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A virtual reality social conditioned place preference paradigm for humans: Does trait social anxiety affect approach and avoidance of virtual agents?

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Approach and avoidance of positive and negative social cues are fundamental to prevent isolation and ensure survival. High trait social anxiety is characterized by an avoidance of social situations and extensive avoidance is a risk factor for the development of social anxiety disorder (SAD). Therefore, experimental methods to assess social avoidance behavior in humans are essential. The social conditioned place preference (SCPP) paradigm is a well-established experimental paradigm in animal research that is used to objectively investigate social approach–avoidance mechanisms. We retranslated this paradigm for human research using virtual reality. To this end, 58 healthy adults were exposed to either a happy- or angry-looking virtual agent in a specific room, and the effects of this encounter on dwell time as well as evaluation of this room in a later test without an agent were examined. We did not observe a general SCPP effect on dwell time or ratings but discovered a moderation by trait social anxiety, in which participants with higher trait social anxiety spent less time in the room in which the angry agent was present before, suggesting that higher levels of trait social anxiety foster conditioned social avoidance. However, further studies are needed to verify this observation and substantiate an association with social anxiety disorder. We discussed the strengths, limitations, and technical implications of our paradigm for future investigations to more comprehensively understand the mechanisms involved in social anxiety and facilitate the development of new personalized treatment approaches by using virtual reality.

KEYWORDS

retranslational research, conditioned place preference, approach–avoidance, social anxiety, virtual reality, personality traits, individual differences

1 Introduction

Social approach and social avoidance behaviors are essential to ensure survival (Darling, 1952). Both avoidance of social harm (e.g., by a foreign invader) and an approach toward social rewards (e.g., acceptance, play, and intimacy) improve well-being in the long run (Nikitin and Schoch, 2021). Although both behavioral mechanisms fulfill important adaptive functions, persistent and intense avoidance of social situations leads to loneliness and isolation and plays a key role in the development and maintenance of various mental disorders, especially social anxiety disorder, which is characterized by fear and avoidance of social situations (Stein and Stein, 2008; Bögels et al., 2010).

The mechanisms of classical conditioning play a major role in the development of social anxiety disorder (Lissek et al., 2008). Particularly, social stimuli or contexts become associated with an aversive unconditioned event and, consequently, elicit fear and maladaptive avoidance behaviors. Imagine, for instance, a school setting with repeated poor social evaluations and rejection by peers. In such a case, rejection by peers can act as an unconditioned stimulus. Unconditioned stimuli are stimuli that lead to an automatic (positive or negative) response as they are per se (without any prior learning) positively or negatively valenced. In our example, the unconditioned stimulus of peer rejection is intrinsically negatively valenced; thus, as a result, the initially neutral context "school" also shows a negative association. The context "school" represents the conditioned stimulus; i.e., a stimulus that was previously neutral but is associated with the valence of the unconditioned stimulus after multiple pairings with the unconditioned stimulus. Thus, the conditioned stimulus "school" can trigger a conditioned response such as avoidance. Such classical conditioning mechanisms can lead to extensive avoidance and are substantially involved in the development of social anxiety disorders (Asher et al., 2017).

Facial expressions are a class of stimuli with particularly high salience in humans (Diamond & Carey, 1986; Dimberg & Öhman, 1996; Dawel et al., 2022). While research suggests that happy facial expressions are behaviorally relevant and trigger specific autonomic responses (Dimberg, 1982; Dawel et al., 2015), angry facial expressions seem to represent the critical unconditioned stimulus in social anxiety disorder (Öhman, 2009; Wieser et al., 2010; Mühlberger et al., 2011). However, the symptoms of patients with social anxiety disorder are similar to behaviors associated with a "normal" state or trait of social anxiety and shyness (Schneier et al., 2002). Therefore, social anxiety may be better captured by dimensional approaches (Ruscio, 2010), in which individuals with high levels of trait social anxiety are at a higher risk for the development of social anxiety disorder and show elevated responses to angry facial expressions as compared to persons with low levels of trait social anxiety (Stein et al., 2002; reviewed in Stein and Stein, 2008).

The conditioned place preference (CPP) test is a behavioral paradigm in animal research that is used to measure appetitive or aversive effects toward specific stimuli. Most of this research focuses on the investigation of the effects of specific substances like drugs or food (Van der Kooy et al., 1982; overviewed in Linhardt et al., 2022; Tzschentke, 2007). The social CPP (SCPP) was developed as an extension to the CPP to examine the appetitive/aversive effects of social cues such as play behavior, sex, or general social interactions, in addition to the appetitive/aversive effects of specific substances (Calcagnetti and Schechter, 1992; Malkesman et al., 2005; Schwabe et al., 2006). Furthermore, the question of how the appetitive or aversive effects of specific substances and social cues may interact (and potentially compensate or amplify) one another can also be tested using SCPP paradigms (Thiel et al., 2008). The experimental setup of the SCPP consists of two separate compartments and three experimental phases. During the initial test (habituation), the animal can freely explore both compartments without the presence of any aversive or appetitive stimuli. In the following conditioning phase, both compartments are presented individually, with one compartment containing an unconditioned social stimulus and the other compartment containing a neutral or no stimulus. In the final test phase, the animal again explores both compartments, which are, like in the habituation phase, free of any aversive or appetitive stimuli. A comparison between habituation (pre-conditioning) and test phase (post-conditioning) reveals whether the animal spent more or less time in the test chamber previously paired with the unconditioned social stimulus and, thus, provides insights into the appetitive versus aversive effects of the unconditioned stimulus, respectively. Finally, individual variations in the strength of such effects can provide information on individual differences in motivational properties associated with specific stimuli.

SCPP paradigms have been successfully applied in animal research to evaluate the appetitive effects of social interactions with conspecifics (Calcagnetti and Schechter, 1992; Thiel, et al., 2009) and to unravel the modulatory roles of play behavior (Calcagnetti and Schechter, 1992), paced sexual intercourse (Paredes and Alonso, 1997; Kummer et al., 2011), and age (Yates et al., 2013). Based on the assumption that the identified processes translate to humans due to similar construct and predictive validity (Everitt et al., 2018), the results of such animal SCPP studies are frequently used to derive conclusions about the underpinnings of human behavior and disorders characterized by motivational dysfunctions.

A relatively direct approach to proving translational validity, however, is to retranslate animal paradigms to human studies and demonstrate similar behaviors (Walz et al., 2016; Kirlic et al., 2017; Gromer et al., 2021). The motivational effects of drugs (Shipman et al., 2006; Childs and De Wit, 2009, 2016; Palmisano et al., 2018), food (Astur et al., 2014), money (Astur et al., 2016), music (Molet et al., 2013), and toys (Hiller et al., 2015) have been successfully investigated in humans by using CPP paradigms (review, Linhardt et al., 2022). A recent pioneer study retranslated the SCPP to humans (Baron et al., 2020). Baron and others used a friendly adult person willing to play with a child as an appetitive stimulus and showed successful CPP in two groups of young children, i.e., typically developing children and children with autism spectrum disorder. However, no study has yet tested whether SCPP can also be transferred to healthy human adults. Moreover, no study has yet used the counterpart in humans, i.e., social conditioned place aversion (SCPA).

In recent decades, virtual reality (VR) has become a powerful tool in clinical psychology not only for research purposes but also for the treatment of mental disorders (Vincelli, 1999; Riva, 2005, 2009; Emmelkamp and Meyerbröker, 2021). One advantage of VR is that the applications provide a relatively high degree of ecological validity (similarity to the real, e.g., most feared, situation; higher than in typical laboratory settings) despite providing high control over the situation (e.g., how the feared agent reacts to the patient; higher control than in reality). Also, in retranslational CPP research, VR has proven to be a promising means (Shipman et al., 2006; for review, see Linhardt et al., 2022). Support for the usefulness of VR to retranslate SCPP or SCPA to humans comes from studies demonstrating that VR paradigms are eligible for testing and manipulating social feelings and behaviors in humans (Fogg, 2003; Weyers et al., 2006; Guadagno et al., 2007; Zanbaka et al., 2007) and studies showing avoidance behavior toward virtual social agents (Garau et al., 2005; Mühlberger et al., 2008; Wieser et al., 2009). However, so far, VR has not been used to investigate SCPP or SCPA in humans.

The main aim of the present study was to test whether the SCPP/SCPA paradigm can be transferred to healthy adult humans using VR—a first step to assess the potential of this paradigm as a clinical tool for the research and treatment of mental disorders like social anxiety disorder. Therefore, we developed a new experimental paradigm in VR with a virtual agent as a social stimulus. Happy versus angry agent facial expressions served as the unconditioned stimuli, with the expectation that they would provide appetitive versus aversive effects. During conditioning, the participants encountered a virtual agent with a happy (SCPP group) or angry (SCPA group) facial expression in one room and a neutral object in the other room. The SCPP and SCPA effects were operationalized as differences in dwell time (Δ time) and verbal preference ratings (Δ ratings) between the habituation (pre-conditioning) and test (post-conditioning) phases. The secondary aim explored the potential moderation effects of individual differences in trait social anxiety on SCPP or SCPA. Our hypotheses were as follows: 1) place conditioning using a positive social stimulus (virtual agent with a happy facial expression) elicits a behavioral and verbal preference for the conditioned room, while place conditioning using a negative social stimulus (virtual agent with an angry facial expression) elicits behavioral and verbal aversion. 2) These effects are moderated by individual variations in trait social anxiety; i.e., increased trait social anxiety is associated with stronger SCPP and SCPA effects.

2 Materials and methods

2.1 Participants

Fifty-eight female students (age: M = 23.3, SD = 4.8 years, range: 18–51 years) from Würzburg University, Germany, completed the experiment for student credits or monetary compensation. The size of this sample was determined by an *a priori* power calculation and economic feasibility. Specifically, based on previous human CPP research, we expected an effect size of Cohen's d ~.62 for dwell time measures (Linhardt et al., 2022), which, for a 95% statistical power, resulted in a minimal sample size of $N > 36$ participants (G*Power, Faul et al., 2007; F-tests, ANCOVA, two groups, df = 1, α = 0.05). More participants than expected preferred the option of receiving student credits instead of monetary compensation, thus our pre-defined amount of money was sufficient to reach a total sample size of 58 participants (36 received money and 22 received student credits). For this initial test of SCPP in humans, complexity was reduced by only recruiting women (absence of sex effects). No other special inclusion or exclusion criteria were applied. The participants were assigned using block randomization to one of two experimental groups. One group (N = 28) was exposed to an appetitive social stimulus in one room (happy-looking agent) and a neutral stimulus (computer on a desk) in the other room. The other group (N = 30) was exposed to an aversive social cue (angry-looking agent) in one room and a neutral stimulus (computer on a desk) in the other room. The study was approved by the ethics committee of the Psychological Institute of the Faculty of Human Sciences of Würzburg University and written informed consent in accordance with the principles of the Declaration of Helsinki was obtained from all participants before testing.

2.2 Apparatus

The experiment was performed in a five-sided Cave Automatic Virtual Environment system (CAVE) at Würzburg University, which is described in detail by Gromer et al. (2018). The CAVE measures 4 × 3 × 2.95 m and uses a stereoscopic image projection technique in which the participants wear interference-filtering glasses (Infitec Premium, Infitec, Ulm, Germany). Using Barco GALAXY NW7 projectors, the images had a resolution of 1627px × 1200px on the floor and door wall,

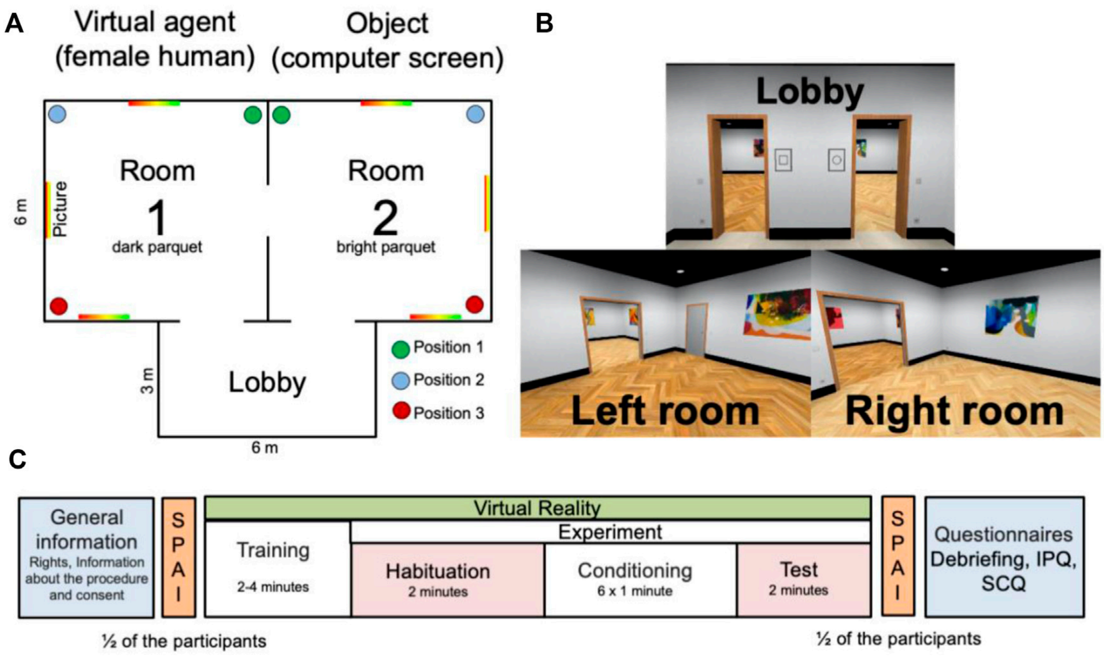

FIGURE 1
Schematic illustration of the social conditioned place preference (SCPP) paradigm in virtual reality (VR) and the experimental setup. **(A)** The two virtual museum rooms and the lobby are connected through doors that can be virtually closed, allowing or denying access to individual rooms during the experiment. Positions 1–3 are the sequence of positions in which the agent and neutral object were placed during the conditioning phase. **(B)** Example screenshots of the virtual environments. During the experiment, these were stereoscopically presented in a 360° + floor. **(C)** Overview of the experimental procedure. After receiving general information, half of the participants completed the SPAI, while the other half received the SPAI after the experiment. This was done to control for the potential effects of the experimental procedure on the social anxiety state score of the SPAI. The experiment started with a brief tutorial (training) in VR to familiarize the participants with navigating the VR environment. During the habituation and test phases, the door between rooms 1 and 2 was open and the participants could explore both rooms freely. During the interjacent conditioning phase, the participants started in the lobby and explored each of the two museum rooms separately six times for 1 minute each with the door between rooms 1 and 2 closed. The experiment ended with psychometric assessments and debriefing.

2016px × 1486px on the front wall, and 1220px × 1200px on the two smaller side walls. The sound was provided using a 7.1 surround system, while an infrared LED system with four cameras (PhaseSpace Impulse, PhaseSpace Inc., San Leandro, CA, United States) was used to track participant movements and orientation. The virtual environment was rendered using the VrSessionMod 0.6, a modification based on the Source Engine SDK 2013 (Valve, Bellevue, WA, United States). CS-Research 5.6 software (VTplus, Würzburg, Germany; www.cybersession.info) was used to script the experimental procedures and data acquisition. Importantly, the participants could move completely free in the CAVE 1) by using the gamepad (Xbox 360 Wireless Controller, Microsoft, Redmond, WA, United States) and 2) by walking physically.

2.3 Virtual reality setup

The experimental area consisted of a lobby (3 × 6 m, starting compartment) and two rectangular rooms 1 and 2 (6 × 6 m, compartments for conditioning and preference testing) located in a virtual art museum. All rooms were connected through doors and the two test rooms, 1 and 2, which differed in floor color (dark or light brown) and in the three paintings hanging on the walls of both rooms (Figures 1A,B). The paintings were "String Theory and Daisy Chains" (Moyer, 2016), "Age of Contradiction" (Pollock, n. d.), "Field of Berries" (Snyder, 2016), "Sunset N01876" (Turner, n. d.), "Mont Sainte-Victoire" (Cézanne, n. d.), and "Rhythms" (Delaunay, 1934).

2.3.1 Social cue: Virtual agent

The animations for the facial expression of the agents (see Figure 2) were designed using Faceposer from the Source Engine SDK toolkit (Valve, Bellevue, WA, United States). The agents' animations were based on the Half-Life 2 idle posture, involving slow body movement and a repeated scripted facial expression, each with a duration of 60 s. While being animated, the agents could not directly interact with the participants. The presence of the angry vs. happy agent was counterbalanced between both rooms.

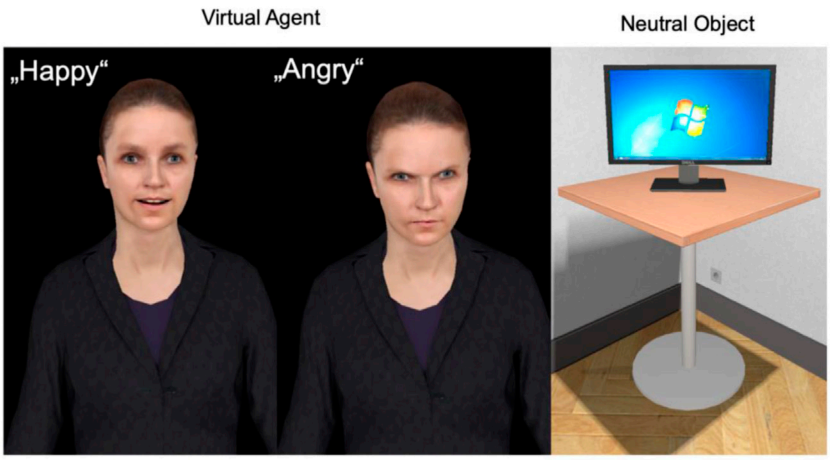

FIGURE 2
Examples of the animated virtual agent used as the social cue. The participants were presented to either the happy or the angry virtual agent in one room. The other room always contained a computer screen as a neutral object.

2.4 Experimental procedures

After obtaining their informed consent, the participants were equipped and instructed to enter the CAVE, where they started with a short tutorial to train the use of the gamepad for navigation in VR. The experiment consisted of a habituation phase (2 min), a conditioning phase (6 × 1 min), and a test phase (2 min; see Figure 1C). The participants did not exit the CAVE until after full completion. In total, the experiment required 20–30 min to complete. We explicitly chose no longer conditioning or test phases as prolonged stays in the CAVE can result in simulator sickness. After the tutorial, the participants were instructed *via* audio to walk to the starting area, i.e., the lobby equidistantly located between the two doors leading into museum rooms 1 and 2. Whether a participant started the experiment in room 1 or room 2 was counterbalanced between both rooms.

2.4.1 Habituation phase

The habituation phase started with instructing participants *via* audio to leave the lobby and enter one of the two museum rooms (1 or 2). For 2 min, the participants freely explored rooms 1 and 2 but could not return to the lobby (the door closed after entering the rooms). During this time, rooms 1 and 2 were free of any agents and objects. The participant position and duration of stay (dwell time, the first variable of interest) in each room were recorded during the habituation phase.

2.4.2 Conditioning phase

During the conditioning phase, the same two rooms were presented to the participants; however, the agent (happy looking for the SCPP experimental group, $N = 30$ vs. angry looking for the SCPA experimental group $N = 28$) was present in one of the two rooms (1 or 2; counterbalanced to control for room effects), while the neutral non-social object (computer screen on a desk) was visible in the other room (Figure 2). The conditioning phase also started in the lobby. The participants were instructed to enter one of the two rooms (e.g., room 1) and to spend 1 min observing the paintings on the walls. After 1 min, the participants were asked *via* audio to verbally rate how much they liked the individual images, the agent, the neutral object, the floor, and the room itself (the latter representing a variable of interest only). These ratings were recorded on Likert scales ranging from 1 ("Did not like the XY at all") to 10 ("Liked the XY very much"). The participants were then teleported back to the start position (lobby) and instructed to enter the other room (e.g., room 2). This procedure was repeated alternately for both rooms three times, with the virtual agent and the neutral objects always in the same room but at a new location within that room (Figure 1A). The order of the conditioning trials was neutral-social-neutral-social-neutral-social or social-neutral-social-neutral-social-neutral (block-randomized across all participants to balance the potential effects of the starting or ending stimuli).

2.4.3 Test phase

After the conditioning phase, the participants were again teleported back to the lobby. They were then asked to enter one of the two rooms (their choice) and explore the rooms freely for 2 min. The participants could freely enter and leave rooms 1 and 2 but could not return to the lobby (door closed). During this test, both rooms (as in the habituation phase) were free of the virtual agent (social stimulus) and neutral object. The duration of stay (dwell time, the first variable of interest) and position were recorded, and the same ratings were assessed.

2.4.4 Post-experimental procedure

After the experiment, the participants were asked to complete the Igroup Presence Questionnaire (IPQ; Schubert, 2003). To avoid sequence effects, half of the participants completed the German version of the Social Phobia and Anxiety Inventory (SPAI, Beidel et al., 1989; Fydrich, 2002) before they entered the CAVE, while the other half completed the SPAI and the IPQ after the experiment. Finally, the participants were debriefed and reimbursed.

2.5 Dependent variables

2.5.1 Social conditioned place preference

The first of the two main dependent variables used to evaluate the SCPP was, in direct analogy to animal studies, the time (in seconds) spent in the room previously paired (in the conditioning phase) with the social cue (angry vs. happy agent). As the overall times of the habituation and the test phases were fixed to 2 min each, the difference between the times spent in this room during the test and habituation phases reflected a change in place preference:

$$\Delta \text{time} = \text{time}_{\text{test}} - \text{time}_{\text{habituation}}$$

The second dependent variable, a human-specific variable, was based on the verbal rating of the preference for the rooms (see Section 2.4.2). Like the dwell time measurements, the variable of interest was the difference between the rating of the room in which the social cue (happy vs. angry agent) presented during conditioning between the test and habituation phases:

$$\Delta \text{rating} = \text{rating}_{\text{test}} - \text{rating}_{\text{habituation}}$$

The positive and negative values of Δ time and Δ rating indicated SCPP and SCPA, respectively.

2.5.2 Social anxiety

The German version of the Social Phobia and Anxiety Inventory (SPAI) consists of 63 items rated on Likert scales ranging from 0 (“never”) and 6 (“always”). The resulting individual metascore as described by Barth (2003) ranges between 0 and 6. Analyzing the reliability of the SPAI questionnaire, we found that the Cronbach’s alpha was highly reliable (63 items; $\alpha = 0.95$).

2.5.3 Presence

Presence refers to the experience of “being” or “acting” in the virtual environment as if it was real and is an important concept for comparing different VR applications and ruling out confounding influences of variations in presence on study findings (Schwind et al., 2019). The Igroup Presence Questionnaire (IPQ; Schubert, 2003) is a self-report questionnaire with 14 items rated on scales ranging from -3 to 3, which are adapted to a range from 0 to 7 for the analysis. The IPQ measures spatial presence (e.g., “I felt present in the world”), involvement (e.g., “I was completely captivated by the virtual world”), and experienced realism (e.g., “How much did your experience in the VR seem consistent with your real-world experience?”) related to the experience in the virtual world. In our sample, Cronbach’s alphas showed poor reliability for the subscale of spatial presence (six items; $\alpha = 0.65$) and realism (four items; $\alpha = 0.58$), but acceptable reliability for involvement (four items; $\alpha = 0.82$; interpretation in accordance with Taber, 2018; Tavakol and Dennick, 2011).

2.6 Data analysis

To account for different measurement scales (dichotomous and continuous), place preference effects were analyzed using linear mixed models in R (LMM, version 3.5.1, R Core Team, 2018) equivalent to an ANCOVA with the between-subject factors condition (happy vs. angry) and SPAI score (continuous) and the dependent variables Δ time or Δ rating. For this analysis, the questionnaire scores were mean-centered to best address potential multicollinearity (Iacobucci et al., 2016, 2017). Pearson correlations were used to retrospectively determine the direction of the interaction between Δ time and SPAI for individual factor levels of the SPAI. The one-sided correlation analyses were conducted in the direction of the expected effect as stated by the hypothesis, with a positive correlation in the condition with the happy-looking agent, and a negative correlation in the condition with the angry-looking agent. The effect sizes for ANCOVAs were reported using partial Eta squared (η_p^2). Figures were also created in R and statistical significance was defined as $p < 0.05$.

2.7 Data and code availability

The computer code (R software version 3.5.1, R Core Team, 2018) for all analyses and figures, as well as all data, can be accessed at https://osf.io/rx5hs/.

3 Results

3.1 Experimental manipulation

3.1.1 Evaluation of agent

An ANCOVA of the post-experimentally assessed dependent variable “valence rating of agent” with the factor condition and SPAI revealed the expected (happy faces were perceived more positively) main effect of the condition (F (1,53) = 29.179, p <

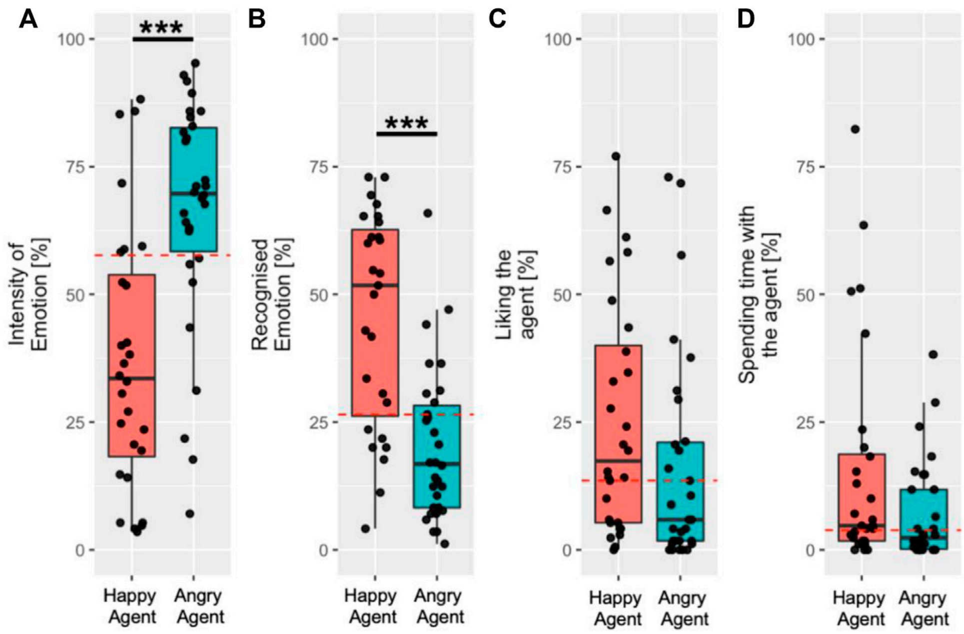

FIGURE 3
Results of post hoc analyses of post-experientially assessed evaluation of the agent. **(A)** Emotional valence ("How positive was the emotion perceived": 0% = "very negative," 100% = "very positive"), **(B)** emotional intensity ("How intensive did the emotion of the agent appear": 0% = "not intensive at all," 100% = "very intensive"), **(C)** preference for the agent ("How much was the agent liked": 0% = "I did not like the agent at all," 100% = "I liked the agent very much"), and **(D)** social preference for the agent ("Would the participant spend more time with the agent": 0% = "Would not like to spend any time with the agent," 100% = "Would like to spend a lot of time with the agent"). Each point represents the rating of one participant. Horizontal lines in the boxes: median. Boxes: +/- 1SD.

0.001, $\eta_p^2 = 0.36$) but no main effect for SPAI (F (1,53) = 0.343, $p = 0.561$, $\eta_p^2 = 0.003$) and no significant condition × SPAI interaction (F (1,53) = 29.179, $p < 0.001$, $\eta_p^2 = 0.36$; Figure 3A).

Similar analyses of the dependent variable "intensity rating of agent" demonstrated that happy agents were perceived as less emotionally intense. We observed a main effect of the condition (F (1,53) = 21.579, $p < 0.001$, $\eta_p^2 = 0.29$) but no main effect of SPAI (F (1,53) = 0.018, $p = 0.894$, $\eta_p^2 = 0.0004$) and no significant condition × SPAI interaction (F (1,53) = 0.177, $p = 0.675$, $\eta_p^2 = 0.003$; Figure 3B).

"Liking the agent" differed only slightly in the expected direction between the happy and negative agents. We observed only a trend-level (not significant) main effect of the condition (F (1,54) = 2.965, $p = 0.091$, $\eta_p^2 = 0.05$), no main effect for SPAI (F (1,54) = 0.531, $p = 0.469$, $\eta_p^2 = 0.009$), and no significant condition × SPAI interaction (F (1,54) = 1.297, $p = 0.260$, $\eta_p^2 = 0.02$; Figure 3C).

Finally, "spending time with the agent" also differed only at the trend level between the happy and angry agents. We observed a trend-level main effect for the condition (F (1,54) = 3.513, $p = 0.066$, $\eta_p^2 = 0.06$), no main effect for SPAI (F (1,54) = 0.179, $p = 0.673$, $\eta_p^2 = 0.003$), and no significant condition × SPAI interaction (F (1,54) = 0.276, $p = 0.601$, $\eta_p^2 = 0.005$; Figure 3D). Because of the between-subject design, the participants did not directly compare the happy and angry agents.

3.1.2 Pre-experimental response biases

Pre-experimental response biases were assessed using four strategies. First, we analyzed the time participants spent during the habituation phase in the room where the agent was later presented during the conditioning phase. These analyses revealed no significant main effect of the condition (F (1,54) = 0.054, $p = 0.817$, $\eta_p^2 = 0.0003$), SPAI (F (1,54) = 0.019, $p = 0.8915$, $\eta_p^2 = 0.001$), and no significant condition × SPAI interaction (F (1,54) = 3.320, $p = 0.074$, $\eta_p^2 = 0.060$). Second, we excluded potential biases in the choice of room side (left vs. right) in the habituation phase (before conditioning) using chi-square tests (X^2 (3, $N = 58$) = 0.884, $p = 0.829$). Third, we verified that the floors and images allowed for clear differentiation between rooms by asking the participants after the experiment in which room they had encountered a person and in which room they saw a computer (the neutral object). All but one participant were able to correctly identify the associated room. Finally, concerning the assessment of social anxiety, neither the time point when the questionnaire was applied (before or after the experiment) nor the two experimental groups differed significantly (both $p > 0.05$).

These results indicated the absence of initial place preferences or social anxiety effects before conditioning, thus representing ideal preconditions to reliably investigate the effect of SCPP or SCPA.

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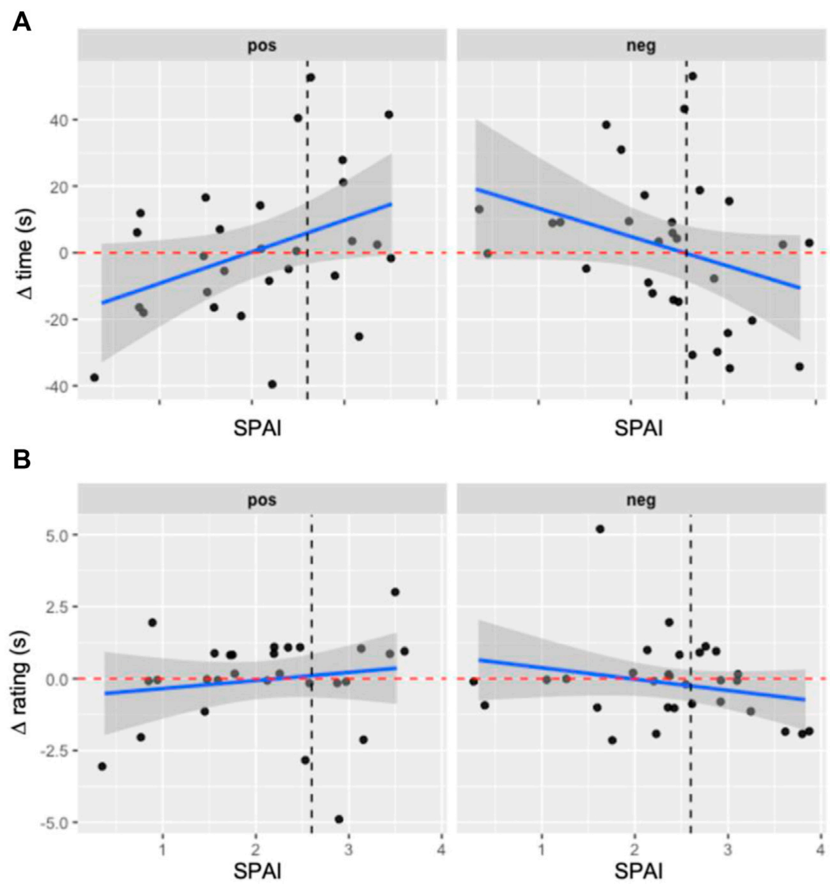

FIGURE 4
Results of explorative correlational analyses between individual differences in trait social anxiety (SPAI) and variations in behavioral (Δ time) and verbal (Δ rating) measures indicating the SCPP/SCPA effect. The SPAI scores are depicted on the *x*-axis, while **(A)** Δ time (time spent in the room in which the agent was presented during conditioning minus the time spent in this room during habituation) and **(B)** Δ rating (preference rating of the room in which the agent was presented during conditioning minus the rating of this room during habituation). A happy-looking agent was presented to half of the participants (left); the other group encountered an angry-looking agent. All graphs depict social anxiety (SPAI score) on the horizontal axis and change in place preference on the vertical axis. Blue line: approximated regression slope. Gray area: estimated error of the linear model.

3.2 Social place preference and social place aversion

To test our hypotheses regarding the presence of SCPP and SCPA effects and the moderation of SCPP and SCPA effects by social anxiety, we conducted two ANCOVAs with the factors condition (happy vs. angry) and SPAI scores; one each with the dependent variables Δ time and Δ rating. The means of Δ time for the SCPP and SCPA groups were 1.25 s (*SD* = 22.07) and 1.66 s (*SD* = 22.32), respectively. The ANCOVA for Δ time revealed no significant main effect for the condition (F (1,54) = 0.002, $p = 0.961$, $\eta_p^2 = 0.0004$) and no main effect for SPAI (F (1,54) = 0.025, $p = 0.875$, $\eta_p^2 = 0.0004$); however, a significant interaction between the condition and SPAI was observed (F (1,54) = 7.745, $p = 0.007$, $\eta_p^2 = 0.13$). Explorative follow-up correlation analyses of the interaction within the happy agent group showed a significant association between a higher Δ time and higher levels of trait social anxiety ($r = 0.38$, $p = 0.022$, Figure 4A). The corresponding analysis within the angry agent group suggested the opposite association, i.e., a negative correlation between Δ time and SPAI ($r = -0.33$, $p = 0.039$, Figure 4B).

The means of Δ preference ratings for the SCPP and SCPA groups were -0.17 (*SD* = 1.44) and −0.04 (*SD* = 1.66), respectively. The corresponding ANCOVA for the dependent variable Δ rating showed no significant main effect for the condition (F (1,54) = 0.077, $p = 0.782$, $\eta_p^2 = 0.001$), no significant main effect for SPAI (F (1,54) = 0.085, $p = 0.771$, $\eta_p^2 = 0.001$), and no significant interaction between the condition and SPAI (F (1,54) = 2.01, p = 0.162; η_p^2 = 0.04; Figures 4C,D).

3.3 Post hoc analysis

3.3.1 Presence in virtual reality

Presence in VR was assessed after the experiment with the IPQ containing three subscales that were separately analyzed. First, an ANCOVA for "experienced realism" and the factors condition and SPAI showed a significant main effect of SPAI (F (1,54) = 5.118, p = 0.028, η_p^2 = 0.03). Participants with higher SPAI scores rated the VR experience as more realistic (r = 0.291, p = 0.027); however, no main effect of condition (F (1,54) = 1.396, p = 0.873, η_p^2 = 0.09) and no significant condition × SPAI interaction (F (1,54) = 0.026, p = 0.872, η_p^2 = 0.0004) was observed. However, "experienced realism" was not associated with room ratings, dwell time, or the interaction with the two conditions (all $p > 0.05$). For the other two IPQ subscales, no significant effects were observed (all $p > 0.05$).

4 Discussion

The present study retranslated the SCPP/SCPA test, a well-established paradigm in animal research, to a VR paradigm for humans. We introduced a happy- vs. angry-looking virtual agent in one of two virtual museum rooms. Our first hypothesis was that agents with happy (versus angry) facial expressions would induce SCPP (versus SCPA). Specifically, we expected that these social encounters would affect later behavior in these rooms, which would be measured as differences in dwell time (analogous to findings reported in animal research) and room preference ratings. We also expected that trait social anxiety moderates these effects, as an angry facial expression assumably triggers social fear.

4.1 Social conditioned place preference in virtual reality

Our first hypothesis, that place conditioning, as induced by happy- vs. angry-looking virtual agents, elicits a general preference or aversion effect in humans, respectively, could not be confirmed. Neither the time spent in the room with the agent nor the preference ratings of that room changed significantly between habituation (pre-conditioning) and the test phase (post-conditioning). Our second hypothesis, that the SCPP/SCPA effects are moderated by individual differences in trait social anxiety, was confirmed for the behavioral measure of dwell time, but not for the verbal ratings (although the results pointed in the expected direction). Specifically, the results of our correlation analyses suggested that an increase in trait social anxiety was associated with stronger SCPP effects, i.e., more time spent in the room where the happy agent was previously encountered. Similarly, we observed that an increase in trait social anxiety was associated with stronger SCPA effects, i.e., less time spent in the room where the angry agent was previously encountered. Although our sample size was relatively small for the correlation analyses and would benefit from replicate trials, these preliminary findings advance the literature.

Specifically, our findings can be interpreted against a broad background of studies identifying differences in the perception, processing, and conditioning toward emotional faces in people with social anxiety (Mühlberger et al., 2008; Wieser et al., 2009; Torro-Alves et al., 2016; Reichenberger et al., 2020), both in VR and reality. Compared to these investigations, our participants had not been diagnosed with social anxiety disorder. The continuous association between individual differences in trait social anxiety and variations in the extent of the avoidance and approach of negative and happy facial expressions, respectively, may suggest that emotional faces are not only relevant in social anxiety disorder but are generally a fundamental guide to human social behavior—at least in women (Öhman et al., 2009; Schmidt et al., 2001). Ultimately, this points to a more dimensional understanding of social anxiety as proposed by Ruscio (2010), and is further supported by recent research findings (Alvi et al., 2020; Rice, 2021).

Several factors could explain the absence of general SCPP or SCPA effects. First, our manipulation of the virtual agents' facial expressions might not have been strong enough. Although the happy agent was perceived as more positive, it was also perceived as less emotionally intense. Moreover, the two other assessed agent dimensions ("liking the agent" and "spending time with the agent") differed only at a trend level in the expected direction between the two conditions. Therefore, future studies could improve the facial expressions, especially for the happy agent, to reach the same emotional intensities between the angry and happy virtual faces. Second, the number of conditioning trials in our study was lower than those in comparable animal paradigms. Animal studies usually use conditioning setups lasting for 1–2 weeks, with single and multiple sessions per day, ranging in length from a few minutes up to 30 minutes (Douglas et al., 2004; Ikemoto and Donahue, 2005; Dixon et al., 2013; Kummer et al., 2014; Golden et al., 2017). Although we implemented a relatively low number of conditioning trials to reduce simulator sickness, future studies may find ways to reduce VR sickness by other means to allow higher numbers of conditioning trials and evaluate their potential to elicit stronger SCPP/SCPA effects. Finally, our study participants did not directly compare the positive and negative facial expressions but rather compared them to a neutral, non-social stimulus (computer on a desk). Although animal research also frequently compares different (social) conditions to another (neutral) condition (Thiel et al., 2008; Kummer et al., 2014), contrasting both agents (happy and angry) might directly increase the SCPP/SCPA effect.

4.2 Study of SCPP in humans based on self-ratings

In addition to investigating the behavioral effects analogous to those in animal studies, our human SCPP/SCPA paradigm allows comparisons of the subjective evaluations of the rooms *via* self-ratings. Regarding our verbal measures, we did not detect any significant effect on general SCPP/SCPA or the moderating role of trait social anxiety. However, the interactions with social anxiety pointed in the same direction as the behavioral dwell time measures and demonstrated trend-level significance ($p < 0.1$). As indicated by our recent meta-analysis (Linhardt et al., 2022), the CPP effects in verbal ratings generally show only small effect sizes and are much weaker than the effects in behavioral measures. Since our power analysis to determine the sample size was based on previous effect sizes of behavioral measures, our power to detect effects in verbal measures might have been too low. A post hoc power analysis showed that we had only 70% statistical power to detect effects (Cohen's $d = 0.33$) within our sample ($N = 58$, $\alpha = 0.05$). Therefore, the sample size in this first exploratory was too small to detect these relatively weak effects with sufficient statistical power.

Our observations of generally smaller effect sizes in verbal self-ratings compared to behavioral measures as well as the significant interaction with social anxiety only for behavioral measures but not for self-ratings sheds light on the question of whether contingency awareness is essential for producing a conditioned reaction. While single-process models suggest that explicit knowledge is essential to produce a conditioned reaction (such as avoidance) (Hogarth et al., 2006; van den Akker et al., 2013), dual-process models assume two parallel processing routes—one leading to conscious contingency awareness and one leading to the production of the conditioned reaction (detailed discussion and review of both models: Lovibond and Shanks, 2002). Especially against the background of potential clinical applications (for instance, different treatment approaches might be required for conscious vs. unconscious aspects), future research is needed to investigate the extent to which contingency awareness might be necessary for conditioned social avoidance. SCPP paradigms might provide a useful means to address these questions when both behavioral and self-ratings assessing contingency awareness are included in the experimental setup of the study.

4.3 Future directions and technical implications

Our findings suggest the following considerations for future studies. First, our evaluation of SCPP/SCPA effects in VR in human adults relied on an exclusively female sample. We did this to reduce the complexity and avoid the potential effects of sex (e.g., matched vs. different sexes in participant and agent). However, future studies should systematically assess whether our observed effects also apply to men. This is especially important as disorders to which individuals with high trait social anxiety levels are predisposed, i.e., social anxiety disorders (Schneier et al., 2002), are not only more prevalent in women than in men but are also characterized by higher severity in women (reviewed in Asher et al., 2017). One potential explanation for this finding is the self-constructural theory (Cross and Madson, 1997; Cross et al., 2011), which suggests that women construct and maintain an interdependent self-construal, in which others represent parts of the self (Markus and Kitayama, 1991), while men construct a more independent self-construal with others being separate from the self. However, men with social anxiety disorder more often seek treatment compared to women (Asher et al., 2017).

Second, future studies should increase the probability of detecting SCPP or SCPA effects in humans with VR paradigms by improving the realism. Our unconditioned social cue (i.e., the happy- vs. angry-looking agent), while being animated, did not interact directly with participants and was also rated as showing a relatively low emotional intensity. Although direct interactions might reduce standardization (as people differ in their interactions), this might improve realism (Kummer et al., 2011). For example, specific VR setups have been developed using 3D-scanned or reconstructed models of positively associated known people, such as family, friends, or celebrities (Achenbach et al., 2017; Latoschik et al., 2017; Waltemate et al., 2018).

Third, social deprivation of animals before social conditioning may contribute to stronger effects in animal research (Douglas et al., 2004). Although this cannot be assessed in humans, the amounts of social encounters before the experiment might be worth including as a covariate (control variable) in future human SCPP research.

Fourth, as 36 participants in our study were compensated with money and 22 with student credits, we cannot rule out the potential effects of different compensation methods on the study findings. Although we consider the confounding influences to be relatively unlikely (as the participants chose their preferred compensation method), future studies should provide the same compensatory method for the entire study sample.

Fifth, future research should confirm the moderating role of social anxiety on SCPP/SCPA effects and also consider other personality traits that may act as moderators on individual approach and avoidance behaviors. For example, in one of the most influential personality theories, Gray (1972) proposed two opposing behavioral systems, the behavioral activation system (BAS) and the behavioral inhibition system (BIS) that contribute to individual differences in stable approach and avoidance tendencies (see also Smits and Boeck, 2006; Corr and McNaughton, 2012). Thus, the BIS/BAS inventory (Carver and White, 1994) might be an additional measure for future SCPP research in humans. The State-Trait Anxiety Inventory

(STAI, Spielberger, 1983) to assess individual variations in trait anxiety and the NEO-FFI (Costa and McCrae, 1989) as a brief personality assessment (Big-5) are additional promising candidate questionaries.

Finally, our study has several technical implications that are of societal relevance and that might be useful to consider in the context of investigating the mechanisms underlying anxiety or substance abuse disorders and developing new treatments. Although the cues that are feared in social anxiety disorder (e.g., negative social interactions and angry facial expressions) are much more complex than those feared in specific phobias (e.g., spiders and dogs), the results of our study demonstrated that even those complex stimuli can effectively be modeled in VR. In contrast to CPP with real human agents, VR allows for a much higher degree of standardization as, e.g., the agents themselves, their facial expressions, and their timing can be perfectly matched between different participants and different conditions. Our paradigm could be easily adapted in several directions. One such direction could be to generate a set of facial expressions of varying intensity levels. These standardized expressions could then be used to assess generalization effects related to social anxiety. Our paradigm could also be further developed for treatment purposes–especially for creating new personally tailored therapies. For instance, if a person feared large old men (e.g., due to trauma), virtual agents could be created to match this maximal feared prototype (CS+), a least feared person (e.g., a friend, safety cue; CS-), and several intermediate agents. Stepwise exposure beginning with the least feared agent and then slowly moving toward the maximally feared agent (known in clinical psychology as gradual exposure; McGlynn et al., 1981) would represent one potential use of VR in anxiety treatment, which would have not been possible without these new technologies. Patients with different mental disorders have benefitted from VR-based treatments, and, overall, patients seem to be committed to VR-based therapies (Vincelli, 1999; Riva, 2005, 2009; Emmelkamp and Meyerbröker, 2021). Lastly, SCPP paradigms provide an "objective" behavioral measure for the severity of social anxiety disorder and could, thus, also be used to evaluate treatment outcomes by comparing variables such as dwell time and self-ratings before and after treatment.

4.4 Conclusion

This study is the first to investigate whether SCPP and SCPA paradigms can be retranslated to the study of social approach and avoidance behavior in adult women. We introduced happy- vs. angry-looking agents and achieved high ecological validity despite high standardization by using VR. Although our results did not demonstrate the expected overall effect of SCPP or SCPA, they suggested that SCPP and SCPA effects in humans might be critically moderated by personality traits such as stable individual tendencies in social anxiety. The advent of this promising field of research provides opportunities to further understand the mechanisms of social approach and avoidance but also presents challenges. The further development of VR applications and a stronger consideration of personality traits are two potential routes for future research to develop effective personalized treatment approaches for mental disorders.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/ Supplementary Material.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Psychological Institute of the Faculty of Human Sciences of Würzburg University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

DK, PP, and KH contributed to the study concept and design. DK collected the data. DK and KH analyzed the data. DG supported the data analysis and wrote the R code for the analysis of movement behavior. KH wrote the manuscript. All authors provided critical feedback during manuscript preparation.

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Conflict of interest

PP is a shareholder of the commercial company VTplus, which develops and sells virtual environment systems for clinical and scientific purposes in the fields of psychology, psychiatry, and psychotherapy.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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