that a virtual human is steered either by another person or by a computer algorithm (Bailenson, Blascovich, Beall, & Loomis, 2003).

Prior studies report positive effects of mainly text based computer-mediated support (e.g., chat groups) on well-being and mental health (c.f., Wright & Bell, 2003); however, current online communication gradually incorporates more natural interactions involving virtual representations of humans (i.e., avatars and agents). Similarly, in therapeutic applications, virtual humans are increasingly used for treatment purposes (i.e., in social anxiety disorders; Kampmann et al., 2016; or PTSD, Kuhn et al., 2014) or as a (temporary) supplement for the therapist for in-between session communication (c.f., Kothgassner, Utermöhlen, & Felnhofer, 2017). In light of the improved availability of sensory information (e.g., non-verbal cues, voice modulation), interacting with a virtual other is not comparable to merely text based communication. A virtual human's behavioral realism (i.e., the extent to which virtual humans behave in the virtual environment as they would in a comparable real-life setting) may influence how virtual others are perceived and reacted to by the user (Blascovich, 2002). Thus, a hitherto unresolved research issue lies in the question whether agents have the same effect on a user as avatars (von der Pütten, Krämer, Gratch, & Kang, 2010). The answer to this question may have wide-ranging implications for programmers, practitioners and researchers, as the use of pre-programmed agents is inherently more cost-effective, more controllable and easier to implement than avatar interaction.

To date, however, data is still inconclusive and two opposing models exist. Studies supporting the *Threshold Model of Social Influence* (Blascovich, 2002) show that computer-controlled agents – in stark contrast to avatars – only prompt social reactions when their behavioral realism is high (e.g., Guadagno, Blascovich, Bailenson, & Mccall, 2007). The *Media Equation Concept* (Nass & Moon, 2000), in turn, has received empirical sustenance for its assumption that users are evolutionarily prepared to react socially to all virtual humans, irrespective of their agency (e.g., Kothgassner et al., 2014; von der Pütten et al., 2010). Hence, this model suggests that both avatars and agents evoke the same user experience in virtual social interactions. One of the main indicators for a virtual social experience is the so-called social presence. It describes the immediate experience of sharing a space with another being (co-presence) as well as the impression that this being is sentient, conscious and alive (Biocca, 1997).

Recent research (Felnhofer et al., 2018; Kothgassner et al., 2017) further differentiates these theoretical assumptions by showing that while immediate and basic social responses to virtual entities are the

Fig. 1. The virtual character providing social support in the TSST-preparation phase.

same for avatars and agents, temporally delayed and higher order reactions seem to depend on agency. Accordingly, these studies found no differences between avatars and agents in social presence experiences, yet, temporally delayed and more complex social behaviors (help and avoidance, both in-game and real-life) were influenced by agency: For instance, those participants who had an unpleasant encounter with a human controlled avatar showed more avoidance towards that avatar and were less helpful in following interactions than those who interacted with a computer agent. The authors argue that this differential effect of agency may be due to interfering cognitive appraisal processes (i.e., the usage of scripts, labels, expectations) which – in the case of agent interaction – lead the user to downplay the significance of an unpleasant encounters by attributing it simply to a computer algorithm or even a program error (Felnhofer et al., 2018; Kothgassner et al., 2017).

However, in these experiments, social behaviors were either studied by means of a neutral virtual interaction (Felnhofer et al., 2018) or based on stressful virtual ostracism experiences (Kothgassner et al., 2017). No research has, to our knowledge, examined these factors in the context of a virtual social support scenario.

1.3. Objective

In sum, comprehensive studies on potential short-term and long-term stress-buffering effects of social support are still missing, especially with regards to a novel channel of support: virtual reality. The increasing use of virtual humans as sources of support (in therapy settings, in games etc.) necessitates a closer examination of the possibly differential effect of computer controlled algorithms (agents) and human controlled entities (avatars) on users' social responses. Thus, this study's main objective was to assess whether social support provided prior to a real-life social evaluative stressor (TSST) would attenuate the immediate physiological and subjective stress response and whether there would be differences with regards to the source of support (avatar vs. agent vs. face-to-face). Additionally, the effect of social support on subsequent real-life social behaviors (helping and social distance) was evaluated while controlling for affective states, social presence and trait social support.

2. Methods

The experiment was conducted in line with the Declaration of Helsinki. Thus, all subjects signed a written consent form prior to their participation and were shortly debriefed after the conclusion of the study.

2.1. Participants

An ad-hoc sample of 56 students (54% female) was recruited for the experiment. Power analysis with g*power (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that a sample of 52 persons was needed to detect medium effect sizes (par.$\eta^2 = 0.06$) with 80% power and a 5% probability for type I error. Upon arrival to the VR-lab, participants were randomly assigned to the following four conditions with $n = 14$ participants each: (1) real social support, (2) avatar social support, (3) agent social support and (4) no social support. Age ($M = 24.36$, $SD = 3.440$) and gender were counterbalanced over the conditions (*ps* = .164 and .697 respectively). The four conditions did not differ regarding Internet usage, experience with computer games or daily computer screen time (all *ps* ranging from 0.432 to 0.939).

2.2. The virtual environment

The virtual environment consisted of an empty waiting room with a number of chairs arranged alongside the walls. The three-dimensional objects were modeled after a real-life waiting room which was also used in this study for condition 1 (real social support). Objects were generated with Blender 3D, real-time rendering was achieved with OGRE 3D and textures were modeled with GIMP. The female and male virtual characters were randomly used in this experiment and were controlled by an experimenter blinded to the condition who chose from pre-programmed verbal statements (for more details see Procedure). Throughout the virtual interaction, participants were seated on a chair facing the entrance (see Fig. 1). Subjects could not leave the chair, but they were able to move their heads and view the entire room. Apart from the sound of an opening door, the room was completely quiet.

2.3. Procedure

Participants were randomly assigned to one of the four conditions which were distinguished by whether the support was provided by a (1) real person (a confederate actor), (2) an agent, (3) an avatar or whether there was (4) no support at all. In conditions 2 and 3 both virtual humans constituted computer algorithms with pre-programmed answers (see below). However, to be able to test for effects of agency on stress, perceived support and subsequent social behaviors, participants in the avatar group were experimentally manipulated by a non-blinded experimenter to believe that they would be interacting with another human (i.e., that the avatar they met in the virtual environment was steered by a factual person); while participants in the agent conditions were instructed that the virtual human was merely a computer program. The confederate actor's gender and the virtual humans' gender were randomly assigned to each participant and equally balanced over the four conditions according to participants' sex. After signing the consent form, participants were provided with the first set of questionnaires and baseline heart rate (HR) measurements were obtained (see Measures).

Subjects were informed that they would take part in a job interview

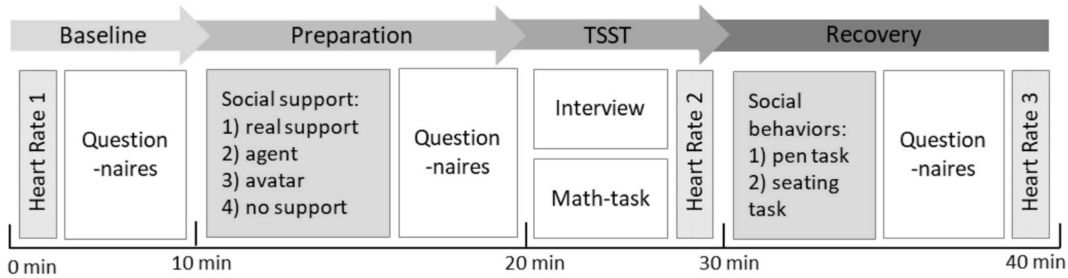

Fig. 2. Experimental procedure.

and were asked to first prepare themselves for the interview in a waiting room (condition 1: real room, conditions 2–4: virtual room). In conditions 2–4, a head mounted display (HMD, Sony HMZ-T1 3D Visor, Tokyo, Japan) with an externally attached head tracking system (TrackIR 5, NaturalPoint, Corvallis, USA) was donned and subjects were asked to speak out loud when verbally interacting with the virtual other.

Overall, the preparation phase lasted 5 min (see Fig. 2). While participants in condition 4 (no support) sat alone in the virtual environment, in conditions 1–3, a person entered the waiting room after approx. 30 s and took a seat next to the participant. Both the confederate actor (condition 1: real support) and the virtual characters (conditions 2: agent and condition 3: avatar) provided the participants with standardized verbal emotional support and non-verbal supportive gestures. Verbal support provided by both virtual humans (avatar and agent) as well as the confederate actor comprised a set of four standardized statements which – in the case of virtual interactions – were initiated by the blinded experimenter by pressing a key ("No need to be nervous, you are doing fine", "Chin up, you can definitely do that", "Take your time! You are doing great", "Don't worry this can happen to anybody"). The support provider made the first supportive statement approx. 20 s after the start of the preparation phase. Non-verbal support, which was also provided by all supporters in a comparable manner, included nodding, smiling, and patting on the shoulder (2 times during the interaction). In case participants tried to strike up a conversation, the confederate actor and the virtual humans encouraged them to keep preparing the interview. The confederate actor was trained to adhere to the standardized protocol as closely as possible; apart from running the simulation with the actor as a participant, the confederate also completed two test runs with a project's associate to ensure standardization.

Following the preparation phase, participants answered another set of questionnaires, and HR measurements were taken. Subsequently, subjects were led to another room, where two confederate actors (male and female) conducted the TSST. The TSST constitutes a social evaluative threat which is highly valid in inducing significant stress levels via the mechanisms of perceived uncontrollability and lack of predictability (Kudielka et al., 2004). According to the traditional TSST-protocol (for a detailed description see: Kirschbaum et al., 1993), participants mastered a 5-min job interview which required them to argue why they thought they were the best candidate for the job (participants were able to chose the type of job themselves). The interview was followed by a 5-min mental arithmetic task, which required participants to serially subtract 13 from 1022. Throughout the interaction, the actors maintained neutral facial expressions and only responded in line with the protocol (i.e., if the participant stopped talking, they encouraged him to keep going and if they made a mistake during the arithmetic task, they replied: "This is incorrect. Please start over from 1022.").

Immediately after the TSST, HR was measured and self-report questionnaires were provided. Also, pen tasks as well as a seating task were conducted to assess social behaviors (prosocial reaction and social distance; see Measures). A co-experimenter who was blinded to the condition measured both the time to pick up the pens and the seating distance. After a 5-min recovery phase, the last HR measurement was taken and participants were provided with the remaining questionnaires. Finally, participants were debriefed about the purpose of the study.

2.4. Measures

Aside from a demographic questionnaire, the following measures were applied in the current study:

Manipulation check. To see whether the agency manipulation was successful, we presented participants with a one-item manipulation check ("How did you perceive the interaction with the virtual character?"). This item was answered on a 5-point Likert scale (1: controlled by a computer, 5: controlled by an individual person).

Social support. The 14-item German *Social Support Questionnaire* (*Fragebogen zur sozialen Unterstützung,* F-SozU; Fydrich, Sommer, Tydecks, & Brähler, 2009) which is based on the Social Support Questionnaire by Sarason, Sarason, and Shearin (1987) was used at baseline to assess subjectively perceived levels of social support. Items were answered on a 5-point Likert scale and included questions regarding emotional support ("There are people, who share joy and sorrow with me"), practical support ("If I need, I can borrow something from friends or neighbors without problems") and social integration ("There is a group of people (friends, clique) that I belong to and meet frequently"). A cumulative value represented overall trait social support. Internal consistency (Cronbach's alpha) was good with $\alpha = 0.89$. After participants received social support (virtually or real-life), we added an additional self-created single item ("As how supportive did you perceive the other person?") on a 5-point-Likert scale (1: not supportive, 5: very supportive).

Social Presence. Participants' social presence was measured with the German version of the *Networked Minds Measure of Social Presence* (*NMMSP;* Biocca, Harms, & Gregg, 2001). The NMMSP assessed the following three dimensions (including subscales) of social presence on a 7-point Likert scale: (1) Co-Presence: Isolation and Mutual Awareness (e.g., "I often felt as if I was all alone."), (2) Psychological Involvement: Mutual Attention, Mutual Understanding and Empathy (e.g., "The other individual was influenced by my moods"), (3) Behavioral Engagement: Behavioral Interaction, Mutual Assistance and Dependent Action (e.g., "My partner did not help me very much"). Participants were provided with the *NMMSP* following the preparation phase. Internal consistencies were $\alpha = 0.64$ (Co-Presence), $\alpha = 0.71$ (Psychological Involvement), $\alpha = 0.72$ (Behavioral Engagement).

Physiological Stress. Heart Rate (HR) was measured at baseline, post TSST and after a short recovery phase using a wrist joint heart rate monitor (boso medistar + , Bosch & Sohn, Jungingen, Germany). A 60-s interval was used as reference to calculate average beats per minute (bpm).

Subjective Stress Measures. Virtual Analogue Scales (VAS, 0–100 mm, 0 = no at all, 100 = very much) were used to measure seven affective states: stress ("How stressed do you feel?"), exhaustion ("How exhausted do you feel?"), shame ("How ashamed do you feel?"), irritation ("How irritated do you feel?"), anger ("How angry do you

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feel?"), relaxation ("How relaxed do you feel?") and worry ("How worried do you feel?") at baseline, post social support (preparation phase), post TSST and after recovery.

Social Behaviors. Participants' social behaviors were triggered via two separate experimental manipulations. Prosocial responses were assessed using a pen task (c.f., Dovidio & Morris, 1975; Twenge et al., 2007): Here, the experimenter seemingly accidentally dropped a set of pens in close proximity to the seated participant. The time it took the participant to react to the mishap and pick up the first pen served as a measure for prosocial behavior. The faster the helping response, the more prosocial the reaction. Social distance, in turn, was assessed using a waiting room setup. The confederate actor was seated in the first chair in a row of four chairs (60 cm distance each). The participant was encouraged to sit down and fill out the remaining questionnaires. Before entering the waiting area, it was disclosed to participants in the real support condition and to participants in the avatar condition that the co-player (who had supposedly been steering the avatar) was present as well. The other two groups (agent and no support) served as control groups and did not receive any instruction prior to entering the room. The distance between the participant and confederate (number of chairs equal to distance in meters) served as an indicator of social distance (c.f., Kothgassner et al., 2017). All groups completed these tasks; the two conditions without prior contact to the confederate actor (no support, agent condition), thus, served as control groups.

3. Results

Data were analyzed using IBM SPSS version 20 (Inc. Chicago, USA). ANOVAs for repeated measures were computed to analyze HR, ratings of stress and affect between the four conditions. We computed ANOVAs to evaluate differences between groups in social presence and social support. All reported results were corrected by the Greenhouse–Geisser procedure when assumptions of sphericity were violated. Tukey's HSD post-hoc tests were conducted where appropriate to control for multiple testing.

Manipulation check. Our agency-manipulation was successful as there was a difference in the conditions ($t(26) = 8.75$, $p < .001$, $d = 3.297$) with participants the avatar group stating that they interacted more with another human being ($M = 4.64$, $SD = 0.497$) than participants in the agent group ($M = 2.36$, $SD = 0.842$).

Perceived Social Support. No difference in trait social support (F-SozU) was reported between conditions at the start of the experiment ($F(3, 52) = 1.40$, $p = .253$). As expected, perceived state social support after the preparation phase was rated higher in the avatar ($M = 2.57$, $SD = 0.852$) and real support ($M = 2.64$, $SD = 0.842$) than the agent ($M = 1.71$, $SD = 0.914$) group ($F(2, 41) = 4.94$, $p = .012$, par.$\eta^2 = 0.202$). Post-hoc tests revealed that both the avatar ($p = .034$, $d = 0.970$) and the real support group ($p = .020$, $d = 1.057$) differed significantly from the agent group. The gender of the avatar, agent or real person did not influence the perceived state social support ($t(39) = 0.23$, $p = .813$).

Social Presence. There were no differences between groups in any of the scales of the NMMSQ (see Table 1). A trend was found in Psychological Involvement and Empathy with higher means of the real support condition in those scales.

Subjective Stress Measures. The TSST successfully induced stress ($F(3, 156) = 11{,}77$, $p < .001$, par.$\eta^2 = 0.185$), exhaustion ($F(3, 156) = 5.34$, $p = .002$, par.$\eta^2 = 0.093$), irritation ($F(3, 156) = 21.04$, $p < .001$, par.$\eta^2 = 0.228$), aggression ($F(2.289, 119.014) = 4.76$, $p = .008$, par.$\eta^2 = 0.084$), shame ($F(2.003, 104.143) = 15.92$, $p < .001$, par.$\eta^2 = 0.234$) and lowered relaxation ($F(2.391, 124.357) = 17.55$, $p < .001$, par.$\eta^2 = 0.252$) – but not worries ($p = .220$) – in all conditions (see Fig. 3(B-H), reported are main effects of time). However, both the avatar and real social support conditions reported to worry less after receiving social support and, consequently, after the TSST (time by condition effect, $F(9, 156) = 4.35$, $p < .001$, par.$\eta^2 = 0.201$, Fig. 3G) than participants in the agent and no support condition (post-hoc, after the support: avatar vs. agent ($p < .001$, $d = 2.047$), avatar vs. no support ($p < .001$, $d = 1.717$), real support vs. agent ($p < .001$, $d = 2.014$), real support vs. no support ($p < .001$, $d = 1.673$); after the TSST: avatar vs. agent ($p = .004$, $d = 1.306$), avatar vs. no support ($p = .030$, $d = 1.241$), real support vs. agent ($p = .003$, $d = 1.269$), real support vs. no support ($p = .020$, $d = 1.186$)).

The avatar and real social support conditions reported less shame after the TSST (time by condition effect, $F(6.008, 104.143) = 2.49$, $p = .027$, par.$\eta^2 = 0.126$, Fig. 3H), compared to the no support condition but not the agent condition (post-hoc: avatar vs. agent ($p = .288$), avatar vs. no support ($p = .023$, $d = 1.300$), real support vs. agent ($p = .160$), real support vs. no support ($p = .009$, $d = 1.230$)). An additional time by condition effect considering irritation ($F(9, 156) = 3.50$, $p = .001$, par.$\eta^2 = 0.168$, Fig. 3E) revealed that participants in the agent condition were more irritated than participants in the avatar condition after receiving social support ($p = .026$, $d = 0.938$; all other post-hoc tests $p > .05$). After the TSST, the agent condition reported more irritation than the avatar ($p = .011$, $d = 1.110$) and real condition ($p = .003$, $d = 1.200$), but not the no support condition ($p = .067$). No other interactions, group effects, or post-hoc tests were significant when controlling for multiple comparisons (all *ps* $> .05$).

Heart Rate: As is evident from Fig. 3A, HR did not differ at baseline ($p = .762$) but showed an increase after the TSST in the agent and no-support condition (time by condition effect, $F(6, 104) = 9.42$, $p < .001$, par.$\eta^2 = 0.352$). Post-hoc tests revealed that after the TSST, the agent condition showed a significantly higher HR ($M = 85.93$, $SD = 14.295$) than the real social support condition ($M = 74.36$, $SD = 9.295$, $p = .033$, $d = 0.930$). Similarly, the no support condition ($M = 85.71$, $SD = 7.620$) had a higher HR than the real social support condition ($p = .038$, $d = 1.336$). The difference between the avatar ($M = 75.14$, $SD = 10.121$) and the agent condition was not significant ($p = .053$, $d = 0.846$). Also, no differences in HR between conditions were found during recovery ($p = .965$).

Prosocial Behavior: Those conditions which received social

Table 1
Scales of the networked minds measure of social presence (NMMSP).

	Avatar Support	Real Support	Agent Support	*F*	*p*
Co-Presence	29.36 (6.059)	29.07 (7.130)	29.21 (6.530)	0.007	.993
Isolation	6.93 (2.129)	6.93 (3.075)	6.21 (2.887)	0.320	.728
Mutual Awareness	22.43 (4.484)	22.14 (4.769)	23.00 (4.674)	0.124	.884
Psychological Involvement	78.71 (10.477)	81.00 (11.191)	72.57 (6.903)	2.823	.072
Mutual Attention	29.29 (2.673)	27.07 (5.255)	27.71 (6.557)	0.701	.502
Empathy	22.29 (3.989)	24.79 (4.560)	21.21 (3.355)	2.941	.065
Mutual Understanding	27.14 (7.695)	29.14 (7.873)	23.64 (7.602)	1.819	.176
Behavioral Engagement	43.93 (8.792)	39.50 (11.044)	40.79 (8.622)	0.797	.458
Dependent Action	25.07 (7.353)	20.86 (9.347)	23.86 (6.904)	1.045	.361
Mutual Support	18.86 (2.538)	18.64 (4.050)	16.93 (5.106)	0.959	.392

Note. Values are means with standard deviations in parenthesis. Dimensions of the NMMSP are printed in boldface. $n = 14$ per group.

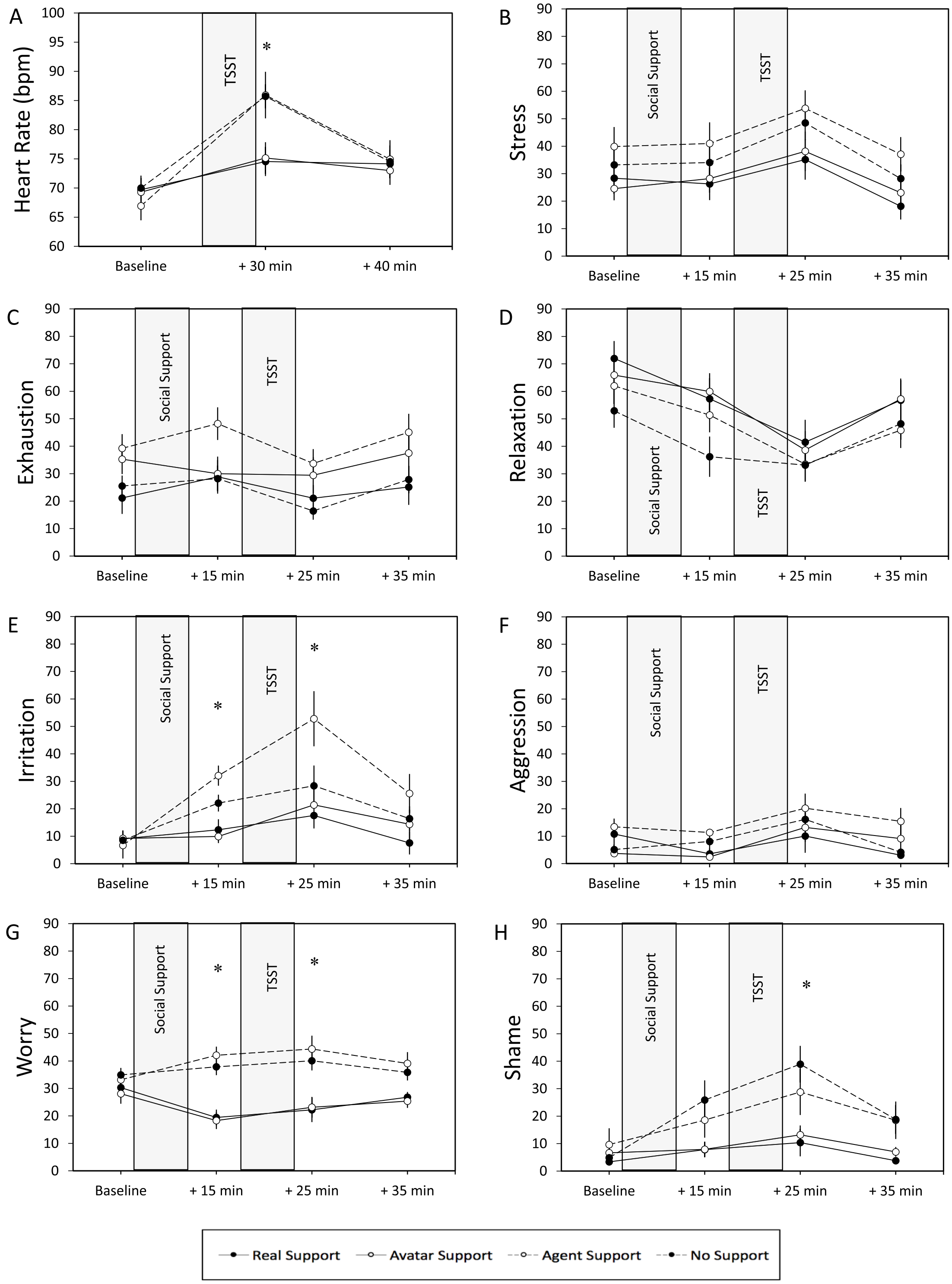

Fig. 3. Heart Rate and Subjective stress measures (VAS) during the experiment (means ± SEM). *Tukey's HSD p < .05.

support by an avatar or in real life, compared to the agent and no-support condition, showed quicker responses to pick up the first pen (F (3, 52) = 37,02, $p < .001$, par.$\eta^2 = 0.681$, post-hoc: avatar vs. agent ($p < .001$, $d = 2.123$), avatar vs. no support ($p < .001$, $d = 3.186$), real support vs. agent ($p < .001$, $d = 2.247$), real support vs. no support ($p < .001$, $d = 3.730$); see Fig. 4A). Furthermore, a significant main effect of condition emerged in the social distance task (F(3, 50) = 3.28, $p = .028$, par.$\eta^2 = 0.165$; see Fig. 4B), yet group differences did not remain significant when controlling for multiple testing (a trend remained with real support vs. no support, $p = .054$, $d = 1.000$; all other $ps > .111$). Two participants (one in the agent, one in the no-support condition) refused to sit down in this task.

4. Discussion

This research set out to examine the effects of social support provided by virtual avatars and agents on both, stress reactivity during a social-evaluative stressor, the Trier Social Stress Test (TSST,

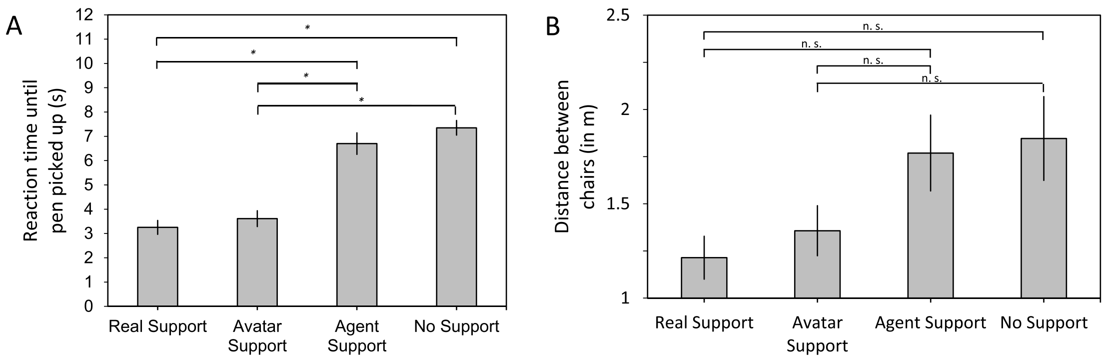

Fig. 4. Group differences (means ± SEM) in prosocial behaviors (Pen and seating task). *Tukey's HSD $p < .05$.

Kirschbaum et al., 1993) and subsequent social behaviors like helping and approach. In light of ever increasing virtual social interactions in MMORPGs and on social network sites as well as in the context of therapeutic intervention, the main objective was to test whether virtual social support could also act as a stress buffer in a stressful situation. Furthermore, the possibly differential effect of human controlled avatars and computer controlled agents on stress reactivity and social behaviors was evaluated.

Results revealed no differences in agency regarding social presence experiences. Participants reported to be equally co-present with avatars and agents as well as with the confederate actor, who provided face-to-face support. Also, they attributed the same amount of sentience to all interaction partners. This finding corresponds with prior research (Felnhofer et al., 2018; Kothgassner et al., 2017; Krämer, Bente, & Piesk, 2003; von der Pütten et al., 2010) and it provides further support for the *Media Equation Concept* (Nass & Moon, 2000) which states that automatic and mindless reactions to social entities – as are reflected in the construct of social presence – are not contingent on agency.

In contrast to social presence, however, experienced social support, stress reactivity and affective responses during the TSST followed agency dependent patterns. Generally, the TSST produced considerable levels of stress and negative affective states (VAS) in all participants and thus, proved to be an effective stress induction method (Kirschbaum et al., 1993). Yet, when comparing the four experimental conditions (avatar support, agent support, real support, no support), group specific patterns in physiological stress reactivity, affective and cognitive stress responses emerged. Participants who were supported face-to-face and those who were supported by an avatar reported to be less worried both after receiving the support and during the TSST than participants in the agent and the no-support conditions. Also, these two groups showed significantly lower levels of shame following the socio-evaluative stressor than controls. Agent supported participants, in turn, were more irritated both after the support scenario and after the TSST and – together with the no support group – had the highest HR levels during stress exposure.

These group differences in stress responses may be interpreted along the lines of the *Buffering Model* (Cohen & Wills, 1985). In contrast to the *Main Effect Model* which describes direct positive effects of support on health regardless of stressors, the buffering hypothesis states that negative effects of stress on health related factors are reduced as a function of social support (Ditzen & Heinrichs, 2014). In the current experiment, only those participants who perceived the social support as helpful also showed less stress related negative outcomes. Thus, the avatar and face-to-face support groups who experienced the verbal and non-verbal assurance as more supportive than those who interacted with a computer agent also reported to be less worried and less ashamed. In contrast, agent supported individuals had an increased physiological stress reactivity (HR) and indicated to be significantly more irritated.

In an attempt to explain these differences, we may revert to the argument introduced by two previous papers which studied the effect of agency on users' responses (Felnhofer et al., 2018; Kothgassner et al., 2017). The authors hypothesize that while immediate reactions (i.e., social presence experiences) are the same for avatars and agents, temporally delayed responses (i.e., perceived support) differ significantly as a function of agency. As explicated by Felnhofer et al. (2018), this differential pattern may be due to cognitive processes (e.g., attributions, labeling) which do not come into effect immediately. Hence, the first assessment of the virtual other (i.e., its sentience, its co-presence) may be automatic (as explicated by the *Media Equation Concept*), while later reactions may be preceded by complex cognitive processes. In other words, agent-based support may have been perceived as less supportive and, consequently, ineffective in terms of stress buffering because participants *ex post facto* attributed it to a mere computer algorithm which devaluated it to a random and impersonal experience (c.f., Felnhofer et al., 2018). Accordingly, the higher levels of irritation in the agent group may result particularly from participants' attribution that they were interacting with a machine. A phenomenon which is commonly associated with heightened levels of irritation towards virtual others or robots is the so called Uncanny Valley phenomenon (Mori, 1970). It hypothesizes that a user's response to an artificial being becomes increasingly positive the more this being's appearance approaches human like appearances, but reaches a point (the uncanny valley) at which a feeling of repulsion and uncanniness occurs in the user. This mechanism may have come into effect with the agents used in this experiment (which on the one hand were high in behavioral realism but on the other hand – apparent to the participant – were controlled by a computer). Further studies, which vary the visual fidelity and behavioral realism of computer controlled virtual humans, are needed to support this hypothesis. Also, measures other than self-report questionnaires (as used here) are needed to test the hypothesis of a time based effect of agency.

In addition to stress reactivity and experienced social support, subsequent real-life social behaviors also differed with regards to the agency of the supporter. Participants in the avatar and the real-support groups showed a considerably faster helping reaction (time to pick up first pen) than those in the agent and the control group. Also, there was a strong trend for group differences in the approach task: Participants who had been emotionally supported by the confederate actor – either via an avatar or face-to-face – kept less seating distance from the confederate. Overall, the current results seem to be more in favor of the assumption that tend and befriend behaviors rather than avoidance come into effect in the face of stress (c.f., Taylor et al., 2000). In our experiment, especially those participants who had previously been supported by another human (face-to-face or via an avatar) were more likely to intensify their prosocial behavior, a finding which is generally in line with prior research (Carter-Sowell et al., 2008; Felnhofer et al., 2018; von Dawans et al., 2012). Again, interfering cognitive processes may explain why individuals with high levels of perceived social support (real and avatar conditions) showed more tend and befriend tendencies than participants in the agent condition (with low perceived support). According to the *Resource Exchange Theory* (Foa, 1971) human social behavior is reciprocal in that “people depend on one another for the material and psychological resources necessary to their well-being” (p. 345). Recent research (Rosenbaum & Massiah, 2007) maintains the notion that people tend to exchange similar resources, i.e. the support provided by a person is likely to be returned. Consequently, participants who were supported by the confederate (face-to-face or via the avatar) have felt the need to repay the deed and show more social behaviors.

5. Limitations and conclusion

Above all, this study's nature is exploratory; hence, the current results represent a first basis for further, more comprehensive analyses. Also, in this this study only specific forms of social support were provided: emotional verbal and non-verbal assurance. Yet, research shows that different forms of support (i.e. instrumental, informative) may have different effects on the receiver depending on what needs are evoked by the situation at hand (Ditzen & Heinrichs, 2014). Furthermore, our participants were supported by a stranger (a randomly assigned male or female actor). A close friend or relative may have exerted an even more pronounced stress buffering effect (c.f., Uno, Uchino, & Smith, 2002). Future studies should not only vary the type of support and the source of support (stranger vs. friend) but also test for different social threats.

In sum, this study's results provide additional empirical evidence for the stress buffering hypothesis of social support (Cohen & Wills, 1985) as well as for the *Resource Exchange Theory* (Foa, 1971). Also, the findings approve both models not only for face-to-face settings but also for virtual social interactions. Specifically, this study shows that verbal and non-verbal emotional support may succeed in decreasing the negative effects of an acute social evaluative stressor both in real-life and in virtual reality. However, in the current study, social support was only effective in terms of stress buffering when it was effectively provided by another human (face-to-face) or if participants thought it was provided by another human (via an avatar). The issue of whether computer controlled virtual humans have the same influence on users as virtual others that are controlled by a factual human has wide ranging implications for a range disciplines and areas of application (from gaming to therapy). Using a computer algorithm is undoubtedly less costly and less cumbersome with regards to programming and implementation. Also, reverting to preprogrammed virtual humans in research ensures standardization and, thus, increases internal validity (c.f., Kothgassner et al., 2016). However, a loophole for this intricate problem has been pinpointed by the current study: as demonstrated here, a human is not required to actually control the avatar; the mere impression of the user that s/he is interacting with another human suffices. This should be considered when virtual humans are deployed in psychological treatment. Hence, the characteristics attributed to the avatar may have an influence on the treatment's effectiveness. Furthermore, this should also be considered in research when evaluating digital social support as a protective factor in the context of resilience and mental health.

Generally, however, the use of virtual humans in health technologies for the purpose of offering social support (i.e., in health APPs or tailored prevention programs) is encouraged as they seem to have a comparable effect to face-to-face support. Provided that virtual social interactions are well designed (i.e., in terms of reciprocity, behavioral realism) and provided that the user believes that s/he is interacting with another human, virtual scenarios may act as a valuable social resource for stress reduction and health maintenance. Future research is, however, still challenged to evaluate virtual social support and its efficiency in the field of practice.

Conflicts of interest

None to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2018.11.003.

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