The relevance of social-emotional learning processes for the development, maintenance, and therapy of social anxiety

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Abstract

Social Anxiety Disorder (SAD) is with 6 – 12 % highly prevalent in the general population and social anxiety affects many people, restricting their personal, social, and professional life (Fehm, Pelissolo, Furmark, & Wittchen, 2005; Kessler et al., 2005; Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012). Women develop an SAD nearly twice as often as men (Fehm et al., 2005; Ohayon & Schatzberg, 2010). Learning models like fear conditioning may depict a significant pathogenesis in anxiety disorders (LeDoux, 2014; Lissek et al., 2005; Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006). Investigating the underlying mechanisms of the development and maintenance of SAD, virtual reality (VR) as new research utilization is a promising tool for fear conditioning (Diemer, Mühlberger, Pauli, & Zwanzger, 2014; Mühlberger, Herrmann, Wiedemann, Ellgring, & Pauli, 2001; Mühlberger, Wiedemann, & Pauli, 2003; Shiban et al., 2017; Shiban et al., 2016b; Shiban, Schelhorn, Pauli, & Mühlberger, 2015b). Shiban, Reichenberger, Neumann, and Mühlberger (2015a) established a useful social fear conditioning (SFC) paradigm to investigate the underlying mechanisms in learning and unlearning social anxiety in humans.

The present dissertation project has four main research goals. The first research aim is to examine if a social threat (e.g., spitting and verbal insult) triggers sensitively more fear responses than an unspecific threat (e.g., electrical stimulation) as unconditioned stimulus (US) in socially anxious participants. The second research goal is to unravel the underlying mechanisms of the gender differences in social anxiety. The third research aim is to investigate the effect of induced and extinguished social fears on gaze behavior (e.g., hypervigilance and attentional avoidance) towards ecological valid socially relevant stimuli in high and low socially anxious individuals. The fourth research goal is to validate virtual social interaction scenarios for psychotherapeutic interventions like social skills training in VR. To this end, four empirical studies were conducted.

In the first study, 43 healthy students actively approached (via a joystick) diverse virtual male agents serving as conditioned stimuli (CS). Participants were randomly allocated to a social threat condition or a conventional electroshock condition. In the social threat condition, the US was spitting (air blast with 2 bar, 10ms) followed by a verbal insult of the agent. In comparison, an electrical stimulation to the participants' lower arm served as the US in the electroshock condition. In 75 % of the conditioning trials, the US was presented as soon as the participant reached the agent (CS+) until a distance of 30 cm where navigation stopped, whereas the other agent (CS-) was not paired with an US. The results regarding the subjective outcome variables showed that SFC was successfully induced and extinguished in healthy participants in VR. Furthermore, the distinction between the CS+ and CS- was significantly greater in the social threat than in the conventional electroshock condition, which reflects a more sensitive differentiation between aversive and non-aversive stimuli in fear learning. Physiological and behavioral outcome variables revealed successful fear conditioning at the beginning of the acquisition, but showed a fast habituation during fear acquisition and extinction.

In the second study, 31 low (LSA) and 29 high socially anxious (HSA) women and men actively approached female and male CS+ and CS- agents. In the conditioning trials, the contingency of the US (spitting and verbal insult) was 75 %. It could be shown that SFC was successfully induced and extinguished concerning each level of emotional reactions including fear ratings, fear-potentiated startle, and avoidance behavior. Concerning gender differences in social anxiety, women reported higher fear ratings than men, and HSA women obtained a significantly larger avoidance behavior to male vs. female agents, whereas HSA men showed no such differentiation. Furthermore, HSA demonstrated a general larger avoidance behavior to agents than LSA participants. Moreover, fear-potentiated startle results point out significantly better social fear conditionability towards male vs. female agents.

In the third study, 27 LSA and 26 HSA students participated in the SFC paradigm in VR investigating emotional-attentional processing in social anxiety. In this study, HSA participants avoided more socially relevant threatening agents than non-threatening agents during fear acquisition, whereas LSA fixated both aversive and non-aversive agents in an equal ratio. However, no hypervigilance was found in both groups during fear acquisition.

In the fourth study, the validity of two virtual social interaction scenarios relating the social skills training by Hinsch and Pfingsten (2015) was investigated. Therefore, 23 HSA and 32 LSA students completed two scenarios in VR with the aim of improving their assertiveness. Concerning the findings, in both scenarios HSA reported significantly higher anxiety and estimated their own competency to be more negative than LSA participants. Furthermore, all participants perceived both virtual social interaction scenarios as realistic.

The first three SFC studies provide new insights into social fear conditioning and extinction of LSA and HSA participants in VR. The validation study suggests that social skills training in VR is a possible psychotherapeutic intervention for socially anxious individuals. All four studies of the dissertation project showed that social-emotional learning processes in social anxiety can be measured reliably using ecological valid socially relevant stimuli in immersive virtual environment. Prospective SFC studies should focus on comparing patients with SAD to healthy participants to examine possible discrepancies in social-emotional learning and to further develop efficient treatments for SAD.

German Abstract – Zusammenfassung

In der allgemeinen Bevölkerung ist die Soziale Angststörung weit verbreitet und soziale Ängste betreffen viele Personen, deren persönliches, soziales, und berufliches Leben dadurch eingeschränkt wird (Fehm et al., 2005; Kessler et al., 2005; Kessler et al., 2012). Frauen entwickeln fast doppelt so häufig wie Männer eine soziale Angststörung (Fehm et al., 2005; Ohayon & Schatzberg, 2010). Lernmodelle wie die Angstkonditionierung (*fear conditioning*) stellen eine signifikante Pathogenese bei Angststörungen dar (LeDoux, 2014; Lissek et al., 2005; Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006). Zur Untersuchung der zugrundeliegenden Mechanismen der Entwicklung und Aufrechterhaltung der Sozialen Angststörung ist die virtuelle Realität (VR) als neue Forschungsanwendung ein viel versprechendes Instrument zur Angstkonditionierung (Diemer et al., 2014; Mühlberger et al., 2001; Mühlberger et al., 2003; Shiban et al., 2017; Shiban et al., 2016b; Shiban et al., 2015b). Shiban et al. (2015a) etablierten ein nützliches soziales Angstkonditionierungsparadigma (SFC), um zugrundeliegende Mechanismen im Lernen und Verlernen von sozialer Angst beim Menschen zu untersuchen.

Das vorliegende Dissertationsprojekt hat vier Hauptziele. Das erste Ziel ist es, ob eine soziale Bedrohung (z.B. das Spucken mit verbaler Beleidigung) bei sozial ängstlichen Personen eine sensitiv stärkere Angstreaktion auslöst als eine unspezifische Bedrohung (z.B. elektrische Stimulation) als unkonditionierter Stimulus (US). Das zweite Ziel ist es, zugrundeliegende Mechanismen der geschlechtsspezifischen Unterschiede in der sozialen Angst zu untersuchen. Das dritte Ziel besteht darin, die Auswirkung erlernter und verlernter sozialer Angst auf das Blickverhalten (z.B. Hypervigilanz und Aufmerksamkeitsvermeidung) in Bezug auf ökologisch valide, sozial relevante Reize in hoch und niedrig sozial ängstlichen Personen zu untersuchen. Das vierte Ziel ist es soziale Interaktionsszenarien in VR für psychotherapeutische Interventionen wie z.B. das Training sozialer Kompetenzen zu validieren. Zu diesem Zweck wurden vier empirische Studien durchgeführt.

In der ersten Studie näherten sich 43 gesunde Studierende aktiv mittels Joystick verschiedenen virtuellen männlichen Agenten, die als konditionierte Stimuli (CS) dienten. Die TeilnehmerInnen wurden entweder einer sozialen Bedrohungs- oder einer konventionellen Elektrostimulationsbedingung randomisiert zugeteilt. In der sozialen Bedrohungsbedingung war der US das Spucken begleitet von einem aversiven Luftstoß (2 bar, 10 ms) gefolgt von einer verbalen Ablehnung des Agenten. In der Elektrostimulationsbedingung diente eine elektrische Stimulation des Unterarms der TeilnehmerInnen als US. In 75 % der Konditionierungstrials wurde der US präsentiert, sobald die TeilnehmerInnen den Agenten (CS+) bis zu einer Entfernung von 30 cm erreichten, während der andere Agent (CS-) mit keinem US gekoppelt war. Die Ergebnisse bezüglich der subjektiven Outcomevariablen zeigen, dass eine SFC bei gesunden TeilnehmerInnen in VR erfolgreich erlernt und verlernt wurde. Darüber hinaus war der Unterschied zwischen dem CS+ und CS- Agenten in der sozialen Bedrohungsbedingung signifikant größer als bei der konventionellen Elektrostimulationsbedingung, was eine sensitivere Unterscheidung zwischen aversiven und nicht-aversiven Stimuli beim Angstlernen widerspiegelt. Die physiologischen und Verhaltensvariablen zeigen zu Beginn der Akquisition eine erfolgreiche Angstkonditionierung, jedoch eine schnelle Habituation während der Angstkonditionierung und Extinktion.

In der zweiten Studie näherten sich 31 niedrig (LSA) und 29 hoch sozial ängstliche (HSA) Frauen und Männer aktiv weiblichen und männlichen CS+ / CS- Agenten an. In den Konditionierungstrials lag die Kontingenz des US (Spucken mit verbaler Beleidigung) bei 75 %. Es konnte gezeigt werden, dass eine SFC auf jeder Ebene der emotionalen Reaktionen (Angstratings, furchtpotentzierter Startle, und Vermeidungsverhalten) erlernt und verlernt wurde. In Bezug auf geschlechtsspezifische Unterschiede bei sozialer Angst gaben Frauen ein subjektiv höheres Angsterleben an als Männer, und HSA Frauen zeigten ein signifikant höheres Vermeidungsverhalten bei männlichen im Vergleich zu weiblichen Agenten, während

HSA Männer keine solche Differenzierung zeigten. Darüber hinaus zeigten HSA TeilnehmerInnen ein allgemein höheres Vermeidungsverhalten gegenüber Agenten als LSA TeilnehmerInnen. Des Weiteren weisen die Ergebnisse des furchtpotenzierten Startle auf eine signifikant bessere Konditionierbarkeit sozialer Angst auf männliche im Vergleich zu weibliche Agenten hin.

In der dritten Studie nahmen 27 LSA und 26 HSA Studierende am SFC-Paradigma in VR teil, um die emotional-aufmerksamkeitsbasierte Verarbeitung bei sozialer Angst zu untersuchen. In dieser Studie zeigten HSA TeilnehmerInnen durch die Angstkonditionierung eine stärkere aufmerksamkeitsbasierte Vermeidung auf sozial relevante bedrohliche Agenten im Vergleich zu nicht bedrohlichen Agenten, während LSA TeilnehmerInnen sowohl aversive als auch nicht-aversive Agenten gleichermaßen häufig fixierten. Während der Angstkonditionierung wurde in beiden Gruppen jedoch keine Hypervigilanz gefunden.

In der vierten Studie wurde die Validität von zwei virtuellen Interaktionsszenarien in Anlehung an das soziale Kompetenztrainging von Hinsch und Pfingsten (2015) untersucht. Dafür absolvierten 23 HSA und 32 LSA Studierende zwei Szenarien in VR mit dem Ziel ihre Durchsetzungsfähigkeit zu verbessern. In Bezug auf die Ergebnisse berichteten HSA TeilnehmerInnen in beiden Szenarien signifikant höheres Angsterleben und schätzten ihre eigenen Kompetenzen negativer ein als LSA TeilnehmerInnen. Des Weiteren empfanden alle TeilnehmerInnen die zwei virtuellen sozialen Interaktionsszenarien als realistisch.

Die ersten drei SFC-Studien geben neue Einblicke in die soziale Angstkonditionierung und Extinktion von LSA und HSA TeilnehmerInnen in VR. Die Validierungsstudie deutet darauf hin, dass ein soziales Kompetenztraining in VR als mögliche psychotherapeutische Intervention für sozial ängstliche Personen verwendet werden kann. Alle vier Studien des Dissertationsprojekts zeigen, dass sozial-emotionale Lernprozesse bei sozialer Angst mit Hilfe ökologisch valider, sozial relevanter Stimuli in immersiver virtueller Umgebung zuverlässig gemessen werden können. Zukünftige SFC-Studien sollten sich darauf konzentrieren, PatientInnen mit Sozialer Angststörung mit gesunden TeilnehmerInnen zu vergleichen, um mögliche Diskrepanzen in sozial-emotionalen Lernprozessen zu untersuchen sowie effiziente Behandlungen für die Soziale Angststörung weiter zu entwickeln.

Outline

The present dissertation project is a summary of my research work conducted at the Institute for Psychology at the Department of Clinical Psychology and Psychotherapy at the University of Regensburg. I planned and conducted four empirical studies that aimed to systematically investigate the relevance of social-emotional learning processes for the development, maintenance, and therapy of social anxiety.

The dissertation project consists of an introduction, the empirical work (four peer-reviewed studies), and a discussion part. First of all, a general theoretical background of characteristics and prevalence of social anxiety disorder (SAD) and well elaborated etiology models of SAD are introduced. In the context of learning theory models, fear conditioning paradigms which may depict central development and maintenance of anxiety disorders are presented. Moreover, empirical findings in fear conditioning as well as their current methodological limitations are discussed. Afterwards, virtual reality as a new research tool and a promising social fear conditioning paradigm and its advantages in investigating the underlying mechanisms of development and maintenance of SAD is introduced. At last, the importance of measuring behavioral responses and current treatments for SAD as well as possible strengths in the application of treatments in VR are given. Finally, the research objectives defined for the dissertation project are reported.

In the empirical work part, four peer-reviewed studies, which were carried out and published in international journals, are presented. Each published study is included with permission from the publishers.

Afterwards, a general summary and discussion of the empirical results, general strength, and limitations of the dissertation project, and an outlook on future anxiety research and practical implications are given.

1. Introduction

1.1 Definition of Social Anxiety Disorder

Social anxiety disorder is defined as an intense anxiety of social or performance situations in which the individual is confronted by unknown persons or could be judged by others (American Psychiatric Association, 2013). Avoidance or escape (e.g., not to visit or leave socially threatening situations), safety behavior (e.g., strategies to prevent an anticipated embarrassment), and socially inadequate behavior (e.g., awkward, self-conscious, or distanced behavior, as well as deficient social perception) as typical behavioral patterns are associated with SAD (Stangier & Fydrich, 2002a).

Epidemiological studies reported a lifetime prevalence of 12-13 % in the general population in the USA (Kessler et al., 2005; Kessler et al., 2012) as well as a median lifetime prevalence of 6.7 % (Fehm et al., 2005), a 12-month prevalence of 2.3 % (Wittchen et al., 2011), and a point prevalence of 4 % (Ohayon & Schatzberg, 2010) for Europe. These values show that SAD is highly prevalent in the general population and social anxiety affects many people restricting their personal, social, and professional life. If people also withdraw from their social contacts, there is a high comorbidity with depression (Stein & Kean, 2000).

Furthermore, women develop an SAD nearly twice as often as men (Fehm et al., 2005; Ohayon & Schatzberg, 2010; Wittchen & Jacobi, 2004). However, there are also empirical findings in clinical samples that no gender differences or even weakly higher frequencies for men have been found. Possible reasons could be that affected men seem more likely to seek help than women (see review from Fehm et al., 2005). Thus, more research is needed to examine possible gender differences in SAD.

1.2 Etiology of Social Anxiety Disorder

There are a variety of explanatory concepts for SAD. The best-known psychological models for the etiology of SAD are learning theories, like classical fear conditioning (Pavlov, 1927) or operant fear conditioning (Skinner, 1951), and the cognitive behavioral theory (Beck, Emery, & Greenberg, 2005; Clark & Wells, 1995; Rapee & Heimberg, 1997), which are often used in empirical research.

Learning theory models are the oldest explanatory approaches to fear and anxiety. Classical fear conditioning means that an organism learns to link two stimuli with each other (Pavlov, 1927). For example, if a student recites a poem (neutral stimulus) and hears a listener randomly laughing (unconditioned stimulus: US), the student may answer with a fear response (unconditioned response: UR). Now, the previously neutral stimulus (reciting a poem) becomes the conditioned stimulus (CS) and causes the new learned fear response (conditioned response: CR). In this context, the tendency of generalization plays an important role, because the same fear response could be shown to all similar stimuli (Hermann, 2002). For example, this could mean an extension of the fear response to other speech situations. Hermann (2002) stated that especially persons with SAD do not experience a reduction of their anxiety by repeated experience of the absence of the feared consequence (e.g., to be embarrassed or rejected), because in SAD a complex stimulus configuration serves as CS, which in very rare cases is systematically repeated without the anticipated negative consequence. The diversity of social situations that results from the different interaction partners is likely to complicate the extinction of social anxiety (Hermann, 2002). According to the two-factor theory, the maintenance of anxiety is due to the negative reinforcement of avoidance behavior (Hull, 1943; Mowrer, 1960). Extinction learning is a core mechanism in exposure treatment for anxiety disorders (please see the review from Craske et al., 2008). Extinction is not assumed to be a kind of forgetting, but rather a new learning process within the fear network, which inhibits the acquired fear expression (Bouton, 1994, 2004; Ewald et al., 2014).

In the case of operant fear conditioning, which may even be relevant for developing anxiety disorders, the consequences of a specific behavior lead to a changed probability of occurrence of the behavior (Skinner, 1951). In operant learning processes, a distinction must be made between positive (e.g., compliment, appreciation) and negative reinforcement (e.g., removal of punishing consequences, avoiding unpleasant situations), punishment or aversive consequences (e.g., rejection, derision, offending), and deletion (e.g., not paying attention to the behavior). For example, if an employee voluntarily demonstrates a self-conceived new work method, which is squired by harsh negative feedback of his boss, the employee might no longer present possible work methods voluntarily in the future.

The cognitive behavioral models highlight biases in the processing of threatening information and stimuli due to dysfunctional cognitive schemata (Beck et al., 2005). These models emphasize the biased cognitive self-representation, which is caused by selective self-attention, deficient memory processes, false attributions of behavioral symptoms, and is sustained by safety behaviors (Clark & Wells, 1995). In comparison, Rapee and Heimberg (1997) highlight that even the supposed standards of potential observers induce the expectation of being viewed as embarrassing and rejected by others. For example, individuals with SAD overestimate negative consequences of social events, while they underestimate the probability of positive confrontations (for a review specifically on expectancy and attention bias, see Aue & Okon-Singer, 2015).

Fear conditioning paradigms are relatively simple procedures and good translational models for the investigation of the acquisition and extinction of anxiety. Therefore, they are commonly utilized in empirical research as central pathogenic pathways in anxiety disorders (Baas, Nugent, Lissek, Pine, & Grillon, 2004; Lissek et al., 2008; Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006). In addition, fear conditioning and cognitive behavioral models can also be combined to systematically examine different aspects of social-emotional learning processes for the development, maintenance, and therapy of social anxiety.

1.3 Fear Conditioning Paradigms

Fear conditioning models may depict a significant pathogenesis in anxiety disorders (LeDoux, 2014; Lissek et al., 2005; Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006). Further fear conditioning paradigms of aversive learning involve generalization processes (Andreatta, Neueder, Glotzbach-Schoon, Mühlberger, & Pauli, 2017; Dunsmoor & Murphy, 2015; Dunsmoor & Paz, 2015; Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015; Lissek & Grillon, 2010; Vervliet & Geens, 2014), contextual stimuli (Glotzbach-Schoon, Andreatta, Mühlberger, & Pauli, 2013; Shiban, Pauli, & Mühlberger, 2013), and more complex operant or instrumental conditioning (Lissek et al., 2005; Shiban et al., 2015a). Relating to Lang's fear response systems (Lang, 1968), the conditioned fear response can be measured with self-reports (e.g., fear and contingency ratings), physiological (e.g., fear-potentiated startle, skin conductance, heart rate), and even behavioral responses, like approach-avoidance behavior in form of eye and head movements as well as interpersonal space between the participant and a stimulus or person (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Kinateder et al., 2015; Mertens, Boddez, Sevenster, Engelhard, & De Houwer, 2018; Mühlberger, Bülthoff, Wiedemann, & Pauli, 2007; Mühlberger, Weik, Pauli, & Wiedemann, 2006; Powers & Emmelkamp, 2008; Shiban et al., 2016b; Shiban et al., 2013). Moreover, it is important to note that emotions comprise subjective, physiological, and behavioral response systems which should all be measured because these diverse responses do not necessarily converge sufficiently with each other (Bradley & Lang, 2000; Lonsdorf et al., 2017; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Mauss & Robinson, 2009). Furthermore, the advantage of assessing physiological responses is that these outcome measures are less prone to bias and less conscious than self-reports (Lonsdorf et al., 2017). Beckers et al. (2013) and Mertens et al. (2018) recommend including behavioral responses like approach-avoidance behavior in fear conditioning models besides assessing self-reports and psychophysiology. Apart from, expanding behavioral tendencies as central outcome variable of fear, aversive learning situations with more uncertainty and complexity should be taken into account in human fear conditioning studies (Beckers et al., 2013; Glotzbach, Ewald, Andreatta, Pauli, & Mühlberger, 2012; Lissek, Pine, & Grillon, 2006). Further methodological considerations for the design, methods, and analysis in fear conditioning research are given by Lonsdorf et al. (2017).

With regard to the diathesis-stress model of psychopathology, also individual differences in personality traits or trait vulnerability to anxiety are predictive (Beckers et al., 2013; Indovina, Robbins, Núñez-Elizalde, Dunn, & Bishop, 2011; Mertens et al., 2018). Moreover, psychosocial stress, which can be induced by the Trier Social Stress Test, influences fear conditioning in both genders differently (Jackson, Payne, Nadel, & Jacobs, 2006; Merz et al., 2013; Zorawski, Blanding, Kuhn, & LaBar, 2006). Furthermore, a number of studies indicate that men use relatively more problem-focused coping strategies or avoidant behaviors whereas women more likely show behavior that involve social support seeking and emotion-oriented strategies when they are confronted with a stressor (for a review see Eschenbeck, Kohlmann, & Lohaus, 2015; Tamres, Janicki, & Helgeson, 2002). These empirical evidences might confirm the diverse prevalence in women and men developing anxiety disorders. Therefore, differences in gender and fear conditionability between more and less prone factors should be emphasized more in the field of aversive learning models. Based on these findings and different prevalence, the underlying mechanisms of gender differences in social anxiety are investigated in the present dissertation project.

Lissek et al. (2005) reported in a single-cue conditioning procedure that anxiety patients exhibit enhanced fear conditioning to CS+ than healthy humans. Duits et al. (2015) state in their review that during fear acquisition enhanced fear responses to CS- stimuli consist in anxiety patients than in healthy controls and an increased fear response to CS+

stimuli during fear extinction. The authors assume that impaired inhibitory fear learning exists in the presence of a non-threatening stimulus, and delayed or reduced fear extinction in individuals with an anxiety disorder.

One limitation in fear conditioning is that stimuli with low ecological validity relating to the nature of SAD are used (e.g., electrical stimulation or simple sensory geometric cues) in most published studies. Therefore, it is still not clear if individuals with social anxiety show sensitively more response to socially relevant cues. As one of the first, Hamm, Vaitl, and Lang (1989) investigated the effect of diverse CS-US belongingness in fear learning processes and found that higher CS-US belongingness has an advantage over lower CS-US belongingness in generating stronger fear responses and higher resistance to extinction. Moreover, Lissek et al. (2008) highlight that disorder-relevant US should be taken more into account investigating emotional learning processes, because socially relevant US are important in aversive learning. Furthermore, Ahrens et al. (2016) accentuate that fear learning in everyday life implicates much more complex stimuli varying in each psychopathology. Therefore, Lissek et al. (2008) investigated in an ecologically enhanced social conditioning paradigm fear learning mechanisms in patients with SAD vs. healthy controls presenting socially relevant US of critical facial expressions and verbal feedback. The authors found enhanced conditioned fear responses (unpleasantness ratings and fear-potentiated startle) in persons with SAD compared to healthy controls, which indicate the importance of using disorder-relevant US to examine fear learning. According the specificity hypothesis, Tinoco-González et al. (2015) assume that a socially relevant US should reveal enhanced fear conditioning in persons with SAD than in other anxiety patients or healthy controls. However, they did not find enhanced fear conditioning in social anxiety. Ahrens, Mühlberger, Pauli, and Wieser (2015) indicated in a discrimination fear learning of socially conditioned stimuli (different faces with insults, compliments, or neutral comments) impaired discrimination ability between relevant and irrelevant social stimuli in high compared to low socially anxious participants. A further study by Ahrens et al. (2016) revealed that SAD is associated with deviances in fear responses to conditioned (fearful face and a shrill scream) as well as generalized threat stimuli (morphing the two CS+ and CS- faces in 20 % steps).

The current dissertation project examines if a social threat (e.g., verbal insult and spitting) triggers sensitively more fear responses than an unspecific threat (e.g., electrical stimulation) as US in socially anxious participants.

1.4 Social Fear Conditioning in Virtual Reality

To overcome these methodological limitations, virtual reality is meanwhile a well-established research method to investigate social-emotional learning processes in an immersive virtual environment with a high ecological validity. Virtual reality is a computer simulation that creates the illusion of being fully immersed in a virtual world to the user. In the recent years, the graphical possibilities have improved significantly, while the costs decrease continually (Rizzo & Koenig, 2017). Typically, the computer-generated environment is presented by wearing a head-mounted display (HMD), headphones and diverse tracking systems that transmit body motion to the VR in real time. Other presentation options are projection systems such as the Cave Automatic Virtual Environment (CAVE) or curved screens (Bombari, Schmid Mast, Canadas, & Bachmann, 2015; Rebenitsch & Owen, 2016; Schroeder, Mühlberger, & Plewnia, 2015).

There are different process variables like presence and immersion in the context of VR. Presence describes the users' experience of being present in the virtual environment (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015a; Diemer & Zwanzger, 2019; Oh, Bailenson, & Welch, 2018). Empirical evidence show that a high level of presence is not only dependent on the quality of VR technique, but is also determined by the emotional value of the VR presentation (Diemer et al., 2015a). In contrast, immersion is objectively measurable and refers to the technical characteristics of a VR system (e.g., used displays, degree of resolution, graphical representation, frame rate, processing the users orientation and position in real time via tracking sensors, field of view, stereoscopy), which are responsible for the experienceable simulation (Diemer et al., 2015a; Diemer & Zwanzger, 2019; Oh et al., 2018). Diemer et al. (2015a) report in their review that the improvement of immersion contributes to an increased level of experienced presence. Furthermore, the authors set up a model that shows the connections between immersion, presence, and emotion (see review by Diemer et al., 2015a).

Although VR is a promising technology, which becomes more and more explored, different VR systems can cause side effects, like so-called cybersickness. Possible symptoms of cybersickness are nausea, headache, sweating, dizziness, disorientation, etc. (Diemer, 2019; LaViola Jr, 2000; Rebenitsch & Owen, 2016). The sensory conflict and the postural instability theory are the most commonly postulated etiology models, which suggest different factors that are responsible for cybersickness in virtual environments. The sensory conflict theory assumes a discrepancy between the sensory perception providing information according the body's orientation and motion which cause the perceptual conflict (LaViola Jr, 2000). For example, if stimuli from the environment outside the VR (e.g., proprioceptive movement perception) are perceived differently by diverse sensory perception (e.g., visual stimuli of movement), cybersickness symptoms will occur (Diemer & Zwanzger, 2019; Rebenitsch & Owen, 2016). The postural instability theory is based on body position during VR that is necessary due to stimuli of the external environment which cannot be maintained. For example, the more unstable the posture, the more symptoms of cybersickness will occur (LaViola Jr, 2000; Rebenitsch & Owen, 2016). Rebenitsch and Owen (2016) report in their review that the prevalence of cybersickness varies from 30 - 80 % depending on VR-system characteristics and the methods which are used to measure cybersickness symptoms. In the worst case, cybersickness leads to abortion of the VR presentation, but occurring symptoms rapidly decrease after simulation is finished (Diemer & Zwanzger, 2019). The risk of cybersickness can be minimized through technical adjustments (e.g., reduction of the visual field, the navigation and the movement speed, higher degree of resolution, and tracking systems in real time), but many of these impact factors still need to be explored (Diemer & Zwanzger, 2019; Rebenitsch & Owen, 2016).

The existing possibility to create an interaction in a virtual environment allows a realistic emotional confrontation with the presented stimulus in VR (Bailenson, Blascovich, Beall, & Loomis, 2003; Blascovich et al., 2002). Valid interaction scenarios in VR require a realistic representation of human gestures, facial expressions, and believable spontaneous communication options between the user and the virtual human (Blascovich et al., 2002; Bombari et al., 2015). Numerous studies showed that VR scenarios can trigger intense fear responses on a subjective, physiological, and behavioral level in healthy (Santl et al., 2019; Shiban et al., 2016a; Shiban et al., 2015a) and phobic participants (Diemer, Lohkamp, Mühlberger, & Zwanzger, 2016; Gromer et al., 2018; Mühlberger et al., 2007) similar to reactions shown during real (interaction) situations (Bombari et al., 2015). Since VR scenarios can easily be standardized and performed in a controlled laboratory setting with an economical and high ecological validity, this technique is ideal for the investigation of social-emotional learning processes. For example, the gender, age, race, or body size of a virtual human as well as the virtual environment can easily be adapted.

Hartanto et al. (2014) showed that a virtual social interaction scenario can be simulated in a credible way that facilitates different levels of anxiety (self-report and psychophysiological response). Many more VR studies reported clear stress reactions using the Trier Social Stress Test (TSST) as reliable and ecologically-valid social interaction scenario to induce psychosocial stress, which could be measured on different stress levels (Jönsson et al., 2010; Ruiz et al., 2010; Santl et al., 2019; Shiban et al., 2016a; Wallergård, Jönsson, Johansson, & Karlson, 2011). The possibility of the standardization and the specific manipulation of social interaction counterparts facilitate measuring individual differences in the behavior and a straightforward replication of these results. Using virtual humans enables high ecological validity and high standardization (Blascovich et al., 2002; Bombari et al., 2015).

Another advantage of using VR is that the perceptual level (presentation of virtual stimuli) can be easily separated from the conceptual level (knowledge of the real laboratory situation), because by presenting the virtual scenario via a HMD the participant is entirely taken out from the physical characteristics of the lab in which the investigation takes place (Dunsmoor, Ahs, Zielinski, & LaBar, 2014; Peperkorn, Alpers, & Mühlberger, 2014; Shiban, Peperkorn, Alpers, Pauli, & Mühlberger, 2016c).

Due to the combination of maximum standardization, experimental control, and high complexity of possible scenarios and multi-sensory stimuli (e.g., visual, auditive, haptic, and odor), VR is a well suited research method to investigate impact factors and emotional learning processes in anxiety disorders (Baas et al., 2004; Diemer et al., 2014; Dunsmoor et al., 2014; Ewald et al., 2014; Glotzbach-Schoon et al., 2013; Glotzbach et al., 2012; Huff, Zielinski, Fecteau, Brady, & LaBar, 2010; McCall, Hildebrandt, Hartmann, Baczkowski, & Singer, 2016; Shiban et al., 2015a).

One of the first fear conditioning study in VR context by Baas et al. (2004) investigated cued fear and contextual anxiety in healthy humans. The authors could show enhanced fear conditioning to the shock context and the CS+. Baas et al. (2004) recommend VR as innovative research method to bridge the gap between animal and human research. As one of the first, Dunsmoor et al. (2014) used virtual social stimuli (agents) to investigate social fear conditioning and extinction in healthy humans. They successfully revealed fear conditioning and extinction according to the fear-potentiated startle. In addition, Huff et al. (2010) showed similar results of fear conditioning in VR.

In contrast to traditional cued fear conditioning, social fear conditioning in VR facilitates the simulation of social interactions with high controllability and enhanced ecological validity (e.g., facial expressions of the agent paired with verbal feedback). Furthermore, participants can interact with diverse stimuli (e.g., agents) and their environment like in in-vivo social situations. Basic interaction options between the participant and the virtual human could be eye contact or approach-avoidance behavior.

The origins of social fear conditioning of humans lie in the fear conditioning of rodents, in which social interactions play a significant role in fear conditioning. Animal models still have a significant impact on the understanding of the underlying mechanisms of anxiety. The current knowledge about neural structures and key processes mediating anxiety was advanced using classical fear conditioning paradigms (see Davis, Walker, Miles, & Grillon, 2010). Toth, Neumann, and Slattery (2012) established a specific animal model of social fear in rodents and used a social fear conditioning (SFC) paradigm for this. During the exploration of a conspecific, the rodent received electric foot shocks, which lead to a reduced investigation of unfamiliar conspecifics. The authors concluded that SFC was successfully induced to a social stimulus (e.g., conspecific) not limited to the initial CS, but rather expanded even to unfamiliar conspecifics. On the next day, the social fear conditioned rodents were exposed to diverse unknown conspecifics several times in the absence of an electrical stimulation. The SFC rodents revealed the familiar social preference behavior. Thus, SFC was successfully induced and extinguished confirming a useful paradigm to investigate also neurobiological mechanisms affecting social anxiety in rodents (Lukas & Neumann, 2012; Toth & Neumann, 2013; Toth et al., 2012; Zoicas, Slattery, & Neumann, 2014).

Shiban et al. (2015a) translated the SFC animal model by Toth et al. (2012) to a human paradigm. In this experimental SFC paradigm, participants actively approached diverse virtual male anthropomorphic humans (agents) that served as conditioned stimuli (CS) in virtual reality (VR). The US for social fear acquisition was a combination of an air blast (5 bar, 10 ms) and a female scream (95 dB, 40 ms). If participants reached a specific distance to the agents (about 30 cm in real world) the US was delivered with a contingency of 75 % for

CS+ agents and never for CS- agents during the acquisition phase. No US was presented during the extinction phase. A generalization phase took place 24 h later and a third unknown agent was presented. Shiban et al. (2015a) could show that participants experienced the CS+ as significantly less pleasant than the CS- agent after fear acquisition, which was also supported by a higher heart rate for CS+ than CS-. These differences vanished during fear extinction. Interestingly, higher socially anxious participants experienced all agents less pleasant whereas lower socially anxious participants rated only the CS+ agent as less pleasant during the generalization phase. In summary, SFC was successfully induced and extinguished in a human sample and research indicates an enhanced generalization of aversive learning to unknown persons in higher socially anxious participants. Shiban et al. (2015a) established a useful paradigm to investigate the underlying mechanisms in learning and unlearning social anxiety in humans.

1.5 Behavioral Fear Responses in Social Anxiety Disorder

In the context of social anxiety research, the behavioral fear response is a central topic, because the avoidance of threatening or unpleasant stimuli and/or situations is a central diagnostic symptom of SAD (Beckers et al., 2013; Mertens et al., 2018). Furthermore, the avoidance of threat, unpleasantness, or new social situations with possible aversive consequences is a well-known feature for the development and maintenance of anxiety disorders (Dymond, Schlund, Roche, De Houwer, & Freegard, 2012; Mineka & Oehlberg, 2008).

Behavioral fear responses are typically measured as the degree of interaction with and the physical distance to the feared stimuli or situations (Mertens et al., 2018). The most used outcome variables in anxiety research are approach-avoidance responses like distance to a social stimulus or a CS (Åhs, Dunsmoor, Zielinski, & LaBar, 2015; Bailenson et al., 2003; Cartaud, Ruggiero, Ott, Iachini, & Coello, 2018; Iachini, Coello, Frassinetti, & Ruggiero, 2014; Wieser, Pauli, Grosseibl, Molzow, & Mühlberger, 2010), avoidant decision-making (Pittig, Alpers, Niles, & Craske, 2015), pressing a button to remove a CS or to avoid the US (Declercq & De Houwer, 2009; Lovibond, Chen, Mitchell, & Weidemann, 2013; Lovibond, Mitchell, Minard, Brady, & Menzies, 2009), and gaze behavior in diverse tasks (Çek, Sánchez, & Timpano, 2016; Chen & Clarke, 2017; Chen, Thomas, Clarke, Hickie, & Guastella, 2015; Shechner et al., 2017; Wieser, Pauli, Alpers, & Mühlberger, 2009a; Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009b).

In a VR study to interpersonal distance behavior in social interactions, Iachini et al. (2014) revealed that women and men approximate female agents more than male ones and that women hold a larger distance towards the agents than men. Cartaud et al. (2018) could show an increase of the electrodermal activity for angry facial expressions in the peripersonal (the area in which one is possibly vulnerable) compared to the extrapersonal (safe) space. Thus, they concluded that the comfort distance is associated with the emotional reaction of a counterpart. Accordingly, the closer a possible threat, the greater the fear responses. Åhs et al. (2015) revealed that aversive learning can increase the interpersonal defensive boundaries and the avoidance of aversive stimuli. The behavioral response to aversive and non-aversive stimuli can be measured directly and easily in VR.

A further interesting approach-avoidance behavioral outcome variable is gaze behavior, which can be assessed continuously and in real time via eye-tracking. Cognitive-behavioral models suggest information processing biases in the development and maintenance of SAD (Aue & Okon-Singer, 2015; Clark & Wells, 1995; Rapee & Heimberg, 1997). Empirical research shows diverse results of enhanced attentional biases towards socially feared stimuli (Çek et al., 2016) and even attentional avoidance towards relevant emotionally threat stimuli (Shechner et al., 2017; Wieser et al., 2009b) in socially anxious persons. These diverse findings have arisen the vigilance-avoidance hypothesis of selective attention (Bögels & Mansell, 2004; Chen & Clarke, 2017; Wieser et al., 2009b). This hypothesis postulates that persons with SAD or high levels of social anxiety direct their initial attention to emotionally threatening stimuli (hypervigilance) and tend to subsequently avoid (attentional avoidance) these threatening stimuli to might decrease their emotional distress. Using VR as an innovative research tool, there is a great possibility to measure the gaze behavior towards ecological valid socially relevant stimuli in interaction situations, as in a job interview or small talk scenario. In addition, gaze behavior can also be a significant index of fear conditioning (Hopkins, Schultz, Hannula, & Helmstetter, 2015). Until now, there are few results concerning the influence of fear conditioning on gaze behavior. One empirical study reports the influence of fear conditioning on gaze behavior in children. Using two neutral faces as CS, the 9-13 years old children looked longer and more frequently towards the eye region of the CS+ than CS- (Michalska et al., 2017).

The present dissertation project investigates the effect of induced and extinguished social fears on physical (e.g., duration of approach) and gaze behavior (e.g., hypervigilance and attentional avoidance) towards ecological valid socially relevant stimuli in high and low socially anxious individuals. In this way, detected underlying mechanisms of the development and maintenance of social anxiety can be used to improve treatment methods to be more suitable and efficient.

1.6 Treatment of Social Anxiety Disorder

The cognitive behavior therapy (CBT) is the most researched and effective treatment for SAD. The term CBT includes many techniques and treatment methods, from behaviorally oriented social skills training (SST), exposure therapy, cognitive therapy (e.g., cognitive restructuring) to progressive muscle relaxation (Butler, Chapman, Forman, & Beck, 2006; Harb & Heimberg, 2002; Hinsch & Pfingsten, 2015; Mayo-Wilson et al., 2014).

A new form of exposure therapy is the Virtual Reality Exposure Therapy (VRET), which has certain practical advantages over in-vivo exposure, including significantly less planning and organization, high controllability and replicability of the exposure situation, and a lower inhibition threshold for exposure (Diemer, Pauli, & Mühlberger, 2015b; Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007; Kampmann et al., 2016a). The efficacy of VRET in the treatment of more complex anxiety disorders such as SAD is still limited. During VRET, computer-controlled stimuli in emotionally relevant situations (e.g., virtual social interaction) are presented which can provoke enhanced levels of social anxiety in participants (Anderson et al., 2013; Bouchard et al., 2017; Kampmann et al., 2016a). Due to the improvement of technical possibilities (e.g., realistic presentation of facial expressions and gesture or virtual humans) more complex interaction situations in VR can be presented (Bombari et al., 2015). As a result, dialogue situations, like job interviews, dating situations, or general contact, have been implemented increasingly in the recent empirical research of VRET on SAD (Anderson et al., 2013; Bouchard et al., 2017; Gebara, Barros-Neto, Gertsenchtein, & Lotufo-Neto, 2016; Hartanto et al., 2014; Kampmann et al., 2016a; see meta-analysis by Kampmann, Emmelkamp, & Morina, 2016b and Carl et al., 2019). In their meta-analysis comparing the efficacy of VRET to in-vivo exposure, Wechsler, Kümpers, and Mühlberger (2019) could show a superiority of in-vivo exposure in SAD, but also highlight the strong benefits of VRET and suggest to include cognitive strategies (e.g., reinterpretations) for an improvement of the treatment of SAD. The focus of VRET is primarily on exposure as well as on inhibition learning, and less on exercises for social skills training in threatening situations.

SST aims at imparting knowledge about conversational and behavioral skills and exercising these social skills to improve social interactions. Empirical results show a performance deficit in SAD, where existing social skills cannot be recalled due to anxiety (Rapee & Spence, 2004). VR as a clinical tool for the treatment of SAD provides the opportunity of presenting fear evoking stimuli or situations in order to reduce anxiety and to develop efficient coping strategies. In addition to the practical advantages mentioned above, the immersive virtual environments offers the benefits of standardization and determining the difficulty of the interaction situations (Bombari et al., 2015).

Since social skills can be successfully trained in role play, social skills training in VR for the use of CBT could be a useful treatment tool for patients with SAD. To enhance the efficacy and availability of SST, validated virtual interaction scenarios for psychotherapeutic interventions are evaluated in this dissertation project.

1.7 Research Objectives

The previous sections have summarized the theoretical background of development and maintenance of social anxiety disorder. Furthermore, the advantages of virtual reality as a promising research tool were presented, as well as methodological difficulties in the area of experimental anxiety research, especially in fear conditioning research. The aim of the present dissertation project is to systematically investigate the relevance of social-emotional learning processes for the development, maintenance, and therapy of social anxiety using experimental studies in virtual reality.

Concerning the used stimuli with low ecological validity relating the nature of SAD in traditional fear conditioning, I want to research the importance of the social relevance of the US in social fear learning. As mentioned above, fear conditioning in HSA participants or patients with SAD can be induced by unspecific stimuli, like electrical stimulation, but also by social stimuli, like critical facial expressions or verbal negative feedback (Ahrens et al., 2016; Lissek et al., 2008). To fill this gap in social-emotional learning processes, a disorder-relevant US (spitting with a verbal rejection) is used to investigate whether high socially anxious individuals show sensitively more fear responses towards social stimuli compared to non-social stimuli (electrical stimulation) in an ecologically enhanced SFC paradigm in VR.

Based on the findings that psychosocial stress influences fear conditioning in both genders differently (Jackson et al., 2006; Merz et al., 2013; Zorawski et al., 2006), that a diverse prevalence exists in women and men developing SAD (Fehm et al., 2005; Ohayon & Schatzberg, 2010; Wittchen & Jacobi, 2004), and that an interpersonal distance behavior in social interactions reveal in women and men variously (Bailenson et al., 2003; Iachini et al., 2014), possible gender differences in social-emotional learning processes are assessed. In this way, I investigate possible gender differences and the influence of the gender of social stimuli (female vs. male agents) in HSA and LSA participants regarding the learning and unlearning of social fear in VR. Consequently, I determine how women and men behave towards female and male virtual counterparts to measure affective learning processes in social anxiety and assess gender specific differences in conditionability or extinction of social fears and its generalization.

Based on the different empirical results of hypervigilance and attentional avoidance in socially anxious individuals (Chen & Clarke, 2017; Shechner et al., 2017; Wieser et al., 2010; Wieser et al., 2009b), I investigate the influence of induced and extinguished social anxiety on physical (e.g., approach-avoidance behavior) and gaze behavior (e.g., hypervigilance and attentional avoidance) towards female and male agents in HSA and LSA participants in the SFC paradigm in VR.

Social skills training by Hinsch and Pfingsten (2015) is an established treatment tool in cognitive-behavioral therapy for social anxiety disorder. SST in virtual reality could be a useful tool and the immersive virtual technology with its benefits of standardization and determination of the difficulty of possible interaction situations could increase its effectiveness and availability for patients with SAD. Therefore, I examine the validity of VR scenarios relating the SST by Hinsch and Pfingsten (2015).

Thus, this project leads to a deeper understanding of variables that modulate social fear conditioning, extinction, and its generalization. These findings could also help to develop new forms of treatments for SAD and possibly other illnesses, which are associated with social-emotional learning dysfunction. The aim of anxiety research is to comprehend how to treat individuals with anxiety disorders more effectively.

With the proposed studies I answer the following questions:

1. Is there an influence of a disorder-relevant unconditioned stimulus in social fear learning and unlearning in high and low socially anxious participants?
2. Are there dissimilarities between social fear conditioned responses in women and men and is there an influence of the gender of the virtual agents?
3. Is there an influence of induced and extinguished social anxiety on physical and gaze behavior towards female and male agents in high and low socially anxious participants?
4. Are the virtual scenarios, which can be used as social skills training in socially anxious individuals, valid?

2. Peer-Reviewed Studies

2.1 Study 1: Disorder Relevant Unconditioned Stimulus in Social Fear Conditioning in Virtual Reality

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Social Fear Conditioning Paradigm in Virtual Reality: Social vs. Electrical Aversive Conditioning

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In a previous study we could show that social fear can be induced and extinguished using virtual reality (VR). In the present study, we aimed to investigate the belongingness effect in an operant social fear conditioning (SFC) paradigm which consisted of an acquisition and an extinction phase. Forty-three participants used a joystick to approach different virtual male agents that served as conditioned stimuli. Participants were randomly allocated to one of two experimental conditions. In the electroshock condition, the unconditioned stimulus (US) used during acquisition was an electric stimulation. In the social threat condition, the US consisted of an offense: a spit in the face, mimicked by a sound and a weak air blast to the participant's neck combined with an insult. In both groups the US was presented when participants were close to the agent (75% contingency for CS+). Outcome variables included subjective, psychophysiological and behavioral data. As expected, fear and contingency ratings increased significantly during acquisition and the differentiation between CS+ and CS− vanished during extinction. Furthermore, a clear difference in skin conductance between CS+ and CS− at the beginning of the acquisition indicated that SFC had been successful. However, a fast habituation to the US was found toward the end of the acquisition phase for the physiological response. Furthermore, participants showed avoidance behavior toward CS+ in both conditions. The results show that social fear can successfully be induced and extinguished in VR in a human sample. Thus, our paradigm can help to gain insight into learning and unlearning of social fear. Regarding the belongingness effect, the social threat condition benefits from a better differentiation between the aversive and the non-aversive stimuli. As next step we suggest comparing social-phobic patients to healthy controls in order to investigate possible differences in discrimination learning and to foster the development of more efficient treatments for social phobia.

Keywords: social fear conditioning, virtual reality, fear-potentiated startle, skin conductance level, avoidance behavior

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INTRODUCTION

Social anxiety disorder (SAD) is one of the most relevant anxiety disorders. It is characterized by intense anxiety when faced with social interactions along with physical symptoms like blushing or trembling, and extreme avoidance behavior concerning social interaction (Fehm et al., 2005; Kessler et al., 2005; American Psychiatric Association, 2013). While learning models are relatively well established in specific phobia, PTSD and panic disorders, learning paradigms for SAD are far less developed, both in animal models and in humans. Besides the diathesis stress model, there is evidence showing that fear conditioning may play an essential role in the development and maintenance of SAD (Mineka and Zinbarg, 2006; Mineka and Oehlberg, 2008).

Cognitive-behavioral therapy is the method of choice for the treatment of SAD; it is widely supported by current research and therefore assumed to be a reliable approach for overcoming anxiety (Arch et al., 2012). Cognitive-behavioral therapy is also often combined with exposure to feared situations in order to maximize the therapeutic success (Wolitzky-Taylor et al., 2008). Nevertheless, the effectiveness of this treatment approach is not always satisfactory and a high number of non-responders remain (Norton and Price, 2007).

Empirical findings show that conditioning mechanisms play an important role in the etiology of the elementary processes of SAD, making them essential to examine in order to maximize the impact of psychotherapeutic interventions (Mineka and Zinbarg, 2006; Mineka and Oehlberg, 2008). Classical fear conditioning (according to Pavlov) is a form of associative learning in which an organism learns to associate two stimuli with each other (Pavlov, 1927). E.g., hearing someone laugh (unconditioned stimulus: US) while giving a speech may result in the speaker showing a fear response (unconditioned response: UR). As a result, the previously neutral stimulus (giving a speech), now called conditioned stimulus (CS), triggers the newly learned fear reaction (conditioned response: CR). Classical fear conditioning is considered a central pathogenic pathway in anxiety disorders (Lissek et al., 2005; Mineka and Zinbarg, 2006; LeDoux, 2014). Operant fear conditioning (learning by consequences) may be also be relevant for the development of anxiety disorders, because it relates to stimuli that reinforced or punished the person during approach behavior. E.g., if voluntarily presenting a paper is followed by the lecturer harshly criticizing the presentation, a student might no longer report voluntarily in the future. Thus, other persons and social interactions might be prototypical stimuli involved in operant learning processes. However, until now little research has been conducted on operant fear conditioning in SAD.

Fear conditioning in mice in social as well as non-social contexts is addressed in the social fear conditioning (SFC) approach investigated by Toth et al. (2012). In this paradigm, naturally occurring preference behavior of male rodents toward an unknown conspecific was paired with an aversive US, namely an electric stimulus applied to the foot for 1 s. During acquisition phase, the rodents learned to associate the appearance of the negative stimulus with the conspecific, which induced social fear including avoidance behavior. In a following extinction phase on the next day, different male conspecifics were presented to the experimental animals in their cage without any negative US. It could be observed that avoidance and fear-driven behavior were extinguished and replaced by the naturally occurring preference behavior again. Therefore, in the course of the experiment, acquisition and extinction of fear were demonstrated. These results suggest that, using the applied paradigm, it is possible to draw conclusions about the etiology of SAD and potential leverage points for future treatment approaches (Toth et al., 2012; Toth and Neumann, 2013; Zoicas et al., 2014).

Many uncontrollable contextual and environmental factors can play a role and therefore turn out to be confounding variables in human experimental as well as therapeutic settings. A way to circumvent this problem is conducting experiments in virtual reality (VR), which also allows for the creation of paradigms of SAD development and the exploration of potential treatment improvements. The use of an artificially designed virtual environment minimizes potentially confounding variables by presenting standardized situations to participants. Subjects are able to interact with their environment and diverse stimuli can be applied in a multimodal manner (Bohil et al., 2011). Furthermore, it is possible to directly record the participant's reactions to the stimuli in the form of verbal ratings, fear-potentiated startle or electrocardiographic data (Mühlberger et al., 2007). Thus, VR allows conducting SFC related experiments in a realistic, standardized environment in an economic and easily administrable manner. An additional advantage of VR that is particularly important in the treatment of SAD is the prevention of avoidance behavior, which often leads to the reinforcement of anxiety symptoms (American Psychiatric Association, 2013). In general, the results of conditioning processes in VR are hugely satisfying (Huff et al., 2010).

Shiban et al. (2015) implemented a procedure similar to the SFC paradigm designed for mice by Toth et al. (2012) in order to investigate SFC in humans in VR. In this experimental setting, participants had to actively approach different agents in VR using a joystick. During the acquisition phase, one of the agents, referred to as CS+, was paired with an US, a loud female scream combined with an air blast. During the extinction and the following generalization test phase, no US was administered. In line with the initial hypotheses, participants rated the CS+ as significantly less pleasant than the CS− after the acquisition phase. These results were also supported by the heart rate pattern, as the heart rate was higher for the CS+ than for the CS− after acquisition. After the extinction phase, the ratings returned to an equal level and the fear-potentiated startle response decreased. Interestingly, during the generalization test, the more socially fearful participants rated every agent as less pleasant, compared to the less socially fearful participants who only rated the CS+ as less pleasant. This indicates that more socially fearful participants tend to generalize the unpleasantness of social stimuli to a broader context. In sum, SFC could be induced and extinguished successfully, thus emphasizing the role of operant conditioning in social fear learning. Nonetheless, the study has some limitations, which could be addressed in order to potentially improve the paradigm.

For instance, it is possible to manipulate the intensity of the social contact between the agent and the participant to investigate the specificity of the paradigm for social situations. We believe that our paradigm provides the opportunity for basic social interaction between the agent and the participant (via eye contact, self-regulated movement of the avatar and movement toward the agent). In the current study we improved upon this aspect by designing a social threat condition and comparing it to a conventional electroshock condition. Furthermore, it could be criticized that the amount of social interaction in the preliminary study was quite low, as the agent did not directly communicate with the participant. This has been taken into account in the current study, as in the social threat condition the agent verbally insults and spits at the participant is much more ecologically valid than the mere administration of an air blast or an electrical stimulation. We assume that it enables us to better use the paradigm for social fear research. In addition, the facial expressions of the agents were adjusted to the verbal utterance in order to create a more realistic and therefore more threatening experience. This also provided the opportunity to investigate the belongingness effect, since the accordance between the US and the CS plays an important role in conditioning. This concept was investigated in a study conducted by Hamm et al. (1989), in which pairs of unconditioned and neutral stimuli were rated according to their belongingness. After a classical conditioning process using rating-defined high- and low-belongingness pairs, finger pulse responses revealed significantly stronger acquisition and resistance to extinction for high-belongingness pairs.

Our current study is a further investigation of the SFC paradigm in VR in a human sample using an operant conditioning setting, which consisted of acquisition and extinction phases similar to those in the preliminary study. In the current study, we tried to maximize the immersion in VR using a head-mounted-display with a larger field of view as suggested in our first SFC study (Shiban et al., 2015). During the SFC process, fear and contingency ratings as well as physiological (fear-potentiated startle and skin conductance level) and behavioral data were collected. In order to take the above-mentioned effects of belongingness into account, a second experimental condition was added to the previous design. Besides the electroshock condition, in which an electrical stimulation to the lower arm serves as an US, an air blast combined with virtual spitting and insulting was employed as the US in the social threat condition. Because the subjective experience of (un)pleasantness was only partly in accordance with the physiological measurements in our first SFC study, we decided to use the skin conductance level (SCL) as an additional measure of distress during social interaction (e.g., Mesa et al., 2014). Moreover, we investigated the avoidance behavior quantified as the time in non-motion before the approach as well as the time in motion of the approach.

In our current study, we expected that (1) in the operant conditioning process, fear and contingency ratings for CS+ would increase after the acquisition phase compared to the baseline phase. Furthermore, (2) the amplitude of the fear-potentiated startle and the SCL as well as the time in non-motion before approaching the CS+ and time in motion of the approach toward CS+ were expected to increase. (3) After the extinction phase, fear and contingency ratings of the CS+ were supposed to return to baseline levels along with the electrophysiological reactions and the behavioral variables. (4) For the CS− and neutral stimulus (NS), no such changes were expected, i.e., the ratings and physiological measurements should remain stable. (5) The acquisition and the resistance to extinction were expected to be higher for the social threat condition than for the electroshock condition due to the belongingness effect of spitting and insulting to socially frightening situations and thus the more realistic simulation of social interaction. Finally, (6) a stronger manifestation of the conditioning process was expected in more socially fearful participants in comparison to less socially fearful participants.

MATERIALS AND METHODS

Participants

Forty-four healthy volunteers were recruited through advertisements at the University of Regensburg. Exclusion criteria were age below 18 or above 55, a current diagnosis of psychiatric disorder, psychological treatment, history of psychotropic drug use, color blindness and uncorrected vision or hearing deficits. These criteria were assessed via a questionnaire after written informed consent had been obtained. Participants were randomly allocated to one of the two conditions. As one participant was excluded due to a technical error during data acquisition, the study comprised a total of forty-three participants (22 participants in the electroshock condition: 68.2% female, aged between 18 and 25, $M = 21.10$, $SD = 1.80$; and 21 participants in the social threat condition: 81% female, aged between 19 and 30, $M = 21.95$, $SD = 2.84$). All of the volunteers were students at the University of Regensburg and were offered credit points as compensation for their participation (see **Table 1**). The Ethics Committee of the University of Regensburg approved the study.

Apparatus

The VR environment consisted of one room (see **Figure 1A**), in which all three phases (baseline, acquisition and extinction) took place. In every phase the participant was positioned at one end of the room and could see the agent at the opposite end of the room. The agents gazed dynamically at the participant and moved their head and upper body slightly (see **Figures 1B,C**). In 75% of the conditioning trials an aversive consequence followed when the participant reached the agent. Aversive consequences consisted of an electric stimulus to the participant's lower arm in the electroshock condition or of an air blast to the right side of the participant's neck (2 bar, 10 ms) accompanied by a sound of spitting followed by an insult in the social threat condition. In addition, when the participant approached the agent a startle sound was administered with a contingency of 75% in all phases. A compressed air tank was regulated via a magnetic valve system channeled the air blast through a tube that was fixed to the participant's torso. A cuff was fixed to the participant's right lower arm to administer the electric stimulus. Each participant's individual pain threshold ($M = 2.42$ mA, $SD = 1.82$ mA) was determined before the VR session started. To this end, different strengths of electrical current were administered to the participant's lower arm and then rated on a pain scale from 0 to 10. The amperage with a mean rating of 5 was used as the US during the VR session. The VR was presented to participants via an Oculus Rift DK2 head-mounted display (HMD; Oculus VR Inc., Irvine, CA, United States; see **Figure 1D**) and was generated via Steam Source engine (Valve Corporation, Bellevue, WA, United States). The presented VR

TABLE 1 | Demographic variables and questionnaire data.

	Electric shock condition (*n* = 22)		Social threat condition (*n* = 21)				
Demographics	***M***	***SD***	***M***	***SD***	***df***	***t***	***p***
Age	21.10	1.80	21.95	2.84	41	−1.195	0.239
SPIN	12.95	9.23	16.67	11.71	41	−1.157	0.254
	n	**%**	***n***	**%**	***df***	χ^2	p^a
Gender *[female]*	15	68.2	17	81.0	1	0.920	0.337

Means (M) and Standard Deviations (SD) and also t- and p-values are given for all participants for the variables age and SPIN (German version of the Social Phobia Inventory by Stangier and Steffens, 2002). Numbers of participants (n) and percent (%) for gender is given; [a]Chi square test, two-tailed.

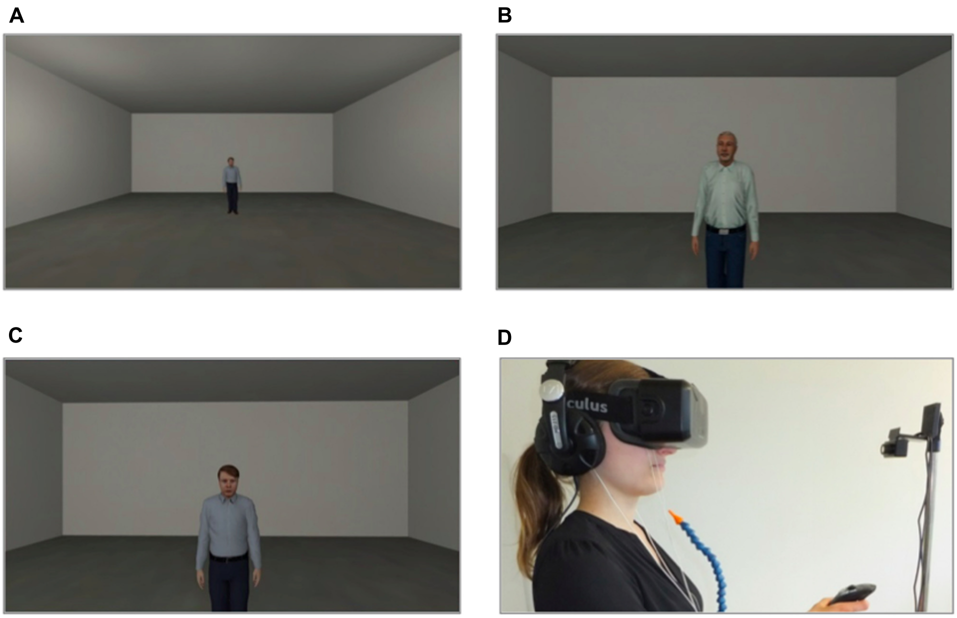

FIGURE 1 | Virtual environment. **(A)** Room where all three phases took place. **(B,C)** Social stimuli (agents) used for the conditioning. **(D)** Setting (VR was presented via a head-mounted display) during the experiment (laboratory room was darkened).

environment was controlled by "cybersession" software (VTplus GmbH, Würzburg, Germany) (see **Figure 1C**). The participant's head position was monitored via the Oculus' electromagnetic tracking device (Oculus VR Inc., Irvine, CA, United States), which adjusts the field of view to any head movements. Sounds were presented over headphones (Sennheiser HD-215, Sennheiser electronic GmbH, Germany). Participants used a joystick (Logitech Extreme 3D Pro Joystick, Logitech GmbH, Germany) to move in the VR environment. Physiological data were monitored, digitally amplified (V-Amp, Brain Products GmbH, Germany) and recorded (Brain Vision Recorder software, Version 1.20, Brain Products GmbH, Germany).

Measures

Participants filled out a demographic questionnaire (age, sex, education, and current occupation) and the Social Phobia Inventory (SPIN; Connor et al., 2000; German Version: Stangier and Steffens, 2002) to assess social fear.

The SPIN consists of 17 items that assess fear, avoidance, and physiological symptoms of social phobia in the previous week. Answers are given on a five-point Likert scale (from 0 = "not at all" to 4 = "extremely"). The German version of the SPIN was evaluated by Sosic et al. (2008). Internal consistency was excellent for a representative sample of 2043 Germans (Cronbach's Alpha = 0.95). Convergent and divergent validity are satisfactory. Furthermore, the German version of the SPIN is a sensitive and specific measure for social phobia as it distinguishes successfully between social phobia and other psychiatric disorders (Sosic et al., 2008).

In order to measure the experienced fear and contingency of the agents, ratings were assessed verbally during the presentations of the agents in the rating phase following each of the three phases ("Estimate your fear now"; "How likely would an aversive stimulus have been?"). These ratings had a range from 0 (very low fear/very unlikely) to 100 (very high fear/very likely).

Baseline phase	- 4x CS+ / 4x CS- / 4x NS - pseudo-randomized - startle: 75% contingency (CS+/CS-/NS)
Rating 1	- fear rating (CS+/CS-/NS) - contingency rating (CS+/CS-/NS)
Acquisition phase	- 12x CS+ / 12x CS- - pseudo-randomized - startle: 75% contingency (CS+/CS-) - US: 75% contingency (CS+)
Rating 2	- fear rating (CS+/CS-/NS) - contingency rating (CS+/CS-/NS)
Extinction phase	- 12x CS+ / 12x CS- / 12x NS - pseudo-randomized - startle: 75% contingency (CS+/CS-/NS)
Rating 3	- fear rating (CS+/CS-/NS) - contingency rating (CS+/CS-/NS)

FIGURE 2 | Experimental procedure. The experimental procedure took place as described above. As unconditioned stimulus (US), electrical stimulation (electro shock condition) or an air blast combined with virtual spitting and insulting (social threat condition) were applied. CS+ = agent paired with aversive US; CS– = agent without aversive US; *NS* = agent without aversive US and not appearing during the acquisition phase.

Besides the subjective measures, physiological data were collected. To record the electromyography of the musculus orbicularis oculi as a measure of fear-potentiated startle, four surface electrodes (Ag/AgCl, Ø = 8 mm) were affixed under the right eye of the participant and on the mastoid bones as reference and ground electrodes. Two additional surface electrodes (Ag/AgCl, Ø = 8 mm) were placed on the base of the thumb on the radial side of the palm of the non-dominant hand in order to record the SCL. The avoidance was measured as the time in non-motion (in s) before approaching the agents and the time in motion (in s) of the approach.

Procedure

The experiment consisted of the questionnaire phase, the baseline phase, the acquisition phase and the extinction phase [total duration was 60 min (30 min in VR); see **Figure 2**].

The baseline phase consisted of four blocks. One block consisted of three presentations of each agent (CS+, CS−, NS), resulting in a total of 12 presentations of each agent per participant. The order within each block was randomized and no US was administered. Which agent was presented as CS+/CS−/NS, was balanced across participants. A startle noise (white noise: 103 dB, 10 ms) was presented with a contingency of 75%.

Conditioning was conducted in 12 blocks. One block consisted of two presentations of both conditioned stimuli with aversive reinforcement in terms of electric stimulus or air blast combined with virtual spitting and the negative utterance "Get lost!" (CS+) and without aversive reinforcement (CS−), resulting in a total of 24 presentations per participant. The NS agent did not appear in this phase. The order within each block was randomized. The CS-US contingency was set at 75%. As in the baseline phase, the startle noise was presented with a contingency of 75%.

The extinction phase consisted of 12 blocks designed in exactly the same way as those in the acquisition phase, except for the absence of the US and the reappearance of the NS agent. Because three agents were presented instead of two, the total number of trials was 36 in this phase. Also in the extinction phase the startle noise was presented with a contingency of 75%. After the baseline, acquisition and extinction phase, a rating phase took place in which each agent was presented (presentation 8 s, inter-stimulus interval 20 s) again without US or startle noise.

In the first session participants were briefed and the informed consent form was signed. After filling out the demographic questionnaire and the SPIN, participants were prepared for the VR part of the experiment. The electrodes, the air blast device, the cuff for the electric stimuli, the HMD and the headphones were adjusted. During the experiment the laboratory room was darkened and participants received recorded instructions via the headphones.

Before the baseline phase started, participants were able to walk around a desk standing in the middle of the room with gray walls and floor in VR. After exploring this virtual environment, the room faded into a gray background and participants relaxed for 2 min in VR. After the baseline phase, participants received the recorded instruction: "You will now meet virtual human beings. Please use the joystick to approach the person. Please try to move directly toward the person. Press the joystick forward to move straight forward and approach the person." Participants had to approach the agents actively using the joystick and as soon as they reached a specific distance to the agents (the equivalent of about 30 cm in the real world), lights faded out and the next agent was presented at the opposite wall. Each trial lasted about 10 s (depending on how fast participants approached the agents). Theoretically, participants could move laterally, diagonally or away from the agent, however, we observed no such behavior. Because the field of view was adapted to head movements, participants could theoretically look away while moving toward the agent. After the baseline phase, the first rating took place; participants approached each of the three agents and as soon as they reached the previously specified distance to the agents, lights faded out and the participants were asked to verbally rate their subjective fear and the contingency of aversive events.

During the acquisition phase, participants again received the recorded instruction to approach the agents actively via joystick and, as soon as they reached the pre-determined distance to the agents, the lights faded out. At this moment, the US was presented for CS+ agents in 75% of the trials. After the acquisition phase, participants rated the agents again as described above.

The following extinction phase differed from the acquisition only in the reappearance of the NS and the absence of aversive US. After the third rating, the experiment was complete.

Statistical Analyses

Physiological data were preprocessed with Brain Vision Analyzer 2.0 software (Brain Products GmbH, Munich, Germany) and

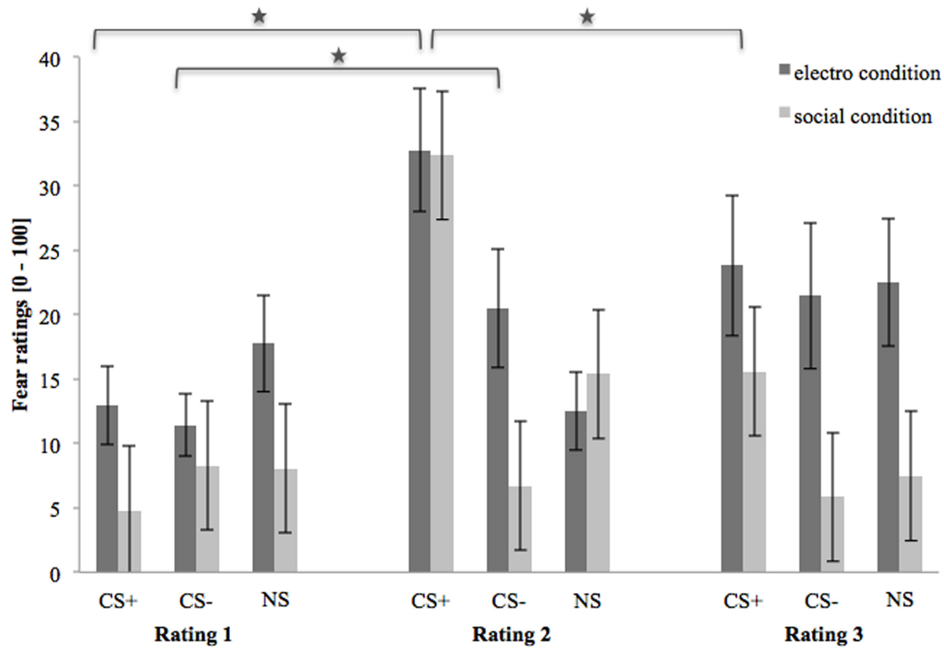

FIGURE 3 | Fear ratings (*n* = 43) for CS+, CS– and NS in the three rating phases for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; *NS* = agent without aversive US and not appearing during the acquisition phase; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting; Rating 1 = after baseline phase; Rating 2 = after acquisition phase; Rating 3 = after extinction phase. Mean fear ratings (0 = very low fear to 100 = very high fear) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

further analyses were performed in SPSS 22.0 (IBM Corp., Armonk, NY, United States).

For each physiological outcome variable (fear-potentiated startle, SCL) and avoidance behavior, means were calculated for the baseline phase, while the first four reactions and the last four reactions in the acquisition and the extinction phase were computed as the means of the beginning and the end of the acquisition and extinction phase, respectively.

For the fear-potentiated startle, first, differences between the two electromyography electrodes were computed (see Blumenthal et al., 2005). Then, a 250 Hz high cut-off filter, a 30 Hz low cut-off filter, and a 50 Hz notch filter were applied, the data were rectified, and a moving average (50 ms) was calculated. For each fear-potentiated startle a baseline correction was conducted using the mean value of the 50 ms before each startle tone as baseline. Next, peaks were marked automatically, controlled manually and corrected if necessary. Finally, T-values for the startle magnitude were calculated. Due to technical errors during data acquisition, six participants had to be excluded from data analysis of the fear-potentiated startle.

For the analysis of the SCL, the difference between the two electrodes was computed, a 1 Hz high cut-off filter and a baseline correction of 1-s duration applied and the SCL exported in order to calculate T-values for the SCL. Due to technical errors during data acquisition, five participants had to be excluded from data analysis of the SCL.

The avoidance behavior was assessed via time in non-motion (latency) and time in motion. Time in non-motion (in s) was defined as the time before approaching the agent. Time in motion (in s) was computed subtracting the time in non-motion from the total time needed for reaching the specific distance to the agent.

The means for each agent (CS+, CS−, NS) of the subjective variable (fear and contingency ratings) measured at the three rating phases (rating 1–3) were calculated.

Participants were divided into two groups (low vs. high social anxiety) via a median split of the SPIN score (median = 13.5 in this study) in order to differentiate between highly and less socially fearful participants.

Two repeated-measures ANOVAs with the within-subject factors phase (rating 1 vs. rating 2 for acquisition and rating 2 vs. rating 3 for extinction) and stimulus (CS+ vs. CS− vs. NS) and the between-subject factors social anxiety (low vs. high) and condition (electroshock condition vs. social threat condition) were conducted for both subjective variables.

For each physiological and behavioral outcome variable, repeated-measures ANOVAs with the within-subject factors time (baseline vs. beginning vs. end of acquisition) and stimulus (CS+ vs. CS−) and the between-subject factors social anxiety (low vs. high) and condition (electroshock condition vs. social threat condition) were conducted for the acquisition phase. For the extinction phase repeated-measures ANOVAs with the within-subject factors time (beginning vs. end of extinction) and stimulus (CS+ vs. CS−) and the between-subject factors social anxiety (low vs. high) and condition

TABLE 2 | Significant results of the ANOVAs for the fear ratings of the acquisition and extinction phase.

Effect	*df*	*F*	η^2	*p*
Acquisition				
Total				
Phase	1, 39	32.1	0.45	<0.001
Stimulus	2, 78	13.9	0.26	<0.001
Phase × Stimulus	2, 78	20.5	0.34	<0.001
Phase × Stimulus × Condition	2, 78	4.96	0.11	0.009
Electroshock condition				
Phase	1, 20	14.4	0.42	<0.001
Stimulus	2, 40	4.72	0.19	0.014
Phase × Stimulus	2, 40	11.8	0.37	<0.001
Social threat condition				
Phase	1, 19	17.6	0.48	<0.001
Stimulus	2, 38	10.2	0.35	<0.001
Time × Stimulus	2, 38	13.1	0.41	<0.001
Extinction				
Total				
Stimulus	2, 74	22.7	0.38	<0.001
Phase × Stimulus	2, 74	10.6	0.22	<0.001

df = degrees of freedom; η^2 = effect size; Phase = Rating 1 vs. Rating 2 for the acquisition and Rating 2 vs. Rating 3 for the extinction; Rating 1 = after baseline, Rating 2 = after acquisition, Rating 3 = after extinction; Stimulus = CS+ vs. CS− vs. NS; CS+ = agent paired with the aversive unconditioned stimulus (US), CS− = agent without aversive US, NS = agent without aversive US and not appearing during the acquisition phase; Condition = electroshock vs. social threat condition; Social Anxiety (low vs. high) was measured with the German version of the Social Phobia Inventory (SPIN; median split = 13.5, Stangier and Steffens, 2002).

(electroshock condition vs. social threat condition) were conducted.

Measuring generalization effects, ANOVAs with the within-subject factor phase (baseline vs. end of extinction) and the between-subject factors social anxiety (low vs. high) and condition (electroshock condition vs. social threat condition) were conducted for the NS as well.

In additional analyses of significant effects of time, stimulus, or social anxiety Student's *t*-tests were performed. Partial η^2 (η_p^2) scores and Cohen's *d* were used as indices of effect size. The significance level was set at two-tailed alpha = 0.05.

RESULTS

Fear Ratings

Figure 3 shows the fear ratings 1–3 (after the baseline, acquisition and extinction phase, respectively). As we can see, in the beginning, (baseline) fear ratings are almost equal for all three stimuli, but slightly higher in the electroshock than in the social threat condition. After the acquisition phase, fear ratings for CS+ are clearly higher than for CS− and NS in both US conditions. Fear ratings for CS− are higher in the electroshock than in the social threat condition, while fear ratings for NS barely differ after acquisition. After the extinction phase, fear ratings for CS+ decrease in both conditions. However, fear ratings for CS+ decreased more in the social threat condition than in the electroshock condition. CS− did not change in either condition over time, whereas the NS increased in the electroshock condition and decreased in the social threat condition. After extinction, all three stimuli are generally rated with higher fear and contingency levels in the electroshock condition than in the social threat condition.

An ANOVA comparing fear ratings before and after acquisition confirmed significant interaction effects of Phase × Stimulus and Phase × Stimulus × Condition (please see **Table 2** for all significant results of the ANOVA). A follow-up ANOVA was conducted for each condition. For the electroshock condition, a significant interaction effect of Phase × Stimulus could be detected. A follow-up *t*-test showed that the fear ratings increased significantly for CS+, $t(21) = -5.04$, $p < 0.001$, $d = 1.12$, and for CS−, $t(21) = -2.46$, $p = 0.023$, $d = 0.54$, and decreased significantly for NS, $t(21) = 2.59$, $p = 0.017$, $d = 0.31$, from pre to post acquisition. For the social condition, an interaction effect of Phase × Stimulus was also significant. Follow-up *t*-test revealed that fear ratings increased significantly only for CS+, $t(20) = -5.67$, $p < 0.001$, $d = 1.52$, from pre to post acquisition, but not for CS− or NS. Therefore, the fear rating results indicate that successful SFC took place under both conditions.

An ANOVA comparing fear ratings before and after extinction confirmed a significant interaction effect of Phase × Stimulus. Follow-up *t*-test showed that fear ratings decreased significantly for CS+, $t(40) = 3.92$, $p < 0.001$, $d = 0.60$, from pre to post extinction, but not for CS− or NS. The fear rating results indicate that social fear extinction was also successful under both conditions.

Contingency Ratings

Figure 4 shows contingency ratings 1–3 (after baseline, acquisition, and extinction phase, respectively). In the beginning, contingency ratings are almost equal for both conditions and all three stimuli. After the acquisition phase, contingency ratings for CS+ are higher than for CS− or NS in both US conditions. Regarding the CS−, contingency ratings are higher in the electroshock than in the social threat condition. In both conditions the contingency ratings for NS decrease slightly after acquisition. After the extinction phase, the contingency ratings for CS+ decrease strongly in both conditions. Contingency ratings for CS− decrease in the electroshock condition and increase slightly in the social threat condition. Conversely, contingency ratings for NS increased slightly in the electroshock condition and decreased slightly in the social threat condition.

An ANOVA comparing contingency ratings before and after acquisition confirmed significant interaction effects of Phase × Stimulus, Stimulus × Social Anxiety, and Phase × Stimulus × Condition (please see **Table 3** for all significant results of the ANOVA). Follow-up ANOVA was conducted for each condition. In the electroshock condition, significant interaction effects of Phase × Stimulus, and Stimulus × Social Anxiety could be detected. Follow-up *t*-test conducted for Phase × Stimulus interaction showed that contingency ratings increased significantly for CS+, $t(21) = -7.49$, $p < 0.001$, $d = 1.88$, and for CS−, $t(21) = -2.38$,

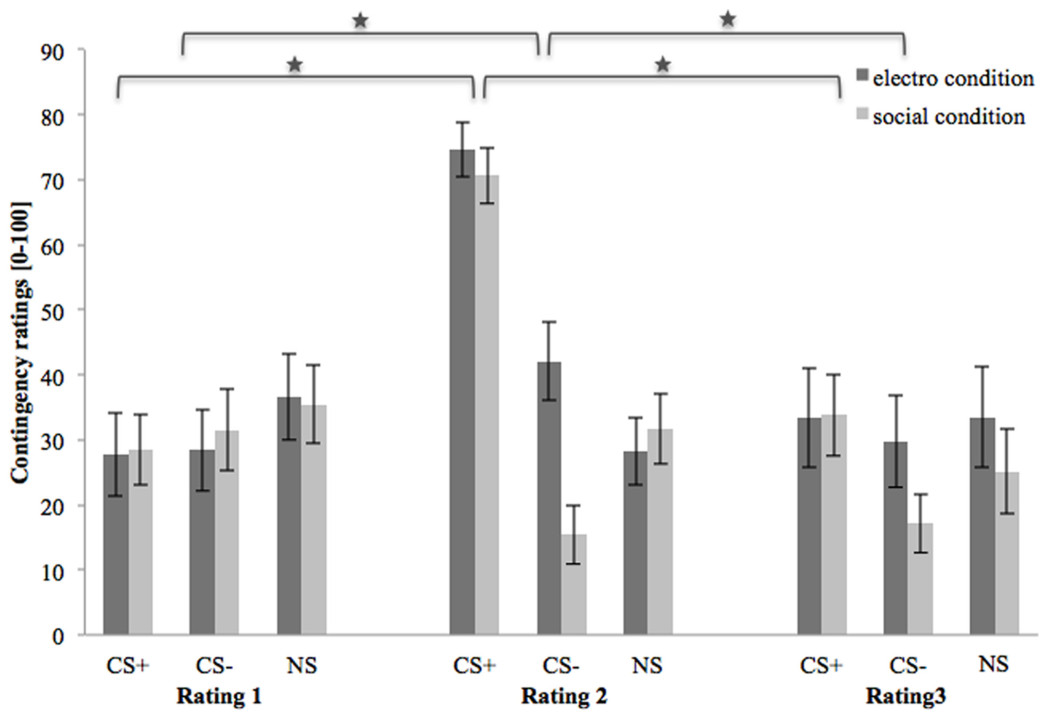

FIGURE 4 | Contingency ratings (n = 43) for CS+, CS– and NS in the three rating phases for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; *NS* = agent without aversive US and not appearing during the acquisition phase; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting; Rating 1 = after baseline phase; Rating 2 = after acquisition phase; Rating 3 = after extinction phase. Mean contingency ratings (0 = very unlikely to 100 = very likely) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

$p = 0.027$, $d = 0.48$, from pre to post acquisition, but not for NS. Follow-up tests of the significant Stimulus × Social Anxiety interaction revealed a significant difference for the less socially fearful participants between CS+, CS−, and NS ($p < 0.020$), and for the higher socially fearful participants between CS+ and CS− ($p < 0.003$), but not NS. Means and standard deviations are presented in **Table 4**. In the social threat condition an interaction effect of Phase × Stimulus reached significance level. Follow-up t-test showed that contingency ratings increased significantly for CS+, $t(19) = -7.50$, $p < 0.001$, $d = 1.88$, and decreased for CS−, $t(19) = 2.47$, $p = 0.023$, $d = 0.72$, from pre to post acquisition. This pattern could not be found for NS. Thus, contingency rating results also indicate that SFC was successful.

An ANOVA on contingency ratings before and after extinction showed significant interaction effects for Stimulus × Condition, Stimulus × Social Anxiety, Phase × Stimulus, and a marginally significant interaction effect of Phase × Stimulus × Condition. Follow-up ANOVAs were conducted separately for the two conditions. In the electroshock condition, interaction effects of Phase × Stimulus and Stimulus × Social Anxiety reached significance level. Follow-up t-test conducted for the Phase × Stimulus interaction effect showed that contingency ratings decreased significantly for CS+, $t(20) = 5.88$, $p < 0.001$, $d = 1.66$, and for CS−, $t(20) = 2.66$, $p = 0.015$, $d = 0.46$, from pre to post extinction, but not for NS. Follow-up tests of the Stimulus × Social Anxiety interaction revealed a significant difference both for the less socially fearful participants between CS+ and NS ($p < 0.020$), and for the highly socially fearful participants between CS+, CS− and NS ($p < 0.022$). In the social threat condition, interaction effects of Phase × Stimulus and Stimulus × Social Anxiety reached significance level. Follow-up t-tests of the Phase × Stimulus interaction revealed that contingency ratings decreased significantly for CS+, $t(19) = 5.91$, $p < 0.001$, $d = 1.58$, but not for CS− or NS. Follow-up tests of the significant Stimulus × Social Anxiety interaction revealed a significant difference both for the less socially fearful participants between CS+, CS− and NS ($p < 0.001$), and for the highly socially fearful participants between CS+, CS− and NS ($p < 0.030$). These results indicate that social fear extinction was successful according to the contingency ratings as well.

Fear-Potentiated Startle

Figure 5 depicts fear-potentiated startle response for the baseline, acquisition and extinction phase. In the electroshock condition fear-potentiated startle response is higher for CS− than for CS+ at the baseline and both stimuli increase at the beginning, until both decrease to the end of the acquisition. In the extinction phase CS+ response is higher than CS−, but the responses to both stimuli decreased from the beginning to the end. In the social threat condition fear-potentiated startle response is higher for CS− than for CS+ at the baseline. CS+ response increases whereby CS− do not change at the beginning, until both decrease at the end of the acquisition. In the extinction phase both stimuli decrease from the beginning to the end.

For the acquisition phase, an ANOVA confirmed a significant main effect of time, $F(1,33) = 7.51$, $p < 0.001$, $\eta_p^2 = 0.19$, and stimulus, $F(1,33) = 5.20$, $p = 0.029$, $\eta_p^2 = 0.14$, but no significant interaction effects. **Figure 5** shows an increase of fear-potentiated startle at the beginning and a fast habituation process at the end of the acquisition phase in both conditions.

For the extinction phase, there was a significant main effect of time, $F(1,31) = 8.46$, $p = 0.007$, $\eta_p^2 = 0.21$, but no other significant main or interaction effects. For NS, a significant main effect of time, $F(1,32) = 7.98$, $p = 0.008$, $\eta_p^2 = 0.20$, could be detected.

TABLE 3 | Significant results of the ANOVAs for the contingency ratings of the acquisition and the extinction phase.

Effect	*df*	*F*	η^2	*p*
Acquisition				
Total				
Phase	1, 38	10.8	0.22	0.002
Stimulus	2, 76	33.9	0.47	<0.001
Phase × Stimulus	2, 76	51.3	0.58	<0.001
Stimulus × Social Anxiety	2, 76	3.29	0.08	0.042
Phase × Stimulus × Condition	2, 76	5.76	0.13	0.005
Electroshock condition				
Phase	1, 20	15.5	0.44	<0.001
Stimulus	2, 40	10.8	0.35	<0.001
Phase × Stimulus	2, 40	25.4	0.56	<0.001
Stimulus × Social Anxiety	2, 40	3.98	0.17	0.027
Social threat condition				
Stimulus	2, 36	28.0	0.61	<0.001
Phase × Stimulus	2, 36	30.9	0.63	<0.001
Extinction				
Total				
Phase	1, 37	13.6	0.27	<0.001
Stimulus	2, 74	71.5	0.66	<0.001
Stimulus × Condition	2, 74	8.04	0.18	<0.001
Stimulus × Social Anxiety	2, 74	6.72	0.15	0.002
Phase x Stimulus	2, 74	31.9	0.46	<0.001
Phase × Stimulus × Condition	2, 74	3.06	0.08	0.053
Electroshock condition				
Phase	1, 19	6.49	0.26	0.020
Stimulus	2, 38	26.0	0.58	<0.001
Phase × Stimulus	2, 38	20.2	0.52	<0.001
Stimulus × Social Anxiety	2, 38	4.30	0.19	0.021
Social threat condition				
Phase	1, 18	7.71	0.30	0.012
Stimulus	2, 36	49.3	0.73	<0.001
Phase × Stimulus	2, 36	14.9	0.45	<0.001
Stimulus × Social Anxiety	2, 36	4.51	0.20	0.018

df = degrees of freedom; η^2 = effect size; Phase = Rating 1 vs. Rating 2 for the acquisition and Rating 2 vs. Rating 3 for the extinction; Rating 1 = after baseline, Rating 2 = after acquisition, Rating 3 = after extinction; Stimulus = CS+ vs. CS− vs. NS; CS+ = agent paired with the aversive unconditioned stimulus (US), CS− = agent without aversive US, NS = agent without aversive US and not appearing during the acquisition phase; Condition = electroshock vs. social threat condition; Social Anxiety (low vs. high) was measured with the German version of the Social Phobia Inventory (SPIN; median split = 13.5, Stangier and Steffens, 2002).

Skin Conductance Level

Figure 6 depicts SCL for the baseline, acquisition and extinction phase. In the baseline, SCL for CS+ response is slightly higher than for CS− in both conditions. In the electroshock condition, for CS+ the SCL increase from the baseline to the beginning and decrease to the end of the acquisition, whereas it decrease for CS− from the baseline to the end of the acquisition. In the beginning of the extinction, SCL for CS+ is higher than for CS−, at the end of the extinction both stimuli do not differ. In the social condition, SCL for CS+ also increase from the baseline to the beginning and decrease from the beginning to the end of the acquisition. SCL for CS− decrease from the baseline to the beginning and subsequently increase to the end of the acquisition. In the beginning of the extinction, both stimuli do not differ and both increase slightly at the end of the extinction.

For the acquisition phase, an ANOVA confirmed significant main effects of stimulus, $F(1,34) = 15.4$, $p = 0.010$, $\eta_p^2 = 0.18$, as well as significant interaction effect of Time × Stimulus, $F(2,68) = 18.5$, $p < 0.001$, $\eta_p^2 = 0.35$. Follow-up t-tests revealed that SCL for CS+ and CS− only differed at the beginning of the acquisition, $t(37) = 6.26$, $p < 0.001$, $d = 1.35$. Thus, there was a significant increase in SCL for CS+ and a significant decrease for CS− from the baseline to the beginning of the acquisition. The SCL results indicate that successful SFC took place under both condition, but also a fast habituation during acquisition.

For the extinction phase, an ANOVA showed a significant main effect of condition, $F(1,32) = 4.95$, $p = 0.033$, $\eta_p^2 = 0.13$, and a significant interaction effect of Time × Stimulus × Condition × Social Anxiety, $F(1,32) = 101.8$, $p = 0.044$, $\eta_p^2 = 0.12$. A follow-up ANOVA was conducted

TABLE 4 | Means (M) and standard deviations (SD) for contingency ratings during acquisition and extinction for high- and low-social anxious and both conditions.

	CS+		**CS−**		**NS**	
	M	***SD***	***M***	***SD***	***M***	***SD***
Acquisition						
Electroshock condition						
Low socially fear	49.9	22.5	35.4	30.5	24.6	22.4
High socially fear	53.4	18.8	35.0	15.3	45.9	24.2
Extinction						
Electroshock condition						
Low socially fear	51.7	22.2	33.9	28.6	23.4	19.3
High socially fear	57.2	22.3	38.4	28.1	43.3	21.8
Social threat condition						
Low socially fear	63.6	13.9	15.6	19.4	27.5	22.4
High socially fear	44.6	19.5	16.7	19.7	29.1	17.3

CS+ = agent paired with US, CS− = agent without aversive US, NS = agent without aversive US and not appearing during the acquisition phase; Social Anxiety (low vs. high) was measured with the German version of the Social Phobia Inventory (SPIN; median split = 13.5, Stangier and Steffens, 2002).

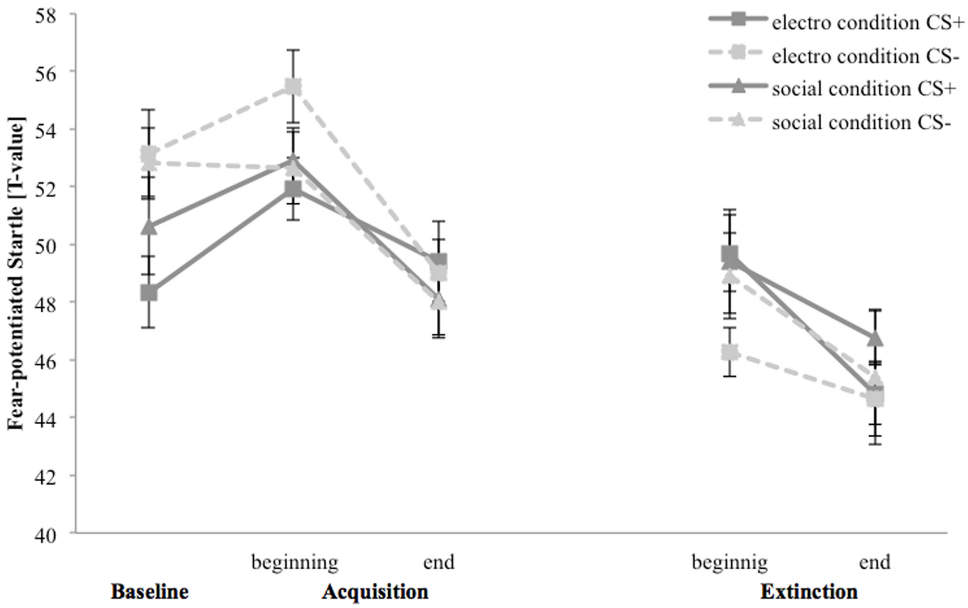

FIGURE 5 | Fear-potentiated startle response (*n* = 37) for CS+ and CS– in the three phases (baseline, acquisition, and extinction) for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting. Mean fear-potentiated startles (presented in *T*-values) was given. Standard errors are presented by error bars.

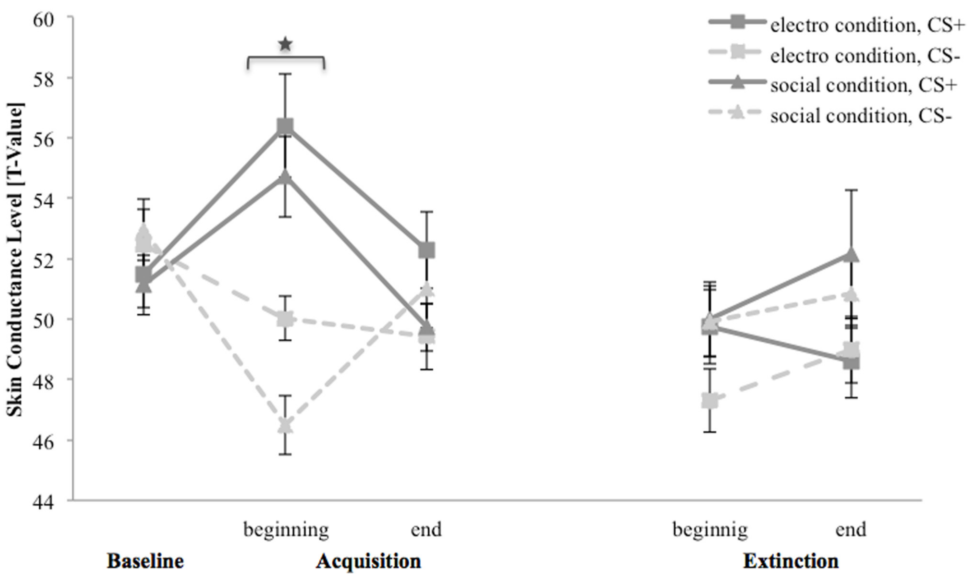

FIGURE 6 | Skin conductance level (*n* = 38) for CS+ and CS– in the three phases (baseline, acquisition, and extinction) for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting. Mean skin conductance level (presented in *T*-values) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

separately for both conditions. In the electroshock condition, no significant main or interaction effects were found. In the social threat condition, a significant interaction effect of Time × Stimulus × Social Anxiety, $F(1,17) = 4.48$, $p = 0.049$, $\eta_p^2 = 0.21$, was detected. Follow-up *t*-tests conducted separately for higher and less socially fearful participants neither showed significant differences between SCL for CS+ and CS− at the beginning nor at the end of the extinction. For NS, a significant main effect of time, $F(1,33) = 7.39$, $p = 0.010$, $\eta_p^2 = 0.18$, could be detected.

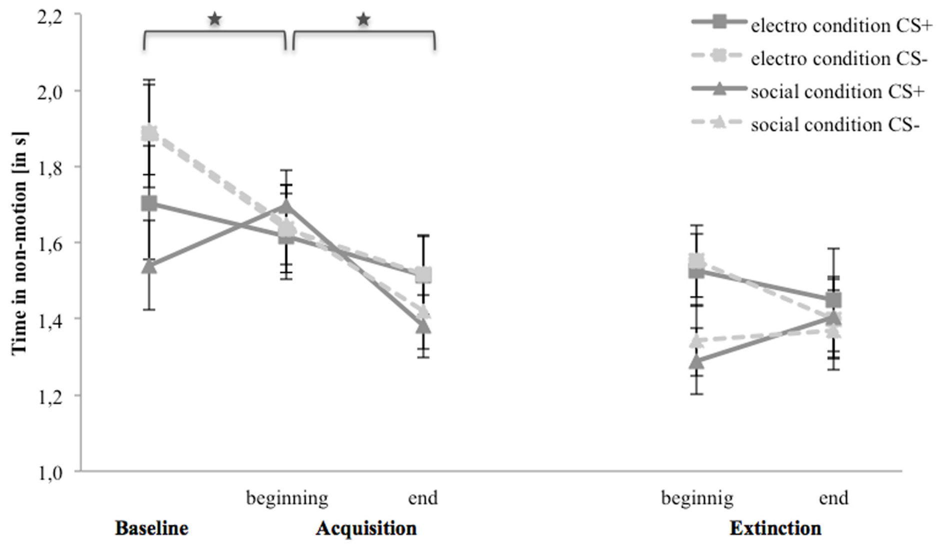

FIGURE 7 | Time in non-motion (n = 36) for CS+ and CS– in the three phases (baseline, acquisition, and extinction) for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting. Mean time in non-motion (in s) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

Avoidance (Time in Non-motion)

Figure 7 shows time in non-motion for the baseline, acquisition and extinction phase. In the electroshock condition, avoidance for both stimuli decreases from the baseline to the end of the acquisition phase as well as from the beginning to the end of the extinction phase. In the social threat condition, avoidance for CS− is higher than for CS+ at the baseline, and to the end of the acquisition phase it decreases for CS−, whereas avoidance increases for CS+ from the baseline to the beginning until it decreases at the end of the acquisition. In the extinction phase, both stimuli do not differ at any point.

For the acquisition phase, an ANOVA confirmed significant interaction effects of Time × Stimulus, and Condition × Social Anxiety (please see **Table 5** for all significant results of the ANOVA). Follow-up ANOVA was conducted separately for both conditions. In the electroshock condition, no significant interaction effects were found. In the social threat condition, a significant interaction effect of Time × Stimulus could be detected. Follow-up t-tests showed that avoidance for CS+ increased from the baseline to the beginning of the acquisition phase, $t(18) = -2.13$, $p = 0.047$, $d = 0.33$, and decreased from the beginning to the end of the acquisition phase, $t(18) = 3.32$, $p = 0.004$, $d = 0.84$. Avoidance for CS− decreased from the baseline to the beginning of the acquisition, $t(18) = 2.35$, $p = 0.031$, $d = 0.53$, as well as from the beginning to the end of the acquisition, $t(18) = 2.77$, $p = 0.013$, $d = 0.51$. Therefore, the time in non-motion results indicate that successful avoidance behavior for CS+ took place in the social threat condition, but also a fast adaptation to the US occurred toward the end of the acquisition.

For the extinction phase, an ANOVA confirmed a significant interaction effect of Time × Condition. Follow-up ANOVA was conducted separately for both conditions. In the electroshock condition, only a significant main effect of social anxiety was found. In the social threat condition, no significant effects were found. For NS, a significant main effect of time, $F(1,32) = 4.81$, $p = 0.036$, $\eta_p^2 = 0.13$, could be detected.

Avoidance (Time in Motion)

Figure 8 shows time in motion for the baseline, acquisition and extinction phase. In the electroshock condition, the avoidance of CS− is higher than of CS+ during the baseline. Avoidance toward CS− decreases from the baseline to the end of the acquisition, whereas it increases for CS+ from the baseline to the beginning and decreases to the end of the acquisition. In the extinction phase participants move faster toward CS− and slower toward CS+ from the beginning to the end of the extinction. In the social threat condition, time to approach both stimuli are equally long during baseline and increase at the beginning of the acquisition, until avoidance to both stimuli stay approximately at the same level at the end of the acquisition. In the extinction phase, the avoidance of CS+ decreases during the extinction, whereas for CS− it stays on an equal level.

For the acquisition phase, an ANOVA confirmed significant interaction effects of Time × Stimulus and Condition × Social Anxiety (please see **Table 6** for all significant results of the ANOVA). Follow-up ANOVAs were conducted separately for both conditions. In the electroshock condition, a significant interaction effect of Time × Stimulus could be detected. Follow-up t-tests revealed that only the CS+ significantly increased from the baseline to the beginning of the acquisition, $t(37) = -2.45$, $p = 0.026$, $d = 0.77$. In the social threat condition, no significant interaction effects were found. Therefore, time in motion results indicate a successful SFC at the beginning of the acquisition in

TABLE 5 | Significant results of the ANOVAs for avoidance (time in non-motion) of the acquisition and extinction phase.

Effect	*df*	*F*	η^2	*p*
Acquisition				
Total				
Time	2, 64	10.5	0.25	<0.001
Stimulus	1, 32	9.83	0.24	0.004
Time x Stimulus	2, 64	9.34	0.23	<0.001
Condition × Social Anxiety	1, 32	5.42	0.15	0.026
Electroshock condition				
Time	2, 30	4.06	0.21	0.027
Stimulus	1, 15	6.71	0.31	0.020
Social threat condition				
Time	2, 34	7.82	0.32	0.002
Stimulus	1, 17	5.27	0.24	0.035
Time × Stimulus	2, 34	7.02	0.29	0.003
Extinction				
Total				
Social Anxiety	1, 32	4.71	0.13	0.038
Time × Condition	1, 32	4.25	0.12	0.047
Electroshock condition				
Social Anxiety	1, 15	9.56	0.39	0.007

df = degrees of freedom; η^2 = effect size; Phase = Rating 1 vs. Rating 2 for the acquisition and Rating 2 vs. Rating 3 for the extinction; Rating 1 = after baseline, Rating 2 = after acquisition, Rating 3 = after extinction; Stimulus = CS+ vs. CS− vs. NS; CS+ = agent paired with the aversive unconditioned stimulus (US), CS− = agent without aversive US, NS = agent without aversive US and not appearing during the acquisition phase; Condition = electroshock vs. social threat condition; Social Anxiety (low vs. high) was measured with the German version of the Social Phobia Inventory (SPIN; median split = 13.5, Stangier and Steffens, 2002).

TABLE 6 | Significant results of the ANOVAs for avoidance (time in motion) of the acquisition and extinction phase.

Effect	*df*	*F*	η^2	*p*
Acquisition				
Total				
Time	2, 64	139.8	0.81	<0.001
Social Anxiety	1, 32	7.07	0.18	0.012
Time × Stimulus	2, 64	4.68	0.13	0.013
Condition × Social Anxiety	1, 32	6.37	0.17	0.017
Electroshock condition				
Time	2, 30	75.1	0.83	<0.001
Stimulus	1, 15	5.60	0.27	0.032
Social Anxiety	1, 15	9.18	0.38	0.008
Time × Stimulus	2, 30	4.67	0.24	0.017
Social threat condition				
Time	2, 30	5.10	0.25	0.039
Extinction				
Total				
Time × Stimulus × Condition	1, 32	5.87	0.16	0.021
Time × Stimulus × Condition × Social Anxiety	1, 32	6.45	0.17	0.016
Electroshock condition				
Time × Stimulus	1, 15	5.02	0.25	0.041
Time × Stimulus × Social Anxiety	1, 15	6.91	0.32	0.019

df = degrees of freedom; η^2 = effect size; Phase = Rating 1 vs. Rating 2 for the acquisition and Rating 2 vs. Rating 3 for the extinction; Rating 1 = after baseline, Rating 2 = after acquisition, Rating 3 = after extinction; Stimulus = CS+ vs. CS− vs. NS; CS+ = agent paired with the aversive unconditioned stimulus (US), CS− = agent without aversive US, NS = agent without aversive US and not appearing during the acquisition phase; Condition = electroshock vs. social threat condition; Social Anxiety (low vs. high) was measured with the German version of the Social Phobia Inventory (SPIN; median split = 13.5, Stangier and Steffens, 2002).

the electroshock condition, but also a fast adaptation to the US occurred toward the end of the acquisition.

For the extinction phase, an ANOVA confirmed significant interaction effects of Time × Stimulus × Condition, and Time × Stimulus × Condition × Social Anxiety. Follow-up ANOVA for the electroshock condition revealed a significant interaction effect of Time × Stimulus, and Time × Stimulus × Social Anxiety. Further follow-up ANOVAs were conducted separately for the low and high social fear groups, but no significant main or interaction effects were found. No significant effects were found in the social threat condition or for the NS.

DISCUSSION

The aim of this study was to replicate and extend the findings of our previous study we conducted on social fear learning (Shiban et al., 2015). In order to improve the paradigm, we investigated the "belongingness effect" (Hamm et al., 1989). To this end, we designed a social threat condition and compared it to an electroshock condition during the different phases (baseline, acquisition and extinction) of the social fear conditioning paradigm (SFC). Participants actively approached virtual agents using a joystick in a setting similar to the one used by Shiban et al. (2015). Social fear learning was examined via subjective ratings (fear and contingency ratings), physiological (fear-potentiated startle, skin conductance level) and behavioral measures (avoidance).

Social fear acquisition was successful according to the fear and the contingency ratings. In both conditions, these measures clearly increased for CS+ compared to CS− from the baseline to the end of the acquisition phase. Interestingly, there was a higher differentiation between CS+ and CS− in the social threat compared to the electroshock condition, which might reflect a tendency toward higher belongingness in the social threat condition. Regarding the physiological outcome variables, the fear-potentiated startle results did not confirm our hypotheses, as no discrimination between CS+ and CS− could be detected. However, with respect to the SCL, successful fear conditioning took place at the beginning of the acquisition, whereas a fast habituation was found toward the end of acquisition, diminishing any discriminant effects between the CS+ and CS−. Furthermore, the avoidance behavior clearly increased for CS+ compared to CS− at the beginning of the acquisition phase for the time in non-motion in the social threat condition and the time in motion in the electroshock condition.

Fear extinction was evident in the ratings, as the differentiation in terms of fear and contingency ratings between the CS+ and the CS− that followed acquisition vanished during

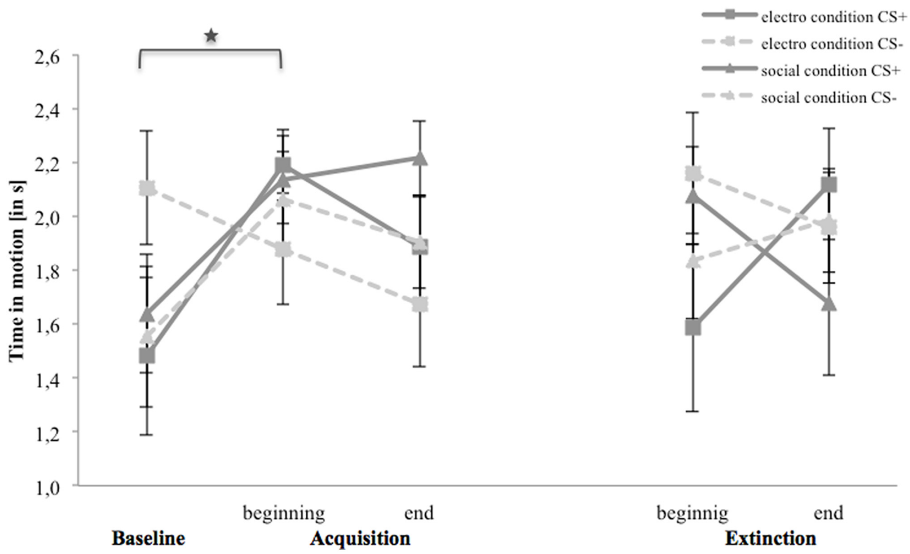

FIGURE 8 | Time in motion (*n* = 36) for CS+ and CS– in the three phases (baseline, acquisition, and extinction) for the electro shock and social threat condition. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; electro condition = electrical stimulation; social condition = air blast combined with virtual spitting and insulting. Mean time in non-motion (in s) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

the extinction phase for both experimental groups. However, no statistically significant extinction was found in the physiological and behavioral variables. It is possible that the physiological level had already been subject to a fast extinction process that can be expected in non-socially phobic individuals before the designated extinction phase of the experiment.

According to our data, social fear can be induced and extinguished confirming the operant conditioning paradigm. Participants did not simply explore the virtual room and the agents in our (operant) fear conditioning paradigm, but actively (using a joystick) approached the agents. They were free to decide how fast they wanted to approach the agents and to which degree they wanted to avoid them. With participants being punished while approaching the stimuli (virtual male agents), our SFC paradigm reflects operant conditioning rather than classical conditioning processes. Interestingly, less socially fearful participants differentially evaluated the contingency of CS+, CS−, and NS after extinction in the electroshock condition and only rated the contingency of the CS+ as high, whereas higher socially fearful participants rated the contingency of the CS+ and the NS on a similar level. Thus, we found a generalization effect in the contingency ratings between CS+ and NS for higher socially fearful participants. No generalization effect was reflected by the physiological measures.

Summarizing the results for the subjective ratings as well as the physiological and behavioral data, our initial hypotheses could be partially confirmed. The habituation at the end of the acquisition phase might reflect a fast adaptation to the aversive US. Possibly the US was not aversive enough to evoke long-lasting fear or the social anxiety of the sample was too low. Due to the belongingness effect, a higher differentiation in the subjective ratings between CS+ and CS− in the social threat condition was found.

Our SFC paradigm might have induced an approach-avoidance conflict. This conflict occurs when a person is faced with the decision to either pursue or avoid something that is advantageous in some respects but disadvantageous in others. In the social threat condition, the avoidance behavior (time in non-motion) clearly differed between aversive (CS+) and non-aversive (CS−) stimuli at the beginning of the acquisition. By comparison, in the electroshock condition the avoidance behavior (time in motion) clearly increased toward aversive compared to non-aversive stimuli at the beginning of the acquisition. Avoiding social situations is a core feature of SAD. Our paradigm showed increased fear and a partial increase in avoidance after the presentation of the first four aversive agents during conditioning. Besides behavioral avoidance, eye-gaze, a non-verbal social cue, is an important aspect of human social behavior. Future studies may therefore consider measuring behavioral approach-avoidance conflict via an eye-tracking method and analyze the recorded movement trajectories as an index of avoidance behavior for social anxiety. Identifying approach- and avoidance-related responses to social stimuli like emotional face stimuli (e.g., via reaction times for pressing a button or joystick responses, or through eye-gaze), has already been investigated in different studies (Mühlberger et al., 2008; Wieser et al., 2009, 2010; Radke et al., 2013). Wieser et al. (2010), e.g., reported that high anxiety was related to less gaze contact and greater backward head movement in response to male virtual agents, which showed a direct gaze. Furthermore, Dechant et al. (2017) revealed that highly fearful participants showed more avoidance in a social fear virtual paradigm than low fearful participants. It should be noted that avoidance behavior is a crucial element not only in fear learning but also in the maintenance of fear. In this study, we only focused on the fear learning process. In order to investigate the mechanisms of avoidance behavior in SAD in its entirety, we recommend future research to also study the role of safety behaviors in the maintenance of SAD.

In past studies using stimuli of low ecological validity with regard to the nature of SAD, it remained unclear whether socially fearful persons react more sensitively to socially relevant stimuli. Our social threat condition utilizes social stimuli, which are likely to be disorder-relevant for SAD. Thus, our social threat condition might be more suitable for investigating social anxiety due to a higher belongingness between the CS and the US and consequently an enhanced ecological validity of the design. Furthermore, not using electric shocks may make the recruitment of clinical samples easier for future studies. Empirical findings indicate that successful conditioning in highly fearful individuals cannot only be induced by effective non-social US (i.e., electric shocks), but also by social stimuli, such as emotional facial expressions paired with compatible verbal feedback (Lissek et al., 2008) or isolated verbal comments (Ahrens et al., 2014). In the present study, conditioning was successful and avoidance behavior could be observed in both conditions. Still, there was a better differentiation between aversive and non-aversive stimuli in the social threat condition. One explanation for not having observed an enhanced belongingness effect in our study could be that the high social anxiety group showed a low SPIN score (median score = 13.5) as well. According to Connor et al. (2000) a SPIN score of 19 distinguishes between social phobia subjects and controls.

It is noteworthy that participants undergoing electrical stimulation typically have a more robust fear response both before and after acquisition and extinction (Schmitz and Grillon, 2012) and rate the shock as more aversive than alternative stimuli such as a female scream (Glenn et al., 2012), suggesting that they tend to overestimate the probability of aversive stimuli when being physically harmed. However, this effect could not be found in the contingency ratings, and although the subjective fear ratings before acquisition were generally higher for subjects in the electroshock condition, the fear ratings for the CS+ after acquisition barely differed. Furthermore, we found a better differentiation between the CS+ and the CS− both after the acquisition and the extinction phases in the social threat condition than in the electroshock condition, indicating that the social threat is more realistic than the electroshock condition. These findings partially confirm our hypothesis that acquisition and resistance to extinction are intensified by a sense of belongingness between the CS and the applied US. This is an important fact which should be taken into consideration in future research.

An issue regarding the experimental setting is the linguistic label of the fear ratings. Many subjects reported that it was not actually fear they had experienced, but a feeling comparable with unpleasantness or, especially in the case of the virtual spitting, even disgust. Being spat at might not only induce social fear (as expected for a socially fearful person) but also cause disgust. Still, being spat at along with hearing the agent say “go away” is a social situation that is expected to elicit emotions similar to the ones induced in a social fearful or phobic patient. In order to investigate if conditioning had caused social fear or simply disgust, we could have asked participants which emotions had been elicited by the conditioning paradigm. Updating the understanding of SAD, future studies should measure disgust and similar emotions. Furthermore, it has to be taken into account that the three virtual agents differed in clothing, hair color and facial design, which might have led to an association of the US with the external stimuli instead of the situation. As a further limitation of the current study, our non-clinical sample was limited to young students with a high proportion of female students, which should be taken into account when generalizing the results to a broader population. However, as social phobia is twice as prevalent in women than in men, females are an interesting target group for our paradigm (Bandelow and Wedekind, 2014).

Despite these facts, all in all our paradigm has been shown to be suitable for investigating the acquisition and extinction of social fear in a VR setting similar to the paradigm used by Shiban et al. (2015). As in this previous work, results support the translation of the SFC paradigm by Toth et al. (2012) from the mice model to human studies. Further research is needed to expand these findings by increasing the sample size and by testing patients suffering from social phobia. Treatment for this widespread health issue could potentially be enhanced by optimizing the extinction process that is strived for in exposure therapy. Furthermore, it is an interesting research question if patients suffering from social phobia could benefit from extinction processes in different contexts as Dunsmoor et al. (2014) could verify for healthy humans.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Ethics Committee of the University of Regensburg with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the University of Regensburg.

AUTHOR CONTRIBUTIONS

JR study conception, data analysis, wrote the manuscript. SP study conception, data acquisition and analysis, and contribution to the manuscript. JW and VZ data analysis, contribution to the manuscript. YS study conception, data analysis, contribution to the manuscript. All authors have approved of the final version of the manuscript and its submission.

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Conflict of Interest Statement: The 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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2.2 Study 2: Gender Differences in Social Fear Conditioning in Virtual Reality

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Men Scare Me More: Gender Differences in Social Fear Conditioning in Virtual Reality

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Women nearly twice as often develop social anxiety disorder (SAD) compared to men. The reason for this difference is still being debated. The present study investigates gender differences and the effect of male versus female agents in low (LSA) and high socially anxious (HSA) participants regarding the acquisition and extinction of social fear in virtual reality (VR). In a social fear conditioning (SFC) paradigm, 60 participants actively approached several agents, some of which were paired with an aversive unconditioned stimulus (US) consisting of a verbal rejection and spitting simulated by an aversive air blast (CS+), or without an US (CS−). Primary outcome variables were defined for each of the 4 levels of emotional reactions including experience (fear ratings), psychophysiology (fear-potentiated startle), behavior (avoidance), and cognition (recognition task). Secondary outcome variables were personality traits, contingency ratings, heart rate (HR), and skin conductance response (SCR). As hypothesized, fear ratings for CS+ increased significantly during acquisition and the differentiation between CS+ and CS− vanished during extinction. Additionally, women reported higher fear compared to men. Furthermore, a clear difference in the fear-potentiated startle response between male CS+ and CS− at the end of acquisition indicates successful SFC to male agents in both groups. Concerning behavior, results exhibited successful SFC in both groups and a general larger distance to agents in HSA than LSA participants. Furthermore, HSA women maintained a larger distance to male compared to female agents. No such differences were found for HSA men. Regarding recognition, participants responded with higher sensitivity to agent than object stimuli, suggesting a higher ability to distinguish the target from the distractor for social cues, which were on focus during SFC. Regarding the secondary physiological outcome variables, we detected an activation in HR response during acquisition, but there were no differences between stimuli or groups. Moreover, we observed a gender but no CS+/CS− differences in SCR. SFC was successfully induced and extinguished according to the primary outcome variables. VR is an interesting tool to measure emotional learning processes on different outcome levels with enhanced ecological validity. Future research should further investigate social fear learning mechanisms for developing more efficient treatments of SAD.

Keywords: social anxiety disorder, social fear conditioning, virtual reality, fear ratings, fear-potentiated startle, avoidance behavior, recognition

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INTRODUCTION

Social Anxiety Disorder and Social Fear Conditioning

According to the DSM-5, social anxiety disorder (SAD) is characterized by a persistent fear of one or more social or performance situations in which the person is exposed to unfamiliar people or to possible scrutiny by others, which is often associated with avoidance of social situations (American Psychiatric Association American Psychiatric Association [APA], 2013). With an odds ratio of 1.5–2.2, SAD is nearly twice as prevalent in women than in men (Fehm et al., 2005). Further empirical evidence on gender differences indicates that psychosocial stress affects fear conditioning in men and women differently (Jackson et al., 2006; Zorawski et al., 2006).

Research on fear and anxiety investigates the mechanisms of emotional learning across species with the purpose of improving treatments tackling the severe effects of anxiety disorders in humans. Many researchers use classical fear conditioning, which has been extensively investigated in animals and in healthy and phobic humans. Such learning paradigms use pairings with an initially neutral stimulus (NS) and an aversive unconditioned stimulus changing the NS to a conditioned stimulus (Mertens et al., 2018). However, there are also other conditioning paradigms of aversive learning involving contextual stimuli (Glotzbach-Schoon et al., 2013; Shiban et al., 2013), generalization processes (Lissek and Grillon, 2010; Vervliet and Geens, 2014; Andreatta et al., 2017) or more complex operant or instrumental conditioning, in which behavior is learned by its consequences (Lissek et al., 2005; Shiban et al., 2015; Reichenberger et al., 2017).

In a single-cue conditioning procedure, anxiety patients present enhanced fear conditioning to CS+ compared to healthy humans (Lissek et al., 2005). In a review, Duits et al. (2015) reported increased fear responses to CS− stimuli during fear conditioning and stronger fear responses to CS+ stimuli during fear extinction in anxiety patients compared to healthy controls. In contrast, Ahrens et al. (2015) suggest that patients with SAD exhibit no generally enhanced conditionability but distinguish in discrimination learning of CS+ and CS− (non-reinforced stimuli) and in terms of resistance to extinction compared to healthy controls. Following this, Ahrens et al. (2016) indicate that it is important to differentiate between individual stimuli in order to save resources and to decrease unnecessary fight-or-flight responses or avoidance behavior if there is no threat. Hermann et al. (2002) showed that SAD patients exhibited an enhanced US expectancy during acquisition, especially for the CS−, which indicates an overgeneralization of the conditioned emotional response and contributes to the etiology of SAD. Ahrens et al. (2016) detected that SAD is not characterized by strong overgeneralization but by discrepancies in fear responses to conditioned and generalized threat stimuli.

Due to the use of stimuli with low ecological validity regarding the nature of SAD in most published studies, it is still being debated if socially anxious humans respond more sensitively to socially relevant stimuli. Ahrens et al. (2015) indicated a potentially impaired ability of highly socially anxious participants to discriminate between relevant and irrelevant social stimuli. The social relevance of the US might play a significant role in fear learning, therefore a disorder-relevant US should be used to examine affective learning in SFC paradigms (Lissek et al., 2008). Fear learning outside of the lab hardly exists to simple sensory cues, like geometric, facial or electrical stimuli, but contains more complex stimuli which vary between psychopathological dysfunctions (Ahrens et al., 2016). Furthermore, Ahrens et al. (2016) suggest that fear conditioning in high socially anxious persons or SAD patients can not only be induced by effectively non-social US (e.g., electrical stimuli), but also by social stimuli, like critical facial expressions with verbal feedback (Lissek et al., 2008), isolated verbal comments (Ahrens et al., 2015) or spitting with verbal rejection (Reichenberger et al., 2017).

Many researchers demand an expansion of the human fear conditioning paradigm by comprising behavioral tendencies as a significant index of fear and focusing more on uncertain than strong fear learning situations, such as contained in single-cue or differential fear conditioning (Lissek et al., 2006; Glotzbach et al., 2012; Beckers et al., 2013). Following this, it is important to construct situations with an amount of complexity and uncertainty. Furthermore, individual factors, e.g., personality traits and dispositions, should be emphasized more in future research as they are predictive for the development of anxiety disorders (Beckers et al., 2013).

The conceptual—theoretical model for SAD (Rapee and Heimberg, 1997) suggest a coupling of a cue (e.g., facial expression, verbal rejection) or situation (e.g., a social situation), emotional and physiological reactions (e.g., fear-potentiated startle reaction), behavior (e.g., approach-avoidance behavior), and cognitions (e.g., threat thoughts). In the following paragraph, each aspect will be explained in more detail in light of social fear conditioning.

Social Situations

According to core fear in SAD (see DSM-5 definition of SAD, American Psychiatric Association American Psychiatric Association [APA], 2013) empirical research should investigate social or performance situations in which the person is exposed to possible scrutiny by others. However, *in vivo* studies make a great effort in planning and organizing a social situation, there is less control over the situation or a counterpart (e.g., social skills training), as well as a higher inhibition threshold for patients (e.g., *in vivo* exposure therapy). In VR participants have the ability to interact with diverse stimuli (e.g., human agents) and their environment similar to an *in vivo* social situation. Hence, SFC in VR offers a great benefit to simulate social interactions with a high controllability and thereby to enhance ecological validity compared to traditional cue-conditioning. VR conveys the feeling of being present in the virtual situation by providing immersive sensory perceptions and allowing interactions with the virtual environment. The feeling of presence might be a crucial factor to investigate social interactions and social fear as it is relevant in real life situations (Diemer et al., 2015). Our SFC paradigm offers basic social interaction opportunities between the participant and the agent (e.g., eye contact, self-regulated movement of the avatar and movement toward the agent). In addition, the facial expressions of the agents are paired with a verbal rejection in order to enhance the US (see Reichenberger et al., 2017). Besides many further advantages with VR, e.g., realistic, standardized environment in an economic and easily administrable manner, the results of conditioning processes in VR are hugely satisfying (Huff et al., 2010).

Emotional and Physiological Reactions

According to Lang's fear response system (Lang, 1968), following outcome measures of conditioned fear are commonly used in fear conditioning: subjective, physiological, and behavioral fear responses (Mertens et al., 2018). In VR we can directly measure the reactions of the participants to the stimuli via subjective verbal ratings (e.g., fear and contingency ratings), physiological (e.g., fear-potentiated startle, electrodermal activity or electrocardiographic) and behavioral data (Mühlberger et al., 2006, 2007; Powers and Emmelkamp, 2008; Shiban et al., 2013; Kinateder et al., 2015). Physiological outcome measures are commonly applied and offer the advantage of being less conscious and less vulnerable to bias in comparison to subjective reports (Lonsdorf et al., 2017). For example, fear-potentiated startle is a less cognitive index of fear than verbal ratings, but also than skin conductance responses (SCRs) (Lipp et al., 2003; Mallan et al., 2009; Beckers et al., 2013).

Behavior

According to Beckers et al. (2013) another important outcome measure is the behavioral fear response in anxiety research. Commonly, an adaptive behavioral strategy is to avoid threatening or unpleasant events. Nevertheless, excessive threat-avoidance is a central diagnostic feature and a known risk factor for the acquisition and maintenance of anxiety disorders (Dymond et al., 2012). Socially anxious humans are more likely to avoid new social situations if aversive consequences occur (Mineka and Oehlberg, 2008). However, individuals with SAD do not always avoid social situations, but sometimes endure them with high levels of distress (Hofmann et al., 2009). Mertens et al. (2018) demonstrate that measuring behavioral fear responses typically involve the physical distance to and the degree of interaction with the CSs using behavioral approach tests (e.g., time for approaching, pressing a button to remove the stimulus or to avoid the US, attentional bias). Besides gender differences in the prevalence of SAD, the gender of the counterpart might also be an influencing factor in the behavioral fear response. In their study on distance in social interactions in VR, Iachini et al. (2014) showed that participants of both genders approach females more closely than male agents. Interpersonal space is defined as a safety space contributing to protect the body from an external threat (Iachini et al., 2014, 2016; Cartaud et al., 2018). Social anxiety is characterized by a prevalence of enlarged interpersonal space for pleasant social interaction (Cartaud et al., 2018). Moreover, Åhs et al. (2015) showed that interpersonal defensive boundaries increase with aversive learning.

Cognitive Processing

Cognitive models of SAD suggest self-perception as an important maintaining factor of the disorder (Clark and Wells, 1995). Individuals with SAD are characterized by negative cognitions like a negative view of themselves and their social skills in social interactions in detail. A further frequently occurring phenomenon is post-event rumination, in which individuals recall the interaction as being more negative than it actually was (Hofmann, 2007). Besides negative cognitions, it raises the question how deeply the social interaction is processed and stored in memory. The signal detection theory (SDT) offers an empirical examination of memory processing and performance in SAD. With the use of the SDT, statistical analysis allows for the differentiation between discrimination ability (sensitivity) and particular response criteria (Velden, 1982; Sawchuk et al., 2002).

Empirical findings of anxiety assume that an information processing bias exists in the detection, discrimination, and response to stimuli that indicate threat and safety. Thus, anxious persons should show different patterns of sensitivity and response criteria toward threat stimuli (Foa and Kozak, 1986; Sawchuk et al., 2002). Pérez-López and Woody (2001) examined recognition memory for reassuring and threatening facial expressions in individuals with SAD and healthy controls. Individuals with SAD were less sensitive to recognizing previously seen stimuli compared to controls but showed no memory bias toward threatening facial expressions. Further empirical studies reported that socially phobic participants are more likely to interpret ambiguous social interactions as negative and are better at remembering negative or critical rather than neutral or happy facial expressions, whereas healthy controls show no such differences (Lundh and Öst, 1996; Gilboa-Schechtman et al., 1997).

The processing of emotional facial expressions has usually been investigated using a series of isolated, de-contextualized, static photographs of humans posing with facial expressions that enhance the dissimilarity among categories (Wieser and Brosch, 2012). However, human face perception and evaluation are always affected by emotional and non-emotional aspects of context features and are regulated by individual traits such as social anxiety (Schwarz et al., 2013). Therefore, the question arises whether SFC leads to improved memory representations for conditioned stimuli.

SFC Paradigm

In previous SFC studies, we could successfully induce and extinguish social fear, which emphasizes the role of conditioning in social fear learning (Shiban et al., 2015; Reichenberger et al., 2017). The current study investigates social fear conditioning in VR in a human sample using our SFC setting, which consisted of a CS habituation, acquisition, and extinction phase similar to both our preliminary studies. Furthermore, we maximized the difference between participants by analyzing low (LSA) and high (HSA) socially anxious participants as well as women and men in an equal ratio. Furthermore, we implemented female and male virtual agents into our SFC paradigm to investigate whether there is dissimilarity between learning and unlearning of social fear in women and men and whether there is an influence of the gender of social stimuli (female vs. male agents). In this way, we will investigate how female or male participants behave toward female or male virtual agents to assess affective learning processes in social anxiety.

In addition to that, we added an unforeseen recognition memory task following the SFC paradigm in VR to investigate recognition processes in LSA and HSA participants. We presented stimuli and distractors of the previously seen female and male agents as well as items like tables, chairs and cupboards in the VR environment during the SFC paradigm.

A further feature of our paradigm is the high belongingness between the CS and the US, which is a possible advantage in recruiting clinical samples (Hamm et al., 1989; Lissek et al., 2008). Moreover, the paradigm involves a degree of complexity and uncertainty. Another advantage is that we use disorder-relevant stimuli to improve the ecological validity of the SFC paradigm.

Hypotheses

The present study investigates whether gender differences occur in social fear conditioning with female and male agents. We tested low and high socially anxious female and male participants in our SFC paradigm in VR with an enhanced ecological validity. Participants actively approached virtual female and male agents using a joystick. According to the conceptual-theoretical model for SAD (Rapee and Heimberg, 1997), we aimed at covering the subjective, physiological, behavioral, and cognitional effects of the acquisition and extinction of social fear. Therefore, we assessed each level of emotional responses on primary outcome (fear ratings, fear-potentiated startle, avoidance, recognition memory performance) and additional secondary outcome variables (personality traits and dispositions, contingency ratings, SCR, HR response). Based on the aforementioned findings, for the acquisition phase we hypothesized that (1) fear ratings for CS+ would increase compared to CS− for pre to post acquisition measurement. Concerning the contingency ratings, we expected increased US expectancy for the CS− post acquisition in HSA compared to LSA. Furthermore, the amplitude of the fear-potentiated startle, the SCR, and the HR response approaching the CS+ and the avoidance behavior during the approach toward CS+ were expected to be higher compared to CS−. After the extinction phase, (2) fear and contingency ratings of the CS+ were supposed to return to baseline levels along with physiological and behavioral outcome variables. (3) According to Duits et al. (2015), we expected increased fear responses to CS− stimuli during fear acquisition and stronger fear responses to CS+ stimuli during fear extinction among HSA compared to LSA participants. (4) Acquisition and resistance to extinction were expected to be higher for women than for men. In addition, we expected to find higher fear responses when approaching male agents in comparison to female agents. (5) We hypothesized that for HSA, recognition memory for CS+ agents would be greater than for CS− and NS agents compared to LSA participants. Finally, (6) we hypothesized that HSA would show a generalization effect for the NS during the extinction phase compared to LSA participants.

MATERIALS AND METHODS

Participants

Seventy healthy volunteers were recruited through advertisements and a screening in first semester events at the University of Regensburg. Hundred and eighty students took part in the screening and questionnaires were used to assess demographic data, exclusion criteria, and different personality traits and dispositions as well as social anxiety using the Social Phobia Inventory (SPIN; Connor et al., 2000; German version: Stangier and Steffens, 2002). The allocation to the low (LSA) and high socially anxious (HSA) group was based on the SPIN cut-off value of 19 stated in the screening. According to Connor et al. (2000), a SPIN score of 19 distinguishes patients with SAD from healthy subjects with a diagnostic accuracy of 79%.

Exclusion criteria being below 18 or above 55 years of age, a current diagnosis of a mental or neurological disorder (excluding SAD), current psychotherapeutic, psychiatric or neurological treatment, history of psychotropic drug use, and pregnancy or lactation, as well as participation in a former social fear conditioning study at the University of Regensburg. These criteria were assessed via a questionnaire after written informed consent had been obtained.

As 10 participants were excluded due to cybersickness symptoms (n = 4) or technical error during data acquisition (n = 6), the study comprised a total of 60 participants (31 participants in the LSA group: 51.6% female, aged between 18 and 43; and 29 participants in the HSA group: 51.7% female, aged between 19 and 33). The allocation of the participants into a low and high socially anxious group can be regarded as successful, since HSA show significantly higher values with large effect sizes in the SPIN, in the Social Interaction Anxiety Scale (SIAS; Mattick and Clarke, 1998; German version: Stangier et al., 1999) and in the Anxiety Sensitivity Index-3 (ASI; Taylor et al., 2007; German version: Kemper et al., 2009) compared to the LSA group (see **Table 1**).

All participants had unimpaired or corrected vision or hearing. All of the volunteers were students at the University of Regensburg and were offered credit points as compensation for their participation. The Ethics Committee of the University of Regensburg approved the study.

Apparatus

The VR environment consisted of one room, in which all three phases (CS habituation, acquisition, and extinction), the subjective ratings and the behavioral avoidance tests (BAT) took place. In each phase, the participant was positioned at one end of the room and could see each female or male agent at the opposite end of the room. The agents gazed dynamically at the participant and moved their head and upper body slightly

TABLE 1 | Significant results of the ANOVA for fear ratings of the acquisition and extinction phase.

Effect	***df***	***F***	η_p^2	***p***
		Acquisition		
Total				
Phase	1, 56	22.1	0.28	< 0.001
Stimulus	1, 56	33.2	0.37	< 0.001
Gender	1, 56	4.43	0.07	0.040
Agent ×Social Anxiety	1, 56	4.26	0.07	0.044
Stimulus × Gender	1, 56	4.48	0.07	0.039
Phase × Stimulus	1, 56	33.3	0.37	< 0.001
Phase × Stimulus × Gender	1, 56	4.47	0.07	0.039
Phase × Stimulus × Gender × Social Anxiety	1, 56	4.33	0.07	0.042
LSA				
Phase	1, 29	12.9	0.31	< 0.001
PStimulus	1, 29	17.4	0.38	< 0.001
PAgent	1, 29	4.78	0.14	0.037
PPhase × Stimulus	1, 29	14.4	0.33	< 0.001
PPhase × Gender	1, 29	4.55	0.14	0.041
HSA				
PPhase	1, 27	10.1	0.27	0.004
PStimulus	1, 27	15.9	0.37	< 0.001
PPhase × Stimulus	1, 27	18.6	0.41	< 0.001
PPhase × Stimulus × Gender	1, 27	7.31	0.21	0.012
HSA women				
PPhase	1, 14	5.86	0.30	0.030
PStimulus	1, 14	11.0	0.44	0.005
PPhase × Stimulus	1, 14	16.0	0.53	< 0.001
HSA men				
PPhase	1, 13	5.25	0.29	0.039
PStimulus	1, 13	7.21	0.36	0.019
		Extinction		
Total				
PPhase	1, 56	22.1	0.28	< 0.001
PStimulus	1, 56	37.9	0.40	< 0.001
PAgent	1, 56	5.67	0.09	0.021
PGender	1, 56	4.50	0.07	0.038
PStimulus × Gender	1, 56	5.55	0.09	0.022
PPhase × Gender	1, 56	5.11	0.08	0.028
PPhase × Stimulus	1, 56	21.1	0.27	< 0.001
PPhase × Stimulus × Agent	1, 56	4.02	0.07	0.050
Female agent				
PPhase	1, 59	26.4	0.31	< 0.001
PStimulus	1, 59	30.2	0.34	< 0.001
PPhase × Stimulus	1, 59	27.1	0.32	< 0.001
Male agent				
PPhase	1, 59	28.3	0.32	< 0.001
PStimulus	1, 59	28.8	0.33	< 0.001
PPhase × Stimulus	1, 59	9.96	0.14	0.003

df, degrees of freedom; η_p^2*, effect size; Phase, pre- vs. post-acquisition for acquisition and post-acquisition vs. post extinction for extinction; Stimulus, CS+ vs. CS−; Agent, female vs. male agent; Gender, women vs. men; Social Anxiety, LSA vs. HSA.*

(see **Figure 1**). In 75% of the conditioning trials, an aversive consequence followed as soon as the participants reached a specific distance to the agents (30 cm) and navigation stopped. Aversive consequences consisted of an air blast to the right side of the participant's neck (5 bar, 10 ms) accompanied by a sound of spitting followed by a verbal rejection. A compressed tank of air, which was regulated via a magnetic valve system, channeled the air blast through a tube that was fixed to the participant's torso. In addition, when the participant approached the agent, a startle sound was administered in 75% of all trials in all phases.

The VR was presented to participants via the HTC VIVE head-mounted display (HMD; HTC Corporation, Taoyuan, Taiwan) and was generated via the Steam Source engine (Valve Corporation, Bellevue, WA, United States). The presented VR environment was controlled by CyberSession Research 5.6 (VTplus GmbH, Würzburg, Germany). The participant's head position was monitored via the HTC VIVE lighthouse tracking system, which creates a 360-degree virtual space with up to 15 × 15 foot radius (HTC Corporation, Taoyuan, Taiwan). This tracking data is transmitted in real time to the CyberSession software using the Valve OpenVR[1], which adjusted the participant's field of view according to the tracked head position. Sounds were presented over headphones (Sennheiser HD-215, Sennheiser electronic GmbH, Germany). Participants used a joystick (Logitech Extreme 3D Pro Joystick, Logitech GmbH, Germany) mounted on a stand to move in the VR environment. Physiological data were monitored, digitally amplified (V-Amp, Brain Products GmbH, Germany) and recorded (Brain Vision Recorder software, Version 1.20, Brain Products GmbH, Germany).

Measures

Participants filled out a demographic questionnaire (age, sex, education, current occupation, and exclusion criteria) and the following questionnaires.

The SPIN was used to assess social anxiety and consists of 17 items that assess fear, avoidance, and physiological symptoms of SAD in the previous week. Answers are given on a five-point Likert scale (from 0 = "not at all" to 4 = "extremely"). The German version of the SPIN was evaluated by Sosic et al. (2008). Internal consistency was excellent for a representative sample of 2043 Germans (Cronbach's α = 0.95). Convergent and divergent validity are satisfactory. Furthermore, the German version of the SPIN is a sensitive and specific measure for SAD as it distinguishes successfully between SAD and other psychiatric disorders (Sosic et al., 2008).

The SIAS assesses anxiety in social interactional situations with 20 items on a five-point Likert scale from 0 = "not at all" to 4 = "very strong." The internal consistency of the German version can be classified as extremely reliable with a Cronbach's α = 0.94 (Heinrichs et al., 2002). Construct and convergent validity were rated as good and reliability as good to excellent (Heimberg and Turk, 2002).

[1]https://github.com/ValveSoftware/openvr

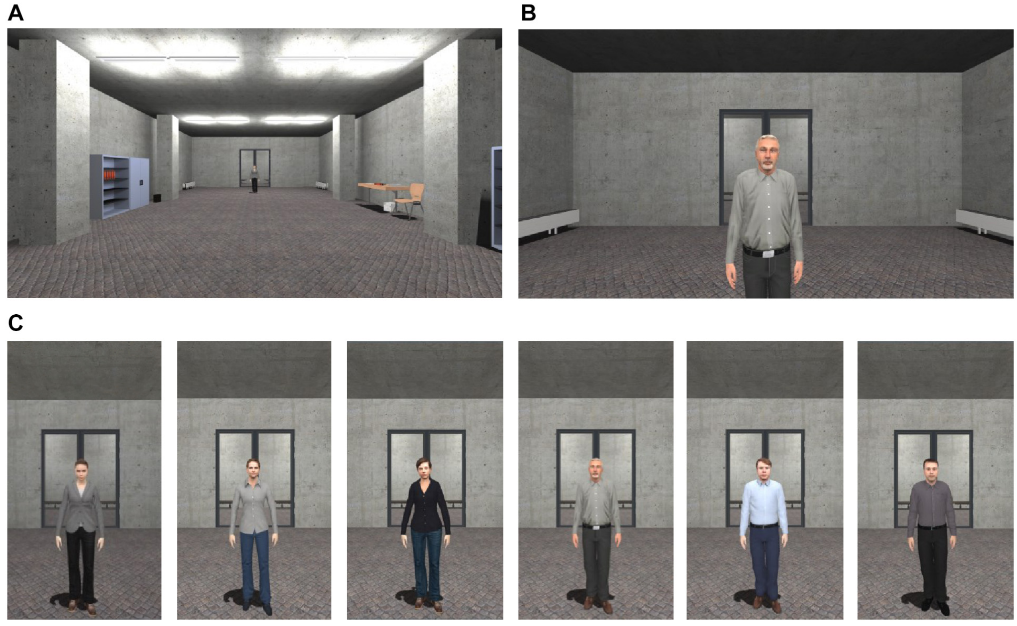

FIGURE 1 | Virtual environment. **(A)** Starting point in the room, in which learning phases (CS habituation, acquisition, and extinction), ratings, and behavioral avoidance task took place. **(B)** End point for approaching the agent. **(C)** Social stimuli (agents) used for social fear conditioning.

The ASI-3 was used to assess participants' fear of physiological arousal related sensations. The questionnaire captures three dimensions of anxiety sensitivity (physical, social, and cognitive concerns) with 18 items on a five-point Likert scale (from 0 = "do not agree" to 4 = "completely agree"). The reliability depends on the sample and ranges from acceptable to excellent (Cronbach's $\alpha = 0.75 - 0.92$). Factorial and construct validity are satisfactory (Kemper et al., 2009).

The Dominance scale of the German Personality Research Form (PRF-D; Stumpf et al., 1985) was employed to quantify the characteristics of dominant behaviors. It investigates dominant personality traits via preferences and behaviors with 16 items on a dichotomous scale ("right" vs. "false"). In a sample of 1086 participants, the PRF-D achieved a good internal consistency (Cronbach's $\alpha = 0.82$). Furthermore, retest-reliability (0.84) as well as convergent and discriminant validity are high (Stumpf et al., 1985).

The Submissive Behavior Scale (SBS; Allan and Gilbert, 1997), which was translated into German for this study, assesses the frequency of submissive behavior with 16 items rated on a five-point Likert scale from 0 = "never" to 4 = "always." Internal consistency proved to be high both in a student, Cronbach's$\alpha = 0.82$, and a clinical sample, Cronbach's $\alpha = 0.85$ (Allan and Gilbert, 1997).

The subtest Ego threat of the German version of the Mainz Coping Inventory (MCI; Krohne et al., 2000; German version: Krohne and Egloff, 1999) captures two coping strategies, Vigilance (VIG) and Cognitive Avoidance (CAV), with 10 items respectively with regard to four stressful situations (public speech, examination, job application, mistake on the job), which are answered by agreement or disagreement. Reliabilities of the CAV (Cronbach's $\alpha = 0.76$) and VIG (Cronbach's $\alpha = 0.80$) are satisfactory (Krohne and Egloff, 1999).

The Simulator Sickness Questionnaire (SSQ; Kennedy et al., 1993) was used to assess symptoms of cybersickness. The questionnaire consists of 16 items and uses a four-point Likert scale (from 0 = "not at all" to 3 = "heavy") to measure potential side effects of VR (e.g., dizziness symptoms). The Igroup Presence Questionnaire (IPQ; Schubert, 2003) consists of 14 items and captures the experience of presence in the virtual environment on a seven-point Likert scale.

In order to measure the experienced fear ("On a scale from 0 to 100, how intense is your fear during the presence of this person?") and contingency ("On a scale from 0 to 100, how likely is an unpleasant stimulus during the presence of this person?") regarding the CS, ratings were assessed verbally on a range from 0 (very low fear/very unlikely) to 100 (very high fear/very likely) during the presentations of the agents in the rating phase following each of the three phases.

Besides these self-reported measures, physiological and behavioral data were collected. To record the electromyography of the musculus orbicularis oculi as a measure of a fear-potentiated startle, four surface electrodes (Ag/AgCl, Ø D 8 mm) were affixed under the right eye of the participant and on the mastoid bones as reference and ground electrodes. Two additional surface electrodes (Ag/AgCl, Ø D 8 mm) were placed on the base of the thumb on the radial side of the palm of the non-dominant hand in order to record the SCR. Two adhesive pre-gelled surface electrodes (Ag/AgCl, Ø = 40 mm) were attached to the middle of the upper chest and on the rib tip of the left half of the body to record the electrocardiography. Avoidance behavior was measured as the minimal distance (in m) to the agent while passing it during the BAT. Recognition processing data were measured as sensitivity *d'* and response criteria β (Velden, 1982).

Procedure

The experiment consisted of filling out questionnaires, the social fear conditioning paradigm in VR (with a CS habituation, acquisition, and extinction phase), further questionnaires after the session in VR and a final recognition memory task (see **Figure 2**).

At the beginning, participants were briefed in written form and the informed consent was signed. After filling out the questionnaires (demographic, SPIN, SIAS, ASI-3, PRF-D, SBS, MCI), participants were prepared for the VR part of the experiment. The electrodes, the air blast device, the HMD and the headphones were adjusted. During the experiment, participants received recorded instructions, which were delivered via the headphones.

At first, participants relaxed for 2 min in VR (gray screen) for a physiological baseline-measure. Subsequent to nine presentations of the startle noise for habituation of the fear-potentiated startle reaction, participants were given a short task to explore the virtual environment to learn the navigation in VR. Following this, participants received the recorded instruction: "You will now meet several human beings. Please try to move directly toward the persons until they are right in front of you." Participants had to approach the agents actively using the joystick and as soon as they reached a specific distance to the agents (the equivalent of about 30 cm in the real world), lights faded out and the next agent was presented at the opposite end of the room. Each trial lasted about 10 s (depending on how fast participants approached the agents). Theoretically, participants could move laterally, diagonally or away from the agent, however, we observed no such behavior.

The CS habituation phase consisted of four blocks. One block consisted of one presentation of each female and male agent (CS+, CS−), resulting in a total of 16 presentations. Which agent was presented as CS+ or CS− was balanced across participants. A startle noise (white noise: 103 dB, 10 ms) was presented at two-thirds of the approach path to the agent with a contingency of 75% in each trial. The unconditioned stimulus (US) was not presented yet.

Afterward, the first rating and BAT took place. Participants approached each of the two female and male agents and as soon as they reached the previously specified distance to the agents,

	Pre questionnaire	– Demographic, SPIN, SIAS, ASI-3, PRF-D, SBS, MCI
Virtual Reality	**Baseline**	– 120 seconds physiological baseline measurement
	CS habituation	– 4 x ♂CS+, ♂CS-, ♀CS+, ♀CS- – pseudo-randomized – startle: 75 % contingency by all agents – trial length about 10 seconds
	Rating	– fear ratings (♂CS+, ♂CS-, ♀CS+, ♀CS-) – BAT (♂CS+, ♂CS-, ♀CS+, ♀CS-)
	Acquisition	– 8 x ♂CS+, ♂CS-, ♀CS+, ♀CS- – pseudo-randomized – US: 75 % contingency (CS+) – startle: 75 % contingency by all agents – trial length about 10 seconds
	Rating	– fear ratings (♂CS+, ♂CS-, ♀CS+, ♀CS-) – contingency ratings (♂CS+, ♂CS-, ♀CS+, ♀CS-) – BAT (♂CS+, ♂CS-, ♀CS+, ♀CS-)
	Extinction	– 8 x ♂CS+, ♂CS-, ♂NS, ♀CS+, ♀CS-, ♀NS – pseudo-randomized – startle: 75 % contingency by all agents – trial length about 10 seconds
	Rating	– fear ratings (♂CS+, ♂CS-, ♂NS, ♀CS+, ♀CS-, ♀NS) – contingency ratings (♂CS+, ♂CS-, ♂NS, ♀CS+, ♀CS-, ♀NS) – BAT (♂CS+, ♂CS-, ♂NS, ♀CS+, ♀CS-, ♀NS)
	Post questionnaire	– CS evaluation, SSQ, IPQ
	Recognition Memory Task	– agents: (6 x target, 6 x distractors) – objects: (6 x target, 6 x distractors)

FIGURE 2 | Experimental procedure. The experimental procedure took place as described above. As unconditioned stimulus (US) an air blast combined with virtual spitting and rejection was applied. CS+, agent paired with aversive US; CS–, agent without aversive US; NS, agent without aversive US and only appearing during the extinction phase. SPIN, Social Phobia Inventory; SIAS, Social Interaction Anxiety Scale; ASI-3, Anxiety Sensitivity Index; PRF-D, German Personality Research Form – Dominance Scale; SBS, Submissive Behavior Scale; MCI, Mainz Coping Inventory; SSQ, Simulator Sickness Questionnaire; IPQ, Igroup Presence Questionnaire.

lights faded out and the participants were asked to verbally rate their subjective fear. Following the respective ratings, lights faded in again and the participants were instructed to pass the agent and to leave the room through the glass door located behind the agent ("Now go through the glass door behind the person and leave the room").

The acquisition phase was conducted in eight blocks. One block consisted of one presentation of each conditioned stimuli (female and male CS+) with and without the US (female and male CS−), resulting in a total of 32 presentations. The US was an air blast combined with virtual spitting and the negative rejection "Get lost!". The facial expressions of the agents are adjusted to the spitting and verbal rejection. The CS–US contingency was set at 75% and the startle noise was also presented with a contingency of 75% in this phase.

After the conditioning phase, the second rating took place. Participants approached each of the two female and male agents and rated their subjective fear and the contingency of aversive events. Subsequently, the BAT took place again as described above. Afterward, there was a 5 min break, during which participants took off the HMD, sat down, and had the opportunity to close their eyes and relax.

The extinction phase consisted of eight blocks designed in exactly the same way as those in the acquisition phase, except for the absence of the US and the appearance of the NS agent of both genders. The total number of trials was 48 in this phase. Just like in the previous phases, the startle noise was presented with a contingency of 75%.

After the extinction phase, the last rating took place. Participants rated their subjective fear and the contingency of aversive events and the third BAT took place for each female and male agent (CS+, CS−, NS).

After the VR experiment and filling out the last questionnaires (short evaluation of the US, SSQ, IPQ), a surprise recognition memory task was conducted. Twenty-four images of virtual agents and objects (e.g., a chair, table, bookshelf, black board) were shown on a computer screen (1600 × 900) and the participants had to decide whether the presented 12 agents and 12 objects appeared in the virtual environment or not (see **Figure 3**). Six of these agents and six objects were shown in VR (stimulus) and six were modified (distractor). Participants used a keyboard to indicate if the agent or object was in the experiment ("y" = "yes") or if it was a modified representation and not presented in the experiment ("n" = "no"). The number of correct answers in the task was recorded. The total duration of the experiment was about 90 min.

Data Reduction and Statistical Analyses

Physiological data were preprocessed with Brain Vision Analyzer 2.0 software (BVA; Brain Products GmbH, Munich, Germany), the behavioral data were preprocessed with MATLAB 9.5 (MathWorks Inc., Germany) and further analyses were performed in SPSS 22.0 (IBM Corp., Armonk, NY, United States).

For the fear-potentiated startle, first, differences between the two electromyography electrodes were computed (see Blumenthal et al., 2005). Then, a 250 Hz high cut-off filter, a 30 Hz low cut-off filter, and a 50 Hz notch filter were applied, the data were rectified, and a moving average (50 ms) was calculated. For each fear-potentiated startle, a baseline correction was conducted using the mean value of the 50 ms before each startle tone as baseline. Next, peaks between 20 and 120 ms were marked automatically, controlled manually and corrected if necessary. Finally, T-values for the startle magnitude were calculated.

For the analysis of the SCR, the difference between the two electrodes was computed and a 1 Hz high cut-off filter was applied. For each SCR, a baseline correction was conducted using the mean value of 500 ms before each presentation of the stimulus as a baseline. SCR was registered as the peak response in the 0.5 – 6 s following stimulus presentation. Peaks were marked automatically, manually controlled and corrected if necessary (see Pineles et al., 2009; Shiban et al., 2016). SCR values $< 0.01\ \mu s$ were defined as non-responses and were set on zero (Lonsdorf et al., 2017). Furthermore, participants with more than 75% non-responses in all trials were excluded from the analysis (Lonsdorf et al., 2017). We had to exclude 8 female and 3 male participants for the SCR analysis.

For heart rate (HR), the difference between the ECG electrodes were computed, a 1.59 Hz (12 dB) high cut-off filter, a 30 Hz (12 dB) low cut-off filter, and a 50 Hz notch filter were administered. Then R-spikes were automatically detected and counted by an algorithm in BVA software, manually controlled and corrected if necessary. The HR per min was exported for 6s following the stimulus, so it could be expected that a minimum of five heartbeats are included in the analysis (see Prescott et al., 1992).

Avoidance behavior was assessed via the minimal distance (in m) to the agent while passing it during the BAT. Due to technical errors during data acquisition, one participant had to be excluded from data analysis of the avoidance behavior.

For the recognition data, sensitivity (*d'*) and response criteria (β) were computed according to the method recommendations outlined by Velden (1982) and Macmillan and Creelman (1991). Sensitivity (*d'*) is the ability of individuals to correctly discriminate the presented target stimuli during the experiment, from distractors which appeared at the time of recall. The decision-making response criteria (β) refer to the individual's decision during the memory task, which can range from a liberal to a conservative response style. Hit rate was the rate of targets presented during the VR procedure that were correctly classified as targets and false alarm rate was the rate of distractors (that were added for the recognition phase) that were incorrectly classified as targets. The sensitivity index and response criteria were calculated by first transforming the hit rate and false alarm rate probabilities into standardized z-scores and then computing the *d'* and β statistic values (see Sawchuk et al., 2002). Under conditions in which the hit or false alarm rate were below 0.05 or above 0.95 they were transformed into 0.05 or 0.95 before conversion to z-scores.

The means for each agent (CS+, CS−, NS) of the fear and contingency ratings and the behavioral avoidance measured at the three rating phases (pre acquisition, post-acquisition, post extinction) were calculated. For each physiological outcome variable (fear-potentiated startle, SCR, HR), means were calculated for the CS habituation phase, while the first four

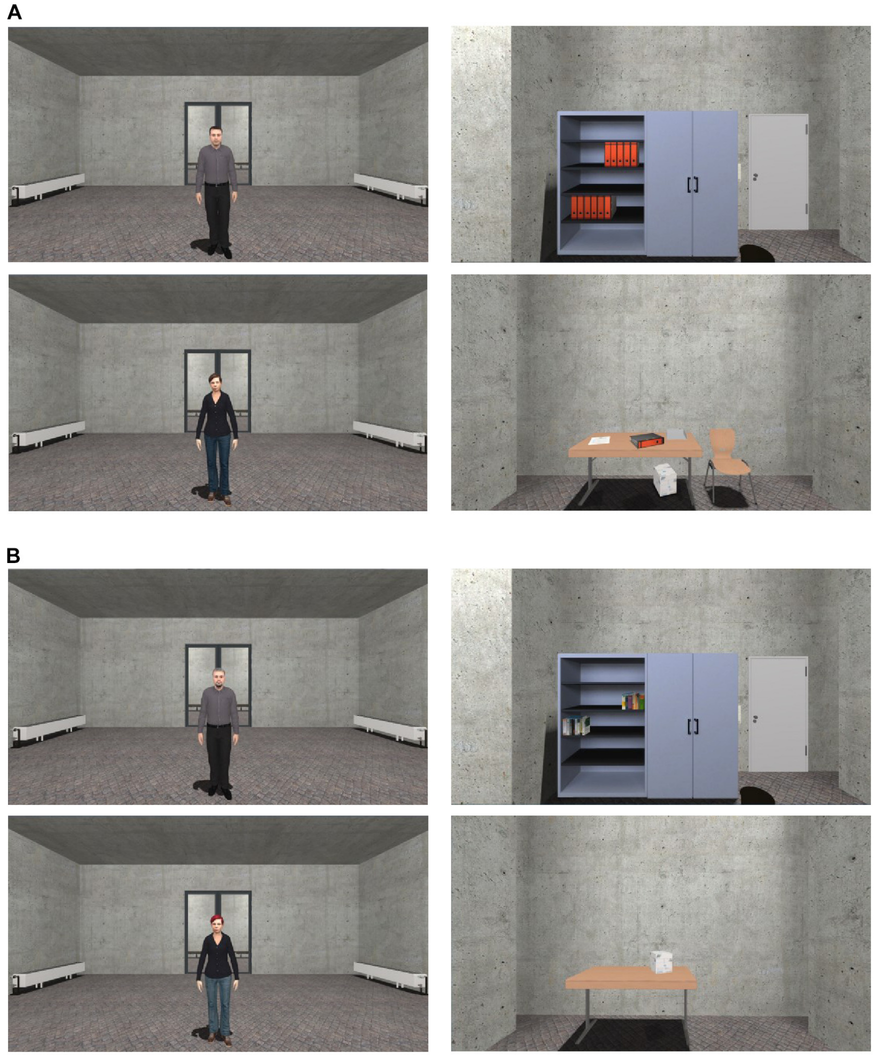

FIGURE 3 | Stimuli of the recognition memory task. Stimuli target **(A)** and distractors **(B)** of the agents and objects were presented. The images were shown on a computer screen in the same size (1600 × 900). For interpretation of the references to color in this figure, the reader is referred to the web version of this article.

reactions and the last four reactions in the acquisition and the extinction phase were computed as the means of the beginning and the end of the acquisition and extinction phase, respectively. Evoked HR was transferred with a baseline correction of the 120 s physiological baseline-measure at the beginning of the VR experiment into the HR response.

Checking for possible differences in the fear ratings before fear acquisition, an ANOVA with the within-subject factors stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were used for pre-acquisition phase. In order to investigate changes in fear ratings with regard to SFC ANOVAs with the within-subject factors phase (pre vs. post-acquisition for acquisition, and post-acquisition vs. post extinction for extinction), stimulus (CS+ vs. CS−) and agent (female vs. male), and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were conducted. Measuring possible generalization effects, an ANOVA was used with the within-subject factors stimulus (CS+ vs. CS− vs. NS) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) during post extinction phase.

An ANOVA with the within-subject factors stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) was used for the post acquisition phase to investigate differences regarding contingency ratings. Furthermore, an ANOVA with the within-subject factors phase (post acquisition vs. post extinction), stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) was conducted to investigate changes regarding SFC.

Checking for possible differences during CS habituation, ANOVAs with the within-subject factors stimulus (CS+ vs. CS−)

and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were used for each physiological outcome variable (fear-potentiated startle, SCR and HR response). In order to analyze conditioning effects regarding physiological data, ANOVAs with the within-subject factors time (beginning vs. end), stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were conducted for the acquisition and extinction phase. Testing for possible generalization effects, ANOVAs with the within-subject factors stimulus (CS+ vs. CS− vs. NS) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were conducted for the physiological variables as well.

For the behavioral avoidance data, ANOVAs with the within-subject factors phase (pre vs. post-acquisition for acquisition, and post-acquisition vs. post extinction for extinction), stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors social anxiety (low vs. high) and gender (women vs. men) were conducted.

For the recognition data, ANOVAs with the within-subject factors stimulus (agent vs. object and CS+ vs. CS− vs. NS) and the between-subject factor social anxiety (low vs. high) were conducted for the *d*' and β parameter.

In follow-up analyses of significant effects of time, stimulus, agent and social anxiety as well as gender Student's *t*-tests were performed. Partial η^2 (η_p^2) scores and Cohen's *d* were used as indices of effect size. The significance level was set at two-tailed $\alpha = 0.05$.

RESULTS

Primary Outcomes for Each Level for Acquisition and Extinction

Self Report: Fear Rating

Figure 4 shows the fear ratings after CS habituation, acquisition, and extinction. As we can see in the first rating, both stimuli are rated almost equal, but higher for HSA than for LSA. After the acquisition phase, fear ratings for CS+ are clearly higher than for CS−. After the extinction phase, fear ratings for CS+ decrease. However, fear ratings for CS− and NS do not differ in the third rating, whereas the CS+ is rated slightly higher than CS− and NS in both groups.

For acquisition an ANOVA comparing fear ratings before and after acquisition confirmed a significant effect of Phase × Stimulus × Gender × Social Anxiety (please see **Table 1** for all significant results of the ANOVA). To disentangle this fourfold interaction further, follow-up ANOVA was conducted for LSA and HSA participants separately. For LSA, we detected significant interaction effects for Phase × Stimulus and Phase × Gender. For the Phase × Stimulus interaction, the follow-up *t*-test showed that the subjective ratings increased significantly for CS+, $t(30) = -4.37$, $p < 0.001$, $d = 0.50$, but not for CS− as expected. Follow-up *t*-test for the Phase × Gender interaction presented that fear ratings increased significantly for women, $t(15) = -3.21$, $p = 0.006$, $d = 0.45$, but not for men, which point to an enhanced fear conditioning in women compared to men. For HSA, a significant effect of Phase × Stimulus × Gender could be detected. A follow-up ANOVA was conducted for HSA women and men separately. For HSA women, a significant interaction effect of Phase × Stimulus could be detected, and the follow-up *t*-test revealed that fear ratings increased significantly for CS+, $t(14) = -3.60$, $p = 0.003$, $d = 0.81$, but not for CS−. As compared to HSA men, only a marginally significant interaction effect of Phase x Stimulus, $F(1,56) = 3.56$, $p = 0.082$,$\eta_p^2 = 22$, was found. Therefore, the fear rating results indicate that successful SFC took place for both LSA and HSA groups.

For extinction an ANOVA comparing fear ratings before and after extinction confirmed significant effects of Stimulus × Gender, Phase × Gender, Phase × Stimulus × Agent (please see **Table 1** for all significant results of the ANOVA). To disentangle this threefold interaction, a follow-up ANOVA was conducted for female and male agents separately. For female agents, a significant interaction effect of Phase × Stimulus could be detected and the follow-up *t*-test revealed that the female CS+, $t(59) = 5.93$, $p < 0.001$, $d = 0.51$, and CS−, $t(59) = 2.08$, $p = 0.042$, $d = 0.12$, significantly decreased. For male agents, we identified also a significant interaction effect of Phase × Stimulus and the follow-up *t*-test highlighted that the male CS+, $t(59) = 4.93$, $p < 0.001$, $d = 0.39$, and CS−, $t(59) = 2.88$, $p = 0.006$, $d = 0.26$, significantly decreased. For the Stimulus × Gender interaction, a follow-up *t*-test showed that women rated the CS+ significantly higher than men, $t(54.146) = 2.34$, $p = 0.023$, $d = 0.61$, however there was no difference for the CS−. For the Phase × Gender interaction, a follow-up *t*-test revealed that women reported significantly more fear after the acquisition phase, $t(53.504) = 2.33$, $p = 0.023$, $d = 0.61$, than men, but not after the extinction phase. The fear rating results indicate that social fear extinction was also successful in the sample. However, no generalization effect was found.

Physiology: Fear-Potentiated Startle

The fear-potentiated startle response for the CS habituation, acquisition, and extinction phase is depicted in **Figure 5**. In the CS habituation phase, the fear-potentiated startle response is slightly higher for CS+ than for CS− in both groups. In the acquisition phase, the fear-potentiated startle response for CS+ is lower than for CS− at the beginning, but higher at the end, indicating that habituation to CS− is stronger than to CS+ during SFC. In the extinction phase, the fear-potentiated startle response to both stimuli decreases from the beginning to the end in both groups.

An ANOVA investigating differences in the CS habituation phase confirmed a significant main effect of Stimulus, $F(1,54) = 5.59$, $p = 0.022$, $\eta_p^2 = 0.09$, with a higher fear-potentiated startle response for CS+ ($M = 55.3$, $SD = 5.17$) than for CS− ($M = 53.6$, $SD = 4.87$).

For the acquisition phase, an ANOVA confirmed significant effects of Time, $F(1,52) = 42.3$, $p < 0.001$, $\eta_p^2 = 0.45$, Agent × Social Anxiety, $F(1,52) = 5.65$, $p = 0.021$, $\eta_p^2 = 0.10$,

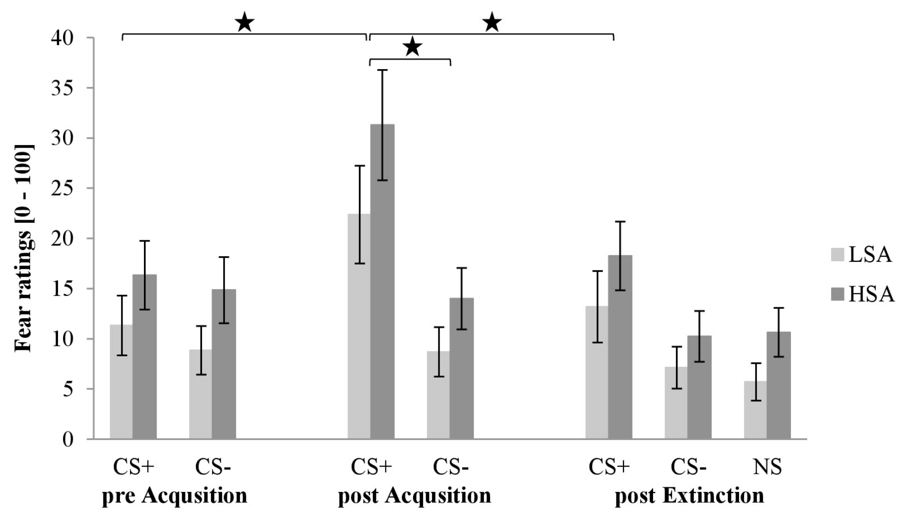

FIGURE 4 | Fear ratings (*n* = 60) for CS+, CS–, and NS in the three rating phases for low (LSA) and high socially anxious (HSA) participants. CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US; NS, agent without aversive US and appearing only in the extinction phase; pre-Acquisition, after CS habituation phase; post Acquisition, after acquisition phase; post Extinction, after extinction phase. Mean fear ratings (0 = very low fear to 100 = very high fear) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

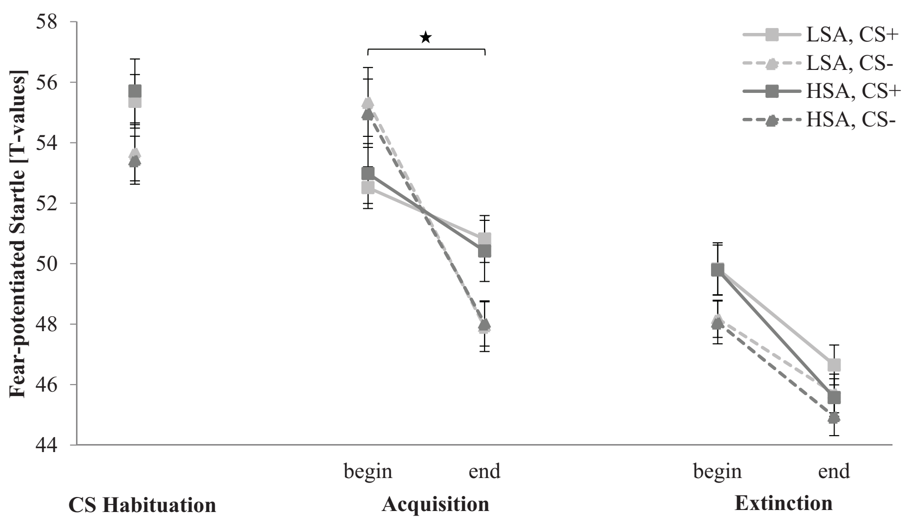

FIGURE 5 | Fear-potentiated startle response (*n* = 60) for CS+ and CS– in the three phases (CS habituation, acquisition, and extinction) for low (LSA) and high social anxiety (HSA). CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US. Mean fear-potentiated startles (presented in *T*-values) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

Time × Stimulus, $F(1,52) = 18.5$, $p < 0.001$, $\eta_p^2 = 0.26$, and Time × Stimulus × Agent, $F(1,52) = 9.69$, $p = 0.003$, $\eta_p^2 = 0.16$. For the Agent × Social Anxiety interaction, a follow-up *t*-test revealed for LSA no significant differences between female and male agents ($p = 0.098$) and also not for HSA participants ($p = 0.139$). For the Time × Stimulus × Agent interaction, a follow-up ANOVA was conducted for female and male agents. For female agents, a significant effect of Time, $F(1,55) = 27.0$, $p < 0.001$, $\eta_p^2 = 0.33$, indicates a decrease in the fear-potentiated startle response from the beginning ($M = 54.1$, $SD = 4.68$) to the end ($M = 49.3$, $SD = 4.80$) of acquisition. Compared to male agents, a significant effect of Time, $F(1,52) = 24.7$, $p < 0.001$, $\eta_p^2 = 0.32$, and Time × Stimulus, $F(1,52) = 29.9$, $p < 0.001$, $\eta_p^2 = 0.37$, could be detected. Follow-up *t*-tests emphasized that the fear-potentiated startle response to the male CS+ was significantly lower than to the male CS− at the beginning of the acquisition, $t(56) = -3.65$, $p < 0.001$, $d = 0.70$, whereas the response to the male CS+ was significantly higher compared to the male CS− at the end of the acquisition, $t(56) = 4.10$, $p < 0.001$, $d = 0.66$. This indicates that according to the fear-potentiated startle, SFC to male agents was successfully in both groups, whereas the female CS+ and CS− did not significantly differ during fear acquisition. These results suggest enhanced fear responses and enhanced social fear conditionability to male compared to female agents.

For the extinction phase, an ANOVA found significant effects of Time, $F(1,56) = 37.1$, $p < 0.001$, $\eta_p^2 = 0.40$, Stimulus, $F(1,56) = 6.75$, $p = 0.012$, $\eta_p^2 = 0.11$, Time × Stimulus × Gender, $F(1,56) = 4.67$, $p = 0.035$, $\eta_p^2 = 0.08$, and Time × Agent × Gender, $F(1,56) = 4.89$, $p = 0.031$, $\eta_p^2 = 0.08$. To unravel this threefold interaction further, a follow-up ANOVA was conducted for each gender separately. For women, the ANOVA confirmed a significant effect of Time, $F(1,29) = 17.6$, $p < 0.001$, $\eta_p^2 = 0.38$, which indicates a further decrease in the fear-potentiated startle response from the beginning ($M = 48.8$, $SD = 3.41$) to the end ($M = 45.5$, $SD = 3.05$) of extinction. For men, the ANOVA affirmed significant effects of Time, $F(1,27) = 20.4$, $p < 0.001$, $\eta_p^2 = 0.43$, Stimulus, $F(1, 27) = 17.6$, $p = 0.040$, $\eta_p^2 = 0.15$, and Time × Stimulus, $F(1,27) = 4.19$, $p = 0.050$, $\eta_p^2 = 0.13$. The follow-up t-test revealed that the CS+ was significantly higher than the CS− at the beginning, $t(28) = 2.68$, $p = 0.012$, $d = 0.76$, but no more at the end of the extinction phase ($p = 0.725$). The fear-potentiated startle results indicate that social fear extinction was successful in both gender groups.

Regarding generalization effects, an ANOVA found significant effects of Stimulus, $F(2,112) = 4.60$, $p = 0.012$, $\eta_p^2 = 0.08$, Agent, $F(1,56) = 4.81$, $p = 0.012$, $\eta_p^2 = 0.08$, and Stimulus × Agent, $F(2,112) = 5.93$, $p = 0.004$, $\eta_p^2 = 0.10$. A follow-up t-test showed that the fear-potentiated startle response to male NS is significantly higher than to CS+, $t(28) = -2.570$, $p = 0.013$, $d = 0.47$, and CS−, $t(59) = -5.076$, $p < 0.001$, $d = 0.84$, at the beginning of the extinction phase. However, the startle response to the female CS+ is significantly higher than to the CS−, $t(59) = 2.328$, $p = 0.023$, $d = 0.38$, but not in comparison to the NS, $t(59) = 1.465$, $p = 0.148$. No clear generalization effect results were found.

Behavior: Behavioral Avoidance Test

Figure 6 shows behavioral avoidance during all three BATs in the rating phases. As we can see in all phases, the distance to both stimuli is larger for HSA than for LSA participants. Furthermore, we can observe a small increase for the CS+ and a decrease for the CS− during SFC in both groups. After the extinction phase, the NS is nearly on the same level as the CS−.

For acquisition, an ANOVA comparing behavioral avoidance before and after acquisition confirmed significant effects of Phase × Stimulus, $F(1,48) = 12.2$, $p < 0.001$,$\eta_p^2 = 0.20$, and Stimulus × Agent × Social Anxiety, $F(1,48) = 4.80$, $p = 0.033$, $\eta_p^2 = 0.09$. A follow-up ANOVA was conducted for both social anxiety groups separately. For LSA, a significant interaction effect of Phase × Stimulus, $F(1,25) = 8.70$, $p = 0.007$, $\eta_p^2 = 0.26$, and Stimulus × Agent, $F(1,25) = 5.26$, $p = 0.031$, $\eta_p^2 = 0.17$, was found. For the Phase × Stimulus interaction, a follow-up t-test showed no significant change in the distance to CS+, but a significant decrease in the distance to CS−, $t(28) = 2.756$, $p = 0.010$, $d = 0.43$, from pre to post acquisition. The follow-up t-test for the Stimulus × Agent interaction presented no significant difference between male and female CS+ or CS−. For HSA, a significant interaction effect of Phase × Stimulus, $F(1,23) = 4.44$, $p = 0.046$, $\eta_p^2 = 0.16$, and Phase × Agent × Gender, $F(1,23) = 4.72$, $p = 0.040$, $\eta_p^2 = 0.17$, was found. A follow-up ANOVA was conducted for both genders. For HSA men, a significant interaction effect of Phase × Stimulus, $F(1,11) = 5.67$, $p = 0.036$, $\eta_p^2 = 0.34$, was found and the follow-up t-test revealed no significant change in the distance to CS+, but a significant decrease in the distance to CS−, $t(12) = 2.202$, $p = 0.048$, $d = 0.49$, from pre to post acquisition. For HSA women, a significant interaction effect of Phase × Agent, $F(1,12) = 5.61$, $p = 0.035$, $\eta_p^2 = 0.32$, was detected and the follow-up t-test showed no significant change in the distance to male CS, but a significant decrease in the distance to female CS, $t(14) = 2.694$, $p = 0.017$, $d = 0.41$, from pre to post acquisition. This indicates that HSA women maintained a larger distance to male compared to female agents, but no such differences were found for HSA men. Thus, the behavioral avoidance results indicate that successful SFC took place for both groups.

For extinction, an ANOVA comparing behavioral avoidance before and after extinction confirmed a significant effect of Phase × Stimulus × Gender, $F(1,46) = 5.13$, $p = 0.028$, $\eta_p^2 = 0.10$. A follow-up ANOVA was conducted for both genders separately. For men, a significant interaction effect of Phase × Stimulus, $F(1,25) = 5.92$, $p = 0.022$, $\eta_p^2 = 0.19$, was observed and the follow-up t-test revealed a marginally significant decrease in the distance to CS+, $t(27) = 1.933$, $p = 0.064$, but not to CS− from pre to post extinction. For women, no significant main or interaction effect was found. Therefore, the behavioral avoidance results show successful fear extinction for men.

Furthermore, **Figure 7** depicts the movement behavior of the LSA and HSA participants in the virtual environment and the differences in group movement behavior comparing LSA and HSA participants. Exploratory analysis of **Figure 7** suggested that LSA passed more closely the agent than HSA participants.

Cognition: Recognition Memory Task

An ANOVA comparing the sensitivity index for the recognition stimulus agent and object confirmed a significant effect of Stimulus, $F(1,58) = 18.3$, $p < 0.001$, $\eta_p^2 = 0.24$, with a higher d' for agent ($M = 1.78$, $SD = 0.68$) than for object ($M = 1.25$, $SD = 0.70$), but no group differences were found. Comparing the sensitivity index for the agents with each other, an ANOVA revealed a significant effect of Stimulus, $F(2,116) = 6.80$, $p = 0.002$, $\eta_p^2 = 0.11$, with the highest value for NS ($M = 2.33$, $SD = 1.14$) compared to CS+ ($M = 1.81$, $SD = 1.19$) and CS− ($M = 1.56$, $SD = 1.19$), but no group differences were found.

Comparing the response criteria for the recognition stimulus agent and object, an ANOVA revealed a significant effect of Stimulus, $F(1,58) = 101.9$, $p < 0.001$, $\eta_p^2 = 0.64$, with a lower β for agent ($M = -0.33$, $SD = 0.47$) than for object ($M = 0.38$, $SD = 0.41$), and a marginally significant effect of Social Anxiety, $F(1,58) = 3.71$, $p = 0.059$, $\eta_p^2 = 0.06$. Tendentially, HSA ($M = -0.06$, $SD = 0.48$) exhibit a more conservative β index than LSA ($M = 0.11$, $SD = 0.46$). Comparing the response criteria for the agents with each other, an ANOVA showed a significant effect of Social Anxiety, $F(1,58) = 5.45$, $p = 0.023$, $\eta_p^2 = 0.09$, which revealed a more conservative index for HSA ($M = -0.47$, $SD = 0.66$) than for LSA ($M = -0.19$, $SD = 0.64$).

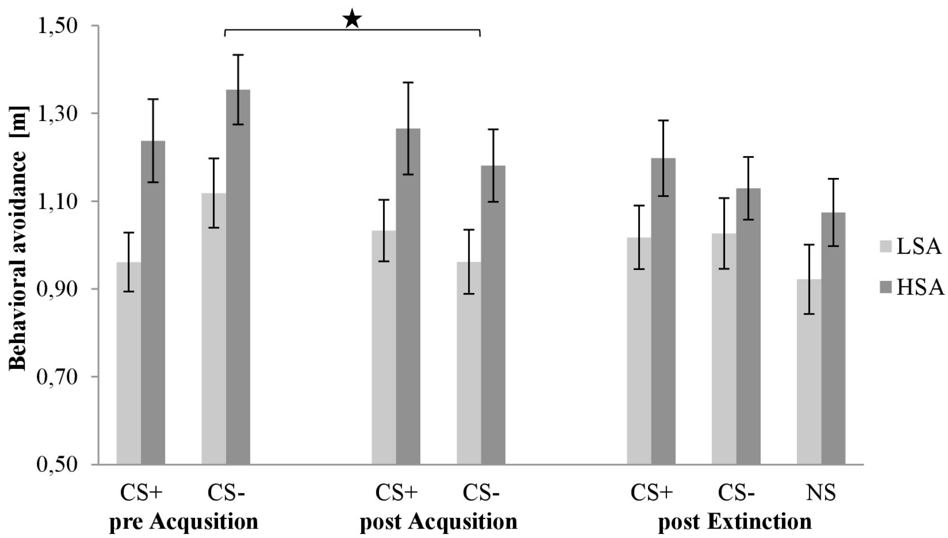

FIGURE 6 | Behavioral avoidance (*n* = 59) for CS+, CS–, and NS in the three rating phases for low (LSA) and high socially anxious (HSA) participants. CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US; NS, agent without aversive US and appearing only in the extinction phase; pre-Acquisition, after CS habituation phase; post Acquisition, after acquisition phase; post Extinction, after extinction phase. Mean behavioral avoidance (presented in meter) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

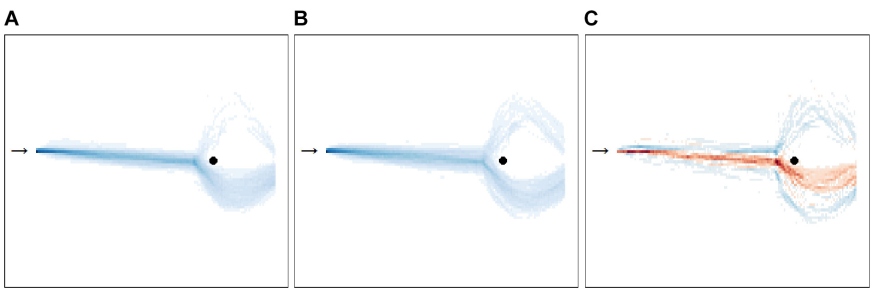

FIGURE 7 | Bird's eye view on the movement behavior (*n* = 59) during all ratings and behavioral avoidance tests (BAT). The heatmap shows the movement behavior for low **(A)** and for high socially anxious **(B)** participants. Participants started at one end of the room (black arrow) and had the task during the rating to approach the agent at the opposite end of the room (black circle). Following this, participants were instructed to pass the agent and to leave the room through the glass door located behind the agent during the BAT. The more intense the blue is, the more participants walked there. The third heatmap **(C)** shows the differences in group movement behavior comparing low (LSA) and high socially anxious (HSA) participants. Blue areas indicate that more HSA participants walked there, whereas red areas indicate that more LSA participants were there. The more intense a color is, the greater the relative difference between both groups. For interpretation of the references to color in this figure, the reader is referred to the web version of this article.

Secondary Outcomes for Each Level for Acquisition and Extinction

Personality Traits and Dispositions

High socially anxious show a significantly higher score in social anxiety (SPIN), in anxiety in social interactional situations (SIAS), in fear of physiological arousal related sensations (ASI-3), in submissive behavior (SBS) as well as a significantly lower score in dominant behaviors (PRF-D) compared to the LSA group. Interestingly, HSA show significantly higher vigilance, but marginally significant lower cognitive avoidance than LSA as coping strategy. Furthermore, HSA report significantly stronger symptoms of cybersickness (SSQ) compared LSA. Regarding the mean of the experience of presence in VR (IPQ) and participants' age, the groups do not differ significantly (see **Table 2**).

Furthermore, there is a marginally significant negative correlation between social fear learning (difference of CS+ and CS− after acquisition) and dominance ($r = -0.22$, $p = 0.086$) as well as a significant positive correlation with submissive behavior ($r = 0.30$, $p = 0.021$).

An exploratory measure of the post questionnaire for the evaluation of the US showed that the spitting and rejection of the male, $F(1,59) = 13.2$, $p < 0.001$, $\eta_p^2 = 19$, and female agent, $F(1,59) = 19.4$, $p < 0.001$, $\eta_p^2 = 25$, caused more fear by women compared to men, but not by HSA compared to LSA.

Self Report: Contingency Rating

The contingency ratings post acquisition and extinction is shown in **Figure 8**. As can be seen in the first rating, the CS+ is rated

TABLE 2 | Demographic variables and personality traits.

	LSA (n = 31)		HSA (n = 29)					
	M	***SD***	***M***	***SD***	***t***	***df***	***p***	***d***
Age	21.77	4.62	21.21	3.21	0.549	58	0.585	-
SPIN	11.13	4.06	27.93	8.36	−9.969	58	< 0.001	2.63
SIAS	16.45	9.58	29.76	13.2	−4.484	58	< 0.001	1.16
ASI-3	19.13	8.79	24.10	9.83	−2.069	58	0.043	0.55
PRF-D	9.77	3.78	5.34	4.03	4.392	58	< 0.001	1.12
SBS	23.10	7.94	28.69	7.71	−2.765	58	0.008	0.73
MCI-VIG	11.16	3.83	13.28	2.79	−2.430	58	0.018	0.64
MCI-CAV	10.55	3.44	8.97	3.02	1.888	58	0.064	-
SSQ	44.40	30.5	66.16	41.5	−2.325	58	0.024	0.61
IPQ	3.42	1.23	2.72	1.62	1.876	58	0.066	-

Means (M) and standard deviations (SD) and also t- and p-values with degrees of freedom (df) and Cohen's d as well as number of participants (n) are given for all participants for demographic variables and questionnaire data. SPIN, Social Phobia Inventory; SIAS, Social Interaction Anxiety Scale; ASI-3, Anxiety Sensitivity Index; PRF-D, German Personality Research Form – Dominance Scale; SBS, Submissive Behavior Scale; MCI-VIG/MCI-COV, Vigilance/Cognitive Avoidance coping strategy of the Mainz Coping Inventory; SSQ, Simulator Sickness Questionnaire; IPQ, Igroup Presence Questionnaire.

higher than the CS− in both groups after acquisition. In the third rating, CS+ is slightly higher than CS− and NS in both groups.

An ANOVA comparing contingency ratings after the acquisition confirmed a significant effect of Stimulus, $F(1,56) = 74.1$, $p < 0.001$, $\eta^2_p = 57$, Gender, $F(1,56) = 12.8$, $p < 0.001$, $\eta^2_p = 0.19$, and a marginally significant interaction effect of Stimulus × Gender, $F(1,56) = 3.87$, $p = 0.054$, $\eta^2_p = 0.07$. An exploratory t-test revealed that women rated the CS+ significantly higher than men, $t(58) = 3.83$, $p < 0.001$, $d = 1.01$, whereas the CS− did not differ between genders ($p = 0.120$).

An ANOVA comparing contingency ratings before and after extinction confirmed significant effects of Phase, $F(1,56) = 15.2$, $p < 0.001$, $\eta^2_p = 21$, Stimulus, $F(1,56) = 82.3$, $p < 0.001$, $\eta^2_p = 60$, Agent, $F(1,56) = 5.31$, $p = 0.025$, $\eta^2_p = 09$, Gender, $F(1,56) = 4.50$, $p = 0.038$, $\eta^2_p = 07$, and Phase × Stimulus, $F(1,56) = 42.5$, $p < 0.001$, $\eta^2_p = 43$, and Phase × Social Anxiety × Gender, $F(1,56) = 5.89$, $p = 0.019$, $\eta^2_p = 10$. To unravel this threefold interaction, a follow-up ANOVA was conducted for LSA and HSA participants separately. For LSA, significant main effects for Phase, $F(1,29) = 21.6$, $p < 0.001$, $\eta^2_p = 38$, Stimulus, $F(1,29) = 46.6$, $p < 0.001$, $\eta^2_p = 62$, Agent, $F(1,29) = 6.20$, $p = 0.019$, $\eta^2_p = 18$, and interaction effects of Phase × Stimulus, $F(1,29) = 8.89$, $p = 0.006$, $\eta^2_p = 24$, and Phase × Gender, $F(1,29) = 25.9$, $p < 0.001$, $\eta^2_p = 47$, could be detected. For the Phase × Stimulus interaction, a follow-up t-test showed that the subjective ratings decreased significantly for CS+, $t(30) = 5.50$, $p < 0.001$, $d = 1.14$, but not for CS−. A follow-up t-test for the Phase × Gender interaction showed that contingency ratings decreased significantly for women, $t(15) = 4.92$, $p < 0.001$, $d = 1.39$, but not for men. For HSA, a significant effect of Stimulus, $F(1,27) = 36.5$, $p < 0.001$, $\eta^2_p = 58$, Gender, $F(1,27) = 8.95$, $p = 0.006$, $\eta^2_p = 39$, and Phase × Stimulus could be detected. A follow-up t-test revealed that fear ratings decreased significantly for CS+, $t(28) = 3.35$, $p = 0.002$, $d = 0.65$, but not for CS−. Thus, contingency rating results also indicate that SFC was successful regarding participants' cognitive appraisal.

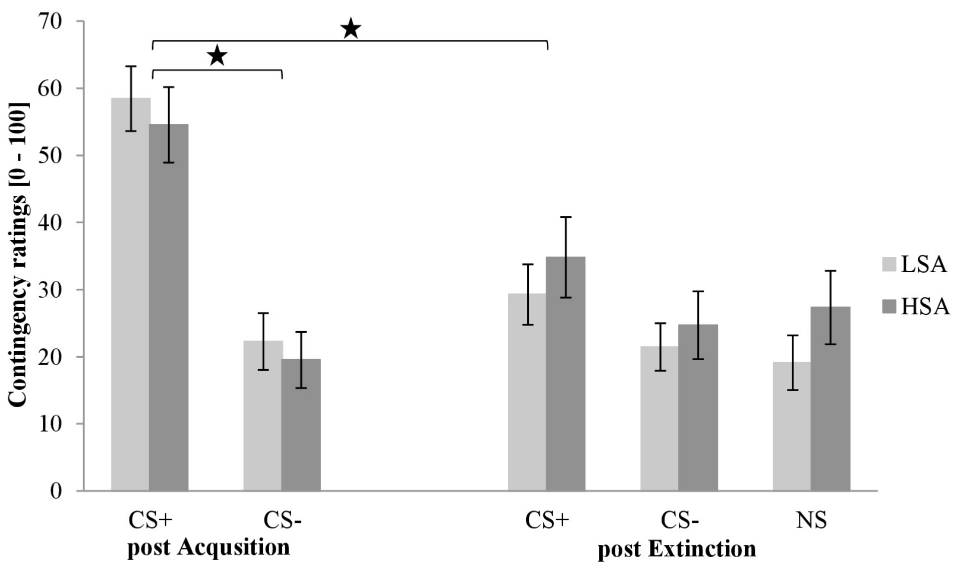

FIGURE 8 | Contingency ratings (n = 60) for CS+, CS–, and NS in the rating phases 2 and 3 for low (LSA) and high socially anxious (HSA) participants. CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US; NS, agent without aversive US and appearing only in the extinction phase; post Acquisition, after acquisition phase; post Extinction, after extinction phase. Mean contingency ratings (0 = very unlikely to 100 = very likely) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

Physiology: Skin Conductance Response

Figure 9 shows the SCR for CS habituation, acquisition, and extinction phase. In the CS habituation phase, the SCR for men is slightly lower for CS+ than for CS−, whereas women do not differ between both stimuli. In the acquisition phase, the SCR increase for women, but not for men. Furthermore, women reveal a higher increase for CS+ than for CS−. In the extinction phase, the SCR for both genders do not differ from the beginning to the end.

Proving differences in the CS habituation phase, an ANOVA confirmed no significant effects. For the acquisition, an ANOVA showed a significant effect of Time, $F(1,45) = 5.45$, $p = 0.024$, $\eta_p^2 = 0.11$, Gender, $F(1,45) = 9.86$, $p = 0.003$, $\eta_p^2 = 0.18$, Time × Gender, $F(1,45) = 8.51$, $p = 0.005$, $\eta_p^2 = 0.16$, Agent × Gender, $F(1,45) = 5.36$, $p = 0.025$, $\eta_p^2 = 0.11$, Time × Agent, $F(1,45) = 6.33$, $p = 0.016$, $\eta_p^2 = 0.12$, Time × Stimulus × Gender, $F(1,45) = 4.71$, $p = 0.035$, $\eta_p^2 = 0.10$, Time × Agent × Gender, $F(1,45) = 6.37$, $p = 0.015$, $\eta_p^2 = 0.12$. A follow-up ANOVA was conducted for both genders separately. For women, a significant effect of Time, $F(1,20) = 7.25$, $p = 0.014$, $\eta_p^2 = 27$, and Time × Agent, $F(1,20) = 12.8$, $p = 0.002$, $\eta_p^2 = 39$, could be detected. Follow-up *t*-test revealed that the SCR to the female agents significantly increase, $t(21) = -4.14$, $p < 0.001$, $d = 0.80$, whereas the SCR to the male agents did not significantly increase from the beginning to the end of the acquisition. For men, significant effects of Agent, $F(1,25) = 6.07$, $p = 0.021$, $\eta_p^2 = 0.20$, Social Anxiety, $F(1,25) = 5.26$, $p = 0.031$, $\eta_p^2 = 0.17$, Agent × Social Anxiety, $F(1,25) = 7.10$, $p = 0.013$, $\eta_p^2 = 0.22$, Time × Stimulus, $F(1,25) = 6.18$, $p = 0.020$, $\eta_p^2 = 0.20$, and Time × Stimulus × Social Anxiety, $F(1,25) = 4.63$, $p = 0.041$, $\eta_p^2 = 0.16$, were located. According this threefold interaction, a follow-up ANOVA was conducted for male LSA and HSA participants. For LSA men, a significant effect of Agent, $F(1,13) = 8.04$, $p = 0.014$, $\eta_p^2 = 0.38$, and Time × Stimulus, $F(1,13) = 7.14$, $p = 0.019$, $\eta_p^2 = 0.35$, were found and the follow-up *t*-tests revealed that the SCR to the CS+ was significantly higher than to the CS−, $t(13) = 2.24$, $p = 0.043$, $d = 0.70$, at the beginning but no more at the end of the acquisition phase. For HSA participants, no significant main or interaction effect was found. The SCR results indicate for women higher fear responses to female compared to male agents, whereas only LSA men showed a differentiation between the CS+ and CS− at the beginning of the acquisition.

For the extinction, an ANOVA confirmed significant effects of Stimulus × Social Anxiety, $F(1,45) = 4.04$, $p = 0.050$, $\eta_p^2 = 0.08$, Agent × Social Anxiety, $F(1,45) = 11.8$, $p < 0.001$, $\eta_p^2 = 0.21$, Time × Agent, $F(1,45) = 6.06$, $p = 0.018$, $\eta_p^2 = 0.12$, and Time × Stimulus × Social Anxiety, $F(1,45) = 4.95$, $p = 0.031$, $\eta_p^2 = 0.10$. Follow-up ANOVA was conducted for both LSA and HSA participants. For LSA, a significant effect of Stimulus, $F(1,22) = 6.26$, $p = 0.020$, $\eta_p^2 = 0.22$, Agent, $F(1,22) = 11.8$, $p = 0.002$, $\eta_p^2 = 0.35$, and Time × Stimulus, $F(1,22) = 4.90$, $p = 0.037$, $\eta_p^2 = 0.18$, could be detected. Follow-up *t*-test showed that the CS+ is significantly higher compared to the CS− at the beginning of the extinction, $t(23) = 3.63$, $p < 0.001$, $d = 0.58$, but not more at the end of the extinction. For HSA participants, only a significant main effect of Agent, $F(1,23) = 5.29$, $p = 0.031$, $\eta_p^2 = 0.19$, which indicates a higher response to female ($M = 0.062$, $SD = 0.065$) compared to male agents ($M = 0.037$, $SD = 0.03$). The SCR results indicate successful extinction for LSA, whereas HSA show no consistent extinction.

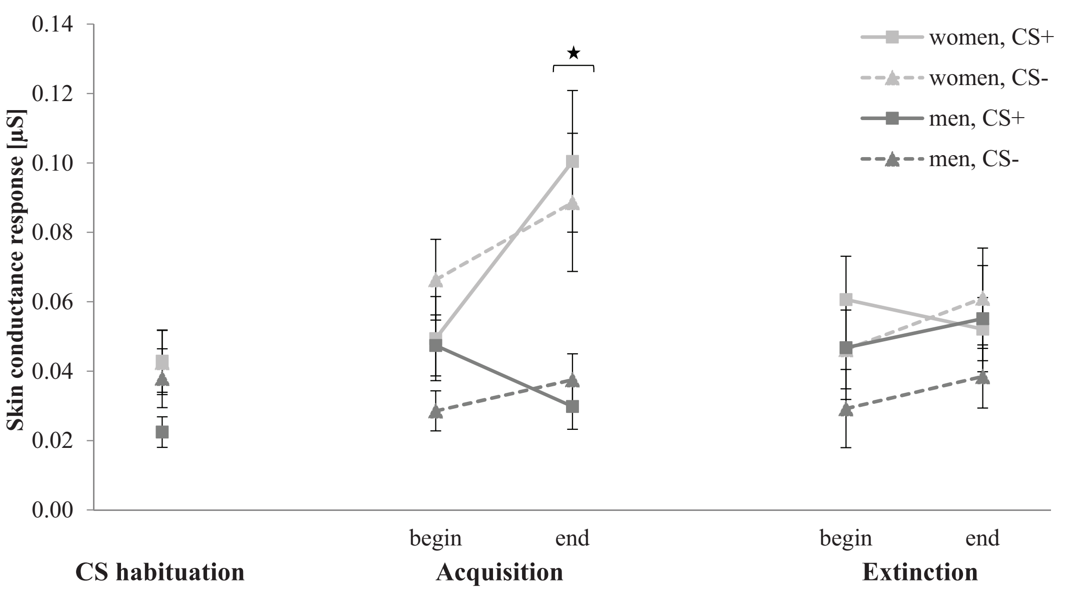

FIGURE 9 | Skin conductance response ($n = 49$) for CS+ and CS– in the three phases (CS habituation, acquisition, and extinction) for both genders. CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US. Mean skin conductance response (presented in µS) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

Physiology: Heart Rate Response

The HR response for the CS habituation, acquisition, and extinction phase is shown in **Figure 10**. The HR response is approximately equivalent for both stimuli in both groups in the CS habituation phase. From the beginning to the end of the acquisition phase, HR response increases for both stimuli in both groups. For HSA, HR response for CS+ is higher than for CS− at the end of the acquisition phase. In the extinction phase, HR response increases slightly for both stimuli to a comparable level from the beginning to the end in both groups.

Investigating differences in the CS habituation phase, an ANOVA confirmed no significant effects. For the acquisition phase, an ANOVA confirmed a significant effect of Time, $F(1,52) = 42.3$, $p < 0.001$, $\eta_p^2 = 0.45$, which indicates an increase from the beginning ($M = 4.59$, $SD = 5.22$) to the end ($M = 7.75$, $SD = 6.24$). The HR response results indicate only activation during the fear acquisition in both groups.

For the extinction phase, an ANOVA revealed significant effects of Time, $F(1,55) = 41.7$, $p < 0.001$, $\eta_p^2 = 0.43$, and Time × Social Anxiety × Gender, $F(1,55) = 4.78$, $p = 0.033$, $\eta_p^2 = 0.08$. A follow-up ANOVA was conducted for each group. For LSA, there was a significant effect of Time, $F(1,20) = 6.05$, $p = 0.023$, $\eta_p^2 = 0.23$, and Time × Agent × Gender, $F(1,20) = 6.05$, $p = 0.023$, $\eta_p^2 = 0.23$. A follow-up ANOVA for the significant interaction showed for men a marginally significant effect of Time × Agent, $F(1,14) = 4.10$, $p = 0.062$, $\eta_p^2 = 0.23$, and for women a significant increase from the beginning to the end of the extinction, $F(1,15) = 11.9$, $p = 0.003$, $\eta_p^2 = 0.44$. For HSA, a significant effect of Time, $F(1,20) = 6.05$, $p = 0.023$, $\eta_p^2 = 0.23$, and Time × Gender, $F(1,20) = 6.05$, $p = 0.023$, $\eta_p^2 = 0.23$, was found. A follow-up *t*-test revealed that during extinction the HR response for women increased significantly, $t(14) = -5.621$, $p < 0.001$, $d = 0.5$, but not the HR response for men ($p = 0.292$). The HR response results show higher activation during extinction for women compared to men in both groups.

DISCUSSION

The present study examined gender differences in low and high socially anxious participants regarding the acquisition and extinction of conditioned social fear to virtual female and male agents. Participants actively approached virtual agents using a joystick in a setting similar to the one used by Reichenberger et al. (2017). During the experiment the following primary outcome variables, which are defined for each of four levels of emotional reactions, include experience (fear ratings), psychophysiology (fear-potentiated startle), behavior (avoidance) and cognition (unforeseen recognition memory task). Secondary outcome variables were personality traits, contingency ratings, SCR and HR response.

In line with previous experiments (Shiban et al., 2015; Reichenberger et al., 2017), the applied SFC paradigm proved to effectively induce conditioned responses. After acquisition, both groups exhibited enhanced social fear responses to the CS+ compared to the CS− agent. Such successful social fear conditioning was reflected by our primary outcome variables, e.g., fear ratings, fear-potentiated startle, and behavioral avoidance.

Consistent with our hypotheses, fear ratings clearly increased for CS+ compared to CS− after the acquisition phase and fear conditioning was enhanced in women compared to men in both groups. Interestingly, there were no increased fear ratings to CS− agents after acquisition in HSA compared to LSA participants. Furthermore, we found no enhanced fear ratings when approaching male agents in comparison to female agents.

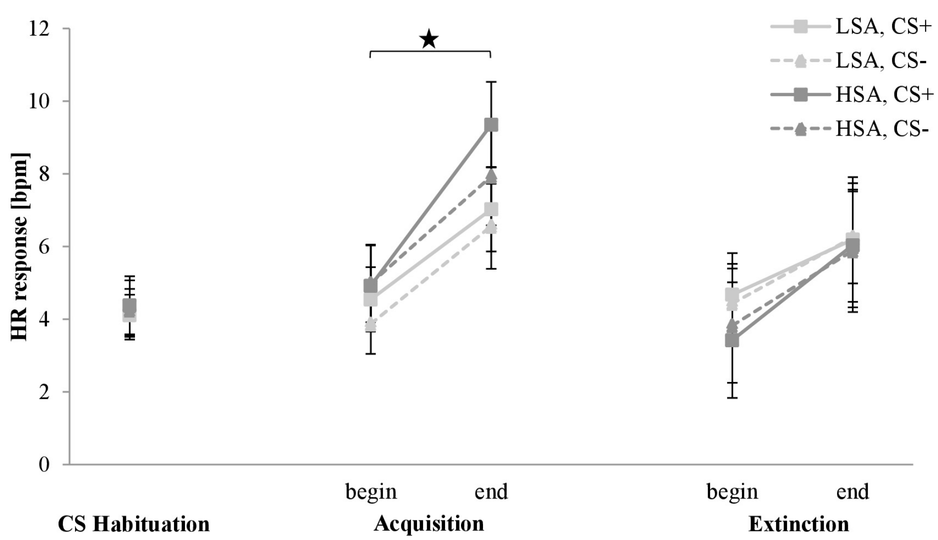

FIGURE 10 | Heart rate (HR) response ($n = 60$) for CS+ and CS– in the three phases (CS habituation, acquisition, and extinction) for low (LSA) and high social anxiety (HSA). CS+, agent paired with aversive unconditioned stimulus (US); CS–, agent without aversive US. Mean HR response (presented in beats per min) was given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

Regarding the primary variable within the physiological measures, a clear difference in the fear-potentiated startle between male CS+ and CS− at the end of the acquisition indicates a successful SFC to male agents in both groups. However, the fear-potentiated startle response to both female CS+ and CS− agents habituated during acquisition. Thus, primary physiological results indicate enhanced fear responses and enhanced social fear conditionability to male than to female agents.

Concerning the primary behavioral outcome, we found a generally increased avoidance to agents in HSA compared to LSA participants in the BATs. Furthermore, there was no significant change in the distance to CS+ before and after acquisition, but a decrease in the distance to CS− in both groups. In line with Iachini et al. (2014), we found a larger distance to male compared to female agents in fear conditioning for HSA women. Interestingly, HSA men do not seem to differentiate between a female or male aversive person.

The subsequently conducted recognition memory task revealed that participants replied with higher sensitivity for agent than for object stimuli. Therefore, we could conclude that the ability of the participants to correctly distinguish between the target and distractor was better for social (agents) compared to neutral (objects) cues and that the attention was focused more on social cues. Furthermore, we found the highest sensitivity for NS compared to CS+ and CS− stimuli. Concerning the social cue, participants were better at distinguishing the target from the distractor for the NS compared to CS+ and CS− agent. Regarding the decision-making response criterion, HSA exhibited a more conservative response style than LSA participants, which means that HSA tend to avoid a false alarm and give rather the response No than Yes. In general, participants showed a more conservative response style for agent than for object stimuli. Furthermore, HSA responded in a more conservative manner than LSA participants by comparing the agents with each other.

Concerning the secondary outcome variables, women estimated the appearance of the US to be more likely in the presence of a CS+ agent than men reflected in the contingency ratings. With regard to HR response, there was activation from the beginning to the end of acquisition, but no differentiation between the stimuli or groups. Moreover, we observed higher SCR in women at the end of acquisition compared to men, but no CS+/CS− differences were revealed. Our SCR and HR response results were only partly in concordance with the primary outcome variables. First of all, an attenuated physiological change following conditioning due to high interindividual differences in fear responses on the physiological level is reported frequently (Craske et al., 1991). Secondly, the segmented time period for SCR and HR response were 6 s after onset approaching the agent, but due to the startle noise at about 6, 5–7 s, it was not possible to analyze the interesting uncertain "second half" approach toward the agent. Following this, we assume that in the first half of the approach participants exhibited a lower sensitivity of fear responses.

Regarding the personality traits and dispositions, we found that rather submissive participants showed enhanced social fear learning, whereas rather dominant participants exhibited a tendency for reduced social fear learning. Regarding the coping strategies, HSA participants reported higher vigilance and lower cognitive avoidance as strategies they usually use in comparison to LSA. Vigilance and cognitive avoidance refer to changes in attentional orientation and information processing in situations where individuals are confronted with threat-related information (Krohne et al., 2000). Following our results, HSA persons are more likely to avert attention from threat-relevant stimuli (e.g., aversive agents, CS+) and to inhibit further processing of such information. In contrast, HSA show an increased intake and comprehensive processing of threatening information. Krohne et al. (2000) suggest these two tendencies as independently varying personality dimensions, and assume that emotional arousal triggers the tendency to cognitive avoidance of threat-related cues (control of anxiety), while uncertainty activates vigilant behavioral tendencies (control of danger). Measuring attentional orientation and information processing in social threat-related situations on a behavioral level, it would be interesting to analyze the gaze of low and high socially anxious via an eye-tracking method.

Regarding fear extinction in the fear and contingency ratings, the variation between the CS+ and CS− that followed acquisition vanished after the extinction phase for both groups. Interestingly, comparing fear ratings before and after extinction in HSA, ratings for CS+ were higher by women than by men, suggesting higher resistance to extinction in women compared to men. However, we found no stronger fear of CS+ agents during fear extinction in HSA compared to LSA. The fear-potentiated startle reflected a further habituation for CS+ and CS− stimuli, indicating successful social fear extinction. No generalization effect was reflected by the subjective and physiological measures.

In the present study, a SPIN cut-off value of 19 was used to distinguish between LSA and HSA participants. According to Sosic et al. (2008) a cut-off score of 25 provides the optimal basis for differentiating between individuals with SAD and healthy controls. Thus, our HSA sample could not be regarded as a clear clinical sample. However, the cut-off value of 19 is sufficient to secure a sample of participants that have significant higher social fear than average persons (Connor et al., 2000). The sample, which consisted mainly of young students, might be another limitation that should be considered when generalizing the results to a broader context.

Besides the higher social fear conditionability in women, the menstrual cycle phase might be another factor influencing conditioning and extinction of social fear. Using a 2-day fear conditioning and extinction protocol, Milad et al. (2006) reported reduced extinction memory among women in the late follicular cycle phase in comparison to women in the early follicular phase and men. Thus, hormones prevailing in the late follicular cycle phase might attenuate extinction recall. The effect of particular hormones in different cycle phases on social fear learning and extinction could also be investigated in a larger female sample using the SFC paradigm in VR in the future.

Furthermore, individual factors, such as personality traits and dispositions, should be emphasized more in future SFC research to better understand their predictive influence for developing SAD (Beckers et al., 2013). For example, we included individual submissive and dominance behavior as well as coping mechanisms, e.g., vigilance and cognitive avoidance, in a first step for a broader investigation. In future, we will measure coping strategies and individual dispositions, e.g., submissive and dominance, with more regard to the presented social interaction for a more comprehensive examination.

CONCLUSION

Our SFC paradigm is a useful tool to investigate the learning and unlearning of social fear in a VR setting with enhanced ecological validity. Regarding fear ratings, women showed an enhanced fear conditioning compared to men, but we found no enhanced fear ratings when approaching male compared to female agents. Furthermore, concerning the contingency ratings women also estimated the appearance of the US to be more likely in the presence of a CS+ agent compared to men. Interestingly, the fear-potentiated startle reflected enhanced fear responses and enhanced social fear conditionability in male compared to female agents. Additionally, HSA women showed a larger behavioral avoidance to male compared to female agents in fear conditioning, whereas HSA men do not seem to differentiate between female or male aversive persons. Interestingly, participants' gender was relevant for measures prone to be influenced by reflective processes (fear and contingency ratings as well as SCR), while more automatic measures like fear-potentiated startle and also behavioral avoidance seem to depend on the gender of the virtual agent. Our SFC paradigm aims to achieve a deeper understanding of the underlying mechanisms of development and maintenance of social anxiety in men and women. Altogether, the present research is one of few examples of a fear conditioning paradigm with social interactions in a standardized and experimentally controlled way, with a disorder-relevant US to examine affective learning, and with a high ecological validity. VR allows more interactive experimental designs which increase the realism of the social interaction and can reveal enhanced behavioral responses (Wieser et al., 2009). Thus, empirical research on social anxiety can benefit from using VR. Our study is the first to investigate the mentioned conditioning effect in a paradigm that aims – in contrast to classical paradigms – to enhance ecological validity while securing experimental control. Furthermore, we included approach behavior to anthropomorphic agents as a feature as well as a dependent variable. Moreover, we involved independent variables such as the gender of participants, gender of agents, and social anxiety in one study and thus could investigate interaction effects between these factors. Furthermore, we consider the novelty and the strength of our study in introducing a VR paradigm, which is a promising tool to measure emotional learning processes on each of the four levels of emotional reactions including experience, psychophysiology, behavior, and cognition with an enhanced ecological validity. Further research is needed to expand our findings by increasing a more heterogeneous sample and by testing individuals suffering from SAD. In addition, next steps could be the involvement of the oxytocin system (Zoicas et al., 2014; Neumann and Slattery, 2016) and including eye-tracking analysis (Mühlberger et al., 2008; Wieser et al., 2009; Dechant et al., 2017).

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Ethics Committee of the University of Regensburg with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the University of Regensburg.

AUTHOR CONTRIBUTIONS

JR conceived the study, data acquisition and analysis, and wrote the manuscript. MP analyzed the data and contributed to writing the manuscript. DF acquired and analyzed the data and contributed to writing the manuscript. JG acquired and analyzed the data, and contributed to writing the manuscript. YS contributed to writing the manuscript. AM contributed to study conception, analyzed the data, and contributed to writing the manuscript. All authors approved the final version of the manuscript for submission.

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2.3 Study 3: Gaze Behavior in Social Fear Conditioning in Virtual Reality

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Gaze Behavior in Social Fear Conditioning: An Eye-Tracking Study in Virtual Reality

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The vigilance-avoidance hypothesis of selective attention assumes that socially anxious persons initially direct their attention toward fear-related stimuli and subsequently avoid these social stimuli to reduce emotional distress. New technical developments provide tools to implicit measure overt attention on fear-related stimuli via eye-tracking in ecological valid virtual environments presented via a head-mounted display. We examined in 27 low (LSA) and 26 high socially anxious (HSA) individuals fear ratings, physical behavior (duration of approach), hypervigilance (time to first fixation), and attentional avoidance (count of fixations) toward virtual female and male agents (CS) during social fear conditioning (SFC) and extinction in virtual reality (VR). As hypothesized, generally SFC was successfully induced and extinguished concerning the fear ratings. Our findings partly support the vigilance-avoidance hypothesis as HSA directed especially at the first half of the fear acquisition their initial attention more at CS+ than CS− agents, and avoided subsequently the CS+ more than the CS− agents during the fear acquisition. In contrast, in LSA participants initial and sustained attention did not differ between CS+ and CS− agents during fear acquisition. We conclude that HSA individuals guide their initial attention to emotionally threatening stimuli and subsequently avoid the threatening stimuli to possibly reduce their emotional distress, whereas LSA individuals regulate themselves less in their (fear) responses during SFC. Measuring implicit gaze behavior within a well-controlled virtual environment is an interesting innovative tool to in deeply investigate the impact of attention on emotional learning processes.

Keywords: social anxiety disorder, social fear conditioning, vigilance-avoidance hypothesis, eye-tracking, virtual reality

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INTRODUCTION

A lot of research has investigated selective attention that describes social anxiety to conceive the architecture of information processing in social anxiety disorder (SAD). The most popular theoretical models of SAD are the cognitive model from Clark and Wells (1995) and the cognitive-behavioral model from Rapee and Heimberg (1997). Both models comprise biases in information processing that develop and/or maintain SAD and implicate the importance of selective attention (e.g., vigilance, avoidance) in social anxiety (Schofield et al., 2012).

Clark and Wells (1995) suggest that central factors of information processing in SAD include increased self-focused attention, safety behavior, and problematic anticipatory and subsequent processing. For example, avoiding attention toward feared stimuli during social interactions serves as safety behavior to regulate the internal distress (e.g., reducing eye contact), to avert feared negative situations (e.g., assessments), and/or to avoid real or perceived feared social appraisal of others as an attempt of self-regulation. Accordingly, conscious attentional avoidance of salient feared stimuli is active during social evaluations and is assumed to maintain SAD.

In comparison, Rapee and Heimberg (1997) focus more on vigilance as selective attention toward emotionally negative information in SAD. The authors emphasize that socially anxious persons utilize an exaggerated attentional allocation toward any sign of impending negative feedback of others, which can lead to biased estimations of a more threatening social environment and that a wisp of negative evaluation will be perceived rapidly and reinforce the threatening negative self-evaluation (Heimberg et al., 2014).

Chen and Clarke (2017) report in their review that there are different results in empirical research among socially anxious humans with attentional bias to relevant emotionally threat stimuli (Gilboa-Schechtman et al., 1999; Perowne and Mansell, 2002; Lange et al., 2011; Çek et al., 2016; Lazarov et al., 2016) and who also exhibited attentional avoidance toward socially feared information (Chen et al., 2002; Wieser et al., 2009b; Singh et al., 2015; Shechner et al., 2017). Mogg and Bradley (2002) suggest that vigilant patterns of attention may be located in initially attentional processing. Furthermore, Chen and Clarke (2017) conclude that there is an association between social anxiety and vigilance (e.g., hyperscanning the environment) as well as attentional avoidance (e.g., reducing eye contact) according to the information processing of emotionally social stimuli.

These mixed empirical results caused the formulation of a vigilance-avoidance hypothesis of selective attention (Bögels and Mansell, 2004; Wieser et al., 2009a,b; Chen and Clarke, 2017). It assumes that socially anxious humans guide their initial attention to emotionally threatening information (hypervigilance) and avoid the negative information subsequently (attentional avoidance) to reduce emotional distress (Bögels and Mansell, 2004; e Claudino et al., 2019).

In recent years the rising use of eye-tracking technology offered novel insights into diverse aspects of selective attention that are responsible in the etiology and maintenance of SAD (Lange et al., 2011; Schofield et al., 2012; Lazarov et al., 2016; Chen and Clarke, 2017). Furthermore, patterns of gaze behavior could be used as sensitive index of fear learning (Hopkins et al., 2015). Using an eye-tracking device allows us to directly and continuously measure visual selective attention in real time. This methodology registers the precise location of eye movement and gaze behavior over the course of time as a relatively naturalistic assessment of attention without an explicit response of the participant. Bögels and Mansell (2004) described in their review a lot of paradigms like the emotional Stroop task (Maidenberg et al., 1996; Becker et al., 2001), visual search task (Rinck et al., 2003), modified dot-probe task (Mansell et al., 2002; Mogg et al., 2004), and eye-tracking tasks (Garner et al., 2006) to investigate hypervigilance and/or avoidance in the information processing of selective attention in social anxiety.

Relating to the nature of SAD, one major deficiency of these experimental paradigms is that participants observe stimuli with a low ecological validity (e.g., images of faces or words on a screen). Consequently, more research is necessary to validate how socially anxious persons respond to more ecological valid socially relevant stimuli. Empirical studies on gaze behavior in social interactions (e.g., interviews or having a speech causing fear of negative evaluation) are rare and have methodical shortcomings, e.g., less valid and reliable measurement of dependent variables and reduced control of independent variables in real interactions (Mühlberger et al., 2008; Wieser et al., 2009a).

Several empirical studies with an innovative technology such as virtual reality (VR) investigated social interaction processes with good experimental control, high ecological validity, low time costs, and highly valid assessments of dependent variables like physical and gaze behavior. Further advantages are the systematic and independent manipulations of eye-gaze directions or gender of the interaction partner as well as the presented social situations, all of which are either very costly or difficult to control *in vivo*. Most importantly, eye and head movements or interpersonal space between the participant and the counterpart can simply be recorded with the use of eye- and head-tracking within VR (Mühlberger et al., 2008; Wieser et al., 2009a,b; Dechant et al., 2017; Reichenberger et al., 2019). This innovative technology gives us the opportunity to assess directly approach-avoidance behavior in social interactions as well.

Wieser et al. (2010) investigated the impact of sex, gaze, and interpersonal distance (0.5 m vs. 1.5 m) on social anxiety in women in a virtual social interaction scenario. Socially anxious women showed attentional avoidance in response to virtual male counterparts, which were farther away and showed a straight gaze. In addition, they revealed more backward movements of the head (avoidance behavior) toward male agents, regardless of the interpersonal space. Moreover, Dechant et al. (2017) reported that HSA presented more attentional avoidance than LSA participants in a virtual social interaction paradigm. As we know, avoidance behavior is a key element in the maintenance of anxiety and also in fear learning.

In our previous study, we investigated differences between the gender and the influence of female vs. male agents in $N = 60$ high and low socially anxious individuals concerning social fear conditioning (SFC) and extinction in VR (Reichenberger et al., 2019). This SFC paradigm used social interactions in a standardized and experimentally controlled way, and disorder-relevant US (spitting simulated by an aversive air blast and verbal rejection) to examine affective learning in social anxiety. We measured with an enhanced ecological validity the experience, psychophysiology, behavior and cognition in emotional learning processes corresponding on each level of emotional reactions. Besides the successfully induced and extinguished SFC, we could present higher social fear conditionability in women, but participants reported no higher fear while approached male than female agents. Interestingly, we found enhanced fear responses in the fear-potentiated startle to male than to female agents which might indicate higher social fear conditionability toward male persons. In addition, high socially anxious women revealed more behavioral avoidance to male than to female agents during fear acquisition. In comparison, HSA men did not discriminate between male or female agents. We concluded that the gender of the participants rather affect reflective processes (e.g., reported fear as well as contingency and skin conductance response), while the gender of the virtual agents influence more automatic measures (e.g., fear-potentiated startle and behavioral avoidance). Besides these self-reported and psychophysiological measures, binocular gaze behavior was also continuously recorded.

In the current study, we analyzed the recorded physical and gaze behavior (hypervigilance and attentional avoidance) during the SFC paradigm in a subsample from Reichenberger et al. (2019). Therefore, we aim to investigate the effect of induced and extinguished social fear on physical behavior (duration of approach) as well as hypervigilance (time of the first fixation) and attentional avoidance (count of fixations) toward female and male agents in HSA and LSA students in the SFC paradigm in VR. Based on the aforementioned empirical results, we hypothesize that (1) hypervigilance and attentional avoidance for CS+ would increase compared to CS− during fear acquisition. (2) In addition, we hypothesize that HSA will show enhanced hypervigilance to CS+ compared to CS− and will avoid more the CS+ compared to CS− than LSA participants during fear acquisition. At least, we expected that hypervigilance and attentional avoidance for CS+ would return to baseline levels and won't differ to CS− during fear extinction.

MATERIALS AND METHODS

Participants

One hundred and eighty Psychology and Media Informatics Science students at the University of Regensburg filled in a pre-screening questionnaire consisting of demographic and exclusion criteria as well as social anxiety using the German version of the Social Phobia Inventory (SPIN; Stangier and Steffens, 2002). Exclusion criteria were age <18 or >55 years, an existing or former diagnosed neurological or mental disorder (excepting SAD), a current neurological, psychiatric or psychotherapeutic treatment, a history of psychotropic drug use, pregnancy or lactation, and an attendance in a previous SFC study (Reichenberger et al., 2019).

Based on our previous study investigating SFC and extinction in VR (Reichenberger et al., 2017) a sample size of 54 was estimated with G*Power 3.1.9.2 to detect medium effects ($f = 0.25$) at power = 0.95 and $\alpha = 0.05$. The current study consists of a subsample from Reichenberger et al. (2019). However, on the basis of eye-tracking failure during data acquisition, we had to exclude seven participants from the original sample of $n = 60$. Thus, the current study contained a sample of 53 undergraduate students (27 LSA: 51.85% female, aged between 18 and 43; and 26 HSA: 53.85% female, aged between 18 and 33). The SPIN cut-off value of 19 differentiates patients with SAD and healthy persons with a diagnostic accuracy of 79% (Connor et al., 2000). A successful segmentation into a HSA and LSA group was given, since HSA reveal significantly higher scores than LSA participants with quite large between group effect sizes in the SPIN and in the German version of the Social Interaction Anxiety Scale (SIAS; Stangier et al., 1999). Please see **Table 1** for the questionnaire data. In addition, the groups did not differ in age [$t(51) = 0.832$, $p = 0.409$] and sex ratio [HSA: 12 men; LSA: 13 men; $\chi^2(1, 53) = 0.021$, $p = 0.884$]. The final sample was free of any neurological or mental disorder (self-report) and had unimpaired or corrected hearing and vision. All of the students received course credit as reimbursement for their attendance. The Ethics Committee of the University of Regensburg approved the study.

Apparatus

The VR was displayed with the HTC VIVE head-mounted display (HMD; HTC Corporation, Taoyuan, Taiwan) and was generated via the Steam Source engine (Valve Corporation, Bellevue, WA, United States). The presented virtual environment was controlled by CyberSession Research 5.6 (VTplus GmbH, Würzburg, Germany). Eye-tracking was continuously recorded binocular with a sampling rate of 250 Hz by the SMI (SensoMotoric Instruments, Boston, United States) head gear integration into the HMD. The trackable field of view is 110° with an accuracy of typ. 0.2° for eye-gaze vectors. CyberSession Research submits the processing of eye-tracking data in log files. All of the sounds were presented over headphones (Sennheiser HD-215, Sennheiser electronic GmbH, Germany). The participants could move in the virtual environment using a joystick (Logitech Extreme 3D Pro Joystick, Logitech GmbH, Germany).

During the study participants were immersed into a virtual room, which was modeled after a corridor of the University of Regensburg (see **Figure 1A**). In all three phases (pre-acquisition, acquisition, and extinction), the starting position was at one end of the room and at the opposite end a female or male agent was presented. The agents moved their head and upper body slightly and gazed dynamically at the participant to appear alive (please

TABLE 1 | Questionnaire data.

	LSA (n = 27)		HSA (n = 26)				
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
SPIN	10.8	3.82	27.3	7.06	−10.624	<0.001	2.98
SIAS	16.2	10.1	29.5	11.1	−4.585	<0.001	1.28
PRF-D	9.78	3.97	5.31	3.74	4.219	<0.001	1.18
SBS	22.6	8.18	27.9	6.51	−2.636	0.011	0.74
VIG	10.7	3.63	13.5	2.69	−3.007	0.004	0.84
CAV	10.4	3.63	9.15	2.63	1.392	0.170	0.25

Means (M) and standard deviations (SD) and also t- and p-values and Cohen's d as well as number of participants (n) are given for low (LSA) and high socially anxious (HSA) participants for questionnaire data. SPIN = Social Phobia Inventory; SIAS = Social Interaction Anxiety Scale; PRF-D = German Personality Research Form – Dominance Scale; SBS = Submissive Behavior Scale; VIG = Vigilance of the Mainz Coping Inventory; CAV = Cognitive Avoidance of the Mainz Coping Inventory.

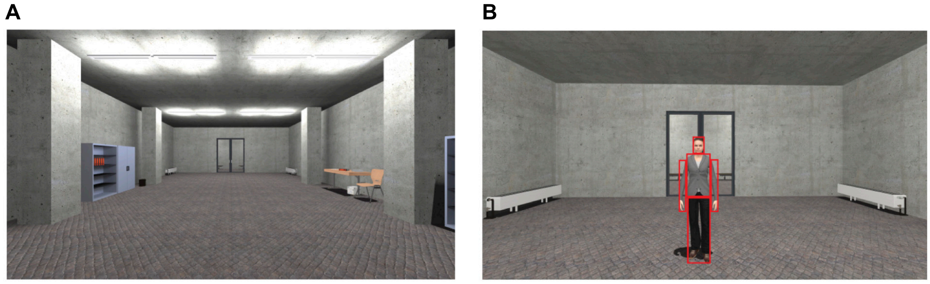

FIGURE 1 | Virtual environment and stimuli. **(A)** Starting point in the room in which the learning phases took place. **(B)** Social stimuli (agents) used for social fear conditioning (SFC) with the dynamic social area of interest (red rectangles). For interpretation of the references to color in this figure, the reader is referred to the web version of this article.

see Reichenberger et al., 2019). The task of the participants was to actively approach in all three phases the female and male agents until a distance of 30 cm where movement stopped. In 75% of the SFC trials female and male agents (CS+) were paired with an aversive unconditioned stimulus (US) existing of a sound of spitting attended by an air blast toward the right neck of the participant (5 bar, 10 ms) followed by the verbal rejection "Get lost!." The agents' facial expression was adapted to the spitting and verbal rejection. The other female and male agent (CS−) was not paired with an US. The pre-acquisition and extinction phase proceeded in exactly the same way as the fear conditioning, except for presenting no US and the appearance of a neutral agent (NS) of both genders in the extinction phase. The order of the agents was pseudo-randomized in each phase (see Shiban et al., 2015; Reichenberger et al., 2017, 2019).

Measures

At the beginning of the experiment, participants completed the following questionnaires: a socio-demographic questionnaire, the SPIN, the SIAS, the Dominance scale of the German Personality Research Form (PRF-D; Stumpf et al., 1985), the Submissive Behavior Scale (SBS; Allan and Gilbert, 1997), and the subtest Ego threat of the German version of the Mainz Coping Inventory (MCI; Krohne and Egloff, 1999) with the two coping strategies Vigilance (VIG) and Cognitive Avoidance (CAV). A detailed description of the questionnaires is given in our previous study (see Reichenberger et al., 2019).

During the VR, we quantified the experienced anxiety in regard of each agent with verbally ratings ("On a scale from 0 to 100, how intense is your anxiety during the presence of this person?") in the rating phases which followed each of the three phases. Participants approached each of the diverse agents until they reached the specific distance of 30 cm to the agents, lights faded out and they verbally rate their anxiety.

Besides these self-reported measures, physical behavior (duration to approach) and binocular gaze behavior was continuously recorded during the SFC paradigm. To ensure that the gaze behavior was measured correctly by the SMI integration eye-tracking device, a 5-point calibration was conducted before the learning phases in VR. The continuous gaze behavior was analyzed as the time to first fixation (hypervigilance) and the mean percentage of the fixation counts (attentional avoidance) in predefined dynamic social areas of interest (AOI) for each agent (CS+, CS−, and NS) in each phase (pre-acquisition, acquisition, extinction). The social AOI was defined by a rectangle around the face and the body of each agent separately (see **Figure 1B**).

Procedure

The study consisted of briefing the participants in written form, signing the informed consent, filling out questionnaires, and the SFC paradigm in VR (see **Figure 2**). At the beginning of the VR, participants could explore the virtual environment and learn how to navigate with the joystick. Afterward, the recorded instruction "You will now meet several human beings. Please try to move directly toward the persons until they are right in front of you" was presented. Therefore, participants approached female and male agents actively until the specific distance of 30 cm to the agents, lights faded out, the participants were returned to the starting point and the next trial with a new agent at the opposite end of the room was presented. Which agent was presented as CS+ or CS− was balanced across participants.

In the pre-acquisition phase each female and male CS+/CS− agent was presented four times, resulting in 16 total trials and the US was not presented yet. Following this, the first rating phase took place for each female and male CS+/CS− agent.

The acquisition phase consisted of 32 trials in total. Each female and male CS+/CS− agent was presented eight times. Only the conditioned agent (CS+) was paired with 75% contingency of the US during the acquisition phase.

Following the fear conditioning, the second rating phase took place for each agent. After that, participants had a 5 min break where they took off the HMD and had the possibility to sit down and close their eyes.

After the break, the extinction phase took place exactly the same way as the fear acquisition, except for the absence of the US as well as the presentation of one additional female and one additional male NS, resulting in 48 total trials. At least, the third rating phase took place for each female and male CS+, CS−, and NS agent. A more detailed description of the procedure is given by Reichenberger et al. (2019).

Phase	Stimulus	Agents	US	Total Trials
Pre-Acquisition	CS+	4 x ♂ 4 x ♀	-	16
	CS-	4 x ♂ 4 x ♀		
Pre-Acquisition Rating	CS+	1 x ♂ 1 x ♀	-	4
	CS-	1 x ♂ 1 x ♀		
Acquisition	CS+	8 x ♂ 8 x ♀	75 %	32
	CS-	8 x ♂ 8 x ♀	-	
Post-Acquisition Rating	CS+	1 x ♂ 1 x ♀	-	4
	CS-	1 x ♂ 1 x ♀		
Extinction	CS+	8 x ♂ 8 x ♀	-	48
	CS-	8 x ♂ 8 x ♀		
	NS	8 x ♂ 8 x ♀		
Post-Extinction Rating	CS+	1 x ♂ 1 x ♀	-	6
	CS-	1 x ♂ 1 x ♀		
	NS	1 x ♂ 1 x ♀		

FIGURE 2 | Experimental procedure. As unconditioned stimulus (US) a sound of spitting attended by an air blast followed by the verbal rejection was applied. The order of the agents was pseudorandomized in each phase. CS+ = agent paired with aversive US; CS− = agent without aversive US; NS = agent without aversive US and only appearing during the extinction phase.

Data Reduction and Statistical Analyses

We utilized MATLAB 9.5 (MathWorks Inc., Germany) to analyze the behavioral data and SPSS 25.0 (IBM Corp., Armonk, NY, United States) to perform further analyses of the subjective and behavioral variables.

The mean fear rating for each female and male agent (CS+, CS−, NS) measured after each phase (pre-acquisition, acquisition, and extinction) were calculated. Investigating changes in fear ratings concerning SFC, two repeated-measures ANOVAs with the within-subject factors time (pre vs. post-acquisition for acquisition, and post-acquisition vs. post-extinction for extinction), stimulus (CS+ vs. CS−) and agent (female vs. male), and the between-subject factors gender (women vs. men) and social anxiety (LSA vs. HSA) were computed.

For the statistical analyses of the behavioral outcome variables, we defined that one trial consisted of the onset (as soon as the participant starts to approach using the joystick) and the offset (30 cm distance to the agent) in each phase.

For the physical behavior (duration of approach) as well as both gaze behavioral outcome variables, we computed means for the pre-acquisition phase, while the first four and the last four approaches in the acquisition and the extinction phase were calculated as the means of the beginning and the end of the acquisition as well as extinction phase, respectively.

Hypervigilance was measured by the time to first fixation on a social AOI in a trial. Since the duration of approach toward the agents was different between the phases and both groups (see **Figure 4**), attentional avoidance was calculated by the mean percentage of the count of fixations (number of fixations in the social AOI divided by the total number of fixations in the trial). The social AOI contain the face and the body of each agent in each approach trial. Fixations were defined based on a spatial (a diameter of 1° visual angle) and a temporal criterion (a minimum of 150 ms). Gaze behavior data were excluded if for more than 20% of the sampling points of a trial the eye-tracker couldn't identify the gaze direction of the participant.

Checking for potential distinctions in pre-acquisition, ANOVAs with the within-subject factors stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors gender (women vs. men) and social anxiety (low vs. high) were calculated for each behavioral outcome variable. In order to analyze conditioning effects, repeated-measures ANOVAs with the within-subject factors time (beginning vs. end), stimulus (CS+ vs. CS−) and agent (female vs. male) and the between-subject factors gender (women vs. men) and social anxiety (LSA vs. HSA) were calculated for the acquisition and extinction phase. Testing for possible generalization effects, ANOVAs with the within-subject factors stimulus (CS+ vs. CS− vs. NS) and agent (female vs. male) and the between-subject factors gender (women vs. men) and social anxiety (low vs. high) were calculated at the beginning of the extinction phase as well.

All of the significant interactions were performed by separate follow-up ANOVAs or Student's *t*-tests. Partial η^2 (η_p^2) scores and Cohen's *d* served as indices of effect size. All statistical analyses utilized a $p < 0.05$ as level of statistical significance.

RESULTS

As expected, significant group differences (see **Table 1**) were found in social anxiety (SPIN), in anxiety of social interactional situations (SIAS), in dominant (PRF-D) and submissive behavior (SBS), and vigilance (VIG). However, groups did not differ in the total score of cognitive avoidance (CAV). As this is a subsample of the study published by Reichenberger et al. (2019), results in these analyses reflect the earlier results based on the whole sample.

Self-Report

Figure 3 displays that in each phase all fear ratings are higher for HSA than for LSA participants. After pre-acquisition, both stimuli are rated almost equal in both groups. After fear acquisition, the self-reported fear for CS+ agents is clearly higher than for CS− agents in both groups. After fear extinction, the ratings for CS+ agents decrease and the self-reported fear for

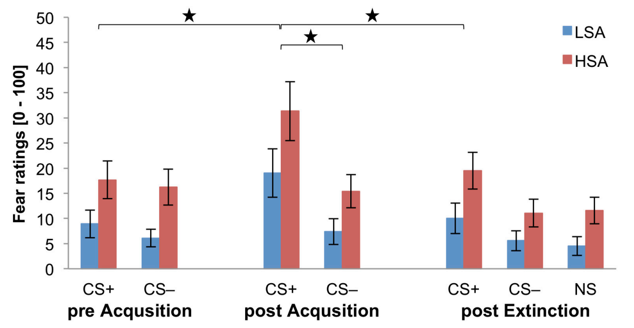

FIGURE 3 | Fear ratings ($n = 53$) for CS+, CS−, and NS in the three rating phases for low (LSA) and high socially anxious (HSA) participants. CS+ = agent paired with aversive unconditioned stimulus (US); CS– = agent without aversive US; NS = agent without aversive US and appearing only in the extinction phase; pre Acquisition = before acquisition phase; post Acquisition = after acquisition phase; post Extinction = after extinction phase. Mean fear ratings (0 = very low fear to 100 = very high fear) were given. Significant differences are indicated with an asterisk. Standard errors are presented by error bars.

CS− and NS agents do not distinguish after fear extinction, whereas the CS+ agents are rated slightly higher in both groups.

For fear acquisition, an ANOVA comparing the self-reported fear pre and post acquisition revealed a significant effect of Time × Stimulus × Gender × Social Anxiety (please see **Table 2** for all significant results of the ANOVA). Follow-up ANOVAs were performed for the HSA and LSA group separately to disentangle this fourfold interaction. For the HSA group, a significant effect of Time × Stimulus × Gender could be approved. Follow-up ANOVAs were conducted for HSA women and men separately. For HSA women, a significant interaction effect of Time × Stimulus could be found and the follow-up t-tests indicate that the self-reported fear increased significantly for CS+, $t(13) = -3.35$, $p = 0.005$, $d = 0.69$, but not for CS− ($p = 0.313$). In comparison, for HSA men a significant main effect of Time $F(1,11) = 4.83$, $p = 0.050$, $\eta_p^2 = 0.31$, Stimulus $F(1,11) = 4.88$, $p = 0.049$, $\eta_p^2 = 0.31$, but not for Time × Stimulus $F(1,11) = 2.83$, $p = 0.121$, $\eta_p^2 = 0.20$, was detected. Exploratory t-tests might give a first hint that also in men the self-reported fear might increase for CS+, $t(11) = -2.29$, $p = 0.043$, $d = 0.5$, but not for CS− ($p = 0.237$). For the LSA group, we found significant interaction effects for Time x Stimulus, and the follow-up t-tests show that the subjective fear increased significantly for CS+, $t(26) = -3.91$, $p < 0.001$, $d = 0.51$, but not for CS− ($p = 0.424$) as expected. In sum, the findings of the self-reported fear reveal that successful SFC took place like in the whole sample by Reichenberger et al. (2019), with the exception of HSA men.

Concerning fear extinction, an ANOVA comparing fear ratings pre and post extinction approved significant effects of Stimulus × Gender, and Time × Stimulus × Agent (please see **Table 2**). Follow-up ANOVAs were performed for female and male agents separately to unravel this threefold interaction. For female agents, a significant interaction effect of Time × Stimulus could be found and follow-up t-tests detect that the self-reported fear significantly decreased for the CS+, $t(52) = 5.57$, $p < 0.001$, $d = 0.53$, but not clearly for the CS−, $t(52) = 1.99$, $p = 0.051$, $d = 0.12$. For male agents, a significant interaction effect of Time × Stimulus was identified and follow-up t-tests highlight that the fear ratings of the CS+, $t(52) = 4.61$, $p < 0.001$, $d = 0.36$, and CS−, $t(52) = 3.23$, $p = 0.002$, $d = 0.31$, significantly

TABLE 2 | Significant results of the ANOVA for fear ratings of the acquisition and extinction phase.

Effect	***df***	***F***	η_p^2	***p***
Acquisition				
Total				
Time	1, 49	18.9	0.28	<0.001
Stimulus	1, 49	23.5	0.32	<0.001
Gender	1, 49	5.13	0.10	0.028
Social Anxiety	1, 49	4.30	0.08	0.043
Time × Stimulus	1, 49	25.8	0.35	<0.001
Time × Stimulus × Gender × Social Anxiety	1, 49	4.13	0.08	0.048
LSA				
Time	1, 25	11.8	0.32	0.002
Stimulus	1, 25	12.0	0.32	0.002
Time × Stimulus	1, 25	10.7	0.30	0.003
HSA				
Time	1, 24	8.05	0.25	0.009
Stimulus	1, 24	11.6	0.33	0.002
Gender	1, 24	4.29	0.15	0.049
Time × Stimulus	1, 24	14.9	0.38	<0.001
Time × Stimulus × Gender	1, 24	5.62	0.19	0.026
HSA women				
Stimulus	1, 13	8.64	0.40	0.011
Time × Stimulus	1, 13	13.7	0.51	0.003
HSA men				
Time	1, 11	4.83	0.31	0.050
Stimulus	1, 11	4.88	0.31	0.049
Extinction				
Total				
Time	1, 49	28.0	0.36	<0.001
Stimulus	1, 49	28.6	0.37	<0.001
Agent	1, 49	4.77	0.09	0.034
Gender	1, 49	5.12	0.10	0.028
Stimulus × Gender	1, 49	4.88	0.09	0.032
Time × Stimulus	1, 49	16.6	0.25	<0.001
Time × Stimulus × Agent	1, 49	5.89	0.11	0.019
Female agents				
Time	1, 49	24.8	0.34	<0.001
Stimulus	1, 49	20.9	0.30	<0.001
Time × Stimulus	1, 49	23.3	0.32	<0.001
Male agents				
Time	1, 49	25.9	0.35	<0.001
Stimulus	1, 49	21.1	0.30	<0.001
Time × Stimulus	1, 49	5.73	0.11	0.021

df = degrees of freedom; η_p^2 = effect size; Time = pre vs. post acquisition for acquisition and post acquisition vs. post extinction for extinction; Stimulus = CS+ vs. CS−; Agent = female vs. male agent; Gender = women vs. men; Social Anxiety = LSA vs. HSA.

decreased. For the Stimulus × Gender interaction, follow-up *t*-tests reveal that women rated the CS+ significantly higher than men, $t(45.7) = 2.48$, $p = 0.017$, $d = 0.68$, however, there was no difference for the CS− ($p = 0.096$). The results of the fear ratings indicate that social fear extinction was also successful in the subsample as it was in the sample reported by Reichenberger et al. (2019). However, no generalization effect was found.

Physical Behavior

Figure 4 displays that at the beginning of the fear acquisition the LSA approach the CS− faster than the CS+, whereas the HSA don't differ between both agents. Interestingly, during fear acquisition HSA need slightly more time to approach the CS+ and CS− agents than the LSA group. During fear extinction, the duration of approach toward the agents differs not between both groups, besides the duration of approach toward the NS agent was shorter for the LSA than the HSA group at the beginning of the extinction.

Investigating differences in the pre-acquisition phase an ANOVA confirmed only a significant effect of Agent, $F(1,49) = 5.48$, $p = 0.023$, $\eta_p^2 = 0.10$, indicating a longer approach time toward male ($M = 9.08$, $SD = 0.25$) than female ($M = 9.01$, $SD = 0.20$) agents.

Relating to the fear acquisition, we detected no significant effect for Social Anxiety, $F(1,48) = 3.08$, $p = 0.086$, $\eta_p^2 = 0.06$, and Time × Stimulus × Social Anxiety, $F(1,48) = 3.02$, $p = 0.088$, $\eta_p^2 = 0.06$, but a significant effect for Agent × Gender × Social Anxiety, $F(1,48) = 4.38$, $p = 0.042$, $\eta_p^2 = 0.08$. Follow-up ANOVAs were conducted for both HSA and LSA participants separately, but no main or interaction effect reached significance. For LSA, the effect of Agent × Gender, $F(1,24) = 3.57$, $p = 0.071$, $\eta_p^2 = 0.13$, and Time × Stimulus, $F(1,24) = 4.13$, $p = 0.053$, $\eta_p^2 = 0.15$, narrowly missed significance. With regard to fear conditioning, exploratory *t*-tests might give a preliminary hint that at the first part of the fear acquisition the approaching time toward the CS+ might be higher than to the CS−, $t(25) = 2.091$, $p = 0.047$, $d = 0.53$, whereas at the end of the fear acquisition the difference of the approaching time seems vanished ($p = 0.415$).

For fear extinction, a significant main effect of Time × Stimulus × Agent × Gender, $F(1,49) = 6.52$, $p = 0.014$, $\eta_p^2 = 0.12$, was found. Follow-up ANOVAs were performed for both genders separately, but no significant main or interaction effect was found. Furthermore, no generalization effect was found.

Hypervigilance

Figure 5 shows that at the beginning of the fear acquisition HSA fixate more early the CS+ than the CS− agent. In comparison, at the end of the fear acquisition HSA show a lower time of the first fixation to the CS− compared to the CS+ agent. The LSA show a small increase of the time of the first fixation toward both agents during fear acquisition. In the extinction phase, we can detect a decrease of the time of the first fixation toward the agents in both groups.

Proving differences before fear conditioning, an ANOVA confirmed no significant differences during pre-acquisition. For fear acquisition, an ANOVA revealed a significant effect of Time × Gender, $F(1,46) = 4.59$, $p = 0.037$, $\eta_p^2 = 0.10$, Time × Stimulus, $F(1,46) = 6.06$, $p = 0.018$, $\eta_p^2 = 0.12$, and Time × Stimulus × Social Anxiety, $F(1,46) = 4.06$, $p = 0.050$, $\eta_p^2 = 0.08$. Follow-up ANOVAs were conducted for the HSA and LSA group separately. For HSA, the interaction effect of Time × Stimulus, $F(1,24) = 12.73$, $p = 0.002$, $\eta_p^2 = 0.35$, reached significance. Follow-up *t*-tests indicate that at the beginning (first half) of the acquisition phase the time till the first fixation toward the CS+ was significantly lower than to the CS−, $t(25) = -2.377$, $p = 0.025$, $d = 0.18$, whereas at the end (second half) of the acquisition phase the time till the first fixation toward the CS+ was significantly higher than to the CS−, $t(25) = 2.687$, $p = 0.013$, $d = 0.21$. For LSA, no significant main or interaction effects were found.

Regarding fear extinction, an ANOVA detected significant effects of Time, $F(1,48) = 7.01$, $p = 0.011$, $\eta_p^2 = 0.13$, and Stimulus × Agent, $F(1,48) = 10.75$, $p = 0.002$, $\eta_p^2 = 0.18$. Follow-up *t*-tests reveal a significant lower time till the first fixation toward the male CS− compared to the female CS−, $t(52) = -3.641$, $p < 0.001$, $d = 0.29$, but no significant difference

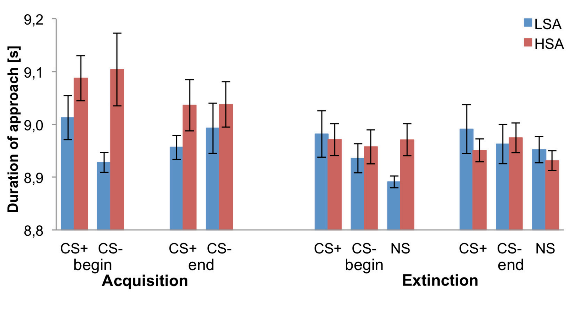

FIGURE 4 | Mean duration of approach for low (LSA) and high socially anxious (HSA) participants ($n = 53$). CS+ = agent paired with aversive unconditioned stimulus (US); CS− = agent without aversive US; NS = agent without aversive US and only appearing during the extinction phase. Standard errors are presented by error bars.

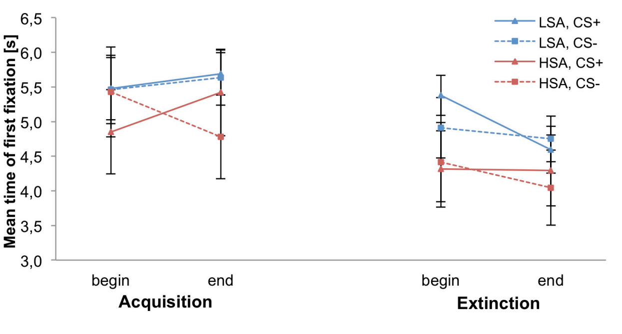

FIGURE 5 | Mean time of the first fixation within the social area of interest (agent) for low (LSA) and high socially anxious (HSA) participants ($n = 53$). CS+ = agent paired with aversive unconditioned stimulus (US); CS− = agent without aversive US. Standard errors are presented by error bars.

between the male and female CS+ (p = 0.125). However, no generalization effect was found.

Attentional Avoidance

As we can see, the mean count of fixations toward the face and the body of the agents (social AOI), as well as toward the environment is higher for the HSA compared to the LSA participants (see **Figure 6**). **Figure 7** displays the mean percentage of the count of fixations that contain the given social AOI (agent) for LSA and HSA participants during fear acquisition and extinction. In the fear acquisition phase, HSA show more attentional avoidance to CS+ than to CS−, whereas LSA avoid both CS+ and CS− in the same level. In the extinction phase, we can detect a higher increase of fixations to CS− than to CS+.

Checking differences in the pre-acquisition phase, an ANOVA showed a significant effect of Stimulus × Agent × Gender, $F(1,46) = 7.33$, $p = 0.009$, $\eta_p^2 = 0.14$, but follow-up ANOVAs conducting for women and men separately detected no significant main or interaction effects for both gender.

Concerning fear acquisition, an ANOVA approved significant effects of Time × Gender, $F(1,46) = 4.76$, $p = 0.034$, $\eta_p^2 = 0.09$, Time × Stimulus × Social Anxiety, $F(1,46) = 8.51$, $p = 0.005$, $\eta_p^2 = 0.16$, and Stimulus × Agent × Social Anxiety, $F(1,46) = 6.20$, $p = 0.016$, $\eta_p^2 = 0.12$. Follow-up ANOVAs were conducted for the HSA and LSA group. For HSA, the interaction effects of Stimulus × Agent, $F(1,24) = 9.84$, $p = 0.004$, $\eta_p^2 = 0.29$, and Time × Stimulus, $F(1,24) = 12.5$, $p = 0.002$, $\eta_p^2 = 0.34$, reached significance. For the Stimulus × Agent interaction, follow-up t-tests show that HSA fixated significantly more frequently the female than the male CS+, $t(25) = -2.51$, $p = 0.019$, $d = 0.22$, whereas between the female and the male CS− was no significant difference ($p = 0.170$). Regarding the Time × Stimulus interaction, follow-up t-tests reveal that HSA looked significantly more frequently toward the CS+ than to the CS− at the beginning of the fear acquisition, $t(25) = 2.39$, $p = 0.025$, $d = 0.22$, whereas at the end of the acquisition they exhibited significantly more fixations counts toward the CS− than to the CS+, $t(25) = -2.98$, $p = 0.006$, $d = 0.22$, indicating an effect of fear conditioning according the attentional avoidance in HSA. For LSA, we detected no significant main or interaction effect.

For fear extinction, an ANOVA showed significant effects of Stimulus x Agent, $F(1,48) = 16.5$, $p < 0.001$, $\eta_p^2 = 0.26$, Time × Agent × Social Anxiety, $F(1,48) = 4.63$, $p = 0.037$, $\eta_p^2 = 0.09$, and Stimulus × Agent × Gender × Social Anxiety, $F(1,48) = 4.96$, $p = 0.031$, $\eta_p^2 = 0.09$. To disentangle this threefold interaction, we conducted follow-up ANOVAs for HSA and LSA separately. For HSA, significant effects of Stimulus × Agent, $F(1,24) = 21.5$, $p < 0.001$, $\eta_p^2 = 0.47$, and Stimulus × Agent × Gender, $F(1,24) = 9.17$, $p = 0.006$, $\eta_p^2 = 0.28$, were identified. Another follow-up ANOVAs were performed for HSA women and men separately. For HSA women, no significant main or interaction effect was detected. For HSA men, we found a significant interaction effect of Stimulus × Agent, $F(1,11) = 17.1$, $p = 0.002$, $\eta_p^2 = 0.61$, and the follow-up t-tests show that HSA men fixated significantly more female than male CS+ agents, $t(11) = -3.17$, $p = 0.009$, $d = 0.9$, whereas no significant difference between the female and male CS− was identified ($p = 0.059$). With regard to LSA, we found significant effects of Gender, $F(1,24) = 8.21$, $p = 0.009$, $\eta_p^2 = 0.26$, Time × Agent, $F(1,24) = 6.76$, $p = 0.016$, $\eta_p^2 = 0.22$, and Time × Stimulus × Agent × Gender, $F(1,24) = 4.77$, $p = 0.039$, $\eta_p^2 = 0.17$. Therefore, another follow-up ANOVAs were conducted for LSA women and men separately. No significant main or interaction effect was found for LSA women. For LSA men, a significant interaction effect of Time × Agent $F(1,12) = 6.94$, $p = 0.022$, $\eta_p^2 = 0.37$, could be detected and follow-up t-tests reveal that the fixations toward female agents significantly increased, $t(12) = -2.24$, $p = 0.045$, $d = 0.94$, whereas the fixations toward the male agents did not change during fear extinction ($p = 0.814$). However, no generalization effect was found.

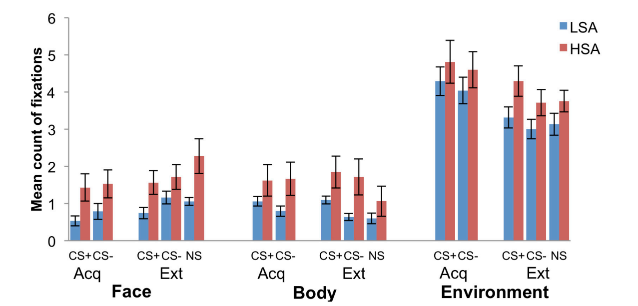

FIGURE 6 | Mean count of fixations within the social area of interest (face and body) as well as environment for low (LSA) and high socially anxious (HSA) participants (n = 53). CS+ = agent paired with aversive unconditioned stimulus (US); CS− = agent without aversive US; NS = agent without aversive US and appearing only in the extinction phase; Acq = acquisition phase; Ext = extinction phase. Standard errors are presented by error bars.

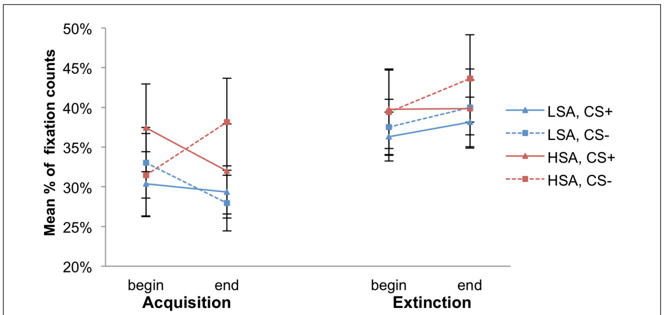

FIGURE 7 | Mean percentage of the count of fixations within the social area of interest (agent) for low (LSA) and high socially anxious (HSA) participants (n = 53). CS+ = agent paired with aversive unconditioned stimulus (US); CS− = agent without aversive US. Standard errors are presented by error bars.

DISCUSSION

The present study is one of the first to investigate social anxiety related physical behavior as well as hypervigilance and attentional avoidance through the use of implicit eye-tracking in HSA and

LSA participants (1) within the context of SFC, (2) with the use of anthropomorphic stimuli (3) in a social interaction with enhanced ecological validity (4) in VR. Therefore, we investigated the effect of induced and extinguished social fear on physical behavior as well as hypervigilance and attentional avoidance toward virtual female and male agents in HSA and LSA students in the SFC paradigm from Reichenberger et al. (2019), where participants actively approached different agents using a joystick. The outcome variables include fear ratings, physical behavior (duration of approach), hypervigilance (time of the first fixation), and attentional avoidance (count of fixations).

Concerning fear ratings, our results showed that social anxiety was successfully acquired and extinguished, except for a clear SFC in HSA men. It would be interesting to investigate whether this results comes from differences in coping strategies in HSA men, from somehow reduced conditionability, from reduced attention or higher variance between HSA men. The findings on the physical behavior might give a preliminary hint that HSA seemed to need more time to approach all agents during fear acquisition than LSA participants, which could mean that HSA were more carefully in approaching agents in this social interaction indicating enhanced social anxiety. With regard to hypervigilance, the HSA fixated the CS+ agents earlier than the CS− agents at the beginning of the fear acquisition, whereas at the end of the fear acquisition they fixated the CS+ agents later than the CS− agents. On the contrary, in LSA participants initial attention did not distinguish between the CS+ and CS− agents during fear acquisition. Moreover, according to our first hypothesis, we found an increased attentional avoidance to CS+ compared to CS− agents for HSA participants during fear acquisition. In contrast, in LSA participants sustained attention did not differ between the CS+ and CS− agents during acquisition, although they reported higher fear ratings for the CS+ than the CS− agents. Therefore we could conclude that LSA might not distinguish between an aversive or not-aversive human according to measures of attentional avoidance. Regarding fear extinction, the variation in attentional avoidance toward the aversive and non-aversive agents after fear acquisition disappeared for the HSA and LSA group after the extinction.

Relating to the vigilance-avoidance hypothesis, our results indicate that HSA directed especially their initial attention at CS+ than CS− agents at the first half of the fear acquisition, and avoided subsequently the CS+ more than the CS− agents at the second half of the fear acquisition to possibly reduce emotional distress. Our findings are compliant with the assumption that HSA or persons with SAD guide their initial attention to emotionally threatening information and tend to avoid eye contact or threatening stimuli to might reduce anxiety directly (Chen et al., 2002; Wieser et al., 2009b; Singh et al., 2015; Shechner et al., 2017). For clear evidence of a hypervigilance bias, we would have expected that HSA participants should guide their initial attention more toward threatening than non-threatening agents at the second half of the fear acquisition as well. The results of our current study are in line with Mühlberger et al. (2008) as well, who found that HSA participants avoided emotional facial expressions in a virtual fear-relevant situation. However, the authors could not affirm clear results of hypervigilance to threat-relevant stimuli, like angry faces, in VR. Relating to these results e Claudino et al. (2019) call into question in their review the ecological validity of other studies, which indicated hypervigilance regarding emotions. Most research mainly used visual search and dot-probe tasks or measured gaze behavior (e.g., hypervigilance in time periods of 500–1500 ms) when persons looked at images of different faces on a computer display. In contrast, we utilized a SFC paradigm in VR, in which the participant had to approach different agents during fear learning. Furthermore, our non-clinical sample consisted of low and HSA students without a diagnosed SAD. Most of the studies found clear hypervigilant patterns of attention in persons with SAD.

Social anxiety is related with selective attention to social threatening stimuli and self-focused attention to internal cues, which are assumed as maintaining factors of SAD. For example, self-focused attention on internal cues (e.g., negative thoughts, emotions, and body sensations), could impair the performance and even inhibit perceiving positive social feedback which invalidates the false impressions of how others judge them (Perowne and Mansell, 2002; Spurr and Stopa, 2002).

Perowne and Mansell (2002) examined in LSA and HSA individuals their self-focused and selective external attention of non-verbal behaviors in a social-evaluative stress situation. The authors revealed that the HSA related more self-focused attention and perceived a more negative view of their performance than the LSA group. However, the HSA showed no less selective attention than the LSA group. These findings are in line that HSA persons monitor others and as far as they find a hint for a negative evaluation they turn their attention to internal cues (Clark and Wells, 1995; Perowne and Mansell, 2002).

Thus, the question arises how could self-focused attention influence hypervigilance and attentional avoidance in the current study? With regard to the cognitive model of Clark and Wells (1995), social anxiety leads to limited attentional processing of external cues. Moreover, the remaining reduced attentional processing of the external social situation tends to be biased, as ambiguous behaviors are more likely to be interpreted as negative (Clark and Ehlers, 2002). Therefore, HSA participants should focus more to internal than to external cues. This assumption is partly in line with our findings on the hypervigilance that at the first half of the fear acquisition the HSA fixated more early the CS+ than the CS− agents, whereas at the second half of the fear acquisition they fixated the CS+ later than the CS− agents. With regard to the attentional avoidance, we found for the HSA a reduced amount of fixations toward the CS+ than to the CS− agents at the end of the fear acquisition. Our findings partly support the vigilance-avoidance hypothesis that HSA directed especially their initial attention at threat-relevant agents with their negative hints, and at the end of the fear conditioning they avoided subsequently the threat-relevant more than the non-threatening agents to possibly reduce their emotional distress. For a clearer insight of the impact of self-focused attention to hypervigilance and attentional avoidance, the self- and other-focused attention could be measured with the Focus of Attention Questionnaire (Woody, 1996) in future studies.

There are less empirical findings relating the effects of fear conditioning on gaze behavior. Michalska et al. (2017) showed that children hold their gaze more often and longer toward the area of the eyes of a CS+ than a CS−. The authors used two neutral faces as conditioned stimuli (CS+ and CS−). However, we know no empirical study measuring eye-gaze during fear conditioning with an enhanced ecological validity in VR.

Regarding ecological validity, Foulsham et al. (2011) examined whether gaze behavior in walking through the real world differs compared to watching videos of the same real world in a laboratory setting. The authors showed that the gaze behavior toward the path nearby and objects in the distance is remarkably different in the real world compared to viewing the videos. Moreover, participants looked more often to persons that were close to them on the video than in the real world. These findings demonstrate that the generalization of laboratory results to attentional processes in natural situations is restricted. Because, our participants were immersed in a virtual environment, where they could actively move and interact with female and male agents, we can assume different responses than toward photographs or videos of humans (McCall et al., 2016). We assume that behavioral and attentional processes measures in VR is more related to real-life situations than traditional laboratory paradigms. Moreover, an potential key element assessing reliable and valid physical or gaze behavior in a virtual environment is social presence, the feeling of the participant to interact with another sentient being which involve cognitive and emotional processes (Blascovich et al., 2002; Oh et al., 2018; Felnhofer et al., 2019). Thus, future research on attention and emotion regulation should include a measure of social presence in VR.

Furthermore, our study measures gaze behavior during approaching different social agents. Therefore, the question arises how physical behavior is related to gaze behavior. McCall et al. (2016) showed in their Affect Gallery paradigm that participants gazed more and came closer to positive than negative images. In contrast, the authors presented in their Crowded Room paradigm that participants gazed more directly at agents with angry or sad than neutral facial expressions, but revealed a larger interpersonal distance toward angry than neutral or sad agents. These results illustrate that gaze behavior does not have to match continuously with physical behavior. For example, in a social situation attention is more directed to a threat-relevant facial expression causing to physically avoid the potential threatening person.

Weeks et al. (2019) recommend the use of eye-tracking techniques in more future studies as these suitable tools could improve social skills training (e.g., providing an objective index of gaze avoidance) or in maximizing the effectiveness of therapeutic exposures (e.g., measuring and/or preventing the potential role as safety behavior). Furthermore, in order to investigate the mechanisms of physical and gaze behavior as an important feature in emotional learning and maintaining processes of social anxiety, eye-tracking indices are an interesting implicit method within fear conditioning.

Some study limitations should be noted. First, our non-clinical sample of mainly young students should be considered in generalizing the results to an additional context. Thus, to generalize our current findings we need a more diverse sample with different demographic and even clinical characteristics. Second, technical failure in eye-tracking led to high data loss for seven participants, which may have impaired the likelihood of determining higher order interactions. Third, in future studies we should also define AOIs for the eyes and mouth region of the agents to investigate possible effects of emotional facial expression within a virtual social interaction.

Moreover, we want to note that the applied US (sound of spitting attended by an aversive air blast) during fear acquisition might not only signal potential social, but also physical harm and might induce general fear or even disgust. However, Grillon et al. (2004) revealed that the anticipation of an air blast was not aversive enough to induce a fear-potentiated startle reflex by unpredictable aversive events in humans. We think that being spat followed by the verbal rejection is rather a social relevant than a physical relevant US within a social situation. Thus, we assume that the triggered fear in our experiment is more a social fear of negative evaluation than a physical impairment. Furthermore, we did not receive any feedback regarding disgust, but unfortunately we used no standardized ratings or questionnaire of disgust, which should be measured in future studies. Moreover, it might be interesting to develop a measurement instrument to disentangle physical and social fear associated with the spit stimulus.

Furthermore, it is important to note that our power analysis based on the data from our prior study by Reichenberger et al. (2017) that contained two between subject conditions defined by social anxiety (LSA vs. HSA). In our current study, we included one more between subject condition defined by participants' gender (women vs. men). In detail, although our LSA and HSA group consisted of an equally distributed ratio of gender as mentioned above, the size of each condition is thus smaller. However, our main hypothesis does not relate to complex interaction effects of social anxiety and gender.

In conclusion, the current study demonstrated the advantages of VR in investigating physical and gaze behavior in social interactions in a highly standardized, experimentally controlled and ecological way. Our results show that HSA seemed to be more careful in approaching agents, fixated the CS+ earlier than the CS− agents at the first half of the fear acquisition, and showed increased attentional avoidance to CS+ compared to CS− agents during SFC compared to LSA participants. Further research could contribute to establishing an implicit and objective measure of physical and gaze behavior, which could potentially serve as a biomarker for SAD.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the University of Regensburg.

The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JR: study conception, data acquisition and analysis, and writing the manuscript. MP: data analysis and contribution to the manuscript. AM: study conception, data analysis, and contribution to the manuscript. All authors have approved the final version of the manuscript and its submission.

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Conflict of Interest: AM is stakeholder of a commercial company that develops and sells virtual environment research systems.

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.

The reviewer SB declared a past co-authorship with one of the authors, AM, to the handling Editor.

2.4 Study 4: Social Skills Training for Social Anxiety in Virtual Reality

Schwerpunktbeitrag

Soziales Kompetenztraining in Virtueller Realität bei sozialer Angst

Validierung relevanter Interaktionssituationen

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Zusammenfassung: *Theoretischer Hintergrund:* Soziale Kompetenztrainings sind wichtige Werkzeuge bei der Psychotherapie der Sozialen Angststörung. Die Durchführung in Virtueller Realität (VR) könnte die Verfügbarkeit und Effektivität erhöhen, allerdings besteht ein Bedarf an validierten VR-Szenarien. *Fragestellung:* Geprüft wird die Validität von zwei in Anlehnung an das Gruppentraining sozialer Kompetenzen von Hinsch und Pfingsten (2015) entwickelten VR-Szenarien. Es wird angenommen, dass die durch das Szenario ausgelösten Komponenten sozialer Angst auf subjektiver, psychophysiologischer und kognitiver Ebene signifikant zwischen höher (HSA) und niedriger (NSA) sozial ängstlichen Personen differenzieren. *Methode:* Insgesamt durchliefen N = 55 HSA und NSA Studierende zwei VR-Szenarien vom Typ „Recht durchsetzen". Zusätzlich wurde experimentell die Blickkontaktdauer des virtuellen Gesprächspartners variiert. Hauptoutcome war die erlebte Angst in den Rollenspielen. Zusätzlich wurden Herzschlagfrequenz, Hautleitfähigkeit sowie die Einschätzung der eigenen Kompetenz erfasst. *Ergebnisse:* HSA im Vergleich zu NSA berichteten für beide Szenarien signifikant höhere Angst sowie negative Verzerrungen in Bezug auf die Einschätzung der eigenen Kompetenz. Zusätzlich zeigte sich eine physiologische Aktivierung während der Rollenspiele, aber keine Differenzierung zwischen beiden Gruppen. Beide VR-Szenarien wurden als realistisch empfunden. *Schlussfolgerungen:* Virtuelle Interaktionsszenarien können zu Trainingszwecken genutzt werden und Soziale Kompetenztrainings in VR haben ein großes Potential für den Einsatz als psychotherapeutisches Verfahren bei Sozialer Angststörung.

Schlüsselwörter: Virtuelle Realität, Soziales Kompetenztraining, Soziale Angststörung, Blickkontakt, Angst, Herzschlagfrequenz, Hautleitfähigkeit

Social Skills Training in Virtual Reality for Social Anxiety: Validation of Relevant Interaction Situations

Abstract: *Background:* Social skills training is an important tool in psychotherapy for social anxiety disorder. The implementation of virtual reality (VR) could increase its availability and effectiveness, but there is a need for validated VR scenarios. *Objective:* We examined the validity of two VR scenarios according to the group training of social skills by Hinsch and Pfingsten (2015). We hypothesize that the subjective, psychophysiological, and cognitive components of social anxiety triggered by the scenario significantly differentiate between higher (HSA) and lower (NSA) socially anxious persons. *Method:* A sample of N = 55 HSA and NSA students underwent two VR scenarios for the training of assertiveness. Additionally, the duration of eye contact by the virtual interaction partner was varied experimentally. The main outcome measure was experienced anxiety. In addition, heart rate, electrodermal activity, as well as the assessment of own's own competence were recorded. *Results:* In both scenarios, HSA compared with NSA reported significantly higher anxiety as well as negative distortions regarding the assessment of one's own competency. With regard to physiology, there was activation but no differentiation between groups. Both VR scenarios were perceived as realistic. *Conclusion:* Virtual interaction scenarios can be used for training purposes, and social skills training in VR has great potential as a psychotherapeutic intervention for social anxiety disorder.

Keywords: virtual reality, social skills training, social anxiety disorder, eye contact, anxiety, heart rate, electrodermal activity

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Angststörungen gehören zu den häufigsten psychischen Störungen (Kessler, Chiu, Demler & Walters, 2005; Wittchen et al., 2011). Das psychotherapeutische Verfahren der Wahl bei Angststörungen ist die kognitive Verhaltenstherapie (KVT), insbesondere die Expositionstechniken (Butler, Chapman, Forman & Beck, 2006). Expositionstherapie in virtueller Realität (VRET) als Form der Computersimulation bietet eine Reihe praktischer Vorteile gegenüber Exposition in vivo, darunter in erster Linie ein deutlich geringerer Aufwand bei Planung und Organisation, eine bessere Kontrolle und Replizierbarkeit der Expositionssituationen sowie auch eine niedrigere Hemmschwelle eine Expositionstherapie zu beginnen (Diemer, Pauli & Mühlberger, 2015; Garcia-Palacios, Botella, Hoffman & Fabregat, 2007). Während inzwischen überzeugende Wirksamkeitsbelege für VRET bei Spezifischer Phobie vorliegen (siehe Diemer et al., 2015; Gregg & Tarrier, 2007; Opriş et al., 2012), ist die Behandlung komplexerer Angststörungen wie der Sozialen Angststörung mittels VRET erst nach und nach in den Fokus der Forschung gerückt. Erste Studien beschränkten sich dabei zunächst auf Vortragsängste (Anderson, Zimand, Hodges & Rothbaum, 2005; Slater, Pertaub, Barker & Clark, 2006; Vanni et al., 2013). Mit der Verbesserung der technischen Möglichkeiten, insbesondere der lebensnahen Darstellung von Mimik und Gestik virtueller Menschen, ist es möglich geworden auch komplexere Interaktionssituationen in virtueller Realität (VR) darzustellen (Bombari, Schmid Mast, Canadas & Bachmann, 2015). In den neueren Arbeiten zu VRET bei Sozialer Angststörung wurden zunehmend Dialogsituationen umgesetzt, darunter Bewerbungsgespräche, Dating-Situationen und allgemeine Kontaktaufnahmen (Bouchard et al., 2017; Gebara, de Barros-Neto, Gertsenchtein & Lotufo-Neto, 2016; Kampmann et al., 2016). Fokus dieser VR-Szenarien lag primär auf Exposition und Inhibitionslernen, weniger auf Übungen, bei der die Exposition mit den gefürchteten Situationen im Kontext von Kompetenzaufbau bzw. -trainings durchgeführt wurde.

Dabei spielt auch das soziale Kompetenztraining eine wichtige Rolle in der KVT der Sozialen Angststörung (Fydrich, 2009). Befunde zur Ätiologie von sozialen Ängsten bestätigen die Annahme eines ursächlichen Kompetenzdefizits zwar nicht, legen jedoch ein Performanzdefizit nahe, bei dem vorhandene Kompetenzen aufgrund der bestehenden Ängste nicht abgerufen werden können (Rapee & Spence, 2004). Da sich soziale Kompetenzen erfolgreich im Rollenspiel trainieren lassen, ist es erstaunlich, dass diese Möglichkeit der Durchführung in VR für Patient_innen mit Sozialer Angststörung noch nicht umfassend untersucht wurde (Hinsch & Pfingsten, 2015). Dabei bietet VR für dieses Training neben den praktischen Vorteilen den zusätzlichen Nutzen, dass die Interaktionssituationen standardisiert und in ihrer Schwierigkeit festgelegt werden können (Bombari et al., 2015).

Bislang liegen empirische Untersuchungen zum Nutzen eines sozialen Kompetenztrainings in VR für Patient_innen mit Schizophrenie (Park et al., 2011) und Autismus (Smith et al., 2017) vor. So verglichen Park et al. (2011) ein soziales Kompetenztraining in VR vs. in vivo in einer Gruppe von $N = 91$ stationären Patient_innen mit Schizophrenie und fanden in der VR-Gruppe eine höhere Motivation sowie bessere Ergebnisse in den Bereichen Konversationsfähigkeiten und Durchsetzungsvermögen, wohingegen Teilnehmer_innen der in vivo-Bedingung in Hinblick auf nonverbale Kommunikation besser abschnitten. Im Bereich Autismus liegen Untersuchungen zu einem VR-Bewerbungstraining vor, das sechs Monate nach dem Training positive Effekte auf den Beschäftigungsstatus der Teilnehmer_innen hatte (Smith et al., 2017). Gestützt auf diese Befunde, die die Machbarkeit und den möglichen therapeutischen Nutzen eines sozialen Kompetenztrainings in VR belegen, haben wir begonnen ein soziales Kompetenztraining in VR für den Einsatz in der KVT von Patient_innen mit Sozialer Angststörung zu entwickeln.

In der vorliegenden Studie soll u. a. geklärt werden, wie realistisch die VR-Gesprächssituationen auf die Teilnehmer_innen wirken. Es bestand eine Herausforderung darin, glaubwürdige VR-Szenarien zu entwickeln, die eine realitätsnahe Konversation entstehen lassen (Bombari et al., 2015). Wir entschieden uns daher im ersten Schritt für Situationen vom Typ „Recht durchsetzen“ (Hinsch & Pfingsten, 2015), bei denen der Agent eine Reihe von Einwänden vorbringt und die Probandin bzw. der Proband instruiert wird, ihre bzw. seine Forderung unbeirrt und ggf. wiederholt vorzubringen.

Aus klinischer Perspektive ging es darum zu belegen, dass die für soziale Angstsituationen stärkere Angstreaktionen bei Proband_innen mit hoher (HSA) vs. niedriger sozialer Ängstlichkeit (NSA) aktivieren. Darüber hinaus wurde die Dauer des Blickkontakts durch den Agenten experimentell variiert. Die Wirkung von Blickkontakt bei sozialen Ängsten ist bisher noch kaum erforscht. Allerdings gibt es Hinweise darauf, dass sozialängstliche Personen Blickkontakt als bedrohlich empfinden (Honma, 2013; Radke, Roelofs & de Bruin, 2013; Wieser, Pauli, Alpers & Mühlberger, 2009; Wieser, Pauli, Grosseibl, Molzow & Mühlberger, 2010). Da das Blickverhalten sich in VR problemlos standardisieren lässt, sollte nun geprüft werden, ob die Intensität des Blickkontakts einen Einfluss auf die Angstaktivierung hat und somit eine Möglichkeit darstellen könnte die Schwierigkeit der VR-Interaktionsszenarien abzustufen.

Zusammengefasst war es das Ziel der vorliegenden Studie, ausgewählte VR-Szenarien für ein soziales Kom-

Tabelle 1. Fragebogendaten für niedrige (NSA) und höher (HSA) sozial ängstliche Personen

	NSA (n = 32)		HSA (n = 23)					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Alter	21.5	2.40	21.6	3.23	-0.127	53	.899	–
SPIN	10.3	4.22	26.6	5.49	-10.04	53	.001	2.76
SPAI	1.56	0.69	2.86	0.67	-6.960	53	.001	1.90
STAI-S Prä	36.9	7.47	43.3	7.28	-3.150	53	.003	0.96
STAI-S Post	35.2	7.00	44.7	10.3	-3.818	53	.001	1.18
STAI-T	35.2	6.33	46.5	7.27	-6.138	53	.001	1.81
SSQ	25.2	18.1	45.0	33.1	-2.820	52	.007	0.85
IPQ	3.68	1.01	3.91	1.20	-0.780	52	.439	–
	Ja	*Nein*	*Ja*	*Nein*	χ^2	*df*	*p*	*d*
Blickkontakt unterschiedlich	16	16	14	9	.638	1	.425	–

Anmerkungen: Mittelwerte (*M*), Standardabweichungen (*SD*) sowie *t*- und *p*-Werte mit Freiheitsgraden (*df*) und Cohen's *d* sowie Stichprobengröße (*n*) sind angegeben. SPIN = Soziale Phobie Inventar; SPAI = Soziale Phobie und Angst Inventar; STAI-S / -T = State und Trait Skala des State-Trait Angst Inventar; IPQ = deutsche Version des Igroup Presence Questionnaire; SSQ = deutsche Version des Simulator Sickness Questionnaire; Prä = vor dem VR-Rollenspiel erhoben; Post = nach dem VR-Rollenspiel erhoben, Blickkontakt unterschiedlich = Einschätzung des Blickkontakts zwischen den Blickkontaktbedingungen.

petenztraining in einer studentischen Analog-Stichprobe zu validieren. Wir erwarteten, dass die durch das Szenario ausgelösten Komponenten sozialer Angst auf subjektiver (Angstratings), psychophysiologischer (Herzschlagfrequenz, Hautleitfähigkeit) und kognitiver Ebene (Einschätzung der eigenen Kompetenz) signifikant zwischen HSA und NSA differenzieren würden. Außerdem erwarteten wir in der Gruppe der HSA eine stärkere Angstreaktion in der Bedingung mit viel vs. wenig Blickkontakt seitens des Agenten.

Methode

Stichprobe

Insgesamt nahmen 55 Personen an der Untersuchung teil. Eingeschlossen wurden nur Personen zwischen 18 und 55 Jahren. Ausschlusskriterien waren das Vorliegen einer aktuellen oder früheren behandlungsbedürftige psychischen Erkrankung (außer Soziale Angststörung), aktuelle oder in der Vergangenheit liegende psychotherapeutische, psychiatrische oder neurologische Behandlung, neurologische oder schwere körperliche Erkrankungen, die Einnahme von Psychopharmaka, Schwangerschaft oder Stillzeit sowie die Beteiligung an der Studienplanung. Die Kriterien wurden mittels Selbstbericht erhoben. Die Stichprobe wurde unter Verwendung des Sozialen Phobie Inventars (SPIN; Connor et al., 2000; deutsche Version: Stangier & Steffens, 2002) mit einem Cut-off Wert von 19 in zwei Gruppen (NSA vs. HSA) eingeteilt. Laut Connor et al. (2000) können Personen mit Sozialer Phobie mit einem SPIN Wert > 19 mit einer diagnostischen Genauigkeit von 79 % von gesunden Personen unterschieden werden. Die Rekrutierung erfolgte durch Aushänge und einem Screening in Erstsemesterveranstaltungen der Universität Regensburg. In dem Screening nahmen 180 Studierende teil und es wurde mittels Fragebögen neben demographischen Daten, Ausschlusskriterien und unterschiedlichen Ängsten der SPIN-Wert erhoben. Die Zuteilung zu den Gruppen erfolgte auf den im Screening oder einer Vorbefragung am Testtag angegebenen SPIN-Wert. In der vorliegenden Studie wurden 32 NSA (68.8 % weiblich, Alter zwischen 18 und 30, *M* = 21.47, *SD* = 2.40) und 23 HSA (78.3 % weiblich, Alter zwischen 18 und 31, *M* = 21.57, *SD* =3.23) eingeschlossen. Die Aufteilung der Proband_innen in eine niedrige und eine höher sozial ängstliche Gruppe kann als erfolgreich angesehen werden, da die HSA Gruppe im SPIN, im Soziale Phobie und Angst Inventar (SPAI; Fydrich, 2002; deutsche Version: Turner, Beidel, Dancu & Stanley, 1989), im State-Trait Angstinventar (STAI; Laux, Glanzmann, Schaffner & Spielberger, 1981; deutsche Version: Spielberger, Gorsuch & Lushene, 1970) State (Prä) sowie Trait signifikant höhere Werte mit großen Effektgrößen im Vergleich zur NSA Gruppe aufweist (s. Tab. 1). Alle Proband_innen hatten eine normale bzw. korrigierte Sehfähigkeit, waren Studierende an der Universität Regensburg und erhielten Versuchspersonenstunden als Entschädigung für ihre Teilnahme. Diese Studie wurde von der Ethikkommission der Medizinischen Fakultät der Universität Regensburg als ethisch unbedenklich bewertet.

Materialien und Apparatur

Die VR-Szenarien wurden über die Oculus Rift DK 2 (Oculus VR Inc., California, USA) präsentiert und für die Aufzeichnung der Kopfposition der Proband_innen und der Ausrichtung des Sichtfelds auf die jeweiligen Kopfbewegungen diente das integrierte elektromagnetische Tracking. Die virtuelle Realität wurde mit Steam Source Engine (Valve Corporation, Bellevue, Washington, USA) erzeugt und während der Erhebung mit CyberSession (CS-Research 5.6.72; VTplus GmbH, Würzburg, Deutschland) kontrolliert. Die Instruktionen im Experiment sowie die Antworten der Agenten wurden über Kopfhörer (Sennheiser HD-215, Sennheiser Electronic GmbH, Deutschland) präsentiert. Um sich im virtuellen Raum zu bewegen wurde ein Joystick (Logitech Extreme 3D Pro Joystick, Logitech GmbH, Deutschland) verwendet. Zur Messung der physiologischen Daten wurde der digitale Verstärker V-Amp (V-Amp, Brain Products GmbH, Deutschland) sowie für die Aufzeichnung der physiologischen Daten die Software Brain Vision Recorder (Version 2.0, Brain Products GmbH, Deutschland) verwendet.

Design, UV, AV

Alle Teilnehmer_innen durchliefen in balancierter Reihenfolge zwei VR-Rollenspiele (Zugabteil und Reisebüro, siehe Abbildung 1). Des Weiteren wurde das Blickkontaktverhalten der Agenten über beide Szenarien ausbalanciert und die Teilnehmer_innen randomisiert den Bedingungen so zugewiesen, dass sie entweder das erste Rollenspiel mit 80 % Blickkontakt und das zweite mit 20 % Blickkontakt und vice versa erlebten. Der Blickkontakt wurde von den Agenten in beiden Bedingungen jeweils für eine Dauer von 2 bis 4 Sekunden gehalten, variiert wurde die Häufigkeit der Blickausrichtung auf die Probandin bzw. den Probanden, wobei 80 % Blickkontakt bedeutet, dass der Agent zu 80 % der Gesamtzeit des jeweiligen Szenarios weiblichen bzw. den männlichen Probanden direkt ins Gesicht blickte. Die restliche Zeit blickte der Agent z. B. im Zugabteil rechts aus dem Fenster und im Reisebüro links in den Computerbildschirm. Es ergaben sich vier verschiedene Abläufe: (1) Zugabteil 80 %, Reisebüro 20 %; (2) Zugabteil 20 %, Reisebüro 80 %; (3) Reisebüro 80 %, Zugabteil 20 %; (4) Reisebüro 20 %, Zugabteil 80 %. Die Versuchsteilnehmer_innen wurden gleichmäßig den vier verschiedenen Abläufen zugeordnet.

Die Mimik der Agenten war in beiden Rollenspielen neutral. Die Antworten der Agenten wurden im Vorfeld eingesprochen und die Lippenbewegungen der Agenten wurden dementsprechend synchronisiert. Der Versuchsleiter präsentierte die Antworten per Tastendruck während beider Rollenspiele, sodass eine möglichst flüssige und realistische Interaktion entstehen konnte.

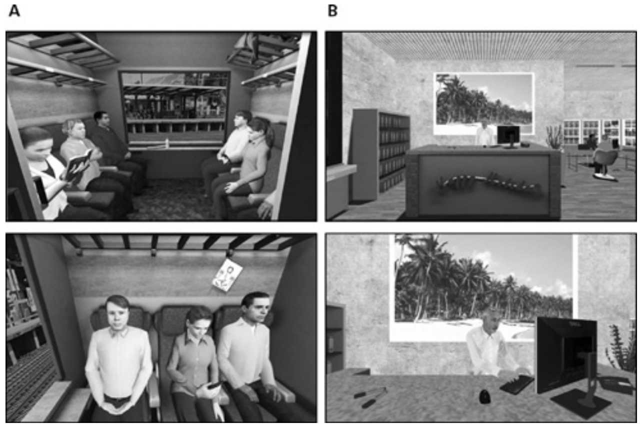

Abbildung 1. VR-Rollenspiele. (A) Szene aus dem Zugabteil mit Interaktionspartner am Fenster. (B) Szene aus dem Reisebüro mit Interaktionspartner am Schalter.

Die Aufgabe der Proband_innen war in beiden Szenarien ihr Recht durchzusetzen. Im Zugabteil sollten sie einen Passagier (Agent) auffordern den von ihnen reservierten Platz freizugeben (siehe Abbildung 1A). Der Agent versuchte die Probandin bzw. den Probanden zunächst davon abzubringen, auf seinen Platz zu bestehen, gab jedoch nach den vier definierten ablehnenden Antworten den Platz frei. Im Reisebüro sollten die Teilnehmer_innen ihre bereits gebuchte Reise stornieren, da weitere nicht abgesprochene Kosten entstanden waren (siehe Abbildung 1B). Auch in diesem Szenario versuchte der Angestellte im Reisebüro die Probandin bzw. den Probanden davon abzubringen sein Recht durchzusetzen. Nach vier abweisenden Antworten wurde auch hier die Reise storniert und die Aufgabe war beendet (die Antworten der Agenten können bei den Autor_innen angefragt werden).

Als abhängige Variable wurde das Angsterleben in Form von Angstratings auf einer Skala von 0 bis 100 erfasst. Als kognitive Variable diente die eigene Einschätzung der Kompetenz bezüglich des Erlebens und Verhaltens während beider Rollenspiele in VR sowie die Bewertung der Realitätsnähe in VR. Als psychophysiologischen Variablen dienten die Herzschlagfrequenz und die Hautleitfähigkeit.

Messungen

Die Teilnehmer_innen füllten zu Beginn der Untersuchung einen demographischen Fragebogen (Alter, Geschlecht, schulische Bildung, etc.), den SPIN (bei ungescreenten Personen), den SPAI, den STAI-S/T, einen selbsterstellten Fragebogen zur Kompetenzeinschätzung bezüglich ihres

Erlebens und Verhaltens während der Rollenspiele in VR sowie die Bewertung der Realitätsnähe in VR (siehe Elektronisches Supplement 1), den Igroup Presence Questionnaire (IPQ; Schubert, 2003) und den Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum & Lilienthal, 1993) aus. Detaillierte Informationen zu den einzelnen verwendeten Fragebögen finden Sie im Elektronischen Supplement 2.

Während der VR wurde das aktuelle Angstniveau zu fünf Messzeitpunkten (Baseline und jeweils am Beginn und Ende beider Rollenspiele) abgefragt. Die Teilnehmer_innen bekamen über die Kopfhörer folgende Instruktion: „Bitte schätzen Sie Ihre aktuelle Angst auf einer Skala von 0–100 ein, wobei 0 überhaupt keine Angst ist und 100 die stärkste Angst, die Sie kennen. Wie stark ist Ihre Angst jetzt?“

Alle physiologischen Messungen erfolgten kontinuierlich und non-invasiv. Zur Erfassung der Herzschlagfrequenz (HF) dienten zwei selbstklebende Elektroden (Ag / AgCl, Ø = 40 mm). Die eine Elektrode wurde auf dem Brustbein, die andere auf dem unteren linken Rippenbogen fixiert. Außerdem wurde eine Reference-Elektrode auf dem rechten sowie eine Ground-Elektrode (beide Ag / AgCl, Ø = 8 mm) auf dem linken Mastoid platziert. Die Haut wurde dafür jeweils vor Anbringung der Elektroden mit Peelingpaste angeraut und mit Alkohol desinfiziert. Für die bipolare Erfassung der Hautleitfähigkeit (EDA) wurden zwei mit Leitpaste (EDA-Paste TD-246, PAR Medizintechnik GmbH) gefüllte Klebeelektroden (Ag / AgCl, Ø = 8 mm) auf dem Thenar-Muskel der Handinnenfläche der nichtdominanten Hand fixiert.

Ablauf

Das Experiment wurde in einem Labor des Lehrstuhls für Klinische Psychologie und Psychotherapie der Universität Regensburg durchgeführt und dauerte ungefähr 60 Minuten. Zu Beginn der Testung wurde die Probandenaufklärung vorgelegt und bei Teilnahme die Einverständniserklärung unterschrieben. Des Weiteren gab es eine mündliche sowie schriftliche Instruktion über die Aufgabe in beiden VR-Rollenspielen (die Instruktionen können bei den Autoren angefragt werden). Nachdem der demographische Fragebogen, bei ungescreenten Personen der SPIN, sowie weitere Fragebögen (SPAI, STAI-S und STAI-T) ausgefüllt wurden, konnten die Elektroden zur Messung der Physiologie angebracht werden. Anschließend wurden die VR-Brille und der Kopfhörer aufgesetzt und das Experiment wurde gestartet. Zu Beginn der VR-Präsentation konnten die Proband_innen in einem neutralen Raum die Steuerung mit dem Joystick einüben. Anschließend folgte für 2 Minuten die Messung der physiologischen Baselinewerte. Im Anschluss erfolgte die Ankündigung des ersten Rollenspiels und ein erstes Angstrating sollte abgegeben werden. Danach folgte das erste Rollenspiel (Zugabteil oder Reisebüro). Zu Beginn des Szenarios wurde zum zweiten Mal die aktuelle Angst erfragt. Daraufhin folgte die Instruktion auf den Agenten zuzugehen und das Gespräch zu beginnen. Die Teilnehmer_innen konnten nun mittels Joystick auf den Agenten zugehen und ihn ansprechen. Nachdem die Teilnehmer_innen nach anfänglicher Ablehnung ihr Recht durchsetzen konnten (den Passagier zum Aufstehen zu bringen bzw. die Reise stornieren zu lassen) wurde wieder die aktuelle Angst erfragt. Es folgte eine Pause von 1 Minute im neutralen Raum und anschließend wurde das nächste Szenario angekündigt.

Das zweite Szenario war im Ablauf identisch zum ersten Szenario und nach Abschluss endete die VR-Präsentation. Anschließend wurden die restlichen Fragebögen (Kompetenzeinschätzung bezüglich des Erlebens und Verhaltens während beider Rollenspiele sowie die Bewertung der Realitätsnähe in VR, erneut der STAI-S, und abschließend der IPQ und SSQ) ausgefüllt und die Elektroden entfernt.

Datenreduktion und statistische Auswertung

Physiologische Daten wurden mit Brain Vision Analyzer 2.0 Software (Brain Products GmbH, München, Deutschland) vorverarbeitet und alle weiteren Berechnungen mit SPSS Statistics 24 (IBM, Corp., Armonk, NY) durchgeführt.

Zur Auswertung der Herzschlagfrequenz (HF) wurden zuerst die Differenzen zwischen den EKG-Elektroden berechnet und ein 1.59 Hz (12 dB) High-Cutoff-, ein 30 Hz (12 dB) Low-Cutoff- und ein 50 Hz Notch-Filter angewandt. Anschließend wurden die R-Zacken automatisch erkannt, gezählt sowie manuell ggf. korrigiert. Für die statistische Weiterverarbeitung wurden die Mittelwerte der HF (Schläge pro Minute) über die Auswertungsperioden berechnet und exportiert. Für jedes der beiden Szenarien gibt es drei Messperioden. Die erste Messperiode beinhaltet den Mittelwert aus den 10 Sekunden nach Beginn der Ankündigung vor dem Szenario sowie den 10 Sekunden nach Beginn der Instruktion im Szenario und wurde mit „Antizipation“ gelabelt. Für die Periode in der Situation wurden die ersten 10 Sekunden (Anfang) sowie die letzten 10 Sekunden aus dem Rollenspiel (Ende) gemittelt und exportiert. Zusätzlich wurde für die Differenzbildung zu Beginn des Experiments eine Baseline von 120 Sekunden erhoben.

Zur Auswertung der Hautleitfähigkeit (EDA) wurde ein 1 Hz High-Cutoff-Filter angewandt. Für die statistische Weiterverarbeitung wurden die gleichen Messperioden mit identischer Länge wie bei der HF exportiert, sodass sich auch hier die Baseline sowie 3 Messperioden für jedes Szenario ergaben. Anschließend wurden T-Werte für die EDA berechnet. Aufgrund von technischen Problemen musste bei der Auswertung der EDA eine Person ausgeschlossen werden.

Die Angstratings wurden am Ende der Baseline sowie jeweils vor und nach dem Rollenspiel erhoben. Weitere Informationen zur Kontrolle von möglichen Reihenfolgeeffekten der Präsentation der Szenarien finden Sie im Elektronischen Supplement 3.

Für die weitere Auswertung der Angstratings und der physiologischen Daten wurde für jede Messperiode die Differenz zur Baseline gebildet. Zur Skalengenerierung bezüglich der eigenen Kompetenzeinschätzung und der Bewertung der Realitätsnähe in VR wurde eine Faktorenanalyse durchgeführt. Dabei wurden diese Items zu einem Mittelwert zusammengefasst, die die größte gemeinsame Varianz zusammen aufklären und inhaltlich am besten zusammenpassen. Die Faktorenanalyse ergab insgesamt sieben Komponenten. Davon wurden fünf Komponenten in der statistischen Auswertung verwendet, da diese inhaltlich am besten zusammenpassten. Hieraus ergaben sich 5 Subskalen zur Kompetenzeinschätzung (Nervosität, Selbstsicherheit, Relevanz des Eindrucks auf Interaktionspartner) sowie zwei zur Bewertung der Realitätsnähe in VR (Realitätsnähe des Interaktionspartners und Realitätsnähe des gezeigten Verhaltens). Die einzelnen Items sowie die Einteilung der Subskalen können im Elektronischen Supplement 4 eingesehen werden. Die Ergebnisse der Faktorenanalyse befinden sich in Tabelle 1 und 2 im Elektronischen Supplement 5.

Für die weitere statistische Auswertung der Angstratings wurde ein multilineares Modell mit den festen Faktoren Zeit (Antizipation vor dem Rollenspiel, Angstangabe nach dem Rollenspiel), Szenario (Zugabteil, Reisebüro), Blickkontakt (80 %, 20 %) und Gruppe (NSA vs. HSA) sowie den Interaktionen Zeit x Szenario, Blickkontakt x Szenario, Blickkontakt x Gruppe und Zeit x Gruppe berechnet. Für beide physiologischen Variablen (HF, EDA) wurde ebenfalls jeweils ein multilineares Modell wie für die Angstratings berechnet, das sich nur darin unterschied, dass der feste Faktor Zeit drei statt zwei Zeitpunkte beinhaltete (Antizipation, Anfang und Ende des Rollenspiels). Für die Subskalen der Kompetenzeinschätzung wurde jeweils ein multilineares Modell mit den festen Faktoren Szenario (Zugabteil, Reisebüro), Blickkontakt (80 %, 20 %) und Gruppe (NSA vs. HSA) sowie den Interaktionen Blickkontakt x Szenario und Blickkontakt x Gruppe berechnet. Für alle berechneten multilinearen Modelle dient die Skalierte Identität als Kovarianztyp und als zufälliger Effekt wurde das Intercept eingeschlossen. Des Weiteren wurde die Versuchspersonennummer als Subjektvariable und die RML (Restricted Maximum Likelihood) als konservativere Schätzmethode für kleinere Stichproben im Modell ausgewählt.

Ergebnisse

HSA weisen im STAI-State (Post) sowie im SSQ signifikant höhere Werte im Vergleich zur NSA Gruppe auf. Im Mittelwert des IPQ sowie im Alter unterscheiden sich beide Gruppen nicht signifikant (s. Tab. 1). Sowohl die Angstratings der HSA ($M = 7.43$, $SD = 7.61$) und NSA ($M = 6.97$, $SD = 8.42$) als auch die physiologischen Baselinewerte der HSA (EKG: $M = 82.4$, $SD = 10.6$; EDA: $M = 31.9$, $SD = 5.72$) und NSA (EKG: $M = 78.8$, $SD = 12.3$; EDA: $M = 30.1$, $SD = 5.08$) unterscheiden sich nicht signifikant voneinander (Angstratings: $p = .834$; EKG: $p = .262$; EDA: $p = .225$). Folglich kann davon ausgegangen werden, dass sich bei signifikanten Unterschieden beim Angstanstieg auch die absolute Höhe der Angst zwischen den Gruppen unterscheidet.

Angstratings

Für HSA ergab sich eine höhere Antizipationsangst sowie ein höherer Angstanstieg nach dem Rollenspiel in beiden Szenarien, während die Angst bei NSA kaum anstieg (siehe Abbildung 2). Bei HSA scheint die Angst auch von vor zu nach den Rollenspielen anzusteigen. Das multilineare Modell zeigt signifikante Haupteffekte Zeit, $F(1,159) = 5.51$, $p = .020$, und Gruppe, $F(1,52) = 19.4$, $p < .001$, sowie einen signifikanten Interaktionseffekt Zeit x Gruppe, $F(1,159) = 4.81$, $p = .030$. Nicht signifikant werden die Effekte Szenario, $F(1,159) = 0.28$, $p = .598$, Blickkontakt, $F(1,159) = 0.22$, $p = .638$, Szenario x Blickkontakt, $F(1,52) = 0.62$, $p = .435$, und Szenario x Zeit, $F(1,159) = 0.01$, $p = .914$ und Gruppe x Blickkontakt, $F(1,159) = 0.75$, $p = .387$. Für HSA ergab sich ein um $b = 13.8$ ($SE = 2.60$) Einheiten höhere baselinekorrigierte Angst im Vergleich zu NSA, $t(91.8) = 4.88$, $p < .001$. Ferner war die baselinekorrigierte Antizipationsangst vor dem Rollenspiel um $b = -4.76$ ($SE = 1.86$) Einheiten niedriger als die nach dem Rollenspiel angegebene Angst, $t(159) = -2.56$, $p = .011$. Des Weiteren berichten HSA vor dem Rollenspiel eine um $b = -4.50$ ($SE = 2.05$) Einheiten niedrigere Antizipationsangst im Vergleich zur Angst nach dem Rollenspiel, $t(159) = -2.19$, $p = .030$. Außerdem besteht über alle Proband_innen hinweg zwischen den Angstratings und dem SPIN-Wert im Zugabteil ($r = .34$, $p < .001$) und im Reisebüro ($r = .43$, $p = .012$) ein signifikanter mittlerer Korrelationskoeffizient (siehe Abbildung 1 im Elektronischen Supplement 6).

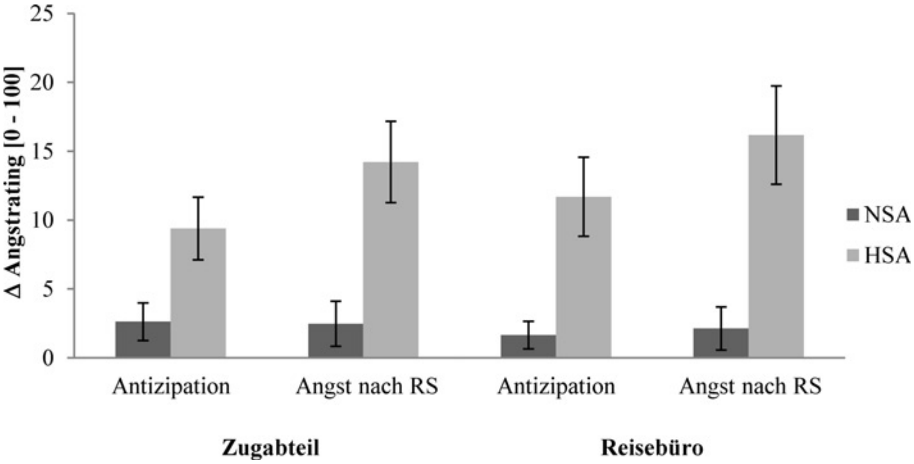

Abbildung 2. Angstrating in beiden Szenarien. Die Abbildung zeigt für die Messperioden die Differenz der subjektiv berichteten Angst zur Baseline für niedriger (NSA) und höher (HSA) sozial ängstliche Personen. *RS* = Rollenspiel. Die Standardfehler werden als Fehlerbalken angezeigt.

Herzschlagfrequenz (HF)

HSA hatten während dem Rollenspiel im Zugabteil gegenüber der Baseline eine ähnlich erhöhte HF wie NSA, während NSA im Reisebüro eine stärker erhöhte HF als HSA aufwiesen (siehe Tabelle 2). Des Weiteren sinkt die HF zum Ende des Rollenspiels in allen Bedingungen leicht ab. Das multilineare Modell zeigt signifikante Haupteffekte Zeit, $F(2{,}266) = 15.0$, $p < .001$, und Szenario, $F(1{,}266) = 9.89$, $p = .002$, sowie einen signifikanten Interaktionseffekt Zeit x Szenario, $F(2{,}266) = 4.20$, $p = .016$. Nicht signifikant werden die Effekte Gruppe, $F(1{,}52) = 0.52$, $p = .476$, Blickkontakt, $F(1{,}266) = 0.14$, $p = .705$, Zeit x Gruppe, $F(2{,}106) = 1.38$, $p = .254$, $\eta_p^2 = .02$, und Blickkontakt x Gruppe, $F(2{,}266) = 1.38$, $p = .254$, Blickkontakt x Szenario, $F(1, 52) = 0.83$, $p = .366$. Am Anfang des Rollenspiels gibt es um $b = 3.07$ ($SE = 1.74$) Einheiten eine marginal größere HF als zur Antizipation, $t(266) = 1.76$, $p = .079$. Ferner ist im Zugabteil während der Antizipation die HF um $b = -5.38$ ($SE = 1.89$) Einheiten signifikant geringer als am Anfang des Rollenspiels, $t(266) = -2.85$, $p = .005$.

Hautleitfähigkeit (EDA)

Die EDA ist über alle Proband_innen hinweg in beiden Szenarien im Vergleich zur Baseline angestiegen (siehe Tabelle 2). Des Weiteren nimmt die EDA in beiden Szenarien jeweils von der Antizipation zum Anfang des Rollenspiels zu, während die EDA zum Ende des Rollenspiels wieder abnimmt. Das multilineare Modell zeigt einen signifikanten Haupteffekt Zeit, $F(2{,}261) = 13.8$, $p < .001$, und Blickkontakt, $F(1{,}261) = 7.9$, $p = .005$, jedoch keinen signifikanten Haupteffekt Szenario, $F(1{,}261) = 2.25$, $p = .135$, oder Gruppe, $F(1{,}51) = 1.18$, $p = .282$, und auch keinen signifikanten Interaktionseffekt Blickkontakt x Gruppe, $F(1{,}261) = 2.03$, $p = .155$, Blickkontakt x Szenario, $F(1{,}51) = 0.01$, $p = .925$, Zeit x Gruppe, $F(2{,}261) = 0.70$, $p = .497$, oder Zeit x Szenario, $F(2{,}261) = 1.61$, $p = .202$. Im Szenario mit 80 % Blickkontakt ist die EDA um $b = 0.37$ ($SE = 0.46$) Einheiten höher angestiegen als im Szenario mit 20 % Blickkontakt, $t(58.4) = -0.81$, $p = .421$.

Einschätzung der eigenen Kompetenz

Die Ergebnisse zeigen, dass sich HSA in beiden Szenarien nervöser und weniger selbstsicher einschätzen im Vergleich zu NSA. Des Weiteren machen sich HSA in beiden Szenarien mehr Gedanken darüber einen guten Eindruck auf den Interaktionspartner zu machen als NSA (siehe Abbildung 3). Das multilineare Modell zeigt für die Skala Nervosität signifikante Haupteffekte Szenario, $F(1{,}51) = 7.30$, $p = .009$, und Gruppe, $F(1{,}52) = 8.89$, $p = .004$, jedoch nicht für Blickkontakt, $F(1{,}51) = 0.38$, $p = .539$, Szenario x Blickkontakt, $F(1{,}52) = 0.05$, $p = .821$, Szenario x Gruppe, $F(1{,}51) = 1.10$, $p = .300$, und Blickkontakt x Gruppe, $F(1{,}51) = 0.12$, $p = .726$. Die HSA berichten um $b = 13.7$ ($SE = 5.22$) Einheiten höhere Nervosität als NSA, $t(66.6) = 2.62$, $p = .011$. Ferner geben Personen im Zugabteil um $b = 5.93$ ($SE = 5.20$) Einheiten höhere Nervosität als im Reisebüro, $t(68.9) = 1.14$, $p = .258$, an. Für die Skala Selbstsicherheit ergaben sich signifikante Haupteffekte Szenario, $F(1{,}51) = 6.39$, $p = .015$, und Gruppe, $F(1{,}52) = 10.3$, $p = .002$, jedoch nicht für Blickkontakt, $F(1{,}51) = 0.13$, $p = .910$, Szenario x Blickkontakt, $F(1{,}52) = 0.01$, $p = .992$, Szenario x Gruppe, $F(1{,}51) = 2.78$, $p = .102$, und Blickkontakt x Gruppe, $F(1{,}51) = 0.24$, $p = .629$. Die HSA berichten um $b = -19.4$ ($SE = 5.89$) Einheiten niedrigere Selbstsicherheit als NSA, $t(65.9) = 3.29$, $p = .002$. Des Weiteren geben Personen im Zugabteil um $b = -1.28$ ($SE = 5.87$) Einheiten niedrigere Selbstsicherheit als im Reisebüro, $t(68.1) = -0.22$, $p = .828$, an. Für die Skala Relevanz

Tabelle 2. Herzschlagfrequenz, Hautleitfähigkeit sowie Bewertung der Szenarien für niedriger (NSA) und höher (HSA) sozial ängstliche Personen in beiden Szenarien

	NSA (n = 32)		HSA (n = 23)	
	M	*SD*	*M*	*SD*
Δ Herzschlagfrequenz	*Zugabteil*			
Antizipation	17.59	10.17	17.39	13.31
Rollenspiel Anfang	24.78	11.69	24.69	15.15
Rollenspiel Ende	23.76	14.61	23.20	15.02
	Reisebüro			
Antizipation	18.36	9.72	17.69	10.19
Rollenspiel Anfang	24.29	11.58	18.13	17.75
Rollenspiel Ende	21.21	13.53	15.26	11.43
	NSA (n = 31)		HSA (n = 23)	
	M	*SD*	*M*	*SD*
Δ Hautleitfähigkeit	*Zugabteil*			
Antizipation	20.88	6.89	18.42	9.49
Rollenspiel Anfang	24.84	6.01	22.11	9.85
Rollenspiel Ende	22.47	6.75	21.26	8.74
	Reisebüro			
Antizipation	20.52	9.01	19.58	9.16
Rollenspiel Anfang	26.44	10.6	24.03	6.65
Rollenspiel Ende	22.74	8.60	19.60	10.3
	NSA (n = 32)		HSA (n = 23)	
	M	*SD*	*M*	*SD*
Bewertung der Szenarien	*Zugabteil*			
Realitätsnähe des Interaktionspartners	2.97	0.68	3.07	0.53
Realitätsnähe des eigenen Verhaltens	1.70	0.69	1.96	0.67
	Reisebüro			
Realitätsnähe des Interaktionspartners	3.19	0.54	2.98	0.55
Realitätsnähe des eigenen Verhaltens	1.56	0.54	1.80	0.61

Anmerkungen: Mittelwerte *(M)* und Standardabweichungen *(SD)* der Differenz der Herzschlagfrequenz (Schläge pro Minute) sowie der Hautleitfähigkeit (in *T*-Werten) zur Baseline für die drei Messperioden und der Subskalen des selbsterstellen Fragebogens getrennt für Zugabteil und Reisebüro.

des Eindrucks auf Interaktionspartner zeigt sich ein signifikanter Haupteffekt Gruppe, $F(1,52) = 14.1$, $p < .001$, aber keine signifikanten Effekte für Szenario, $F(1,51) = 2.25$, $p = .140$, Blickkontakt, $F(1,51) = 0.01$, $p = .934$, Szenario x Blickkontakt, $F(1,52) = 1.28$, $p = .264$, Szenario x Gruppe, $F(1,51) = 0.24$, $p = .628$, und Blickkontakt x Gruppe, $F(1,51) = 0.08$, $p = .777$. Die HSA berichten um $b = 0.66$ ($SE = 0.20$) Einheiten eine höhere Relevanz des Eindrucks auf den Interaktionspartner als NSA, $t(67.9) = 3.29$, $p = .002$.

Beide Gruppen gaben in den Skalen Realitätsnähe des Interaktionspartners und Realitätsnähe des eigenen Verhaltens in beiden Szenarien ähnliche Werte an (siehe Tabelle 2). Weder für die Skala Realitätsnähe des Interaktionspartners noch für die Skala Realitätsnähe des eigenen Verhaltens ergab sich ein signifikanter Effekt. Realitätsnähe Interaktionspartner: Szenario, $F(1,51) = 0.49$, $p = .489$, Gruppe, $F(1,52) = 0.18$, $p = .672$, Szenario x Blickkontakt, $F(1,52) = 0.07$, $p = .789$, Szenario x Gruppe, $F(1,51) = 0.43$, $p = .515$, Blickkontakt x Gruppe, $F(1,51) = 0.22$, $p = .640$. Realitätsnähe des gezeigten Verhaltens: Szenario, $F(1,51) = 0.65$, $p = .424$, Gruppe, $F(1,52) = 2.59$, $p = .113$, Szenario x Blickkontakt, $F(1,52) = 0.01$, $p = .913$, Szenario x Gruppe, $F(1,51) = 0.75$, $p = .389$, Blickkontakt x Gruppe, $F(1,51) = 1.32$, $p = .256$.

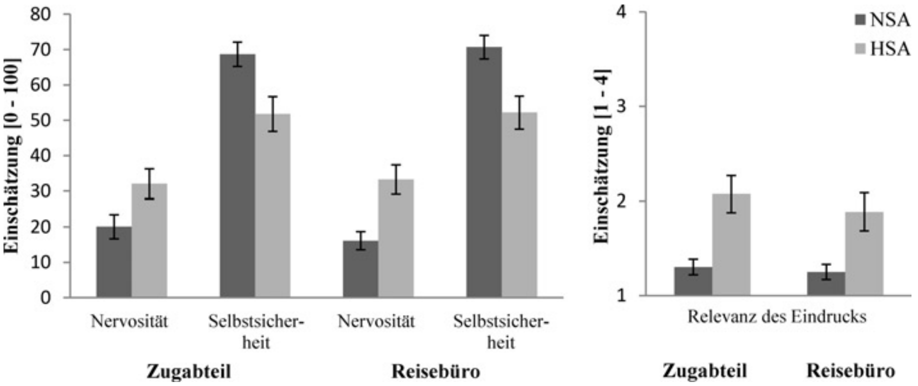

Abbildung 3. Einschätzung der eigenen Kompetenz in beiden Szenarien. Die Abbildung zeigt die Einschätzung zur Nervosität, Selbstsicherheit und Relevanz des Eindrucks auf Interaktionspartner der niedrigen (NSA) und höher (HSA) sozial ängstlichen Personen in beiden Szenarien. Die Standardfehler werden als Fehlerbalken angezeigt.

Diskussion

Das Ziel der Studie war in einer studentischen Stichprobe ausgewählte Szenarien für ein soziales Kompetenztraining, welches an das Gruppentraining sozialer Kompetenzen (GSK; Hinsch & Pfingsten, 2015) angelehnt war, zu validieren. Dabei sollten die durch das Szenario ausgelösten Komponenten sozialer Angst auf subjektiver, psychophysiologischer sowie kognitiver Ebene signifikant zwischen HSA und NSA differenzieren. Des Weiteren wurde eine stärkere Angstreaktion in der Bedingung mit viel vs. wenig Blickkontakt seitens des Agenten in der Gruppe der HSA erwartet.

Bei der Betrachtung der Angstratings zeigen die Ergebnisse, dass HSA sowohl im Zugabteil als auch im Reisebüro signifikant höhere Anstiege der Angst als NSA berichtet haben. Auch bei den Angaben zu ihren Symptomen und der Bewertung ihres Verhaltens zeigt sich, dass sich HSA im Vergleich zu NSA in beiden Szenarien als nervöser und weniger selbstsicher einschätzten sowie die Relevanz des Eindrucks, den sie auf den virtuellen Interaktionspartner gemacht haben, als höher angaben. Jedoch gab es auf subjektiver und kognitiver Ebene keine Differenzierung zwischen viel vs. wenig Blickkontakt.

Im Gegensatz zu den Angaben der Proband_innen zeigte sich bei den physiologischen Variablen zwar eine erhöhte Aktivierung während der Rollenspiele in Vergleich zur Antizipationsphase sowie höhere Anstiege im Zugszenario als im Reisebüroszenario, aber es wurden keine Unterschiede zwischen den Gruppen gefunden. Dieser fehlende Gruppenunterschied entspricht früheren Befunden, dass physiologische Unterschiede in Abhängigkeit von der emotionalen Aktivierung gerade in Situationen mit körperlicher Aktivität oft nicht gefunden werden können, gerade bei Analogstudien (Diemer, Lohkamp, Mühlberger & Zwanzger, 2016; Pan, Gillies, Barker, Clark & Slater, 2012). Auch auf der physiologischen Ebene konnte keine Differenzierung zwischen viel vs. wenig Blickkontakt gefunden werden.

Interessanterweise bewerteten beide Gruppen den Agenten sowie den Realismus des Szenarios für beide Szenarien ähnlich, so dass Unterschiede in der Angst und den Bewertungsskalen nicht auf Unterschiede in der „Immersion" in das virtuelle Szenario zurückgeführt werden können.

Zusammengefasst konnte gezeigt werden, dass unsere Szenarien physiologische Aktivierung auslösten und dass HSA in den Rollenspielen signifikant höhere Angst, mehr Symptome und negativere Bewertungen angaben als NSA.

Auch weisen die Ergebnisse darauf hin, dass beide VR-Szenarien glaubwürdig und realistisch wirkten und eine realitätsnahe Konversation entstehen konnte. Damit belegen unsere Befunde die Machbarkeit sowie die Glaubwürdigkeit von virtuellen Rollenspielen für ein soziales Kompetenztraining in VR. Um den Einsatz des sozialen Kompetenztrainings in VR weiterzuentwickeln und den therapeutischen Nutzen sowie die Wirksamkeit in der KVT zu untersuchen, sollen im nächsten Schritt in einer weiterführenden Studie Patient_innen mit Sozialer Phobie untersucht werden und die Szenarien in einem psychotherapeutischen Kontext auf ihre Wirksamkeit getestet werden.

Bisherige empirische Befunde haben gezeigt, dass sozialängstliche Personen Blickkontakt als bedrohlich empfinden (Radke et al., 2013; Wieser et al., 2009; Wieser et al., 2010). Unsere Ergebnisse konnten allerdings keine Differenzierung zwischen viel vs. wenig Blickkontakt nachweisen. Allerdings konnte auch die experimentelle Variation der Dauer des Blickkontakts durch den Agenten von beiden Gruppen nach dem Experiment nicht berichtet werden (siehe Tabelle 1). In einer kürzlich erschienen Studie zur Diagnostik sozialer Angst mit Hilfe virtueller Szenarien wurde gezeigt, dass die Analyse von Blickverhalten mittels Eye Tracking in virtuellen sozialen Situationen geeignet ist, um niedriger und höher sozial ängstliche Personen zu unterscheiden (Dechant, Trimpl, Wolff, Mühlberger & Shiban, 2017). Zukünftige Studien sollten nicht nur das Blickverhalten der virtuellen Agenten in den Fokus nehmen, sondern auch das Blickverhalten der Proband_innen mittels Eye-Tracking erfassen, um so auch einen Index für die Dauer des Blickkontakts zu bekommen. Ein solcher Index für die Dauer des Blickkontakts könnte auch für das Feedback und die Variation der Rollenspiele genutzt werden. Des Weiteren gibt es Befunde, dass sich das Blickkontaktverhalten während des Sprechens und während des Zuhörens unterscheidet. Demnach halten dominante Personen während des Sprechens mehr Blickkontakt als während des Zuhörens, während sich dieses Muster des Blickkontaktes bei submissiven Personen genau umgekehrt darstellt (Dovidio, Ellyson, Keating, Heltman & Brown, 1988). Da Personen mit sozialer Angst häufig andere Personen als dominant oder bedrohlich erleben und als Reaktion darauf submissives Verhalten, Flucht oder Vermeidung zeigen, scheint insbesondere bei sozialen Ängsten auch die Dominanz als wichtige zu erfassende Dimension eine besondere Bedeutung zu zukommen (Johnson, Leedom & Muhtadie, 2012). So sollte in zukünftigen Studien auch hier mittels Eye-Tracking das Blickverhalten der Proband_innen während des Sprechens und während des Zuhörens sowie die Dominanz als weitere Dimension erfasst und analysiert werden. Außerdem wäre es interessant Künstliche Intelligenz zu nutzen, um die VR-Szenarien mit einem virtuellen Agenten noch realistischer zu gestalten und die Reaktionen des virtuellen Agenten den Äußerungen der Probandin bzw. des Probanden individuell anzupassen.

Als Limitationen der Studie ist die Stichprobe aus Studierende zu nennen. Da nur studentische Proband_innen untersucht wurden, ist eine Generalisierung auf die Allgemeinbevölkerung nicht zulässig und müsste in weiteren Studien überprüft werden. Allerdings sind Studierende auch eine Gruppe, für die soziale Kompetenztrainings besonders hilfreich sein könnten. Ferner sollte die Gesamtsituation, in der die Studierenden getestet wurden, nicht vergessen werden, da die Testsituation für die Teilnehmer_innen eine potenziell zusätzliche angstauslösende Komponente beinhaltet haben könnte. Unsere Erhebung wurde durch den Versuchsleiter so neutral wie möglich durchgeführt und die statistische Auswertung erfolgte über die Differenz der Messwerte zur Baseline, um eine auf die generelle Untersuchungssituation bezogene Angstreaktion aus der spezifischen Auswertung herauszunehmen. Außerdem konnten wir zeigen, dass HSA und NSA sich in ihrer subjektiven und physiologischen Angstreaktion während der Baseline nicht signifikant unterscheiden (alle p's > .225). Außerdem wurde nur eine Analogstudie mit beschränkter Probandenzahl durchgeführt. Die Ergebnisse können deshalb nur bedingt auf Personen mit sozialer Angststörung verallgemeinert werden. Aus unseren Erfahrungen heraus ist allerdings zu erwarten, dass Proband_innen mit Angststörungen sich noch leichter auf virtuelle Situationen einlassen können als gesunde Proband_innen und ihre Furchtnetzwerke durch die virtuellen Szenarien sehr leicht getriggert werden können. Außerdem wurden nur zwei Szenarien vom Typ Rechte durchsetzen untersucht. Zukünftige Untersuchungen sollten weitere Szenarien in anderen Kompetenzbereichen mit einbinden.

Abschließend unterstützen unsere Ergebnisse bisherige Befunde, wonach HSA höhere Angstwerte als NSA berichten (Dechant et al., 2017; Radke et al., 2013; Wieser et al., 2009; Wieser et al., 2010). Zudem zeigten HSA die für die Soziale Phobie typischen negativen Verzerrungen in Bezug auf die Einschätzung der eigenen Kompetenz sowie der Symptome, die in der Rollenspielsituation aufgetreten sind. Es ist zu erwarten, dass solche Rollenspiele mit virtuellen Interaktionspartnern für Soziale Kompetenztrainings gewinnbringend eingesetzt werden können.

Elektronische Supplemente (ESM)

Die elektronischen Supplemente sind mit der Online-Version dieses Artikels verfügbar unter https://doi.org/10.1026/1616-3443/a000444

ESM 1. Fragebogen (ESM_1.pdf). Das Dokument zeigt den selbst erstellten Fragebogen zur Einschätzung der eigenen Kompetenz und der Bewertung der Realitätsnähe in VR.

ESM 2. Beschreibung der verwendeten Fragebögen (ESM_2.pdf). Das Dokument gibt detaillierte Informationen zu den einzelnen verwendeten Fragebögen.

ESM 3. Kontrolle von Reihenfolgeeffekten (ESM_3.pdf). Das Dokument gibt detaillierte Informationen zum methodischen Vorgehen zur Kontrolle von möglichen Reihenfolgeeffekten durch die Präsentation der Szenarien.

ESM 4. Subskalen des selbsterstellten Fragebogens (ESM_4.pdf). Das Dokument zeigt die einzelnen Items sowie die Einteilung der Subskalen des selbst erstellten Fragebogens.

ESM 5. Faktorenanalyse (ESM_5.pdf). Das Dokument zeigt in Tabelle 1 und 2 die Ergebnisse der Faktorenanalyse für den selbst erstellten Fragebogen.

ESM 6. Abbildung 1 (ESM_6.pdf). Die Abbildung zeigt den Zusammenhang zwischen Angstrating und SPIN-Wert in beiden Szenarien.

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3. Discussion

The research goal of this dissertation project is to systematically investigate the relevance of social-emotional learning processes for the development, maintenance, and therapy of social anxiety using experimental studies in virtual reality. In order to achieve this aim, three empirical studies looked at different aspects of social fear conditioning in VR and one empirical study examined the validity of two virtual interaction scenarios which can be used as social skills training in socially anxious individuals. Therefore, four empirical studies were conducted to answer the following research questions.

The first study should figure out if a social threat (e.g., spitting and verbal insult) triggers sensitively more fear responses than conventional unspecific threat (e.g., electrical stimulation) as unconditioned stimulus in socially anxious participants (Reichenberger, Porsch, Wittmann, Zimmermann, & Shiban, 2017b). The second study aimed to examine the underlying mechanisms of gender differences in social-emotional learning and unlearning processes of social anxiety (Reichenberger, Pfaller, Shiban, & Mühlberger, 2019). In addition, the third study investigated the effect of induced and extinguished social anxiety on physical behavior (e.g., duration of approach) and gaze behavior (e.g., hypervigilance and attentional avoidance) towards ecological valid socially relevant stimuli in high and low socially anxious individuals (Reichenberger, Pfaller, & Mühlberger, 2020). At last, the fourth study aimed to validate two virtual social interaction scenarios for psychotherapeutic interventions like social skills training in VR (Reichenberger, Diemer, Zwanzger, Notzon, & Mühlberger, 2017a).

In the following, the empirical results of the four dissertation studies are presented and discussed. The following Table 1 displays an overview of the research goals, methods, and main findings of the four studies of the dissertation project.

Table 1. Short summary of the empirical findings in study 1 to 4.

Study	Research Goal	*N*	Design	Outcome variables	Main results
1	Figure out the effect of disorder-relevant US in SFC in VR.	43	Between-subjects Design	– Fear- and Contingency Ratings – Fear-potentiated Startle – Skin Conductance Level – Avoidance Behavior (time in motion, time in non-motion)	The SFC was successfully induced and extinguished concerning the subjective outcome variables. The physiological and behavioral outcome variables successfully revealed fear conditioning at the beginning of the acquisition, but showed a fast habituation during fear acquisition and extinction. The distinction between CS+ vs. CS- was significantly greater in the social threat than in the conventional electroshock condition.
2	Analyzing gender differences in SFC in VR.	60 (LSA = 31, HSA = 29)	2 x 2 Between-subjects Design	– Personality Traits and Dispositions – Fear- and Contingency Ratings – Fear-potentiated Startle – Skin Conductance	The SFC was successfully induced and extinguished concerning each level of emotional reactions including fear ratings, fear-potentiated startle, and avoidance behavior. Women reported higher fear ratings than men.

				Response – Heart Rate Response – Avoidance Behavior (minimal distance to the agent) – Recognition Memory (sensitivity *d’* and response *β* criteria)	HSA women obtained a significantly larger avoidance behavior to male vs. female agents, whereas HSA men showed no such differentiation. HSA revealed a generally larger avoidance behavior to agents than LSA participants. Fear-potentiated startle results point out significantly better social fear conditionability towards male vs. female agents.
3	Investigating physical and gaze behavior in SFC in VR.	53 (LSA = 27, HSA = 26)	2 x 2 Between-subjects Design	– Fear Ratings – Physical Behavior (duration of approach) – Gaze Behavior: Hypervigilance (time to first fixation), Attentional Avoidance (count of fixations)	HSA needed some more time to approach the CS+ and CS- agents during SFC compared to LSA. HSA showed less time till the first fixation towards the CS+ than the CS- agents at the beginning (first half) of the fear conditioning, and revealed more attentional avoidance to CS+ than CS- agents during fear conditioning. LSA showed no difference in initial and sustained attention between both aversive and non-aversive agents during SFC. However,

					HSA showed no enhanced initial attention towards the CS+ than the CS- at the end (second half) of the fear conditioning.
4	Validating two virtual interaction scenarios for social skills training in VR.	55 (LSA = 32, HSA = 23)	Between-subjects Design	– Personality Traits and Dispositions – Fear Ratings – Heart Rate Response – Skin Conductance Level – Competence Assessment	In both scenarios HSA reported significantly more anxiety and estimated their own competency to be more negative than LSA participants. All participants perceived both virtual social interaction scenarios as realistic and reliable.

3.1 Summary and Integration

In the following, the most significant findings of each empirical study are summarized and combined with theoretical and methodological models within the common anxiety research. In the first SFC study by Reichenberger et al. (2017b), it could be shown that social fear conditioning was successfully induced and extinguished concerning the subjective outcome variables (fear- and contingency ratings) in a healthy student sample ($N = 43$) in virtual reality. Furthermore, the physiological (skin conductance level) and behavioral (avoidance behavior) outcome variables successfully revealed SFC at the beginning of the fear acquisition, but showed a fast habituation during fear acquisition and extinction. However, fear learning as indexed by the fear-potentiated startle could not be demonstrated. In relation to my first research goal, the distinction between CS+ vs. CS- was significantly greater in the social threat than in the conventional electroshock condition.

A significant match of CS-US pairings (both on sensory and sematic level) can facilitate fear conditioning and resistance to extinction compared to a CS-US mismatch (Hamm et al., 1989; Lonsdorf et al., 2017). Moreover, Lissek et al. (2008) recommend to use disorder-relevant US in fear conditioning for stronger fear associations and conditioned responses.

The major differentiation between aversive and non-aversive agents in the social threat compared to in the conventional electroshock condition might describe the superior CS-US belongingness (e.g., spitting and verbal insult) in this fear conditioning procedure that was used to investigate the underlying mechanisms of the development and maintenance of social anxiety. However, it has to be mentioned that the distinction between CS+ vs. CS- was significantly greater in the social threat than in the conventional electroshock condition, because the CS- was significantly higher in the conventional electroshock condition than in the social threat condition. Moreover, the sample was divided with a median split of the

Social Phobia Inventory (SPIN; German version: Stangier & Steffens, 2002) with a cut-off score of 13.5 into a lower and higher socially anxious group. Connor et al. (2000) suggest a SPIN cut-off score of 19 and Sosic, Gieler, and Stangier (2008) recommend a SPIN cut-off score of 25 for a sensitive differentiation between a clinical social anxiety and healthy group. Therefore, one might observe no enhanced belongingness effect in the social threat compared to the conventional electroshock condition in HSA participants.

However, it is important to note that there is an advantage using subclinical samples like high socially anxious individuals who do not possess a fully diagnosed mental disorder. A high proportion of patients with SAD displays a high comorbidity with depression or additional anxiety disorders (Fehm et al., 2005; Goldstein-Piekarski, Williams, & Humphreys, 2016; Stein & Kean, 2000). Most of the clinical studies investigating the underlying mechanisms in fear learning in social anxiety utilized SAD patients with comorbid disorders (Ahrens et al., 2016; Hermann, Ziegler, Birbaumer, & Flor, 2002; Lissek et al., 2008; Tinoco-González et al., 2015; Veit et al., 2002). Therefore, it is important to take into account that comorbid disorders influence the subjective and physiological level of fear in patients with SAD (McTeague & Lang, 2012; Tinoco-González et al., 2015).

Furthermore, it is necessary to consider that in the electroshock condition the US intensity was determined in a staircase procedure individually by adjusting the participant's individual pain threshold. Lonsdorf et al. (2017) recommend that such a calibration of an electro-tactile US prior to fear conditioning might critically impact the salience, which also affects the fear conditioning and expression. Thus, the influence of the subjective aversiveness of an US on fear learning and fear responses is not yet clear (Lonsdorf et al., 2017). Wiech and Tracey (2013) highlight that pain, like an electro-tactile stimulation, is a somatosensory experience, but also effects cognitive, affective, and social processes.

With regard to the empirical evidence and my results, a socially relevant US will enhance significantly better fear conditionability in a subclinical higher socially anxious or clinical SAD group (Ahrens et al., 2016; Lissek et al., 2008; Reichenberger et al., 2017b; Tinoco-González et al., 2015). It can be concluded that the better the fit of CS and US, the stronger a fear response will be triggered.

The second SFC study by Reichenberger et al. (2019) revealed that social fear learning and social fear extinction was successful concerning the primary outcome variables for each level (fear ratings, fear-potentiated startle, and avoidance behavior) in a high and low socially anxious sample ($N = 60$) in virtual reality. In relation to my second research goal, women reported higher fear ratings than men, and HSA women obtained a significantly larger avoidance behavior to male vs. female agents, whereas HSA men showed no such differentiation between the agents' gender. Moreover, HSA revealed a generally larger avoidance behavior to agents than LSA participants. Furthermore, fear-potentiated startle results point out significantly better social fear conditionability towards male vs. female agents.

The current findings are in line with previous research (Guimaraes, Hellewell, Hensman, Wang, & Deakin, 1991; Jackson et al., 2006; Merz et al., 2013). For example, Guimaraes et al. (1991) showed higher fear conditionability reflected in skin conductance responses in women than in men as well. The authors concluded that gender differences in associative mechanisms are key elements for the higher prevalence of anxiety disorders in women. However, it is important to note that enhanced skin conductance responses are also observed for increased orienting and selective attention to CS+ stimuli (Dolcos et al., 2019). Furthermore, Sevenster, Beckers, and Kindt (2014) reported that the skin conductance response depends on a conscious discrimination of threat and safety learning, and therefore skin conductance response does not seem to be an ideal correlate for fear learning, whereas the fear-potentiated startle reflex seems to be independent of an aware discriminative fear conditioning.

Thus, these results might indicate that the gender of the participants affects more reflective processes, which can be measured by subjective ratings and skin conductance responses, whereas the virtual agents' gender is more relevant for automatic processes (e.g., measured by the fear-potentiated startle and behavioral avoidance).

Moreover, diverse personality traits or vulnerability to anxiety may influence fear conditioning differently. In addition, Dolcos et al. (2019) report in their review that individual differences like age, gender, and personality influence attentional and emotional processes. Therefore, future studies should take into account individual dispositions such as traits of personality and vulnerability. In this way, the second study could reveal that social fear learning was positive correlated by submissive behavior traits as well as negatively influenced by dominance behavior traits (Reichenberger et al., 2019).

A significant novelty of this study was measuring approach-avoidance behavior via the movement of the participants in a behavioral avoidance task within the SFC paradigm with enhanced ecological validity. In detail, the interpersonal space between the participants and the agents was assessed during each rating phase. In this way, it could be shown that HSA participants obtained a generally larger avoidance behavior to agents than LSA participants indicating higher fear responses in individuals with high socially anxiety. Moreover, HSA women revealed a significantly larger avoidance behavior to male vs. female agents, whereas HSA men showed no such differentiation between the agents' gender. Therefore, I focused on the behavioral fear response as central diagnostic symptom of SAD. Furthermore, it is less conscious as well as less prone to bias fear response. A further novelty of the SFC paradigm by Reichenberger et al. (2019) is the uncertainty (e.g., 75 % US contingency) and complexity employed (e.g., using anthropomorphic stimuli like female and male CS+, CS-, and neutral agents in a social interaction) as demanded by Mertens et al. (2018), Beckers et al. (2013), and Lissek et al. (2006).

In the third SFC study by Reichenberger et al. (2020), it could be shown in a student sample (*N* = 53) that at the first half of the fear conditioning high socially anxious individuals guide their initial attention more to socially relevant threatening than non-threatening stimuli, and showed more attentional avoidance towards socially relevant threatening than non-threatening stimuli during fear acquisition. In comparison, the initial and sustained attention of LSA students towards aversive and non-aversive agents was similar during the fear acquisition. Moreover, the differentiation in hypervigilance and attentional avoidance between CS+ and CS- agents vanished during fear extinction.

The results of the gaze behavior partially confirm the vigilance-avoidance hypothesis (Bögels & Mansell, 2004; Chen & Clarke, 2017; Wieser et al., 2009a; Wieser et al., 2009b), because only at the first half of the fear acquisition phase HSA students guided their initial attention towards CS+ agents more than to CS- agents and avoided the CS+ agents more than the CS- agents at the second half of the fear acquisition phase. However, I assumed that persons with high levels of social anxiety direct their initial attention more to CS+ than CS- agents at the first and second half of the fear acquisition phase for a significant confirmation of a hypervigilance bias. In sum, the gaze behavior results support the vigilance-avoidance hypothesis in part (Reichenberger et al., 2020).

It is important to note that the SFC paradigm by Reichenberger et al. (2020) may be not sensitive enough to assess general evidence of a hypervigilance bias in social anxiety. Most of the empirical studies revealed hypervigilance (in initial time periods of 500-1500 ms) in humans with SAD using dot-probe or visual search tasks (Bögels & Mansell, 2004). The SFC in the virtual environment consisted of approaching different female and male CS+ / CS- agents during social fear learning. At the onset of each trial, the participants started to approach the agents directly, which could also influence the gaze behavior (e.g., initial fixations, hypervigilance) during the movement. Therefore, future studies should focus more on initial time periods and on the possible associations between approach-avoidance behavior and patterns of selective attention in individuals with SAD.

Relating to the findings of the fear ratings, social anxiety was successfully induced and extinguished like in the sample by Reichenberger et al. (2019), with the exception of a distinct social fear conditioning effect in high socially anxious men. Possible explanations that HSA men revealed no clear SFC could be that they use different coping strategies (e.g., cognitive avoidance or problem-focused coping behavior), they report their fear less freely, and they have got a reduced conditionability or a higher variance in the self-reported fear than HSA women. For example, there is empirical evidence that men use relatively more problem-focused or avoidant coping strategies whereas women more likely show behavior that involves social support seeking and emotion-oriented coping strategies when they are confronted with a stressor (Eschenbeck et al., 2015; Tamres et al., 2002). Thus, it would be interesting to examine if HSA women and men apply different coping strategies in social-emotional learning processes or when they are confronted with a social-evaluative stressor.

Concerning the physical behavior results during social fear learning, it could be shown a first hint that HSA students are slower in approaching all agents than LSA students which was measured by longer approach times indicating higher social anxiety in this social interaction. Therefore, it might reflect that HSA persons are more cautious in approaching socially relevant threatening and non-threatening agents than LSA persons. Furthermore, they possibly reveal an intensified social anxiety in a social interaction.

The findings of this study partially support previous results of hypervigilant and attentional avoidance biases in humans with high levels of social anxiety (Chen & Clarke, 2017; Mühlberger, Wieser, & Pauli, 2008; Wieser et al., 2009a; Wieser et al., 2009b). However, both Bögels and Mansell (2004) as well as Chen and Clarke (2017) report in their reviews empirical evidence for a short-period hypervigilance and sustained avoidance behavior of social threat-relevant stimuli in paradigms with high ecological validity in persons with SAD or high levels of social anxiety. Nevertheless, they stated that the causal relationship for hypervigilance and attentional avoidance is still not clear and needs more investigation. Moreover, it is important to note that the generalization of laboratory findings to attentional processes in real world situations is limited (Foulsham, Walker, & Kingstone, 2011; McCall et al., 2016). However, measuring physical and gaze behavior in virtual reality is more realistic than in traditional paradigms in a laboratory setting. Furthermore, the findings of the third SFC study display that physical behavior and gaze behavior do not have to be congruent in every situation. For example, attention is guided more to a socially relevant threatening facial expression (e.g., angry face) in a social situation, which could lead to avoid the potential threatening person physically (McCall et al., 2016).

Nevertheless, using eye-tracking sensors in a well-controlled virtual environment to measure implicit gaze behavior during social fear acquisition and extinction can contribute to get a better insight of selective attention in emotional learning processes. Moreover, it would be interesting to figure out how selective attention processes will change during specific CBT treatment methods like exposure therapy or social skills training in-vivo as well as in-virtuo.

In the fourth study, validating social skills training for social anxiety in VR by Reichenberger et al. (2017a), a sample of high and low socially anxious ($N = 55$) was investigated. HSA showed significantly higher anxiety ratings and more negative competency estimations in both virtual social interaction scenarios (travel agency and train cabin) than LSA students. However, concerning the assessed physiology (heart rate response, skin conductance level), fear activation but no distinction between the HSA and LSA group was found. Furthermore, the results did not show a differentiation in the fear reactions between few vs. many gaze behaviors by the agents. Moreover, the experimental variation of the gaze duration could not be reported in any of the groups after the experiment. However, all participants perceived both virtual social interaction scenarios as reliable and realistic.

These findings emphasize the feasibility and reliability of such social interaction scenarios for social skills training in virtual reality. Further studies should test the effectiveness of these virtual scenarios in a psychotherapeutic context using patients with SAD in order to investigate the psychotherapeutic gain in CBT (Reichenberger et al., 2017a).

Further empirical studies should assess more submissive and dominant personality traits as well as gaze behavior as significant submissive and dominant dimension of social anxiety, because persons with SAD or high levels of social anxiety often experience their counterpart as dominant or threatening and usually react with escape, avoidance, or submissive behavior (American Psychiatric Association, 2013; Stangier & Fydrich, 2002a). Moreover, Mineka and Öhman (2002) report that personality factors or trait vulnerabilities strongly influence learning experiences, which has to be considered in more detail in prospective empirical research.

The application of such social interaction scenarios for social skills training in virtual reality has many advantages. For example, Cláudio, Carmo, Gaspar, and Teixeira (2015) recommend in their empirical work the utilization of an interactive evaluation context (e.g., a job interview) in VR for treatment approaches to SAD. This can be applied easily with different expressive and talkative agents by diverse degrees of emotion, attention, or lack of interest. Moreover, they highlight the possibility of an interactive virtual environment for exposure therapy to fulfill the needs of a patient with suitable configuration and interactions in VR.

Explanatory approaches assume that the reasons of social anxiety are insufficient social skills and that affected people fear that they will not be able to fulfill the social expectations and social norms. However, it is often not possible to distinguish between social skills (competence as the availability of the behavioral repertoire) and actual behavior (performance as the specifically shown and observable behavior) in social interaction situations (Fydrich, 2002). Therefore, future studies should assess whether persons have knowledge and skills that can be viewed as socially competent (e.g., social skills questionnaires), and should measure the behaviors actually shown in such virtual social interaction situation (e.g., physical approach-avoidance behavior, gaze behavior, facial expressions, voice recording, as well as widespread psychophysiology) distinguishing between social competence and social performance (Fydrich, 2002).

The findings of the fourth study might support anxiety research on the application of virtual social interactions for the treatment of SAD or mental disorders with social skills deficits. This validation study showed that a virtual simulation of social interaction can evoke fear in individuals with low and high levels of social anxiety. However, including more diverse virtual scenarios with more flexible verbal feedbacks of different agents of both gender and facial expressions may enhance fear activation improve treatment efficacy.

3.2 General Strengths and Limitations

In the following, general strengths of this dissertation project are highlighted. A significant relevance of these four empirical studies is the utilization of immersive virtual reality, which may enhance the psychological and behavioral anxiety research. Regular experiments in a laboratory setting indicate in a restricted manner about social-emotional learning processes in social anxiety and it is usually not possible to translate the conclusions directly into real life. In contrast, the findings of virtual paradigms are rather natural and therefore implications can be transferred more directly into real life. With the implementation of VR, the used stimuli and environments in which the social fear conditioning paradigms and social skills training took place are easily standardized, adapted, and specifically manipulated in a controlled laboratory setting with an economical and high ecological validity. For example, the topic, duration, and the severity of each social interaction can easily be controlled.

Due to the combination of maximum standardization, experimental control, high complexity of potential social interaction scenarios, and authentic simulations (high level of presence), virtual reality is meanwhile a well-established research method to investigate social-emotional learning processes (Dunsmoor et al., 2014; Reichenberger et al., 2020; Reichenberger et al., 2019; Reichenberger et al., 2017b; Shiban et al., 2015a) as well as cognitive-behavioral therapy items like social skills training for SAD (Bouchard et al., 2017; Cláudio et al., 2015; Kampmann et al., 2016a). Therefore, both experimental control and ecological validity can be provided concurrently. Moreover, the first steps in virtual exposure to feared stimuli or situations are easier for many patients with anxiety disorders, which makes immersive virtual reality attractive and variously usable (Diemer, 2019; Diemer & Zwanzger, 2019; Garcia-Palacios et al., 2007; Reichenberger et al., 2017a).

Another strength of this dissertation project is the sample size of each study (study 1: $N = 43$, study 2: $N = 60$, study 3: $N = 53$, study 4: $N = 55$) as well as the selection of the participants (low vs. high socially anxious women and men). Moreover, each study of the dissertation project used widespread measurements of fear responses via self-reports (e.g., fear and contingency ratings), and even psychophysiological (e.g., fear-potentiated startle, skin conductance, heart rate) as well as behavioral responses (e.g., approach-avoidance behavior in form of eye and head movements as well as interpersonal space between the participants and the agents), which are less prone to bias and less conscious than self-reports (Lonsdorf et al., 2017). Furthermore, the social fear conditioning studies 1 – 3 of the dissertation project utilized more complexity (e.g., using different anthropomorphic stimuli such as female and male CS+, CS-, and neutral agents) and uncertainty (e.g., 75 % US contingency) within a social interaction with high ecological validity in virtual reality compared to traditional fear conditioning paradigms in a laboratory setting.

In the following, general limitations of this dissertation project will be discussed critically. The first general limitation is the non-clinical sample, which consisted mainly of young students with low and high levels of social anxiety. This is important to note before the findings of all four studies are generalized to a broader population.

Second, the agents' verbal insults or responses were recorded in advance and the lip movements of the agents were synchronized accordingly. Either the participant was close enough to the agent that an automated trigger activated the verbal insult (study 1-3), or the examiner presented the answers of the agent if a response button was pressed (study 4). Therefore, it was possible to create a fluid and realistic interaction, but the dialogues were still fixed (study 4). Artificial intelligence might support even more individualized responses (e.g., flexible dialogues) and might increase uncertainty, and therefore a wider range of the level of difficulty in social interactions would be possible.

Furthermore, facial expressions deliver information about the emotion and social intention of the counterpart. Therefore, they are important for social interactions. In the dissertation project all utilized computer-generated humans (study 1-4) presented a neutral face. Wieser and Brosch (2012) reviewed that social and affective face processing is determined by sender related criterion (e.g., eye gaze, expression dynamics, body posture, prosody), perceiver related characteristics (e.g., affective learning, cognitive biases, personality traits), and environmental related features (e.g., visual scene, verbal descriptions of social situations). In future studies the influence of social-emotional learning processes on affective face processing is of high interest.

Moreover, the quantity of virtual situations and humans was restricted within the dissertation project. The social anxiety towards threatening virtual agents or situations may differ between the participants. The more virtual interaction scenarios with different virtual agents and diverse instructions are available, the greater the field of application and the need of each person with high levels of social anxiety can be adjusted individually.

Additionally, it is important to note that all four studies in the dissertation project measured the physical presence of the virtual environment, which was assessed with the

Igroup Presence Questionnaire (IPQ) by Schubert (2003), but did not focus on the concept of social presence (Oh et al., 2018). There exist links between immersion, presence, and emotion in virtual reality (Diemer et al., 2015a). Felnhofer, Hlavacs, Beutl, Kryspin-Exner, and Kothgassner (2019a) and Oh et al. (2018) differentiate the concept "presence" into two different constructs of social presence and physical presence. Felnhofer et al. (2019a, p. 2) define social presence as "the impression of being in the presence of another sentient being" which includes a cognitive and emotional processing of the counterpart. Blascovich et al. (2002, p. 112) define that "social presence increases the more the user believes that a virtual human within a shared virtual environment is controlled by and represents a real person in the physical world in real time".

In a small sample size of 12 healthy and 12 SAD participants, Felnhofer et al. (2019a) investigated the influence of social and physical presence towards experienced anxiety (state anxiety and heart rate) in three social interaction tasks (e.g., place an order in a café, react to an unknown person, and respond to a false order) in virtual reality. Besides the finding that participants with SAD showed higher anxiety levels in all three social interaction tasks, they also experienced more social (co-presence and mutual attention) and physical (subscale *sense of being there* of the IPQ) presence than the healthy group. Felnhofer et al. (2019a) concluded that social presence in virtual environments influences emotional responses in persons with SAD more than physical presence in virtual environments. The authors assume that attentional processes are significant for the interaction between social presence and emotional responses. It is important to note that social presence seems to be a key element indicating emotional responses in persons with high levels of social anxiety or with a diagnosis of SAD in virtual environments (Felnhofer et al., 2019a).

Ling, Nefs, Morina, Heynderickx, and Brinkman (2014) analyzed in a meta-analysis that positive correlations between presence and anxiety are given in specific phobias like fear of animals, flying, or heights. However, they found no correlation between presence and anxiety for SAD in virtual reality. While the physical presence seems to be sufficient to positively influence anxiety in specific phobias in a virtual environment, the social presence seems to be more important to trigger anxiety in persons with SAD (Ling et al., 2014).

Therefore, it could be assumed that a natural social interaction with a computer-generated counterpart has to activate cognitive and emotional processes in order to trigger social anxiety and an activation of the person's anxiety network.

Furthermore, there are empirical findings that an avatar (e.g., operated by another human) affects humans differently than an agent, which is controlled by a computer (Blascovich et al., 2002; Kothgassner et al., 2019). For example, Kothgassner et al. (2019) investigated the influence of social support from diverse persons (agent, avatar, real human) on social-evaluative stress (via the TSST). Interestingly, they found that there was no difference in the social presence experiences regarding the impression of the agent or avatar, but participants, who received support from an agent, showed higher stress reactions (e.g., worries and heart rate) after the TSST than participants with avatar or real support. Furthermore, in two prosocial behavior tasks participants with agent support showed different social behavior (longer reaction time for prosocial behavior and larger distance to an unknown person) compared to participants with avatar or real person support (Kothgassner et al., 2019). The authors concluded that virtual social support can be equated with support in real life as long as the individual believes that a real person controls the virtual interaction partner in real time.

Blascovich et al. (2002) developed a threshold model of social influence, which is affected by behavioral realism and social presence. The authors assume that agents may only trigger social reactions if their behavioral realism is high or the user believes the virtual interaction partner is an avatar. In contrast, the media equation concept by Nass and Moon (2000) and empirical results indicate that persons respond equally social to all virtual interaction partners, regardless if the counterpart is an agent or avatar (Kothgassner et al., 2019). Previous studies indicated that direct and basic social reactions (e.g., social presence experiences) towards virtual interaction partners do not differ, whereas high order responses (e.g., approach-avoidance) differ between agents and avatars (Felnhofer et al., 2019a; Felnhofer et al., 2018; Felnhofer et al., 2019b; Kothgassner et al., 2019). These aspects might have wide ranging implications for the social fear conditioning research with ecological valid socially relevant stimuli (e.g., interaction partners). Therefore, it would be interesting to investigate if there is an influence of agents and avatars in induced and extinguished social anxiety in a social fear conditioning paradigm with high and low socially anxious individuals.

In summary, it can be said that social presence is influenced by the level of interactivity and visual representation of the virtual interaction partner (e.g., visual realism like moving, breathing, and blinking naturally), the perceived agency (e.g., avatar vs. agent), and the presentation of multiple interaction partners (see review by Oh et al., 2018). More research is needed in the field of social presence in virtual environments and their influences.

3.3 Outlook

At last, a short outlook is given. Social anxiety disorder must no longer be trivialized, because the prevalence, the tendency of chronicity, and the psychological and social consequences of this mental disorder are severe (Stangier & Fydrich, 2002b). Despite the attention, which is meanwhile paid to SAD, there is still a great need to examine the underlying mechanisms of development and maintenance of social anxiety and develop more appropriate treatment approaches.

With regard to the growing number of virtual reality software and the falling acquisition costs of the hardware (e.g., head-mounted display), the application of VR is becoming more popular and easier to implement in the next steps better speech recognition software can be used to identify answers from the participant and to select fitting responses from a virtual agent. Therefore, automated processes might enhance treatment effectiveness as well as better and larger care possibilities. For example, emotional responses in virtual threatening situations could be detected multimodal (e.g., subjective anxiety, skin conductance level, heart rate, respiration, attentional gaze behavior, cognitive apprehensions). Then, relevant parameters could be extracted and suggestions for intervention derived. The multimodal data acquisition and the combination of human experience and artificial intelligence might provide a comprehensive view of the state of the participant. Thus, depending on the emotional state of the person, a suitable interaction scenario with different levels of difficulty could be applied. Therefore, an innovative concept for behavioral practice in virtual reality could be developed for SAD. In this way an autonomous use of the artificial system in the context of homework as well as self-optimization of the system by evaluating the experiences would be conceivable.

Another possibility of immersive virtual reality is the utilization of CAVE systems, which provide the perception of the own body, supply a greater field of view than HMDs, and allow almost unrestricted movements of the user (Gromer et al., 2018). Moreover, the application of fans and surround sound systems may further improve the immersion. Another great advantage is the tracking of naturalistic movement and orientation in social interaction situations with diverse virtual humans. Therefore, it would be interesting to investigate the underlying mechanisms of social-emotional learning and unlearning processes of social anxiety in a more immersive virtual reality system such as CAVE as well.

One task of future research is to verify the external validity of the empirical findings obtained under controlled experimental conditions and to improve the ecological validity of experimental research (Stangier & Fydrich, 2002b). Moreover, it is important to note that it is necessary to specifically validate the findings of this dissertation project in clinical samples. Furthermore, the application of improved methods of natural detection in real time of social-emotional processes or problematic cognitions (e.g., smartphones, fitness-tracker, VR technologies) could also help to specifically advance treatment approaches for psychotherapeutic interventions in social anxiety disorders.

Exposure therapy, cognitive therapy, and social skills training are effective treatment approaches that address different aspects of SAD. All of these methods can be linked and offered in VR. For example, the targeted redirecting of the attention to external stimuli (e.g., via eye-tracking) and the reduction of safety behavior in virtual interaction scenarios as well as the behavioral validation of negative expectations (e.g., job interview or small talk scenario) can be conducted in virtual reality scenarios.

One further task of future research is to examine neural correlates of social-emotional learning processes in social anxiety by using fMRI-based designs. Most empirical studies provide evidence for increased amygdala, hippocampus, and ventral prefrontal cortical responsivity in fear conditioning (Ahrens et al., 2015; Andreatta et al., 2015; Indovina et al., 2011). Empirical findings let one assume that the associative connection between the CS and the US takes place in the amygdala (LeDoux, 2000). Morris, Öhman, and Dolan (1998) indicated that a subliminal presentation of a successful conditioned stimulus, such as an angry facial expression, induces an activation of the amygdala. Hermann (2002) concludes that for the social anxiety disorder an anxiety provoking stimulus (e.g., a socially relevant situation) is composed with a variety of individual cues (e.g., facial expression, nonverbal behavior, or verbal statements) that can trigger the fear even without conscious processing of the fear relevant stimulus. Therefore, the SAD could underlie on a hyperirritable neural anxiety network especially in confronting with socially relevant stimuli such as facial expressions (Hermann, 2002). Previous studies should aim to investigate the neural anxiety network of social-emotional learning processes in individuals with SAD or high levels of social anxiety with ecological valid socially relevant stimuli in a highly ecologically virtual environment by using fMRI-based designs.

Moreover, the SFC paradigm could be used to investigate the contribution of neurotransmitter like oxytocin on social anxiety and its extinction. There is empirical evidence that the oxytocin system influences several aspects of social behavior. The neuropeptide oxytocin is well-known for its pro-social, anxiolytic, and stress-attenuating effects, and the oxytocin system seems to be relevant for SAD as well (Guastella, Howard, Dadds, Mitchell, & Carson, 2009; Kirsch et al., 2005; Neumann & Slattery, 2016; Sabihi, Dong, Maurer, Post, & Leuner, 2017; Slattery & Neumann, 2008). In rodents, oxytocin seems to decrease social fear expression in a social fear conditioning paradigm (Zoicas et al., 2014). In humans, the administration of oxytocin in combination with exposure therapy increased the positive evaluations of appearance and speech performance in patients with SAD (Guastella et al., 2009). Future research could aim to examine the influence of oxytocin on social fear learning in individuals with SAD or high levels of social anxiety which could advance existing treatment approaches in social anxiety disorder.

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5. Appendix

Table of Contents

1 Appendix A: Consent information Study 1

Probandeninformation zur Studie: „Konditionierung und Extinktion von sozialer Angst beim Menschen”

Sehr geehrte Versuchsteilnehmerin, sehr geehrter Versuchsteilnehmer,

Sie haben Gelegenheit, an einer Studie teilzunehmen, mit der wir untersuchen wollen, unter welchen Bedingungen Menschen lernen, in sozialen Situationen Angst zu empfinden und wie dieser Lernprozess wieder gelöscht werden kann. Sie werden aus der Teilnahme keinen unmittelbaren Nutzen für sich ziehen können. Wir hoffen jedoch, durch unsere Arbeit mehr darüber zu erfahren, wie Angststörungen entstehen und welche Bedingungen sie aufrechterhalten, um so langfristig die Behandlung zu verbessern.

Vor der Untersuchung werden Sie einige Fragebögen ausfüllen, in denen wichtige Daten bezüglich Ihrer Person (anonymisiert) festgehalten werden. Dann wird der Versuchsleiter zur Messung Ihrer Schweißdrüsenaktivität, Muskelspannung sowie Herzaktivität mehrere Messelektroden anbringen. Dazu wird Ihre Haut mit Alkohol und einer Peelingpaste gereinigt, um den elektrischen Widerstand zwischen Haut und Messelektrode so gering wie möglich zu halten. Aufgrund dieser Hautreinigung kann es zu Hautrötungen oder leichten Hautirritationen kommen, die aber innerhalb kurzer Zeit abklingen. Diese Messungen sind nicht-invasiv und werden in der Regel nicht als störend empfunden.

Während der Untersuchung werden wir Ihnen eine Virtuelle Welt, d. h. von einem Computer erzeugte Räume, zeigen. Sie sollen diese Räume und die darin enthaltenen Gegenstände oder Personen aufmerksam betrachten. In seltenen Fällen kann die Virtuelle Realität Übelkeit oder Schwindel auslösen, ähnlich wie eine Karussellfahrt. Falls dies passiert, so teilen Sie uns das bitte sofort mit. Vor Beginn des Experiments haben Sie die Möglichkeit, sich mit der virtuellen Welt vertraut zu machen.

Während dieser Untersuchung werden Sie manchmal über einen Schlauch einen kurzen, starken Luftstoß an Ihrem Hals spüren beziehungsweise schwache Stromstöße an Ihrem Unterarm. Diese Eindrücke werden unangenehm für Sie sein und Sie werden sich vielleicht erschrecken. Jedoch sind sie unschädlich und wichtig für die physiologischen Messungen. Bitte versuchen Sie, die Luftstöße bzw. Stromstöße sowie auftretende akustische Reize nicht weiter zu beachten.

Alle erhobenen Daten dienen ausschließlich Forschungszwecken, werden streng vertraulich behandelt und ohne Namensgebung unter einer Codenummer abgespeichert. Die anonymisierten Daten werden für unbestimmte Zeit gespeichert. Der Codierungsschlüssel wird ein Jahr nach Abschluss der Studie vernichtet. Bis dahin können Sie, auch noch nach der Untersuchung, die Löschung Ihrer Daten verlangen.

Die Teilnahme an der Untersuchung ist völlig freiwillig. Sie können jederzeit - ohne Angabe von Gründen - die Teilnahme abbrechen. Dadurch entstehen Ihnen keinerlei persönliche Nachteile.

Falls Sie noch weitere Fragen haben, stellen Sie diese bitte jetzt.

2 Appendix B: Informed Consent Study 1

Einverständniserklärung zur Studie: „Konditionierung und Extinktion von sozialer Angst beim Menschen”

Name der Probandin / des Probanden

____

Ich bin über die geplante Untersuchung *„Konditionierung und Extinktion von sozialer Angst beim Menschen”* ausführlich unterrichtet worden. Die Informationen habe ich inhaltlich verstanden und ich hatte die Gelegenheit, Fragen zu stellen. Diese wurden beantwortet, ich fühle mich ausreichend informiert und willige hiermit nach ausreichender Bedenkzeit in die Untersuchung ein. Mir ist bekannt, dass ich meine Einwilligung auch noch während des Experimentes ohne Angabe von Gründen widerrufen kann. Ich weiß, dass die Untersuchung wissenschaftlichen Zwecken dient und die gewonnenen Daten eventuell für wissenschaftliche Veröffentlichungen verwendet werden. Hiermit bin ich einverstanden, wenn dies in einer Form erfolgt, die eine Zuordnung zu meiner Person ausschließt. Auch diese Einwilligung kann ich binnen eines Jahres widerrufen. Die anonymisierten Daten werden für unbestimmte Zeit gespeichert. Der Codierungsschlüssel wird ein Jahr nach Abschluss der Studie vernichtet. Bis dahin kann ich, auch noch nach der Untersuchung, die Löschung meiner Daten verlangen.

Regensburg, ______________ ____________________________________

Datum Unterschrift der Probandin/des Probanden

Regensburg, _______________ ______________________________________

Datum Unterschrift des Versuchsleiters

3 Appendix E: Consent Information Study 2, 3

Probandenaufklärung zur Studie: „Konditionierung und Extinktion von sozialer Angst beim Menschen”

Sehr geehrte Interessentin, sehr geehrter Interessent,

bitte lesen Sie die nachfolgende Aufklärung aufmerksam durch. Im Folgenden werden Ihnen Fragestellung und Ablauf dieser Untersuchung erklärt. Sollten Ihnen Teile der Aufklärung unklar sein oder Sie weitere Informationen über einzelne Aspekte der Untersuchung wünschen, gibt Ihnen Ihr/e Untersuchungsleiter/in gerne Auskunft.

Ihre Teilnahme an dieser Studie ist freiwillig. Sie werden in dieser Studie also nur dann einbezogen, wenn Sie dazu schriftlich Ihre Einwilligung erklären. Sie können jederzeit, auch ohne Angabe von Gründen, Ihre Teilnahme beenden, ohne dass Ihnen dadurch irgendwelche Nachteile entstehen.

Wie ist der Ablauf der Studie?

Zunächst werden Ihnen Fragebögen zu allgemeinen Angaben zu Ihrer Person und zu bestimmten Ängsten vorgelegt. Das Experiment findet in virtueller Realität, d.h. in einer Computersimulation, statt. Sie haben zu Beginn die Möglichkeit, sich vorher mit der virtuellen Welt vertraut zu machen.

Im Experiment treffen Sie auf Personen. In dieser Situation sollen Sie sich den Personen nähern. Sie werden manchmal über einen Schlauch einen kurzen, starken Luftstoß (5 bar, 10 ms) an Ihrer Backe spüren. Über Kopfhörer werden Sie manchmal ein kurzes Rauschen (103 dB, 40 ms) hören. Diese auditiven Eindrücke können für Sie unangenehm sein und Sie werden sich vielleicht erschrecken, sie sind jedoch wichtig für unsere physiologischen Messungen. Die Luftstöße sowie die Geräusche sind gesundheitlich unbedenklich.

Zur Messung Ihrer physiologischen Reaktionen (z.B. Hautleitfähigkeit, Herzrate, Schreckreflex) wird Ihr/e Versuchsleiter/in Messelektroden auf Ihre Hand, ihrem Oberkörper und Ihrem Gesicht anbringen. Zu verschiedenen Zeitpunkten werden wir Sie bitten, erneut Fragebögen auszufüllen. Der Untersuchungszeitraum umfasst ca. 1,5 Stunden und wird in nur einer Sitzung abgehalten.

Welche Risiken sind mit der Teilnahme an dieser Studie verbunden?

Während der Studie werden Sie sich mit für Sie möglicherweise unangenehmen Situationen in virtueller Realität auseinandersetzen. Das kann unter Umständen anstrengend sein. Während der Untersuchung werden wir Ihnen eine virtuelle Welt, d.h. von einem Computer erzeugte Räume, zeigen. In seltenen Fällen kann die virtuelle Realität Übelkeit und Schwindel auslösen, ähnlich wie eine Karussellfahrt. Falls dies passiert, teilen Sie uns das bitte sofort mit. Außerdem werden wir neben der Blickerfassung die Hautleitfähigkeit, Herzrate und Schreckreflex messen. Vor dem Anbringen der Elektroden wird die Haut mit einer alkoholischen Lösung desinfiziert und mit einer Art Peeling behandelt. Das kann zu einer kurzfristigen Hautirritation führen. Anhaltende Folgen sind nicht zu erwarten.

Wer kann an dieser Studie teilnehmen?

Teilnehmen können Männer und Frauen zwischen 18 und 55 Jahren. Ausschlusskriterien für diese Untersuchung sind:

- das Vorliegen einer behandlungsbedürftigen psychischen, neurologischen oder schweren körperlichen Erkrankung (außer soziale Phobie)
- derzeitige psychotherapeutische, psychiatrische oder neurologische Behandlung
- derzeitige Einnahme von Psychopharmaka
- Schwangerschaft oder Stillzeit

Was geschieht mit meinen Daten?

Die im Rahmen dieser Studie Sie betreffende, personenbezogene Daten und Angaben werden verschlüsselt auf elektronischen Datenträgern aufgezeichnet und verarbeitet. Die pseudonymisierten Daten werden für unbestimmte Zeit gespeichert. Der Codierungsschlüssel wird ein Jahr nach Abschluss der Studie vernichtet. Bis dahin können Sie, auch noch nach der Untersuchung, die Löschung Ihrer Daten verlangen. Ergebnisse und Daten dieser Studie können als wissenschaftliche Publikation veröffentlicht werden. Dies geschieht in anonymisierter Form, d.h. ohne dass die Daten einer spezifischen Person zugeordnet werden können. Die vollständig anonymisierten Daten dieser Studie können als offene Daten im Internet in einem Datenarchiv zugänglich gemacht werden. Damit folgt diese Studie den Empfehlungen der Deutschen Forschungsgemeinschaft (DFG) und der Deutschen Gesellschaft für Psychologie (DGPs) zur Qualitätssicherung in der Forschung.

4 Appendix F: Informed Consent Study 2, 3

Einverständniserklärung zur Studie: „Konditionierung und Extinktion von sozialer Angst beim Menschen“

Hiermit willige ich,

____

Vorname & Name der Teilnehmerin / des Teilnehmers

____

Straße & Hausnummer

____

Postleitzahl & Ort

__________________________ ____________________________

Geburtsdatum Code-Nr.

ein, an der Studie „Konditionierung und Extinktion von sozialer Angst beim Menschen“ teilzunehmen.

Bei der Studie werde ich mit Elektroden versehen und werde Verhaltensübungen in virtueller Realität durchlaufen. Im Experiment treffe ich auf Personen und während bestimmter Abschnitte werde ich Luftstöße (5 bar, 10 ms) an der Backe verspüren sowie Töne der Lautstärke von ca. 103 dB dargeboten bekommen. Des Weiteren werde ich einige Fragebögen bezüglich allgemeiner Daten, zu bestimmten Erlebens- und Verhaltensweisen sowie Ängsten ausfüllen.

Ich bin über die geplante Untersuchung ausführlich unterrichtet worden. Die Informationen über den Ablauf der Untersuchung, die möglichen Risiken der Teilnahme und den Umgang mit meinen Daten habe ich inhaltlich verstanden. Mir ist bewusst, dass es ihm Rahmen der Untersuchung zur Auseinandersetzung mit möglicherweise schwierigen Situationen in virtueller Realität kommen kann und dies unter Umständen unangenehm sein kann. Ich hatte die Gelegenheit Fragen zur Untersuchung zu stellen und diese wurden beantwortet, ich fühle mich ausreichend informiert und willige hiermit in die Untersuchung ein. Mir sind die

Ausschlusskriterien für die Teilnahme an der Studie bekannt und ich erkläre hiermit, dass ich keine dieser Kriterien erfülle.
Ich erkläre mich damit einverstanden, dass im Rahmen dieser Studie mich betreffende, personenbezogene Daten/Angaben verschlüsselt auf elektronischen Datenträgern aufgezeichnet und verarbeitet werden dürfen. Ich bin auch damit einverstanden, dass Ergebnisse und Daten dieser Studie als wissenschaftliche Publikation veröffentlicht werden. Dies geschieht in anonymisierter Form, d.h. ohne dass die Daten einer spezifischen Person zugeordnet werden können. Die vollständig anonymisierten Daten dieser Studie werden als offene Daten im Internet in einem Datenarchiv zugänglich gemacht. Damit folgt diese Studie den Empfehlungen der Deutschen Forschungsgemeinschaft (DFG) und der Deutschen Gesellschaft für Psychologie (DGPs) zur Qualitätssicherung in der Forschung.

Mir ist bekannt, dass ich meine Einwilligung jederzeit ohne Angabe von Gründen und ohne nachteilige Folgen für mich zurückziehen kann und dass ich bis zu einem Jahr nach der Studie einer Weiterverarbeitung meiner Daten widersprechen und ihre Löschung bzw. Vernichtung verlangen kann.

________________________________ ________________________________

Ort, Datum Unterschrift des/der Teilnehmers/in

Ich erkläre mich hiermit einverstanden, für Einladungen zur Teilnahme an Folge- und Kooperationsprojekten des Lehrstuhls für Klinische Psychologie und Psychotherapie unter folgender Emailadresse kontaktiert werden zu dürfen.

________________________________ ________________________________

Telefon Email

Erklärung des/der Aufklärenden:

Hiermit erkläre ich ______________________________, den/die o.g. Teilnehmer/in am __________________ über die o.g. Studie aufgeklärt und ihm/ihr diese Informationen und Einwilligungserklärung vorgelegt zu haben.

________________________________ ________________________________

Ort, Datum Unterschrift des/der Teilnehmers/in

5 Appendix G: Consent Information Study 4

Probandenaufklärung zur Studie: „Sozial-emotionales Lernverhalten in Abhängigkeit der sozialen Ängstlichkeit"

Sehr geehrte Interessentin, sehr geehrter Interessent,

bitte lesen Sie die nachfolgende Aufklärung aufmerksam durch. Im Folgenden werden Ihnen Fragestellung und Ablauf dieser Untersuchung erklärt. Sollten Ihnen Teile der Aufklärung unklar sein oder Sie weitere Informationen über einzelne Aspekte der Untersuchung wünschen, gibt Ihnen Ihr/e Untersuchungsleiter/in gerne Auskunft.
Ihre Teilnahme an dieser Studie ist freiwillig. Sie werden in dieser Studie also nur dann einbezogen, wenn Sie dazu schriftlich Ihre Einwilligung erklären. Sie können jederzeit, auch ohne Angabe von Gründen, Ihre Teilnahme beenden, ohne dass Ihnen dadurch irgendwelche Nachteile entstehen.

Wie ist der Ablauf der Studie?

Zunächst werden Ihnen Fragebögen zu allgemeinen Angaben zu Ihrer Person und zu bestimmten Ängsten vorgelegt. Das Experiment findet in virtueller Realität, d.h. in einer Computersimulation, statt. Der erste Teil beginnt mit zwei Verhaltensübungen. In diesen virtuellen Szenarien (einem voll besetzen Zugabteil sowie einem Reisebüro) werden Sie die Aufgabe haben, Ihr Recht durchzusetzen. Genauere Anweisungen erhalten Sie vor Beginn der Verhaltensübung. Sie werden auch die Möglichkeit haben, sich vorher mit der virtuellen Welt vertraut zu machen. Im zweiten Teil des Experiments treffen Sie erneut auf Personen. In dieser Situation sollen Sie sich den Personen nähern. In diesem zweiten Teil werden Sie manchmal über einen Schlauch einen kurzen, starken Luftstoß (5 bar, 10 ms) an Ihrer Backe spüren sowie über Kopfhörer ein kurzes Rauschen (103 dB, 40 ms) hören. Diese Eindrücke können für Sie unangenehm sein und Sie werden sich vielleicht erschrecken, sie sind jedoch wichtig für unsere physiologischen Messungen. Die Luftstöße sowie die Geräusche sind gesundheitlich unbedenklich. Zur Messung Ihrer physiologischen Reaktionen (z.B. Hautleitfähigkeit, Herzrate, Schreckreflex) wird Ihr/e Versuchsleiter/in Messelektroden auf Ihre Hand, ihrem Oberkörper und Ihrem Gesicht anbringen. Zusätzlich wird Ihre Stimme während des Experiments mit einem Mikrofon aufgezeichnet. Diese Daten werden streng vertraulich behandelt und nicht an Dritte weitergegeben. Zu verschiedenen Zeitpunkten werden wir Sie bitten, erneut Fragebögen auszufüllen. Der Untersuchungszeitraum umfasst ca. 1,5 Stunden und wird in nur einer Sitzung abgehalten.

Welche Risiken sind mit der Teilnahme an dieser Studie verbunden?

Während der Studie werden Sie sich mit für Sie möglicherweise schwierigen Situationen in virtueller Realität auseinandersetzen. Das kann unter Umständen anstrengend und unangenehm sein. Während der Untersuchung werden wir Ihnen eine virtuelle Welt, d.h. von einem Computer erzeugte Räume, zeigen. In seltenen Fällen kann die virtuelle Realität Übelkeit und Schwindel auslösen, ähnlich wie eine Karussellfahrt. Falls dies passiert, teilen Sie uns das bitte sofort mit.
Außerdem werden wir Hautleitfähigkeit, Herzrate und Schreckreflex messen. Vor dem Anbringen der Elektroden wird die Haut mit einer alkoholischen Lösung desinfiziert und mit einer Art Peeling behandelt. Das kann zu einer kurzfristigen Hautirritation führen. Anhaltende Folgen sind nicht zu erwarten.

Wer kann an dieser Studie teilnehmen?

Teilnehmen können gesunde Männer und Frauen zwischen 18 und 55 Jahren. Ausschlusskriterien für diese Untersuchung sind:

- das Vorliegen einer schweren körperlichen oder psychischen Erkrankung
- derzeitige psychotherapeutische Behandlung
- derzeitige Einnahme von Psychopharmaka
- das Vorliegen einer Rot-Grün Schwäche
- Schwangerschaft oder Stillzeit

Was geschieht mit meinen Daten?

Alle erhobenen Daten dienen ausschließlich Forschungszwecken, werden streng vertraulich behandelt und verschlüsselt (pseudonymisiert) unter einer Codenummer abgespeichert und verarbeitet. Die pseudonymisierten Daten werden für unbestimmte Zeit gespeichert. Der Codierungsschlüssel wird ein Jahr nach Abschluss der Studie vernichtet. Bis dahin können Sie, auch noch nach der Untersuchung, die Löschung Ihrer Daten verlangen. Die erhobenen Daten werden nach Abschluss der Studie wissenschaftlich ausgewertet und in anonymisierter Form veröffentlicht.

6 Appendix H: Informed Consent Study 4

Einverständniserklärung zur Studie: „Sozial-emotionales Lern-verhalten in Abhängigkeit der sozialen Ängstlichkeit“

Hiermit willige ich,

____

Vorname & Name der Teilnehmerin/des Teilnehmers

____

Straße & Hausnummer

____

Postleitzahl & Ort

__________________________ ______________________________

Geburtsdatum Code-Nr.

ein, an der Studie „Sozial-emotionales Lernverhalten in Abhängigkeit der sozialen Ängstlichkeit“ teilzunehmen.

Bei der Studie werde ich mit Elektroden versehen und werde Verhaltensübungen in virtueller Realität durchlaufen. Im ersten Teil des Experiments ist es meine Aufgabe in zwei unterschiedlichen Situationen mein Recht durchzusetzen. Im zweiten Teil des Experiments treffe ich erneut auf Personen und während bestimmter Abschnitte werde ich Luftstöße (5 bar, 10 ms) an der Backe verspüren sowie Töne der Lautstärke von ca. 103 dB dargeboten bekommen. Des Weiteren werde ich einige Fragebögen bezüglich allgemeiner Daten, zu bestimmten Erleben- und Verhaltensweisen sowie Ängsten ausfüllen.

Ich bin über die geplante Untersuchung ausführlich unterrichtet worden. Die Informationen über den Ablauf der Untersuchung, die möglichen Risiken der Teilnahme und den Umgang mit meinen Daten habe ich inhaltlich verstanden. Mir ist bewusst, dass es ihm Rahmen der Untersuchung zur Auseinandersetzung mit möglicherweise schwierigen Situationen in virtueller Realität kommen kann und dies unter Umständen unangenehm sein kann. Ich hatte die Gelegenheit Fragen zur Untersuchung zu stellen und diese wurden beantwortet, ich fühle mich ausreichend informiert und willige hiermit nach ausreichender Bedenkzeit in die Untersuchung ein. Mir sind die Ausschlusskriterien für die Teilnahme an der Studie bekannt und ich erkläre hiermit, dass ich keine dieser Kriterien erfülle.

Mir ist bekannt, dass ich meine Einwilligung auch noch während des Experiments ohne Angabe von Gründen widerrufen kann. Ich weiß, dass die Untersuchung wissenschaftlichen Zwecken dient und die gewonnenen Daten eventuell für wissenschaftliche Veröffentlichungen verwendet werden. Hiermit bin ich einverstanden, wenn dies in einer Form erfolgt, die eine Zuordnung zu meiner Person ausschließt. Auch diese Einwilligung kann ich binnen eines Jahres widerrufen. Die anonymisierten Daten werden für unbestimmte Zeit gespeichert. Der Codierungsschlüssel wird ein Jahr nach Abschluss der Studie vernichtet. Bis dahin kann ich, auch noch nach der Untersuchung, die Löschung meiner Daten verlangen.

________________________________ ________________________________

Ort, Datum Unterschrift des/der Teilnehmers/in

Ich wurde darüber informiert, dass ich während der Untersuchung mit einem Aufnahmegerät aufgezeichnet werde. Diese Aufzeichnungen dienen ausschließlich der wissenschaftlichen Auswertung und werden nicht an Dritte weitergegeben. Damit bin ich einverstanden.

________________________________ ________________________________

Ort, Datum Unterschrift des/der Teilnehmers/in

Ich erkläre mich hiermit einverstanden, für Einladungen zur Teilnahme an Folge- und Kooperationsprojekten unter folgender Emailadresse und / oder Telefonnummer kontaktiert werden zu dürfen.

_______________________ ________________________________

Telefon Email

Erklärung des Aufklärenden:

Hiermit erkläre ich ______________________________, den/die o.g. Teilnehmer/in am __________________ über Wesen, Bedeutung, Ablauf und Risiken der o.g. Studie mündlich und schriftlich aufgeklärt und ihm/ihr eine Ausfertigung der Information sowie diese Einwilligungserklärung übergeben zu haben.

________________________________ ________________________________

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7 Appendix I: Personal Information and Exclusion Criteria Study 1, 2, 3, 4

VP-Nr.: ______________________

ALTER	_________ Jahre		
GESCHLECHT	☐ männlich	☐ weiblich	☐ anderes
STUDIENFACH	________________________________		
STUDIENABSCHNITT	☐ Bachelor	☐ Staatsexamen	
	☐ Master	☐ Diplom	
SEHBEEINTRÄCHTIGUNG	☐ Ja	☐ Nein	
	☐ Brille	☐ Kontaktlinsen	

		Ja	Nein
1.	Sind Sie zurzeit in psychotherapeutischer, psychiatrischer oder neurologischer Behandlung?	☐	☐
2.	Hatten Sie in der Vergangenheit oder haben Sie aktuell eine behandlungsbedürftige psychische, neurologische oder schwere körperliche Erkrankung?	☐	☐
3.	Nehmen Sie gegenwärtig Psychopharmaka ein?	☐	☐
4.	Sind Sie schwanger oder stillen Sie aktuell?	☐	☐
5.	Liegt bei Ihnen eine bekannte Rot-Grün Schwäche vor?	☐	☐