

# Afraid to Be There? Evaluating the Relation Between Presence, Self-Reported Anxiety, and Heart Rate in a Virtual Public Speaking Task

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## Abstract

The link between anxiety and presence in a virtual environment (VE) is still a subject of an unresolved debate, with little empirical research to support theoretical claims. Thus, the current study analyzed presence, self-reported anxiety, and a physiological parameter (heart rate [HR]) in a sample of 30 high anxious and 35 low anxious participants. Both groups delivered a 5 minute speech in a virtual lecture hall. Results indicate no mediating influences of presence on group differences in self-reported state anxiety during the speech, but point toward negative correlations between state anxiety and the iGroup Presence Questionnaire (IPQ) scales “sense of being there” and “realism.” Furthermore, HR was found to be unrelated to self-reported presence. Only the IPQ scale “spatial presence” showed a marginally significant influence on group differences in state anxiety. The present results support the assumption that presence and anxiety are logically distinct, meaning that presence does not directly influence the intensity of an emotion felt in a VE. Rather, it constitutes a precondition for an emotion to be at all elicited by a VE. Also, HR has proven to be no adequate substitute measure for presence, since it only assesses anxiety not presence. It may, however, mediate the interplay between trait anxiety and state anxiety. Possible implications of the current findings are discussed alongside the problem of using presence questionnaires that seem to be prone to subjective bias (i.e., participants confusing presence and emotion).

## Introduction

FOR VIRTUAL EXPOSURE TO BE AN EFFECTIVE therapeutic tool, sufficient levels of subjectively perceived anxiety and physiological arousal are necessary.<sup>1</sup> Both, however, are believed to be attained only if the person is actually present in the virtual environment (VE). This experience of being there in an artificially created environment is commonly defined as the “perceptual illusion of non-mediation,”<sup>2</sup> or, in other words, as a disregard of the technology’s mediating role in the creation of an environment. Hence, a person who is subject to this illusion reacts to an artificial environment as if it was real,<sup>3</sup> and may therefore experience the same level of anxiety as in a comparable physical environment. Despite this theoretical reasoning, the empirical relationship between presence and anxiety is still far from being understood.<sup>4</sup> Research to date has produced mixed findings, which on the one hand may be attributable to cross-study differences in

used methodologies, but on the other hand may also trace back to disagreements concerning the theoretical basis of this link. Considering this, the current study aimed at investigating the relationship between anxiety and presence in students with social anxiety using a virtual lecture hall.

### *Self-reported anxiety*

The link between presence and emotions has been identified as a critical topic for examination,<sup>5</sup> and has resulted in a lively scientific debate in the past decade.<sup>6–12</sup> This debate has mainly evolved around the question about the relationship’s direction, that is, whether an emotion increases the sense of presence, or whether presence enhances an emotion, or whether, after all, they interact with each other reciprocally.<sup>7,10</sup> Some studies have found positive correlations between presence and self-reported anxiety,<sup>4,10,13,14</sup> while others have failed to find any connections.<sup>1,15,16</sup> Most of

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these studies, however, have methodological limitations: they evaluate small samples<sup>16</sup> with no controls,<sup>4</sup> or use single-item measures of presence or anxiety instead of validated questionnaires,<sup>7,10,16</sup> or they present these single-item measures concomitantly,<sup>7,10</sup> thus inflating statistical correlations. Also, they seem to follow the presupposition that the more presence a person experiences, the more anxiety he/she will report in an anxiety inducing VE, or, conversely, the more anxiety the person feels, the more presence he/she will report. Accordingly, in some studies, highly anxious subjects were reported to experience more presence in an anxiety inducing environment than nonanxious controls.<sup>13,14,16</sup> Some scholars,<sup>8,10</sup> however, criticize that these positive correlations may simply be caused by the fact that respondents confuse emotion with presence (i.e., “I am more anxious, therefore I must be more present”<sup>10</sup>).

Naturally, this would contradict the above mentioned definition of presence. There, a higher level of presence does not equal a more intense emotion; it rather reflects a concordance between the emotion experienced in a VE and an emotion experienced in a comparable real life situation.<sup>11,12</sup> This is in line with Slater<sup>12</sup> who states that “it is wrong to assume that high presence always implies strong emotion.” Thus, presence may be rather thought of as a gateway to emotion: there must be a certain amount of presence to be at all able to feel the emotion the VE is meant to elicit. Yet, the intensity of the emotion is not directly dependent on presence but rather on the interplay between personal characteristic (e.g., high trait anxiety) and the VE’s (emotional) content. Considering the above stated premises, presence is—at most—expected to mediate the relationship between trait and state anxiety (following the presence as a gateway hypothesis). Yet, it is not anticipated to be directly correlated to the intensity of anxiety felt in a VE.<sup>12</sup>

### Heart rate measures

Given that self-reported presence questionnaires seem to be prone to bias, corroborative physiological measures such as heart rate (HR) have been suggested to be used alongside subjective measures of presence.<sup>5,17</sup> Logically, these two measures should correlate if they target the same construct.<sup>8</sup> One could argue that if HR (or any other physiological indicator) should ever serve as an alternative indicator of presence, it should somehow be related to what participants subjectively report about their sense of being in the VE. Despite this requirement, only a very small number of studies<sup>16,18–21</sup>—in contrast to a vast majority<sup>22–28</sup>—has actually statistically correlated presence and physiological measures, and only one study<sup>19</sup> found a significant positive correlation between presence and change in HR.

However, from a theoretical point of view, an increase in HR—similar to self-reported anxiety—cannot be expected to go hand in hand with an analogous increase in presence, since an increase in HR merely reflects higher levels of anxiety, not presence.<sup>7</sup> Considering this, presence may again be understood as a gateway: it enables the physiological reaction but does not directly influence its intensity. In this sense, it is only a question of whether the physiological reaction in a VE matches the reaction that is expected in similar real life circumstances (see similarity paradigm<sup>8</sup>). Studies<sup>23,29</sup> comparing nonanxious subjects to anxious sub-

jects in stressful VEs found that the latter group exhibited higher physiological arousal, as they would do expectedly in a comparable physical environment. This result was interpreted as indirect evidence for presence, since participants reacted to the VE as they would have done in a comparable physical environment.

Given these contradicting assumptions, more research is warranted directly correlating presence and HR to assess convergent validity and to test whether HR could at all be used as a corroborative measure of self-reported presence. Furthermore, studies are needed to evaluate the claim that presence acts as a gateway to a physiological reaction, thus mediating the interplay between participants’ trait anxiety and their subjectively perceived state anxiety in a VE.

### Aim of study

In this study, presence shall on the one hand be introduced as a covariate to test for its mediating influence on differences between highly anxious and low anxious participants regarding their anxiety reaction (self-reported and HR) when holding a speech in front of a virtual audience. Additionally, intercorrelations between anxiety and presence shall be assessed to reinforce Slater’s<sup>12</sup> claim and to test for convergent validity. Thus, three main research questions (RQ) can be stated for the current study:

**RQ1: Are there differences between high anxiety and low anxiety participants in self-reported anxiety when accounting for influences of presence?**

**RQ2: Are there differences between high anxiety and low anxiety participants in HR measurements when accounting for influences of presence?**

**RQ3: Are there intercorrelations between presence, HR, and self-reported anxiety?**

### Methods

All participants were recruited via university courses, and received credits for their participation. The study was conducted according to the Declaration of Helsinki, and thus a comprehensive informed consent was provided to all participants prior to their participation.

### Participants

The sample consisted of 65 German speaking students. Participants with a score  $\geq 35$  on the Social Interaction Anxiety Scale (SIAS<sup>30</sup>; see measures) were assigned to the high anxious group, whereas students with scores below this cutoff formed the low anxious group. Hence, 30 participants reported high levels of social anxiety (2 males, 28 females; age:  $M = 22.97$ ,  $SD = 2.512$ ), and 35 showed low social anxiety (7 males, 28 females; age:  $M = 24.46$ ,  $SD = 2.924$ ). No participant reported a clinically relevant history of a social anxiety disorder. All participants had corrected to normal eye sight and reported no prior experience with experimental VEs. Further exclusion criteria were existing heart diseases or a history of psychiatric disorders, as well as psychiatric medication and medication influencing blood pressure. The majority of participants in both groups (75.4%) reported to have a lot of computer experience, compared to

only 24.6% of participants who indicated to have only little computer experience. There was no difference between the two groups,  $\chi^2(1) = 0.871$ ,  $p = 0.397$ .

### Procedure

After signing the informed consent form, participants were led to a quiet room to fill out a demographic survey and psychological questionnaires. Upon completion of the pre-assessment, participants were instructed to deliver a 5 minute speech in front of a virtual audience. For this purpose, they were provided with a printed version of the 20 slide presentation and asked to get acquainted with it during a 5 minute preparation period. The number of 20 slides was chosen to guarantee the participants would not finish the presentation before the 5 minute period ended.

Furthermore, a fairly original theme (Bhutan's geography and governmental form) was selected to ensure the subject's novelty. After the preparation period, the electrocardiogram (ECG) was attached, and the participant was asked to rest for 1 minute. This relaxation phase constituted the baseline for the subsequent ECG measurements. Then, the participants were shown how to flip the virtual presentation slides using the F710 Wireless Gamepad (Logitech Europe S.A., Switzerland), and the head mounted display (eMagine Z800 3D; Bellevue, WA) with an integrated head tracking unit (360° horizontal, >60° vertical), and two stereoscopic SVGA OLED displays (resolution: 800×600 triad pixels) were donned. The experimenter took a seat behind a screen from where he/she could control the simulation and observe the physiological measurements without being seen by the participants. When the simulation ended, the participants were again led to the assessment room to fill out the remaining questionnaires.

### Virtual public speaking scenario

The virtual public speaking scenario was modeled after a typical university lecture hall using Visual Studio C++ Express as well as the Ogre3d ([www.ogre3d.org/](http://www.ogre3d.org/)) graphics engine in combination with QuickGUI. The textures were processed with GIMP ([www.gimp.org/](http://www.gimp.org/)), and real time rendering was achieved with Blender 3D ([www.blender.org/](http://www.blender.org/)). A standardized protocol was applied for the experiment, resulting in both a constant number of 20 male and female virtual characters in the audience and a constant distribution of emotions among the virtual listeners. Half of the virtual characters displayed a neutral expression, whereas four characters had a slight frown and four smiled. Two charac-

ters who were seemingly bored rested their heads on the table (see Fig. 1).

Additionally, the virtual room was filled with the sound of a quiet murmur, which, at times, was interrupted by a slight cough. During the whole presentation, participants—represented by their first person view avatars—were standing on a podium with a display of the slides in front of them. They could turn their heads but could not move freely around the hall.

### Measures

Both psychological self-report questionnaires and physiological measures were applied alongside a short demographic survey.

**Participant selection.** In order to assign participants to the high anxious or the low anxious group, the SIAS<sup>30</sup> was applied. It assesses the trait component of interaction anxiety using 20 items (e.g., “I have difficulty talking with other people”) on a 4-point Likert scale (“not at all” to “extremely”). This scale was used to avoid a participant's tendency to choose the rather uninformative, neutral middle category, and to allow for a better discrimination between the two groups. In the current study, the internal consistency was satisfactory (Cronbach's  $\alpha = 0.87$ ), and a cutoff value of  $\geq 35$  was used for group assignments.

**Self-reported anxiety.** Participants were asked to rate their level of situational anxiety prior to and shortly after holding the presentation on the 20-item state version (Form X1) of the State-Trait Anxiety Inventory (STAI<sup>31</sup>). The items (e.g., “I am nervous”) were answered on a 4-point Likert scale (“very” to “not at all”). Internal consistency was very high, with  $\alpha = 0.89$  for pre-assessment and  $\alpha = 0.93$  for post assessment.

**Presence.** The German version of the iGroup Presence Questionnaire (IPQ<sup>32</sup>) was applied immediately after the exposure in order to assess the level of presence experienced in the virtual lecture hall. The IPQ comprises 14 items on a 7-point Likert scale (“strongly agree” to “strongly disagree”), which add up to three scales: (a) “spatial presence” assesses the physical sense of actually being in the virtual environment (e.g., “I felt present in the virtual space”); (b) “involvement” evaluates the amount of attention focused on the virtual stimuli (e.g., “I was completely captivated by the virtual world”); and (c) “realism” reflects the participant's

**FIG. 1.** Participants' view of the virtual lecture hall from the front and when turning the head to the left.



TABLE 1. DIFFERENCES BETWEEN HIGH AND LOW ANXIOUS PARTICIPANTS REGARDING FACTORS OF PRESENCE ( $N=65$ )

	N	M	SD	T	p
Sense of being there	35	3.97	1.902	1.057	0.295
	30	3.50	1.656		
Spatial presence	35	20.69	6.641	-0.460	0.647
	30	21.43	6.388		
Involvement	35	14.80	5.487	-0.519	0.606
	30	15.53	5.906		
Realism	35	13.97	4.436	-0.689	0.493
	30	14.77	4.861		

perception of the virtual environment as real and believable (e.g., “The virtual world seemed more realistic than the real world”). An additional single item—“sense of being there” (“In the computer generated world I had a sense of ‘being there’”)—assesses the experience of perceiving the virtual simulation as a place that has been visited. In the present study, the scales’ internal consistencies were comparable to those found in previous studies<sup>33</sup>: “spatial presence” ( $\alpha=0.77$ ), “involvement” ( $\alpha=0.82$ ), and “realism” ( $\alpha=0.76$ ).

**Psychophysiological measures.** HR was selected as a measure of the participants’ stress-related sympathetic activity. It was recorded via M-EXG (Schuhfried BFB 2000 x-pert; Moedling, Austria) using three one-way electrodes (3M Medica RedDot electrodes; Perchtoldsdorf, Austria) of which two were positioned on the chest and one on the neck (reference). HR was monitored at 5 millisecond intervals throughout the speech; 60 second intervals were computed using the Kubios HRV software (Biosignal Analysis and Medical Imaging Group, Kuopio, Finland) for further analysis. High HR values (beats per minute) indicate high physiological arousal, whereas low HR values represent lower physiological stress.

## Results

Statistical analyses were carried out using SPSS v19 (SPSS, Inc., Chicago, IL), considering a significance threshold of  $p<0.05$ . There were no differences regarding the baseline levels of HR measures ( $T_{49.5} = -1.654$ ,  $p=0.104$ ), but as expected, anxious individuals reported

higher levels of self-reported anxiety ( $T_{63} = -4.706$ ,  $p<0.001$ ) before the virtual public speaking task. Additionally, no significant differences could be found between high and low anxious participants concerning their level of presence during the virtual public speaking task (see Table 1). Furthermore, Table 2 shows intercorrelations of HR and state anxiety with the IPQ subscales. Only the scales “sense of being there” ( $r=-0.306$ ) and “realism” ( $r=-0.280$ ) showed a significant negative correlation with the STAI after the presentation.

### Self-reported anxiety

Considering self-reported state anxiety measures before and after the virtual public speaking task (see Fig. 2), results from the repeated measurements ANOVA point at a significant group difference,  $F(1, 59)=13.570$ ,  $p<0.001$ ,  $\eta^2=0.187$ ) and an interaction effect of time  $\times$  group for the current sample,  $F(1, 59)=9.242$ ,  $p=0.004$ ,  $\eta^2=0.135$ , but they reveal no main effect of time,  $F(1, 59)=0.048$ ,  $p=0.827$ ,  $\eta^2=0.001$ . There was no significant mediating influence of the covariates “sense of being there,”  $F(1, 59)=0.027$ ,  $p=0.871$ ,  $\eta^2=0.001$ ; “spatial presence,”  $F(1, 59)=0.187$ ,  $p=0.667$ ,  $\eta^2=0.003$ ; “involvement,”  $F(1, 59)=2.161$ ,  $p=0.147$ ,  $\eta^2=0.035$ ; and “realism,”  $F(1, 59)=0.096$ ,  $p=0.757$ ,  $\eta^2=0.002$  on group differences in self-reported anxiety.

### Heart rate measures

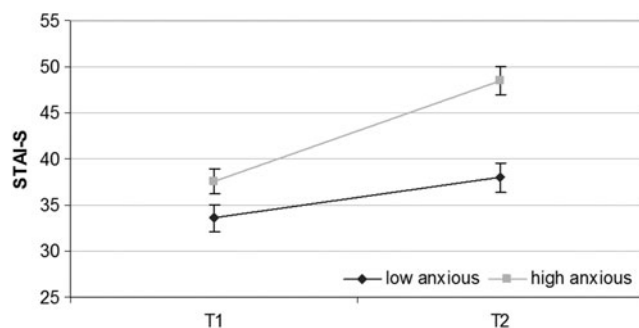
The Greenhouse–Geisser correction was used to interpret the results because Mauchly’s test indicated that the assumption of sphericity had been violated ( $\chi^2=173.160$ ,  $p<0.001$ ,  $\epsilon=0.54$ ). A repeated measures ANOVA was used to analyze HR data of the high anxious and low anxious groups (see Fig. 3). Results indicate a significant main effect of time,  $F(2.700, 159.295)=6.035$ ,  $p=0.001$ ,  $\eta^2=0.093$ , and a significant group effect,  $F(1, 59)=4.493$ ,  $p=0.038$ ,  $\eta^2=0.071$ . These results show a significantly higher increase of physiological arousal in the group of social anxious participants compared to individuals with lower social anxiety. Moreover, no statistically relevant interaction effect of time  $\times$  group could be found,  $F(2.700, 159.295)=2.073$ ,  $p=0.113$ ,  $\eta^2=0.034$ , for the HR measures. The inclusion of presence subscales as covariates revealed a marginally significant influence of “spatial presence,”  $F(2.700, 159.295)=2.685$ ,  $p=0.047$ ,  $\eta^2=0.044$ ) on HR, while the other subscales

TABLE 2. INTERCORRELATION MATRIX OF ANXIETY MEASURES AND PRESENCE ( $N=65$ )

	<i>iGroup Presence Questionnaire</i>				<i>Self-report measure<sup>o</sup></i>		<i>Heart rate measure<sup>#</sup></i>					
	<i>Being there</i>	<i>Spatial presence</i>	<i>Involvement</i>	<i>Realism</i>	<i>T1</i>	<i>T2</i>	<i>Baseline</i>	<i>T1</i>	<i>T2</i>	<i>T3</i>	<i>T4</i>	<i>T5</i>
Sense of being there	—	0.703**	0.498**	0.772**	−0.154	−0.306*	−0.190	−0.172	−0.164	−0.167	−0.158	−0.199
Spatial presence		—	0.677**	0.729**	0.059	−0.177	−0.030	−0.084	−0.075	−0.098	−0.104	−0.111
Involvement			—	0.563**	0.204	−0.052	−0.121	−0.147	−0.109	−0.141	−0.091	−0.123
Realism				—	−0.069	−0.280*	−0.088	−0.116	−0.082	−0.087	−0.077	−0.073

\*\* $p<0.01$ ; \* $p<0.05$ . <sup>#</sup>Heart rate measures of a 5 minute virtual speaking task (T1–T5) and a 1 minute baseline. <sup>o</sup>Self-reported STAI measures were assessed before (T1) and after (T2) the virtual speaking task.





**FIG. 2.** Self-reported STAI state anxiety measure before and after the virtual public speaking task (mean  $\pm$  SEM).

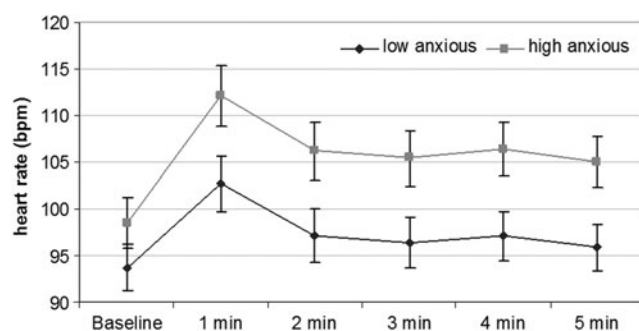
of “involvement,”  $F(2.700, 159.295)=0.978$ ,  $p=0.398$ ,  $\eta^2=0.016$ , and “realism,”  $F(2.700, 159.295)=0.741$ ,  $p=0.516$ ,  $\eta^2=0.012$ , as well as “sense of being there,”  $F(2.700, 159.295)=1.138$ ,  $p=0.333$ ,  $\eta^2=0.019$ , showed no significant influence.

## Discussion

Despite a substantial body of studies on presence and anxiety, their relationship still remains a subject of an extensive and, at times, conflicting debate, which has yet to arrive at a consensus. The most common assumption is that presence and anxiety must somehow be related to each other, but it is unclear whether this relationship is a linear one (i.e., a correlation) or whether presence may only act as a precondition for anxiety to appear at all. Also, there is much debate about corroborating subjective presence measurements with physiological indicators. However, only a very small number of studies has actually evaluated the correlational validity between these measures. To add to a better understanding of the interplay between presence and anxiety, the current study set out to analyze presence, self-reported anxiety, and HR in a sample of high anxious and low anxious participants, both holding a speech in front of a virtual audience. Below, the findings are presented separately for each anxiety measure.

### Self-reported anxiety

As expected, participants with high social anxiety reported significantly more anxiety (STAI) prior to the presentation than participants with low social anxiety. This finding may be regarded an indirect validation of our group assignments



**FIG. 3.** Heart rate baseline and recordings during the 5 minute virtual public speaking task (mean  $\pm$  SEM).

(based on SIAS cutoff  $\geq 35$ ). In addition to higher preratings, anxious participants also reported significantly more anxiety after the presentation. Here, we detected an interaction effect of time  $\times$  group: while the low anxious group exhibited only a minor increase in anxiety between pre and post assessment, the high anxious group—as expected<sup>29</sup>—showed a large increase in the post questionnaire. According to theoretical reasoning, the precondition for such a reaction is that participants are in fact present. Only if they are present can they react to a VE as they would in a comparable physical environment (i.e., phobics experience anxiety when encountering a phobic stimulus whereas nonphobics do not). Our findings support this assumption, and thus constitute indirect evidence for satisfactory presence levels.

This indirect evidence is further confirmed by high IPQ scores in our sample. However, in light of past research,<sup>13,14,16</sup> it might at first be surprising that our groups did not differ on the IPQ. Earlier findings imply that anxious subjects tend to report more presence than nonanxious controls in anxiety inducing VEs. Yet, this contradicts Slater,<sup>12</sup> who states that a higher level of anxiety does not equal more presence, unless the participant confuses emotion and presence in a self-report measure.<sup>10</sup> Logically, an increase in emotional intensity should not cause higher presence ratings in post questionnaires. Former studies, however, have shown that subjective presence measures may produce inconsistent responses influenced by prior experiences.<sup>34</sup> Considering this, alternative presence measures that are less prone to bias (e.g., behavioral indices) are needed to shed more light on the link between presence and emotions.

Following the above stated assumptions,<sup>12</sup> we did not expect presence to be directly correlated with self-reported anxiety in our study. Instead, we assumed presence would, at most, mediate group differences in state anxiety. Surprisingly, we found two significant correlations between post exposure anxiety (STAI) and “realism” as well as “sense of being there.” Even more surprising, these correlations were negative, implying two possible relationships: either more anxiety caused less presence (i.e., the person was too afraid to be present), or more presence was responsible for less anxiety. Literature supports the first relation: Bouchard et al.<sup>7</sup> found that presence scores decreased while anxiety scores increased. They interpreted this finding as evidence for a behavioral inhibition caused by fear during virtual exposure. Their participants reported feeling too paralyzed to explore the VE, and hence were less present. Similarly, participants in the present study might have tried to control their anxiety by shifting their attention away from the virtual audience and toward the surrounding physical environment, thus reducing their sense of actually being in the VE and impeding their evaluation of the environment’s believability and realism. In future studies, behavioral measurements such as gaze direction and duration may prove to be helpful additional indicators for avoidance behavior and concomitant decreases in presence.

To test for the hypothesis of whether presence would mediate group differences in state anxiety, we included it as a covariate in the analysis. However, we found no influences of presence. This result may be interpreted as a reinforcement of the hypothesis that presence only acts as a precondition for an emotion and does not influence its intensity. The emotional intensity may instead be attributed to the meaningfulness of the VE’s content or its emotional relevance and appeal.<sup>6,13</sup>

Hence, the interplay between trait characteristics and the VE's content, rather than presence itself, seems to be decisive of the intensity of the emotion experienced by the participant.

### HR measures

Similar to past research,<sup>10,23,29</sup> we found a substantially higher physiological arousal in highly anxious participants compared with low anxious participants during the speech. At baseline, however, the high anxious and low anxious groups did not differ in HR measures. This is in line with the assumption that phobic individuals do not show more physiological arousal during relaxation than nonphobic controls, but that they tend to be more sensitive to their bodily signals and rather interpret them as signs of fear.<sup>35</sup>

Considering that in our study the two groups did not differ in their level of presence, it is safe to assume that trait anxiety, not presence, was responsible for the group differences in HR during the virtual public speaking task. Presence may have acted as a gateway by first transporting the participant into the VE and then opening the gate for the interplay between the participants' trait characteristics and the VE's content. Furthermore, no direct correlations were found between HR and presence in the current study, contradicting the assumption that physiological indices such as HR may serve as a substitute measure for presence questionnaires. Even the notion that HR may corroborate self-report questionnaires of presence has to be called into question in light of present and previous<sup>16,18</sup> findings. In effect, HR is not a measure of presence but simply one of anxiety.<sup>7</sup>

Interestingly, however, including presence as a covariate in the analysis revealed one significant influence: the IPQ scale of "spatial presence" showed a tendency to mediate the relationship between trait anxiety and HR arousal in the virtual public speaking task. This result has to be interpreted with caution, since it is only marginally significant with a medium effect size. Yet, it is particularly remarkable that the IPQ scale "spatial presence" in particular showed a mediating influence. Spatial presence may be thought of as a key concept of presence, since—out of all other scales—it most embraces the experience of "being there," of being perceptually embodied in a place other than the one in which the physical body is located.<sup>36</sup> In particular, the interaction with the environment (i.e., tracking head movements and translating them into the VE) is thought to add to the perceptual illusion of nonmediation and embodiment.<sup>2</sup> Considering this, it is conceivable how, above all, a sense of spatial and physical presence may have mediated the physiological sensations experienced by anxious and nonanxious participants. However, the level of interactivity with the VE was quite low in our study, since participants were only able to move their heads and flip the slides but could not move around freely. Further studies, including more interactivity with the VE (i.e., walking around and interacting with virtual objects) could produce more conclusive results.

### Limitations and Conclusion

This study's results are predominantly in line with Slater's<sup>12</sup> reasoning about emotions and presence. However, there are at least three limitations to our findings: First, it may be argued that participants were aware of being observed by the experimenter during their VE exposure, which

may have impacted their experienced anxiety and presence. Without a doubt, this is a great concern of experimental studies in general. Yet, in view of the substantial presence levels reported in both groups, one may claim that our participants were well immersed and focused on the VE, thus "forgetting" the observation. Nevertheless, future studies should consider using one-way mirrors to decrease the observational nature of the experimental setting and increase external validity. Second, the current findings are based on a population of students who, more than the average adult, are used to presenting in front of an audience. It is therefore safe to assume that their average anxiety level (both self-reported and physiological) may be well below the general public's level because of prior practice. This should be taken into account when generalizing the findings. Third, our sample consisted mostly of women. This is particularly noteworthy, since previous studies have implied gender differences in experiences of and behaviors in VEs.<sup>37</sup> Thus, future research should balance samples set out to include analyses of gender differences when studying the link between presence and emotions.

Also, given that HR is not an appropriate direct indicator of presence, it should rather be treated as an indirect measure. It should predominantly be used when comparing reactions to a virtual and a physical stimulus to test for similarities in HR reactions to both stimuli.<sup>7</sup> Alternative physiological indicators such as skin conductance level or electroencephalogram could be evaluated accordingly. Of course, one has to keep in mind that physiological measures are reliant on situations in which the expected response is obvious and predictable, such as an anxiety inducing environment.<sup>38</sup>

### Acknowledgments

We would like to thank Jasmine Gomm, Anna Hoffmann, Elisabeth Kastenhofer, Nora Pösl, and Janka Scharfenberger for helping us to acquire parts of the data, and Anna-Katharina Heinzle for her support with the analysis of the HR data. We would also like to thank Mario Lehenbauer for his assistance in the early phases of the study.

### Author Disclosure Statement

No competing financial interests exist.

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