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Image-Based Exposure Treatment: Subjective Fear and Skin Conductance Response Patterns in Spider Fearful Individuals

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Abstract

In the European population about one-fifth of individuals experience fear of spiders and in many cases the resulting distress interferes with everyday life. The current state-of-the art treatment option, exposure therapy (ET), shows high drop-out rates, a large variation in practice and is thus suboptimal. Therefore, we aim to develop an efficient computer-assisted ET paradigm that involves adaptation of the stimuli (images) to the individuals' fear states, which can be operationalized for example by physiological arousal, or subjective fear. The present study lays the groundwork for such a development. We exposed spider fearful individuals (*N* = 51) to a novel database comprising spider-related images, and assessed subjective fear and skin conductance response (SCR) for every stimulus. Treatment effects were examined by means of standardised pre- and post-questionnaires (Fear of Spiders Questionnaire; Spinnenangst-Screening, SAS), and by repeated collection of ratings on the variables fear, and disgust. Firstly, the results revealed habituation effects for SCR and for the SAS. Secondly, SCR and mean fear rating were identified as predictors of subjective fear by means of linear as well as non-linear machine learning models (regularised linear least absolute shrinkage and selection operator regression; ensemble of randomized trees analyses). Thirdly, high-fearful individuals reported significantly higher fear levels in response to the exposure than low-fearful individuals. Thus, it was confirmed that the novel database has a fear-inducing quality in spider-fearful individuals. In addition, it was shown that SCR patterns have a predictive value with regard to subjective fear but that further and possibly more precise predictors should be explored to eventually develop an adaptive ET paradigm. Most importantly, the study provided basic insights into the mechanisms underlying spider fear and guided the generation of objectives for follow-up research.

Keywords: computer assisted image-based exposure therapy, spider fear, spider phobia, skin-conductance response

Introduction

Fear is “the emotional response to real or perceived imminent threat” (American Psychiatric Association DSM-5 Task Force, 2013) and has repeatedly been advocated as one of the basic human emotions (Bradley & Lang, 2007). The term *basic emotions* is central to divergent theories on human emotional life and refers to a limited set of emotions that are distinct (Ortony & Turner, 1990). For example, basic emotions have been suggested to be the constituents of all other more complex human emotions (Ortony & Turner, 1990). In another instance, the term has been adopted to describe basic-level emotions that serve a fundamental function in survival and that are therefore experienced by all humans (New & German, 2015). Some of the most prominently advocated basic emotions are fear, anger, happiness, and sadness, thus fear is considered central to human emotional life (Ortony & Turner, 1990).

Importantly, fear is closely related to but must be differentiated from anxiety (American Psychiatric Association DSM-5 Task Force, 2013). Anxiety is an emotion that arises in the anticipation of (diffuse) threat in the future and is associated with a long-lived response in the form of muscle tension, vigilance, and avoidance (American Psychiatric Association DSM-5 Task Force, 2013). In contrast, fear is a short-lived emotional response to a specific and imminent threat (American Psychiatric Association DSM-5 Task Force, 2013). Fear and anxiety are both relevant in anxiety disorders, however the present study focuses on the immediate emotional response to an identifiable, present threat and thus on fear.

A fear response is an adaptation to environmental stimuli (New & German, 2015). It can be elicited by any salient cue that signifies potential harm (American Psychiatric Association DSM-5 Task Force, 2013). On the neurological level, all fear responses are initiated and mediated by a subcortical network and most importantly the amygdala (Aue, Hoeppli, & Piguet, 2012; Öhman & Mineka, 2001). Due to massive projections to distinct brain areas, as for example the hippocampus, the amygdala mediates fear-related memory, attention, and perception (Aue et al., 2012; Hartley & Phelps, 2010). The experience of fear is therefore associated with increased amygdala activity (Roth, 2005) and with arousal of the autonomic nervous system (Aue et al., 2012; Christopoulos, Uy, & Yap, 2019; Knopf & Pössel, 2009). Thus, on a psychophysiological level, fear induces an increased sympathetic tone leading, among others, to increased heart rate and blood pressure, the secretion of sweat, and changes in respiration (Aue et al., 2012; Roth, 2005). This fear response, designated as the fight-or-flight

response (Roth, 2005), can speed up decision making, facilitate quick reactions, and enhance perception (Hartley & Phelps, 2010) and memory (Christopoulos et al., 2019). It thus prepares an individual to withstand threats (Öhman & Mineka, 2001) which ultimately promotes survival.

Pathological Fear and Epidemiology

In spite of these benefits, fear responses can be maladaptive as is the case in anxiety disorders (American Psychiatric Association DSM-5 Task Force, 2013; G. C. Davey, 2004). Individuals with anxiety disorders experience autonomic fear responses and excessive subjective fear in the absence of threat (Shin & Liberzon, 2010) or for inappropriate periods of time after a threat has diminished (American Psychiatric Association DSM-5 Task Force, 2013). Fear responses can usually be controlled or modified by the individual (Hartley & Phelps, 2010) but people suffering from anxiety disorders fail to elicit such emotion regulatory processes (Christopoulos et al., 2019). They therefore develop fear of potential fear responses and prevent these by avoidance behaviour which can significantly interfere with everyday life (American Psychiatric Association DSM-5 Task Force, 2013).

An anxiety disorder can manifest in one of thirteen subtypes as classified by the Diagnostic and Statistical Manual 5th edition (DSM-V). One of these subtypes is *specific phobia*, namely "the marked fear or anxiety about a specific object or situation" (American Psychiatric Association DSM-5 Task Force, 2013). Epidemiology studies report a lifetime-prevalence of about eight to twelve percent for specific phobias (specified by DSM-V criteria) which classifies them as one of the most prevalent mental diseases in Europe (Oosterink, De Jongh, & Hoogstraten, 2009). Diagnostic criteria further subcategorize specific phobias according to their content, one of these categories being the Animal Type (American Psychiatric Association DSM-5 Task Force, 2013). Specifically arachnophobia, commonly known as spider phobia (Piercey, Charlton, & Callewaert, 2011), is the third most common of all specific phobias with a point prevalence of 2.7 percent (Oosterink et al., 2009). Aside from those individuals diagnosed with specific animal phobia, a high proportion of non-phobic individuals experience severe spider fear, too. Non-pathological spider fear is, with a point prevalence of 23 percent, even more common in the general population than spider phobia (Oosterink et al., 2009).

Theories on the Origin of Spider Fear in the Population

The high prevalence of spider fear (subclinical) and spider phobia (pathological) may be explained by variations of the biological preparedness theory: Seligman (1971) described compelling differences between classically conditioned fear and phobia (e.g. dissimilarities in response to extinction and resistancy to change). He questioned the classical conditioning approach to phobias and suggested that phobic fears are distinctive in that they are learned exceptionally easily (Seligman, 1971). As the contents of many phobic fears have always been threatening to the human species, these fears are evolutionary relevant and predisposed to develop in humans (Öhman & Mineka, 2001). This proneness to acquisition of specific fears has been called *biological preparedness* (Seligman, 1971).

In line with the theory of biological preparedness, evolutionary relevant threats have been reported to uniquely capture human attention (LoBue, 2010; Öhman, Flykt, Esteves, & Institute, 2001). For example, New & German (2015) hypothesised that the human visual system maintains mechanisms that enable a quick detection of evolutionary enduring threats. In support of this hypothesis, past studies found a strong specific visual attention capture among others for snakes (Öhman et al., 2001) and spiders (New & German, 2015). Thus, persistence of mechanisms that ensured survival in ancestral environments may serve as an explanation for the high prevalence of spider fear and spider phobia in the present. However, the object of specific phobias, such as a little spider in the corner of the bedroom, is usually no threat to survival today (New & German, 2015) and spider fear and phobia can instead be debilitating in everyday life (American Psychiatric Association DSM-5 Task Force, 2013).

Treatment

Psychotherapy offers various approaches to the effective treatment of excessive spider fear (De Jong, Andrea, & Muris, 1997). The most commonly used are variations of behavioural treatments (Davey, 2007), as for example, *systematic desensitization*, *modelling* (G. C. Davey, 2004), *counterconditioning* (Davey, 2007), and *exposure* (Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008). These behavioural treatments are usually supplemented by cognitive approaches, such as *cognitive restructuring* and *psychoeducation* (Davey, 2007).

Exposure therapy (ET) is generally seen as a gold standard for the treatment of specific phobias (Wolitzky-Taylor et al., 2008). The approach is based on the idea that confrontation with the feared object (i.e. a spider) eventually leads to a reduction in fear (Davey, 2007) and in avoidance behaviour (Healey, Mansell, & Tai, 2017). Habituation, inhibitory learning, and

extinction learning are the main mechanisms suggested to underlie the success of exposure therapies (Healey et al., 2017; A. J. Matthews, Wong, Scanlan, & Kirkby, 2011). However, researcher have been indecisive with regard to the question which of these is the fundamental mechanism of ET (Abramowitz, Deacon, & Whiteside, 2019).

Indeed, ET consistently yields large effect sizes and outperforms alternative treatments of specific phobia (Matthews et al., 2011; Wolitzky-Taylor et al., 2008). Exposure approaches vary with respect to time and phenomenology: there are single session (1 – 3 hours) versus repeated exposure approaches, prompt (flooding) versus gradual approaches, and in vivo versus imaginative, or virtual approaches (Andersson et al., 2009; Davey, 2007; Granado, Ranvaud, & Peí Aez, 2007; Matthews et al., 2011; Öst, 1989; Watson, Gaind, & Marks, 1971). In particular, in vivo exposure involves the confrontation with the object or situation in real life (e.g. touching a real spider). This approach consistently leads to high success rates and is considered superior to the approaches mentioned before (Watson et al., 1971; Wolitzky-Taylor et al., 2008).

Even though effective treatments exist, few affected individuals, and predominantly those with significant impairments seek treatment (Narrow, Regier, Rae, Manderscheid, & Locke, 1993). Potential reasons for the absence of treatment demand have been considered in the past (Wolitzky-Taylor et al., 2008). Firstly, many individuals are unaware of the treatment options available, nor do they know of the treatment success rates (Matthews, Naran, & Kirkby, 2015). In fact, a high intensity of fear brings many phobic individuals to see themselves as simply untreatable (Wolitzky-Taylor et al., 2008). Secondly, a large proportion of people affected by specific phobia deliberately avoid treatment because it usually involves exposure to the feared object or situation, which they are naturally reluctant to (Silva, Bouchard, & Belanger, 2011). Thirdly, phobic contents tend to be very *specific* and can therefore be avoided in everyday life (Wolitzky-Taylor et al., 2008). In addition, for those individuals that enter treatment, dropout rates are high because treatment can be distressing and involves (cognitive or physical) exposure to the feared object (Matthews, Scanlan, & Kirkby, 2010).

Computer Assisted Treatment

To increase the number of treatment entries and completions, computer assisted exposure therapies have been developed (Dewis et al., 2001; Matthews, Scanlan, & Kirkby, 2012). The approach involves the exposure of a patient to images or videos of the feared object or situation displayed on a screen (Piercey et al., 2011). Computer assisted exposure offers the

advantages of flexibility with respect to location, duration, and time as well as the option to self-administer the treatment (Andersson et al., 2009; Dewis et al., 2001; Matthews et al., 2015; Piercey et al., 2011). In addition, computer assisted exposure is anticipated as being more bearable than in vivo exposure. Even though this only holds for adults and not for children, it may at least encourage affected adults to enter treatment (Silva et al., 2011). Lastly, computer assisted exposure is more cost-effective and practically easier to implement than in vivo exposure (Andersson et al., 2009).

In practice, several examples of computer assisted exposure approaches have been shown to achieve considerable reductions in phobic symptoms (Matthews et al., 2012). Matthews, Scanlan, and Kirkby (2010) reported significant decreases in avoidance behaviour (behavioural avoidance test) and phobic symptomatology (fear of spider questionnaire, FSQ) in response to computer assisted exposure to spider images. Similarly, Granado et al. (2007) developed a computer assisted exposure to images and invited spider phobic individuals to repeatedly self-administer treatment over a period of four to six weeks. In comparison to a control group, the treatment group achieved clinically significant improvements on a behavioural as well as a subjective assessment scale of spider phobia. Andersson et al. (2009) offered a four-week internet-based exposure treatment for spider phobic individuals and achieved significant improvements on a behavioural assessment in 46 percent of the subjects. Also, subjects significantly improved on the self-report spider phobia questionnaire (SPQ) and results were confirmed at 1-year follow-up. Dewis et al. (2001) tested a computer assisted repeated exposure treatment for spider phobia in children and yielded significant decreases in phobic symptomatology measured by a behavioural assessment as well as the SPQ. Moreover, Olatunji et al. (2008) observed a habituation effect of physiological arousal (skin conductance level, SCL) in spider-fearful individuals in response to repeated exposure to spider videos. Taken together, the presented selection of study results shows that computer-assisted exposure is a promising approach in the treatment of spider fear and spider phobia.

A standard procedure of computer assisted treatment for spider phobic individuals does not yet exist. Treatment approaches so far differ with regard to many variables such as exposure frequency, time span, content, or type of guidance. In the past, diverse procedures and stimuli have been applied and distinct measures have been used to assess fear. Thus, past research is lacking standardization of procedures and measures with regard to computer-assisted ET. The implementation of a uniform ET paradigm based on most recent scientific

insights could strengthen control over the treatment, improve treatment outcome, and increase efficiency. Therefore, a model of fear comprising cognitive, physiological, and behavioural variables that correlate with fear-inducing stimuli should be developed. A detailed understanding of the mechanisms underlying fear could then aid in the development of an empirically grounded and standardized paradigm for computer assisted ET.

As shown by past research, a constant level of fear during exposure facilitates treatment success and is therefore worthwhile (A. J. Matthews et al., 2011). Therefore, a model of fear could be applied in an adaptive ET paradigm in which stimuli are adjusted to the individual level of fear. This would lead to a continuous demand of patients and avoid over- or underload. Specifically, patients would be exposed to stimuli that are individually threat-relevant (i.e. induce arousal) but that prevent excessive fear (i.e. a panic attack). On the long run, a model of fear could be used to implement a bio- or neurofeedback ET paradigm which trains individuals in controlling their fear response by providing them with feedback of their physiological state. Such a paradigm could lead to a highly efficient decrease in fear and therefore constitute a novel computer assisted treatment approach – also for disorders other than spider phobia. To implement a novel treatment paradigm, however, consistent research must be conducted to overcome the limitations of past research and to ground the treatment on firm scientific evidence.

Aim of the Study

The present study aimed to implement the groundwork of a validated computer assisted and adaptive ET paradigm for spider fear which requires a number of prerequisites. To continuously assess fear levels it is relevant to understand cognitive and physiological fear correlates. Based on such evaluation of the current fear state, the exposure stimulus will be adapted. This adaptation is based on a simplistic input-output model which predicts the current fear level and determines the selection of the stimulus for the subsequent trial. Thereby, the approach enables an individualized presentation of stimuli, avoiding too high or too low intensities which eventually increases the treatment efficiency. To choose adequate stimuli, an image database enclosing spider-related images hierarchically ordered by intensity and covering all intensities must be set up. Such a database can be applied to selectively present high-, low-, or medium-intensity images in the adaptive paradigm.

In pursuit of these aims, an image database enclosing spider-related images was created and empirically tested for its effects on spider-fearful individuals in the present study.

Based on the results, the image database can be adapted and supplemented for future studies. As a first step towards a model of fear, cognitive and physiological correlates of exposure-induced fear were examined to investigate the mechanisms underlying ET. The following psychophysiological variables were continuously recorded during exposure: electrodermal activity (EDA), respiration, pulse, electrocardiogram (ECG), and pupil size. Subjective fear was assessed for each single stimulus presentation. In addition, cognitive variables (subjective disgust, boredom, agitation, exhaustion, fear) were examined at four time points in the experimental procedure. The fear of spiders questionnaire (FSQ), Spinnenangst-Screening (SAS) [spider fear screening], and spider phobia questionnaire (SPQ) were administered as pre-post measures. To understand how exposure affects fear, the changes of fear correlates in response to being exposed to a large number of images and the effect of time were analysed. Moreover, it was attempted to predict subjective fear based on SCR patterns by use of linear as well as non-linear machine learning models.

Electrodermal Activity as Dependent Variable

Of the five physiological measures that were acquired, only EDA was analysed in this study. EDA is the change in electrical conductance of the skin following the secretion of sweat (Christopoulos et al., 2019). Components of EDA are skin conductance level (SCL) and skin conductance response (SCR). SCL comprises the so-called, slowly varying, tonic activity (Christopoulos et al., 2019) that also occurs in the absence of external stimuli (Boucsein et al., 2012). The present study examined SCR, which comprises phasic activity and quickly changes in response to external stimuli (Bach et al., 2018; Christopoulos et al., 2019).

The acquisition of EDA involves the application of a low but constant voltage between two points of the skin and the measurement of the current that flows between them (Boucsein et al., 2012). Changes in current flow are a direct function of the resistance of the skin (Ohm's law), which is altered by the secretion of sweat by eccrine sweat glands. Eccrine sweat glands are mainly located on palmar and plantar surfaces, where SCR is usually assessed (Boucsein et al., 2012). The sympathetic nervous system controls the opening of sweat glands via sudomotor nerve fibres (Bach et al., 2019). Activation of sudomotor nerve fibres shows a positive monotonic relationship with SCR amplitude (Bach et al., 2019). Therefore, SCR amplitude is considered an adequate proxy of sympathetic arousal (Benedek & Kaernbach, 2010) which is in turn interpreted as an indicator of psychological arousal (Bach et al., 2019). In line with this assumption, variations in emotional arousal have been associated with

changes SCR (Boucsein et al., 2012; Christopoulos et al., 2019; Lang, Greenwald, Bradley, & Hamm, 1993). Since SCR scales with the number of sweat glands that are activated by the sympathetic nervous system, higher arousal is accompanied by a stronger SCR (Christopoulos et al., 2019). Such patterns have been observed for arousal induced by natural stimuli as well as images (Lang et al., 1993).

SCR is not specific to any emotion as for example fear but it can be observed in association with distinct emotions (Boucsein et al., 2012; Christopoulos et al., 2019). Therefore, it is relevant to explore the relationship between SCR and fear induced by exposure to fear-inducing stimuli such as spider images. Only if fear is adequately operationalized, it can be modelled and selectively affected by an exposure paradigm. The results of this investigation are expected to provide insights into the dynamics of SCR in response to exposure to fear-relevant stimuli and to therefore contribute to the development of a model of fear.

Fear Ratings as Dependent Variable

In addition to bodily responses, self-reported fear ratings are a popular cognitive measure of fear. Disgust accompanies fear when spider phobic individuals are exposed to spiders in vivo (Sawchuk, Lohr, Tolin, Lee, & Kleinknecht, 2000). However, it seems that the predominant self-reported emotional response of spider phobic individuals to image- and video-based exposure is fear instead of disgust (Sawchuk, Lohr, Westendorf, Meunier, & Tolin, 2002) and interestingly, computer assisted exposure of high-fearful individuals to spider images has led to fear habituation (Matthews, Scanlan, & Kirkby, 2010; Matthews et al., 2015). Similarly, Olatunji et al. (2009) reported habituation of fear and disgust in spider fearful individuals following image- and video-based repeated exposure to threat-relevant stimuli. In the present study, subjects were therefore asked to report their subjective level of fear after each image presentation. The aim was to test the fear-inducing properties of the novel image database and to evaluate the effects of image-based exposure in a sample of spider fearful individuals.

Research Questions and Hypotheses

The main questions assessed in the present study are the following:

(1) Habituation of spider fear in response to the ET paradigm:
    a) Do subjective fear and SCR show a general habituation effect in response to exposure to the spider database?

   b) Does subjective fear show an image-specific habituation effect in response to the twofold presentation of images?

(2) Is SCR sensitive to variations in subjective fear and can fear ratings be predicted from SCR by use of a linear model?

(3) Can individuals with high spider-fear be differentiated from individuals with low spider-fear
   a) based on SCR patterns and
   b) based on subjective fear levels?

With respect to subjective fear and SCR, we expected (1a) a general habituation effect, i.e. a general decrease of both fear ratings and SCR over time (Matthews et al., 2012; Olatunji & Deacon, 2008; Watson, Gaind, & Marks, 1972), and (1b) a picture-specific habituation effect, i.e. a decrease in fear ratings between the first and the second presentation of an image (Matthews et al., 2011). In addition, (1a) a general habituation effect, i.e. significant decrease from pre- to post assessment, was expected for FSQ and SAS values as a result of the exposure treatment (Matthews et al., 2011). In line with the general decrease of trial-based fear ratings, we expected (1a) a general habituation effect for fear, i.e. a decrease among the four breaks (Matthews et al., 2012; Olatunji & Deacon, 2008; Watson et al., 1972). Furthermore, we expected (2) to find an association between SCR and subjective fear (Christopoulos et al., 2019) and aimed to examine whether fear ratings can be predicted from SCR by use of a linear model. Lastly, (3) a significantly stronger SCR as well as significantly higher fear ratings were expected for high-fear individuals in comparison to low-fear individuals (Aue et al., 2012). In addition to the above-mentioned analyses, changes among the four breaks in agitation, exhaustion, and boredom were assessed to evaluate the study setup.

Methods

Subjects

Subjects were recruited via announcements on the university webpage for study participation and via public Facebook advertisements. Ninety-five volunteers were screened by an online questionnaire. The eligibility criterion was spider fearfulness, operationalised by the sum score of the FSQ (score ≥ 24, Rinck & Becker, 2007). Exclusion criteria were non-corrected visual impairment and visual impairment corrected by glasses instead of contact lenses, past

or present neurological or psychiatric conditions, current pregnancy, and current or past excessive alcohol or drug consumption. Attachment of electrodes on the ankles as part of the experimental procedure was announced, and agreement with that procedure was another eligibility criterion.

Fifty-five eligible subjects, all residing in Austria at that time, participated in the experiment which took place between November 2019 and February 2020. As remuneration, subjects received either seven course credits or financial compensation (20,- Euros). All subjects finished the experimental procedure. Two subjects were excluded from data analysis because their FSQ-score was below 24. To estimate the participants' tendency to give random responses, catch trials were included in the experimental procedure and as exclusion criterion for data analysis a minimum of 80 percent correct responses was pre-determined. One subject did not reach that criterion and was excluded from further analysis. Another subject was excluded because of technical problems during recording. The final sample for the analysis of questionnaire and fear rating data comprised fifty-one individuals. Before the analysis of SCR, twenty-two more subjects were excluded due to insufficient SCR signal quality. The final sample for the analysis of SCR data comprised twenty-nine subjects. The descriptive statistics of both samples and the results of the pre-questionnaire are shown in

Table 1

Results of the Pre-Questionnaires per Sample

Questionnaire	Sample							
	Questionnaires and fear ratings (n = 51)				SCR (n = 29)			
	M	*Mdn*	*SD*	min-max	*M*	*Mdn*	*SD*	Min-max
Age (years)	21.71	21.00	3.07	18 – 30	20.89	21.00	2.55	18 – 28
SPQ	14.49	13.00	5.87	5 – 29	15.28	14.00	6.15	7 – 29
STAI-T	40.73	38.00	10.02	22 – 69	42.24	40.00	10.64	22 – 69
FSQ	56.02	52.50	17.65	25 – 102	57.34	54.00	19.78	24 – 102
SAS	17.44	17.00	3.69	8 – 24	17.38	17.00	3.90	8 – 24

Note. The sample for SCR data analysis comprises a reduced number of the subjects in the sample for questionnaire and fear rating data analysis. Thus, *Questionnaires and fear ratings* and *SCR* are no independent samples.

table 1. The study was approved by the Ethics Committee of the University of Vienna beforehand.

Stimuli

The experiment was coded in PsychoPy3 v3.2.4 (Van Rossum & Drake, 2009) and presented full screen (2560 x 1440 pixels) with a grey background. A database with 175 spider-related images was established. The images were derived from online platforms with free stock photos, from the Geneva Affective Picture Database (GAPED, Dan-Glauser & Scherer, 2011), and some images were self-taken. To increase heterogeneity, we pre-identified some image characteristics such as *subjective size* or *texture* of the spiders (Appendix 1) that could potentially be key drivers of fear expression. Figure 1 displays examples of spider-related images that were part of the database. Sixteen neutral images (e.g. furniture, bike) and 16 beforehand mentioned catch trials were also added to the database. In the catch trials, subjects were instructed to move an indicator (red dot) to the far left/ right end of a slider representing the rating scale. The response was rated as correct when the indicator had been placed within a 5 percent range from the correct position.

Figure 1

Examples for Different Types of Spider Images that Were Part of the Database

To minimize confound by uncontrolled variance in low-level visual properties, all images in the database were edited according to specific criteria. Low-level visual properties of images have been shown to be associated with response patterns in scene-selective regions (Watson, Hartley, & Andrews, 2014) and to affect eye-movements, preference, and cognitive load (Valtchanov & Ellard, 2015). Therefore, mean luminance of images was normalized in the hue, saturation, lightness (HSV) colour space (M_{hsv} = 0.5615, SD_{hsv} = 0.2466) and the CIELAB colour space (M_{lab} = 728.687, SD_{lab} = 174.884). Luminance matching was performed with the Spectrum, Histogram, and Intensity Normalization and Equalization

(SHINE) colour toolbox (Dal Ben, 2019), an adaptation of the SHINE toolbox (Willenbockel et al., 2010) implemented in MATLAB 9.7 (The MathWorks, 2019). In addition, images were adjusted for size (600 x 800 pixels). Even though no eye tracking data were analysed in the present study, luminance and size matching was relevant because the aim of the project is to implement a database that can flexibly be used in research as well as practice and in other settings.

Seventeen of the spider-related images were presented twice to each participant to assess potential changes in cognitive and physiological measures elicited by the repeated presentation. Image presentation was completely randomized and split into four equal blocks separated by short breaks. In total, each individual completed 228 trials (Table 2). The 16 neutral images were additionally employed for practice trials that preceded the experiment.

Table 2

Content and Frequency of Experimental Trials

Categories	*n*
Spider-related images	175
Spider-related images presented twice	17
Neutral images	16
Catch trials	16
Pauses	4
Total	228

Measures

Fear Estimates

Each fear stimulus was presented for five seconds. After stimulus presentation, subjects were asked to indicate the degree of fear the image had elicited. The instruction was given in writing on screen. The rating was made by moving an indicator via computer mouse across the horizontal rating scale. The left and right extremes of the rating scale were defined as ‘no fear’ and ‘a lot of fear’, respectively. Ratings were made self-paced. The responses on the continuous rating scale were recorded as values between 1 and 100. In total, 224 fear estimates were recorded for each subject.

Physiological Data

Physiological signals were amplified by use of the 16-channel BrainAMP ExG MR (Brain Products GmbH, Gilching, Germany) and recorded continuously with a sampling rate of 5000 Hertz (Hz). The BrainVision Recorder (Software version 1.22.0101, Brain Products GmbH, Gilching, Germany) was used to filter and digitize the signals. Online, the signals were subjected to a low cutoff filter of 10 Hz and a high cutoff filter of 250 Hz. These filters trim the amplitude of low and high frequency digitized signals, respectively (*BrainVision Recorder User*

Manual Software version 1.22., 2019). Amplitude resolution was set to 0.5 microvolts (µV) and data was sent from the amplifier to the recorder across a range of ± 16.384 millivolts (mV).

EDA was assessed by application of the GSR MR set, which comprises the GSR MR Module, skin conductance electrode paste, and a pair of Ag/AgCl sintered MR electrodes (BrainProducts GmbH, Gliching, Germany). The electrodes were placed on the inner mid-segment of the index and middle fingers of the non-dominant hand. Online low cut-off filters were set to DC and online high cut-off filters were set to 250 Hz. A signal resolution of 152.6 µV and a range of ±5000 mV were specified. The relevant skin sections were cleaned beforehand by use of alcohol, NuPrep skin prep gel, water, and a dry cloth. To increase signal quality and decrease noise, EDA electrodes were additionally fixated with tape and a strap on each finger and the arm was put on a pad which prevented contact between the surface of the table and the electrodes.

Questionnaires

The four standardized questionnaires described in the following sections were administered during screening (pre). SAS and FSQ were additionally administered after the task (post). Potential changes following exposure were assessed based on the difference between the pre- and post-scores.

Spider Phobia Questionnaire (SPQ). The SPQ has been developed to evaluate spider phobia on three different dimensions, which are vigilance, preoccupation, and avoidance-coping (Rinck et al., 2002; Watts & Sharrock, 1984). Each dimension is measured on an individual scale. The SPQ is a frequently used measure that has been translated into various languages (Olatunji et al., 2008). In the present study, the German translation (Rinck et al., 2002) of the English language original (Watts & Sharrock, 1984) was administered. The questionnaire consists of 43 questions which are answered in a binary response format (yes/no). Vigilance is measured by twelve items, preoccupation is measured by eleven items, and avoidance-coping is measured by ten items. The remaining ten items, namely five cognitive-behavioural questions and five questions on spider knowledge, are not assigned to a scale. Further, five questions are inversed-scored. After inversion of those responses and exclusion of the ten unscaled items, the sum of all positively answered questions results in the individual SPQ score. Scores can range between 0 and 33 and higher scores indicate stronger fear.

As an indicative reference, Rinck et al. (2002) reported a mean SPQ score of 3.2 (*SE* = 2.5, range 0 - 10) for a non-phobic control group and a mean SPQ score of 16.7 (*SE* = 6.2, range 6 - 28) for a spider-phobic group classified by DSM-V criteria for specific phobias. Good internal consistency (Cronbach's $\alpha < .80$) as well as very good test-retest reliability ($r_{tt} = .94$ for a one week interval), and good criterion validity (based on discriminant ability between spider fearful individuals and controls) have been reported for the German version of the SPQ (Rinck et al., 2002).

Fear of Spiders Questionnaire (FSQ). To assess spider fear and spider fear-related behaviour, the German version of the FSQ was administered (Rinck et al., 2002). The FSQ has been developed as a supplement of the SPQ (Szymanski & O'Donohue, 1995). It is a self-report questionnaire consisting of 18 items. Each item consists of a statement regarding spider-related behaviour or spider-related attitudes. Subjects indicate their individual agreement with each item on a 7-point Likert-Scale. Responses are added to an individual sum score which can take any value from 0 to 108. Rinck & Becker (2007) consider individuals with a FSQ score below or equal to eight as non-anxious and individuals with a FSQ score above or equal to 24 as spider-fearful. Independent studies approve construct validity of the FSQ as it adequately discriminates between phobic and non-phobic individuals (Szymanski & O'Donohue, 1995).

Spinnenangst Screening (SAS). The SAS is a 4-item questionnaire that has been constructed to increase efficiency of assessment in large samples by lowering the number of questions. Individuals indicate the degree of applicability of four spider-related statements on a 7-item Likert-Scale which results in a sum score between 0 and 24. Individuals with a minimum SAS score of five are considered as *low-fearful* and individuals with a minimum SAS score of 15 are considered as *high-fearful* (Rinck & Becker, 2007). Same as the SPQ, Rinck et al. (2002) report very good internal consistency (Cronbach's $\alpha < .90$), good test-retest reliability ($r_{tt} = .88$ for a one week interval), and good criterion validity (based on discriminant ability between spider fearful individuals and controls) for the German version of the SAS.

State-Trait-Anxiety Inventory - Trait (STAI-T) Form Y. The STAI is a self-report questionnaire which attempts to assess anxiety on two scales, namely, the *state-anxiety* and the *trait-anxiety* (T-anxiety) scales (Spielberger, Gorsuch, & Lushene, 1970). In the present study the German version of the 20-item T-anxiety scale was administered (Laux, Glanzmann, Schaffner, & Spielberger, 1981). It measures individual differences in permanent, dispositional

levels of anxiety. Higher levels on T-anxiety indicate a stronger propensity to experience anxiety and to make threat-appraisals in stressful situations (Spielberger et al., 1970). Individuals indicate how the 20 different anxiety related statements apply to them on a 4-point Likert-Scale ranging from 'almost never' (score 1) to 'almost always' (score 4). Seven items are inversed and need to be reversed before estimation of the individual score. The trait anxiety score is the sum of weighted responses, which can spread from 20 to 80.

The STAI-T is a well-established measure that is used in research as well as clinical settings (Bieling, Antony, & Swinson, 1998). Bieling, Antony, & Swinson (1998) reported a mean STAI-T score of 47 (*SD* = 13.51) for patients with specific phobia and a mean STAI-T score of 33 (*SD* = 6.32) in a non-clinical control group. These results are in line with the norms provided by the Manual for the State-Trait Anxiety Inventory (healthy adults *M* = 35 – 41; male neuropsychiatric patients with anxiety reactions *M* = 48, Spielberger et al., 1983).

Break Questionnaire. Image presentations were intermitted by breaks (after 56 trials) which comprised paper-pencil questionnaires. In the break questionnaires, fear, agitation, disgust, boredom, and exhaustion were assessed on a 11-point rating scale that ranged from 0 (minimal degree of respective condition) to 10 (maximal degree of respective condition). The breaks were self-paced. After completion of the questionnaires, subjects were instructed to autonomously start the next experimental block by mouse click.

Procedure

Experimental Setup

An experimental session lasted 90 to 120 minutes. Experiments took place between 8:00 am and 20:00 pm and the lightning conditions of the room were kept constant. The experiment was conducted by an experimenter and an assistant. The experimenter was responsible for the social and especially verbal interaction with subjects. The assistant provided support in the preparation of physiological measures and was responsible for initiation of the software programs. Three researchers were trained to take both roles in the standardized experimental procedure and it was strived for a roughly equal role allocation. Verbal instructions and small talk initiated by the experimenter during the preparation of physiological measures were standardized. Questions to commence small talk were (1) 'How did you find out about the experiment', (2) 'What is your field of study?', and (3) 'Do you have plans for the upcoming holidays'.

Upon arrival subjects signed the informed consent and received a short written description of the course of the experimental session. Then, the physiological measurements were prepared. First, the respiration belt was attached, then the subject was asked to sit down, and the mobile eye-tracker was put on. The relevant skin sections for ECG and EDA measures were cleaned and electrodes were applied respectively. Lastly, the pulse detector was attached, and the non-dominant hand was put into position on the pad.

Subjects were positioned centrally in front of the screen and were instructed to take a relaxed sitting position which would allow them to stay inert. Then the eye-tracker was prepared: The angle of the front camera and positioning of both eye-tracking cameras were adjusted. As soon as a stable confidence level of 1.0 for pupil detection was achieved, calibration and an accuracy check were performed. Then, a visual signal check was done for the remaining measures (ECG, EDA, pulse, respiration) and to ensure correct acquisition of the signals, sanity checks were performed. In case of inconsistencies, the affected measure was renewed (i.e. cleaning and readjustment of electrodes) and signal as well as sanity checks were repeated.

When the setup was finished, subjects received a detailed verbal and written introduction into the experimental procedure. To avoid confound by training effects, a practice trial with five randomly chosen neutral images was completed. Subjects could ask questions and received verbal feedback from the experimenter. After the practice trial, subjects were once again instructed to keep an inert position during the experimental trials and to focus on the content of the images (i.e. to avoid cognitive distraction). A partition wall was placed between the subject and the researchers to avoid experimenter effects. The experimenter and assistant stayed within the experimental room, however.

Experimental Procedure

The experiment started with a relaxation period of 90 seconds and the presentation of a mountainside on screen. Then, the first of four blocks of 56 images was automatically initiated. A fixation cross was presented for 3 to 5 seconds before each image presentation. Images were presented for 5 seconds, succeeded by the self-paced fear-rating. Then the next trial started again with a fixation cross. After the first block, a break questionnaire was administered and the next block starting with another relaxation period was individually initiated by the subjects. The last block was also followed by a break questionnaire and a relaxation period. After the experiment was finished, all sensors and electrodes were

removed from subjects and the post-questionnaire was administered on screen. Finally, subjects were debriefed and received their compensation.

Data Analysis

Pre-processing of questionnaire and fear rating data as well as the analyses and construction of graphs were done by use of R-Studio version 1.1.463 (RStudio Team, 2016) which is an integrated development environment for R (version 3.6.3; R Core Team, 2017). Before the analysis of SCR data and fear ratings, the trials which involved catch trials, neutral images, and pauses were removed from the data. All analyses were conducted using an alpha level of 0.05. Tests for the presence of outliers and extreme cases were done by use of boxplot methods (R function identify_outliers). If not stated otherwise, the Shapiro-Wilk test was applied to test for normal distribution of data and the results of all Shapiro-Wilk tests are reported in Appendix 2.

Pre-Processing of SCR Data

SCR data was assessed to draw conclusions on the psychological arousal (i.e. fear level) that was evoked by the experimental procedure. Thus, SCR was used to deduce fear level which is a psychological construct and cannot be observed directly. This inverse inference is based on the assumption that psychological arousal due to fear is closely related with sympathetic arousal (sudomotor nerve activity) which evokes SCR (Bach & Friston, 2013). To achieve the inverse inference, we used the model-based approach of processing SCR signals offered by the Psycho-Physiological Modelling (PsPM) toolbox version 4.2.1 (Bach et al., 2019) which is implemented in MATLAB 9.7 (The MathWorks, 2019).

PsPM models the relationship between the psychological variable and the SCR as a linear time invariant (LTI) system that takes an empirically validated canonical response function as a transfer function that converts the input (the trials modelled as a boxcar function) into the output (the SCR). Concretely, we created one general linear model (GLM) with three regressors: one for the trial of interest, one for all the other trials and one constant. We repeated this process for each trial and each subject. We used this trial-wise analysis as opposed to the most intuitive approach of fitting all the trials of one subject by a single GLM because it was proven to be more accurate in a simulation analysis on fMRI data (Mumford, Turner, Ashby, & Poldrack, 2012). The resulting beta values estimated by each GLM represent the most likely estimate of the amplitude of the signal that can be attributed to each stimulus. Therefore, SCR was operationalized by beta values in the statistical analysis.

Measurement of SCR is prone to artefacts due to movements on the electrode. Therefore, quality checks were performed by visual inspection of the data and those cases showing excessive noise or artefacts were discarded. This procedure resulted in the above-mentioned exclusion of twenty subjects from the analysis of SCR data.

Statistical Analysis

Research Question 1: Habituation

To test for general habitation effects, fear ratings, SCR, FSQ and SAS scores, and the break-questionnaire fear ratings were separately assessed for changes over time (1a). To test for image-specific habituation effects, fear ratings were examined for differences between the first and the second image presentations (1b).

General Habituation: Fear Ratings. The sample mean of fear ratings was determined per trial. A Spearman correlation coefficient was employed to determine the relationship between trial and mean fear ratings. In addition, a linear regression analysis with trial as predictor variable was performed to assess the changes of fear ratings over all trials. The assumptions of the simple linear regression model (linearity of relationship between dependent and independent variable; normality of residuals; homogeneity of variance of residuals; independence of error terms of residuals) were tested by means of visual inspection of the respective plots.

General Habituation: SCR. Similarly to the fear rating analysis, the sample mean of beta values was determined per trial, it was tested for potential outliers of the distribution of means, and it was tested for normality of the distribution. The Spearman correlation coefficient was employed to determine whether trial correlated with mean beta values. In addition, a linear regression analysis with trial as predictor variable was performed to assess the changes of SCR over all trials. The assumptions of the simple linear regression model were tested by means of visual inspection of the respective plots.

General Habituation: Pre-Post Questionnaires. To determine whether spider fear significantly decreased from before to after the exposure, the SAS difference scores and the FSQ difference scores were estimated by subtracting the individual pre-scores from the respective post-scores per person and per trial. For each of the two questionnaires a paired t-test was employed to test whether the differences between mean pre- and post-scores were significant.

General Habituation: Break Questionnaire, Fear. The fear ratings collected at the four measurement time points (breaks) were subjected to a non-parametric Friedman test to examine the null hypothesis that the mean fear scores did not differ between time points. Importantly, four additional variables were assessed by the break questionnaires and examined for changes over time (exploratory analysis). Multiple comparisons increase the familywise error rate, which is the probability of incorrectly rejecting the null hypothesis (Type I error) in at least one of the multiple hypothesis tests. Therefore, a Holm-Bonferroni correction for multiple comparisons was performed per test by adjustment of the corresponding p-value. A Kendall's W (coefficient of concordance) test was performed as a measure of effect size.

Image-Specific Habituation: Fear Ratings. To assess a potential decrease in fear ratings after the twofold presentation of images, the difference scores of fear ratings were calculated per trial and subject (1^{st} fear rating – 2^{nd} fear rating). The non-parametric Wilcoxon signed rank test was applied to test the null hypothesis that the median difference between the first and the second fear rating was zero. In addition, the effect size r was estimated.

Research Question 2: Relationship Between SCR and Subjective Fear

The sensitivity of SCR to variations in subjective fear was determined by use of a correlation analysis between beta values and fear ratings. The distribution of beta values and fear ratings were separately tested for normality. The data set comprised 192 data points per each of the 29 subjects. Therefore, the Shapiro-Wilk test, which tends to result significant for large sample sizes (> 5000) could not be applied. Instead, the Anderson Darling test of normality was performed and in the following, the non-parametric Spearman correlation coefficient was determined. To test whether SCR linearly predicts fear ratings, a simple linear regression model was built with beta values as predictor of fear ratings. However, in the simple linear regression model, all data points (5568 beta values and respective fear ratings) were treated equally in that it was neither controlled for individual variability (i.e. 192 exposure trials within each subject) nor for the stimuli specific variability (i.e. presentation of same stimuli to all subjects). To account for this limitation of the simple linear regression, a linear mixed model with fear rating as dependent variable was built using the lme4 package (version 1.1-23). Random intercepts and slopes were included per subject and per image.

Based on the results of these analyses, an exploratory analysis was performed to assess whether fear ratings could be predicted from beta values by use of machine learning

approaches (Python 3.7.7., scikit-learn 0.22.2). Firstly, data were subjected to a Least Absolute Shrinkage and Selection Operator (LASSO) regularised linear regression with fear ratings as target. As predictors, beta values and the order of image presentation were added to the LASSO regression. The variable *order of image presentation* was used to account for the repeated presentation of images within as well as between individuals. Instead of order of image presentation, the variable *image ID* could have been entered as predictor into the model. However, image ID was a categorical variable and would have produced 192 dummy coded variables. To avoid such circumstance, the order of image presentation was applied as predictor. In addition, two more variables were added as predictors to the model: the presentation time of the fixation cross (cross jitter) and the reaction time of the participant when making the fear rating. To assess whether a non-linear model yielded a more precise prediction of the target, the data were subjected to an ensemble of randomized trees (ERT) analyses. The analysis comprised the same features (beta value, presentation order, jitter of the fixation cross, reaction time) and target (fear rating) as the LASSO regression.

To examine whether the results of the two models were replicable after control for repeated measures, the variable *subject ID* was used to control data separation in the nested cross-validation of both models. Apart from this, the LASSO regression and the ERT analyses were performed in the same manner as beforehand. In addition, these analyses (LASSO regression and ERT analyses with and without control of data separation in cross validation) were repeated after inclusion of the feature *mean image rating*.

To estimate the model fit and the complexity of each model, a nested cross-validation was performed per each of the above-mentioned analyses (LASSO regressions; ERT analyses). The term *model fit* refers to the degree to which the model can predict the target (fear rating). The inner cross-validation encompassed the random partitioning of the data into 90 percent training data and 10 percent test data. This process was repeated 50 times with the aim to estimate the tuning parameter. The outer cross-validation comprised the same data partitioning as the inner cross-validation and was repeated 100 times with the aim to assess the model fit. Feature importance was evaluated by means of a group shuffle split (repeated 100 times): the target was replaced by a randomized array of its values and the change in the proportion of explained variation from the original feature to the randomized feature was observed. The performance of the final model was compared to a trivial predictor, namely the mean fear rating across all 100 models produced in the nested cross-validation. Thus, a model

with a coefficient of determination (R^2_{avg}) of the value zero would predict fear ratings equally well as a model using the mean fear rating as the only predictor.

Research Question 3: Low- Versus High-Fearful Individuals

SCR. To test whether low-fearful individuals could be differentiated from high-fearful individuals based on SCR, a medium split of the sample for SCR analysis (*N* = 29) was done based on pre-FSQ values (*Mdm* = 54). Subjects with a pre-FSQ value of maximum 54 were classified as *low-fearful* individuals (*n* = 15) and subjects with a pre-FSQ value of minimum 55 were classified as *high-fearful* individuals (*n* = 14). To ensure independence of data within each group, the mean beta value was estimated per subject and used for further analysis. The non-parametric Figner-Killeen Test of homogeneity of variances was employed to test the null hypothesis that the variance is equal across the two groups. Finally, the non-parametric Kruskal-Wallis test was applied to test the null hypothesis that beta values of high- and low-fearful individuals are the same.

Fear Ratings. To test whether low-fear individuals could be differentiated from high-fear individuals based on subjective fear, a medium split of the sample for SCR analysis (*N* = 51) was done based on pre-FSQ values (*Mdm* = 52). Subjects with a pre-FSQ value of maximum 52 were classified as *low-fearful* individuals (*n* = 26) and subjects with a pre-FSQ value of minimum 53 were classified as *high-fearful* individuals (*n* = 25). To ensure independence of data points within each group, the mean fear rating was estimated per subject and used for further analysis. The non-parametric Figner-Killeen Test of homogeneity of variances was employed (H_0: The variance is equal across the two groups). To test the null hypothesis that fear ratings of high- and low-fearful individuals are the same, the non-parametric Kruskal-Wallis test was applied.

Exploratory Analyses

The remaining variables assessed by the break questionnaires (agitation, exhaustion, boredom, disgust) were examined for changes among the four time points. Per variable, a non-parametric Friedman test was employed to test the null hypothesis that the mean scores of the respective variable significantly differ between time points. For the above-mentioned reason, a Holm-Bonferroni correction for multiple comparisons was performed per test by adjustment of the corresponding p-value. In addition, as a measure of effect size, Kendall's W was estimated for each variable.

Results

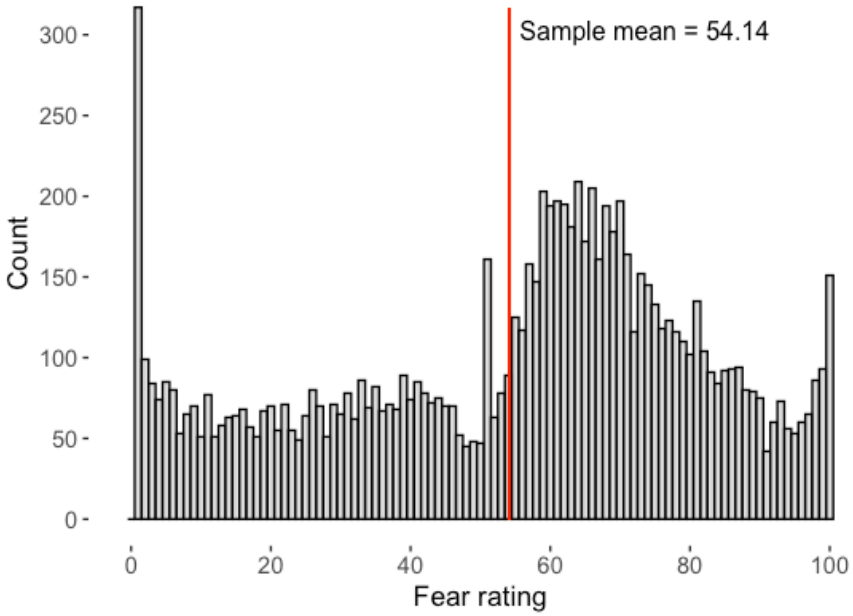
Research Question 1: Habituation

Fear Ratings

The distribution of fear ratings in the sample (*n* = 51) is shown in figure 2. The mean fear rating data comprised no extreme cases. The Spearman Correlation coefficient revealed that trial and mean fear ratings were not significantly correlated, $r_s(190) = -0.093$, $p = .20$. A simple linear regression model was built with trial as predictor of fear rating. As could be expected based on the Spearman Correlation coefficient, the regression equation yielded no significant result ($F(1, 190) = 0.93$, $p = .336$, $R^2 = 0.005$). The assumptions of the model were accepted based on visual inspection of the residual plots (Appendix 3). The distribution of mean fear ratings per trial and the regression line of the simple linear model are displayed in figure 3.

Figure 2

Distribution of Fear Ratings in the Sample (*n* = 51)



SCR

A similar analysis was performed to test for a general habituation effect of SCR. One outlier was identified as an extreme case and was removed from the data. The non-parametric Spearman rank correlation coefficient revealed a small association between trial and sample mean beta value, which was highly significant $r_s(189) = -0.26$, $p < .00$. Moreover and in line with the hypothesis of a general habituation effect, the regression equation of the simple linear regression model was highly significant ($F(1, 189) = 15.32$, $p < .00$, Figure 4). The assumptions of the model were accepted based on visual inspection of the residual plots (Appendix 4).

Pre- Post Questionnaires

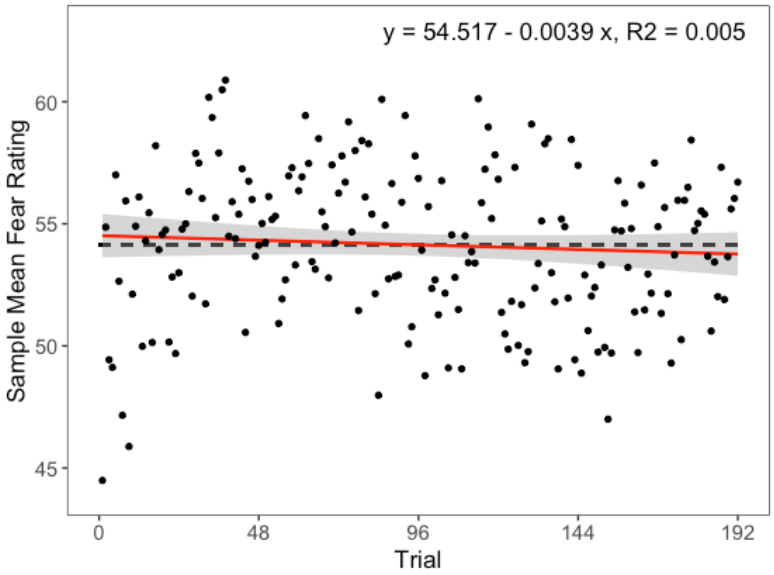
The FSQ difference scores comprised no outliers. A paired t-test for FSQ scores yielded no significant difference between pre- and post-values. The distribution of SAS difference scores comprised one outlier, which was no extreme case and therefore remained in the data. The paired t-test for SAS scores revealed a significant difference between mean pre- and post-values. The results of both paired t-tests are displayed in figure 5 and the numeric output is presented in Appendix 5.

Break Questionnaire, Fear

The fear ratings did not comprise any outliers at neither of the four time points. The results of the Friedman test revealed no significant changes of fear ratings across the four measurement

Figure 3

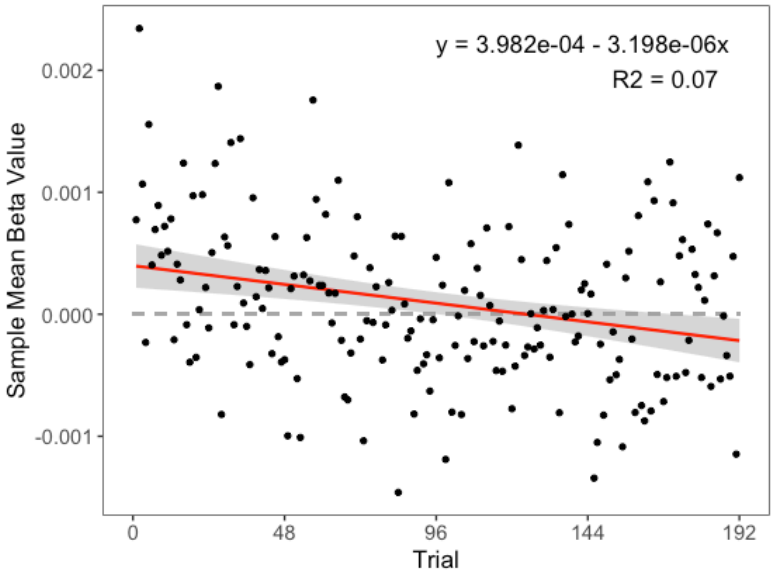
Scatterplot of Sample Mean Fear Ratings per Trial and Regression Line of the Simple Linear Regression Model



Note. The dashed line represents the grand sample mean of fear ratings (y = 54.137).

Figure 4

Scatterplot of Sample Mean Beta Values per Trial and Regression Line of the Simple Linear Regression Model



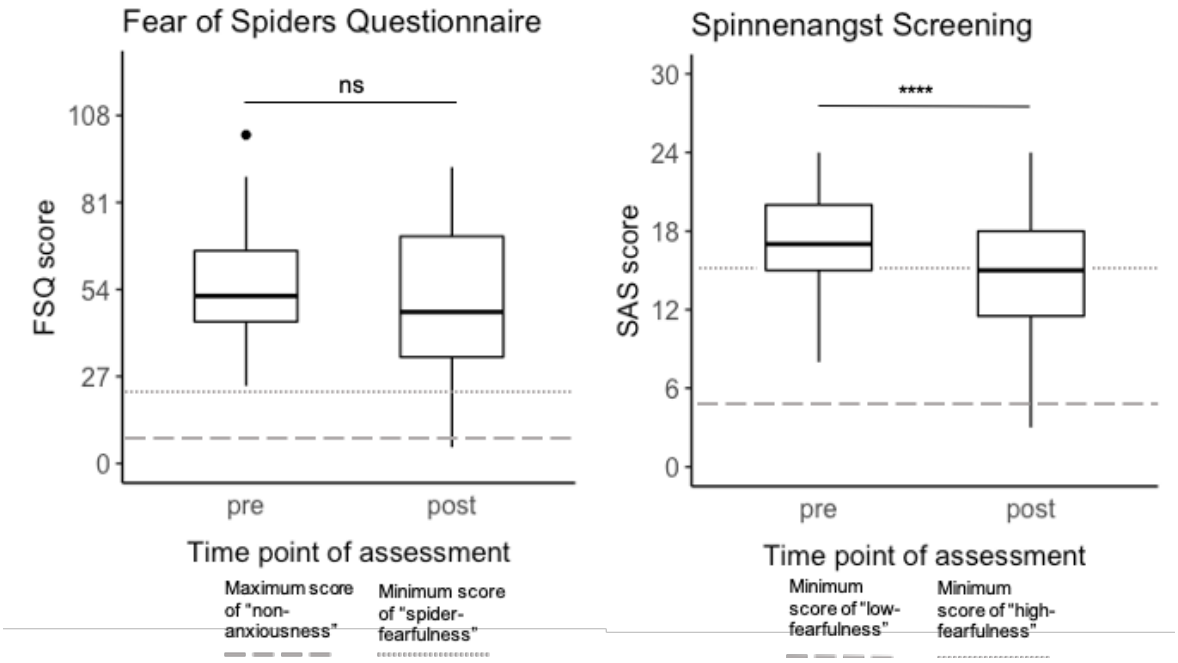
Note. The dashed line represents the point where there is no SCR (y = 0.000).

occasions ($x^2(3) = 6.50$, $p = .09$, $p_{\text{Holm-Bonferroni}} = .27$). A Kendall's W test rendered a small effect size (W = .04).

Image-Specific Habituation: Fear Ratings

Figure 5

Distribution of Pre- and Post-Scores of the SAS and FSQ and Results of the Paired t-Tests



Note. ns = not significant, **** $p < .0001$

The non-parametric Wilcoxon signed rank test revealed that the paired differences between the first and second ratings of twofold presented images were non-significant ($Mdn_{\text{1st fear rating}} = 59$, $Mdn_{\text{2nd fear rating}} = 58$, z = -0.25, $p = 0.80$). The test rendered a small effect size (r = .008).

Research Question 2: Relationship Between SCR and Subjective Fear

The results of the Anderson Darling tests of normality were highly significant for fear ratings ($p < .00$) as well as for beta values ($p < .00$). Therefore, it could not be assumed that the data came from normally distributed populations and the non-parametric Spearman correlation coefficient was performed to assess the relationship between the two variables. The Spearman correlation coefficient yielded a significant result and indicated a positive relationship between beta values and fear ratings, $r_s(5566) = 0.18$, $p < .00$. The simple linear regression equation yielded a highly significant result ($F(1, 5566) = 137.6$, $p < .00$), with a proportion of explained variation (R^2) of 0.024.

To account for the beforehand mentioned limitation of the simple linear regression, the data were subjected to a linear mixed model. Random intercepts and slopes were included per subject and per image. Thereby, individual variability and stimuli specific variability were taken into account. The assumption of normality of residuals was accepted after visual inspection of the quantile-quantile-plot (Appendix 6). To test for linearity in the independent variable, the residuals were plotted against the outcome variable (Appendix 6), which revealed that the assumption of linearity was violated. The assumption of equal variances of residuals across groups was tested by visual inspection of the residuals versus fits plot, which revealed that the assumption of homogeneity of variances of residuals was violated (Appendix 6).

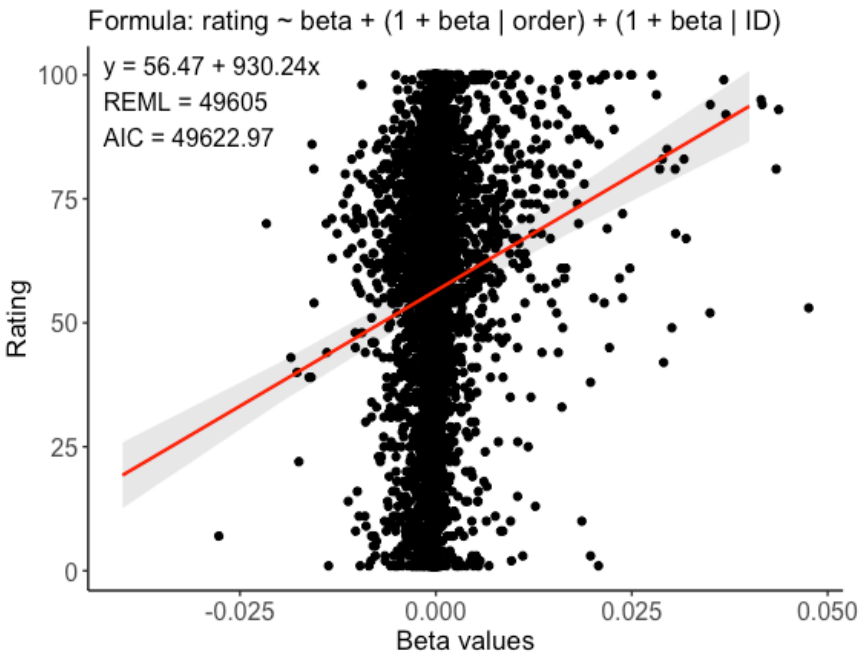
With the aim to implement a linear relationship, a non-linear transformation of beta values was performed ($\log_2(x)$). It was accounted for the fact that there were negative as well as positive values (if beta value = 0, then $\log_2(1)$; if beta value < 0, then - $\log_2$ (absolute beta value); if beta value > 0, then $\log_2$ (beta value)). The data transformation did not yield the expected result, as the assumptions of linearity and of homogeneity of variances were again rejected based on visual inspection of the residual plots (Appendix 7). Therefore, it was concluded that fear ratings could neither be predicted from beta values by use of a simple linear regression, nor by use of the linear mixed model. Figure 6 displays the scatterplot and regression line of the linear mixed model, which clarifies that conclusion.

Using LASSO regularised linear regression on average two percent of the variance could be explained and the model predicted significantly better than the trivial predictor (R^2_{avg} = .02, *SD* = .01, *Mdn* = .02, $p < .00$). The evaluation of feature importance revealed that the variable beta value was the only relevant predictor of rating and responsible for all the explained variance of the data. The proportion of explained variation of the variable beta value was reduced by approximately 1.0 in all models. Meanwhile, the proportion of explained variation of the remaining predictors (presentation order, jitter of the fixation cross, reaction time) did not show any meaningful changes in response to the group shuffle split. Thus, beta value was identified as a sensible predictor of fear ratings.

The ERT analyses – comprising the same features (beta value, presentation order, jitter of the fixation cross, reaction time) and target (fear rating) as the LASSO regression – yielded significantly better predictions of fear ratings than the trivial predictor and the model explained on average four percent of the variance (R^2_{avg} = .04, *SD* = .01, *Mdn* = .04, $p < .00$).

Figure 6

Scatterplot of Beta Values and Ratings and Regression Line of the Linear Mixed Model



Again, beta value was identified as a meaningful predictor of fear rating. The estimation of feature importance also revealed that presentation order was in at least 50 percent of the models a relevant predictor of the target. However, taking into account all models, the variable was presumably still no significant predictor. The remaining features (jitter of the fixation cross, reaction time) were no significant predictors of fear ratings either.

The results of the LASSO regression with control of data separation in cross validation revealed that the prediction of the models was no better than that of the trivial predictor (R^2_{avg} = - 0.14, *SD* = .19, *Mdn* = - 0.07, *p* = 1.0). Similarly, the ERT analyses with control of data separation in cross validation did not yield better predictions of fear ratings than the trivial predictor (R^2_{avg} = - .17, *SD* = .26, *Mdn* = - 0.08, *p* = 1.0). Therefore, the LASSO regression as well as the ET analysis were performed again using an additional predictor.

The novel feature added to the analyses was *mean image rating*. Again, data separation in cross validation was first not controlled. The LASSO regression yielded significantly better predictions of fear ratings than did the trivial predictor (R^2_{avg} = .30, *SD* = .03, *Mdn* = .30, *p* < .00). Similarly, fear ratings could be significantly better predicted from the ERT analyses without control of data separation than from the trivial predictor (R^2_{avg} = .29, *SD* = .04, *Mdn* = .30, *p* < .00). Both analyses (LASSO regression and ERT analyses) identified mean image rating and beta value as relevant predictors of the target even though the importance

of the features strongly differed (proportion of reduction $R^2_{\text{mean image rating}} < .80$, proportion of reduction $R^2_{\text{beta value}} < .20$).

The analyses with the additional feature mean image rating were repeated with control of data separation in cross validation by use of subject ID. The LASSO regression yielded significantly better predictions of fear ratings than did the trivial predictor and on average 18 percent of the variance could be explained ($R^2_{avg} = .18$, *SD* = .27, *Mdn* = .22, $p < .00$). The most relevant predictor was mean image rating: the reduction in the proportion of explained variation after the group shuffle split was above 0.8 for all models. Beta value was again a significant predictor of fear rating but the proportion of explained variation of beta value decreased by less than 0.2 in all models after the group shuffle split. As in the previous analyses, the remaining three features did not yield any sensible predictions of fear ratings. The ERT analyses were performed by use of the same features as in the LASSO regression and subject ID was applied to control for data separation in cross-validation. The results revealed that fear ratings could significantly better be predicted from the applied features than from the trivial predictor and on average 21 percent of the variance could be explained ($R^2_{avg} = .21$, *SD* = .27, *Mdn* = .26, $p < .00$). Similarly to the results of the LASSO regression, the most relevant predictor was mean image rating. In 50 percent of the models beta value was a relevant predictor, too.

Research Question 3: Low- Versus High-Fearful Individuals

The result of the non-parametric Figner-Killeen test was non-significant ($p = 0.57$), thus the assumption of homogeneity of variances of beta values was accepted. The results of the non-parametric Kruskal-Wallis test indicated no difference between the SCR of low- and high-fearful individuals and the effect size was small (Figure 7).

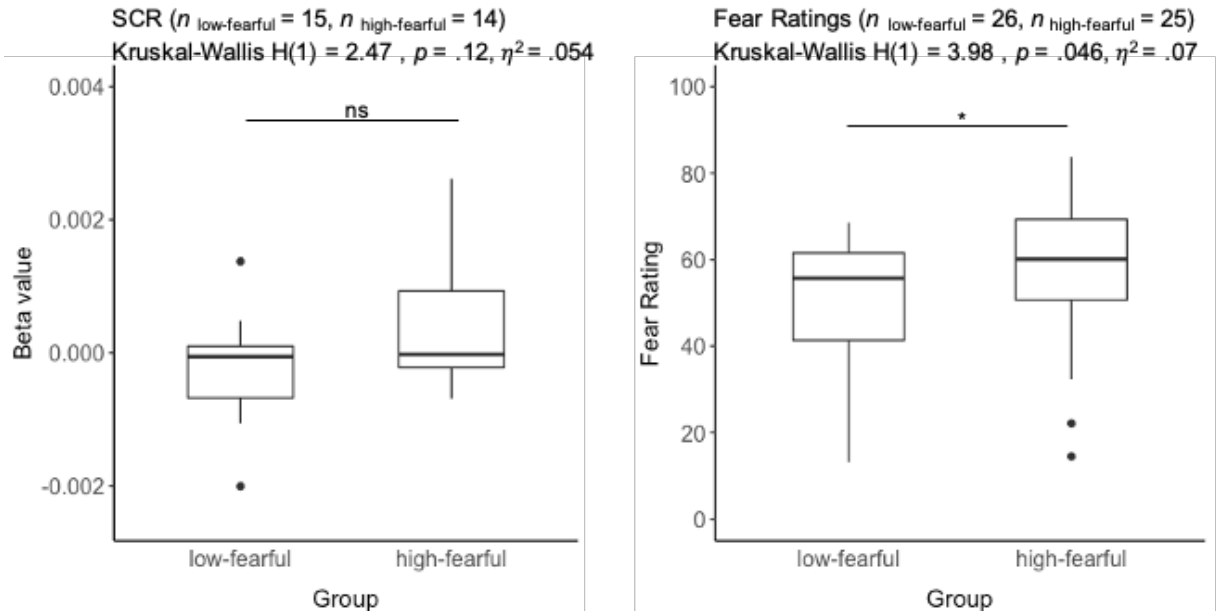
The result of the non-parametric Figner-Killeen test indicated a homogeneity of variances for fear ratings ($p = .54$). The results of the Kruskal-Wallis test yielded a significant difference between the fear ratings of the two groups and a medium effect size (Figure 7). Appendix 8 displays the descriptive data of SCR and fear ratings for each group.

Exploratory Analyses

The non-parametric Friedman test was employed to assess the changes among measurement time points per variable (Figure 8). *Disgust* ratings did not comprise any outliers. The Friedman test revealed no significant differences among disgust ratings of the different time points ($x^2(3) = 4.61$, $p = .20$, $p_{\text{Holm-Bonferroni}} = .41$) and the effect size was small (W = .03).

Figure 7

Results of the Kruskal-Wallis tests for Beta Values and Fear Ratings



Note. Individual mean beta values and individual mean fear ratings were employed for analysis.

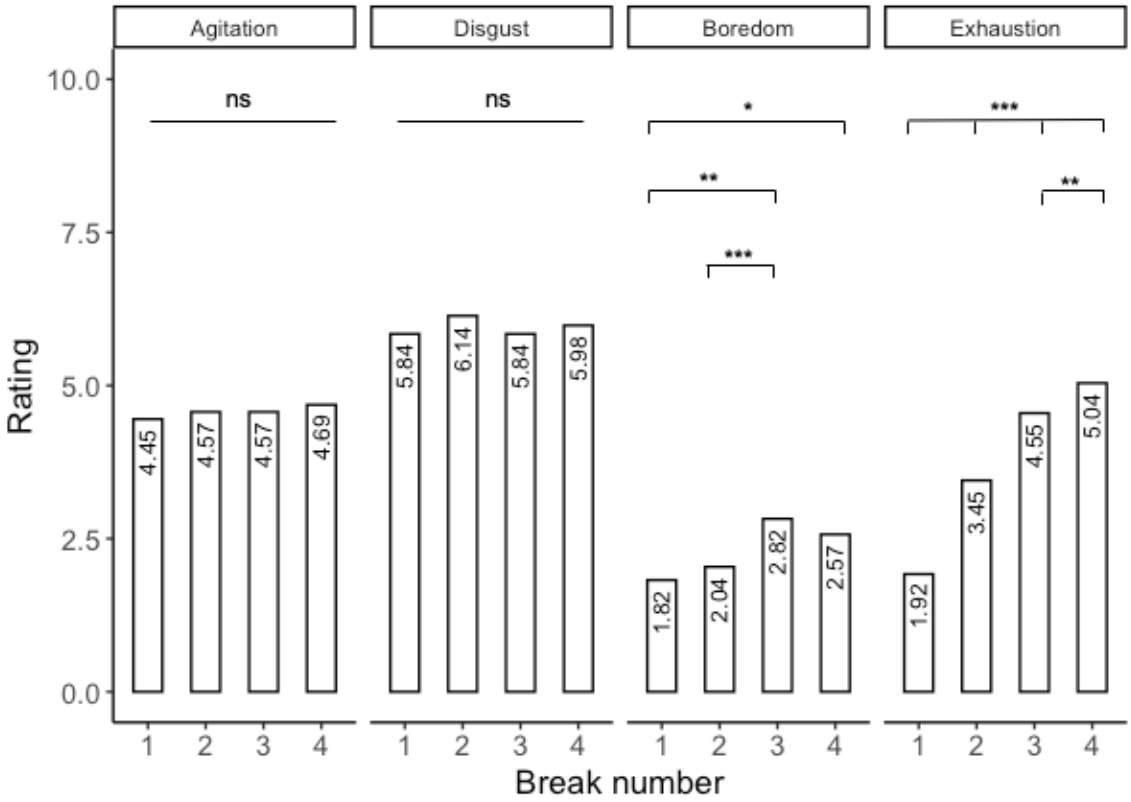
The *agitation* ratings comprised no outliers. There was no significant difference among the ratings of each time point (Friedman's test, $x^2(3) = 3.48$, $p = .32$, $p_{Holm\text{-}Bonferroni} = 0.41$) and the effect size was small (W = .02). The *boredom* ratings comprised three outliers but no extreme cases, which therefore remained in the dataset. The Friedman test revealed a significant difference among the *boredom* ratings of the four time points ($x^2(3) = 24.1$, $p < .00$, $p_{Holm\text{-}Bonferroni} < .00$). The effect size was small (W = .16). Finally, *exhaustion* ratings included no outliers. The results of the Friedman test revealed significant differences among the *exhaustion* ratings of the four time points ($x^2(3) = 116$, $p < .00$, $p_{Holm\text{-}Bonferroni} < .00$). The effect size was large (W = .75). Figure 8 displays the results of a pairwise t-test for *boredom* and *exhaustion*.

Discussion

The purpose of this study was to implement a spider-related database, to assess its effects on spider-fearful individuals, and to evaluate the predictive value of SCR with regard to subjective fear. Thereby, it was aimed towards the establishment of a model of fear which is the base for future adaptive ET paradigms. The physiological as well as cognitive responses of 51 spider-fearful individuals to the repeated exposure to spider-related images were observed.

Figure 8

Break Questionnaire Variables: Comparisons between Four Time Points



Note. The printed values are the sample mean values of the respective rating (N = 51). The reported significance levels of the pairwise comparisons refer to the Bonferroni corrected p-values (* p < .05, ** p < .01, *** p < .001, **** p < .0001).

Habituation effects were observed for SCR as well as spider-fear (SAS). Subjective fear did not habituate over time, however, it significantly differentiated between high- and low-fearful individuals. By use of machine learning models, SCR and mean fear rating were identified as significant predictors of subjective fear.

Treatment Effects

With regard to the first research question we expected a general habituation effect for fear ratings, SCR, and fear assessed by the break questionnaires and for spider fear assessed by the pre- and post-questionnaires. Additionally, we expected an image-specific habituation effect of fear-ratings. The results of the fear rating analysis neither confirmed the hypothesis of a general habituation effect nor of the image-specific habituation effect. Indeed, mean fear ratings remained stable over 224 exposures to the image database (M = 54.14, Figure 2).

Against expectations, the fear ratings assessed by the break questionnaires did not show any habituation effect either.

A potential explanation for the results is that the subjective fear evoked by the stimuli was either not high enough or not stable enough to induce habituation. This can either be attributed to the stimuli themselves (i.e. low fear inducing quality of images) or to the method of image presentation. In the present study, the images were randomly presented to the subjects. The procedure was thus non-graded and non-adaptive. A graded (or hierarchical) approach encompasses the steady increase in the strength of the fear inducing stimulus with the aim to foster a reduction in fear, namely habituation (Matthews et al., 2011). The graded exposure is the most common exposure therapy paradigm applied in research and practice (Abramowitz et al., 2019). In an adaptive paradigm, strength of the fear inducing stimulus is increased in dependency of the current fear level of the subject (Matthews et al., 2011). The adaptive paradigm avoids fear levels that are too high (i.e. a panic attack) but ensures a constantly high level of fear, which facilitates habituation (Matthews et al., 2011). It has therefore been suggested to be more efficient (Matthews et al., 2011). Finally, it can be argued that in the present study, subjective fear level was not constantly large enough to habituate over time because the stimuli were not strong enough or because they were presented in random order.

Apart from the above-mentioned aspects, a tentative explanation for the results of the fear rating analysis is the subject's style of answering the question for fear of a respective spider. Presumably, subjects did not consistently indicate their present level of fear but the level of fear they would experience at a real encounter with the spider. Such unobserved differences in answering style might account for the lack of habituation of subjective fear. To rephrase the question for subjective fear could prevent confound in future studies. For example, an adapted version of the question used by Olatunji et al. (2009) could be applied to avoid misinterpretations ("After seeing the picture[…], I feel ...[answering options]").

It can be precluded that the time span of exposure was too short to evoke habituation of subjective fear. Past computer assisted exposure studies that observed a habituation of subjective fear have applied much shorter exposure trials (Matthews et al., 2011). Moreover, it has been argued that continuous (i.e. exposure to one image for 30 seconds) versus intermitted exposure (i.e. repeated shot-duration exposure) do not differ with regard to the

degree of habituation that is evoked (Matthews et al., 2011). Therefore, the presentation time of the stimuli was unlikely to block habituation of subjective fear.

In contrast to the results of subjective fear, the analysis of SCR data yielded the expected habituation effect: there was a weak but significant negative association between trial and beta values. This result is in line with earlier findings which showed a decrease in physiological arousal over the time of repeated exposure to spider stimuli (Olatunji et al., 2008). It is unlikely that the habituation of SCR was caused by a physiological relaxation of the subjects over time. About 45 minutes passed from the time of subject's arrival to the start of the experiment. During that time, the procedure was prepared and explained to the participant. In addition, there was a practice trial and five relaxation periods over the course of the experiment. The claim that the habituation effect has not been evoked by non-experimental stimuli is supported by the exploratory analysis of the break questionnaires: Agitation did not decrease over time and thus did not confound the habituation effect of SCR.

Overall, the present results imply that the repeated exposure to spider images facilitated the desired treatment effect. This finding strengthens the argument that SCR is a relevant correlate of spider fear and mirrors the fear level during exposure. Nonetheless, it remains to be mentioned that the assessment as well as the pre-processing of SCR is prone to artefacts. Therefore, the interpretation of beta values should be treated with caution and attempted to be replicated in future studies. This is particularly important, as the present results do not suffice to fully understand the patterns of fear in response to exposure, which is necessary for the development of a computer assisted adaptive exposure paradigm.

The results of the analysis of the FSQ scores (comparison pre-post) did not confirm the hypothesis: FSQ scores did not decrease in response to the exposure to spider images. On the contrary, SAS scores did show a highly significant decrease from pre- to post assessment. Multiple reasons may account for these results. The two questionnaires both assess spider phobia but strongly differ with regard to the number of questions (SAS: 4 questions; FSQ: 18 questions). The SAS assesses the four criteria of spider-phobia of the DSM-IV, while the FSQ assesses the agreement with spider-fear related statements (Rinck et al., 2003). Importantly, the SAS has been developed to serve as an efficient screening, but it is no stand-alone diagnostic tool. Our results justify the claim that the FSQ and the SAS assess different dimensions of spider fear and should therefore jointly be applied in future studies, too. Based

on the results, it can be assumed that the changes in SAS-scores represent a tendency for a decrease of spider fear in the sample.

Prediction of Subjective Fear

With regard to the second research question, we hypothesised that SCR and subjective fear are linearly related and that fear ratings can therefore be predicted from beta values by means of a simple linear regression model. The results disprove the employment of a simple linear regression to predict subjective fear. Instead, the prediction can be modelled by machine learning procedures. Both the LASSO regularised linear regression as well as the ERT analyses achieved a meaningful prediction of fear rating data.

From the results of the analyses without control of data separation in cross validation it can be concluded that a prediction of fear ratings is possible by use of a linear, as well as a non-linear model: the variables beta value and mean image rating are relevant predictors. However, the cross-validation for these models was done without any control of data separation to counter subject cluster learning. Specifically, the data of a subject were possibly part of the training data as well as of the test data. As there is a greater variability between the ratings of subjects than within the ratings of one subject, the prediction of the target is improved by the presence of within subject data in the training data and the test data. Thus, the models that did not involve control of data separation in cross validation hold for the present data but not for the data of novel subjects.

After control of data separation in cross validation the linear as well as the non-linear models (LASSO regression and ERT analyses without image mean rating as feature) did not yield any better predictions than the trivial predictor. This result confirms that beta value was – even though significant – a weak predictor in the previous analyses, because its predictive ability partly depended upon the subject cluster learning in the cross validation. Thus, it makes an important difference whether it is controlled for data separation in cross validation.

After controlling for data separation and extension of the models by the feature image mean rating, the linear as well as the non-linear models (LASSO regression and ERT analyses) yielded significantly better predictions than the trivial predictor. Slightly better predictions of fear ratings were achieved by the ERT analyses. This result promotes the use of non-linear modelling in the prediction of subjective fear in future studies. In line with our hypothesis, SCR was shown to be a relevant predictor of subjective fear. However, mean fear rating was the more important predictor. As the averaged proportion of explained variation of the best

predicting model (ERT analyses) was still below 25 percent, it can be concluded that other meaningful predictors of subjective fear have not been regarded in the present study. For example, the remaining physiological measures recorded (ECG, pulse, pupil size) have not been taken into account and could be included in future studies.

Discriminant Ability of Fear Correlates

With regard to the third research question, we hypothesised that high-fearful individuals could be distinguished from low-fearful individuals based on their SCR and their subjective fear in response to exposure. This was indeed the case for fear ratings, which significantly differed between high- and low-fearful individuals. The result justifies the claim that the spider stimuli of the present database have a fear relevance for spider fearful individuals and a differential value for individuals with different fear-levels. Beta values on the contrary, did not differ between the groups. Interestingly, these results contrast the outcome of the habituation analysis, which revealed a habituation effect for SCR but not for subjective fear. Thus, fear ratings were sensitive for preliminary differences between individuals fear while SCR was sensitive for overall changes over time, independent of preliminary fear. With regard to the results of the SCR analysis, it can be hypothesized that the difference in SCR between high- and low fearful individuals was not strong enough in the present sample to be recognized. The overall variability in SCR was small and most values were very close to zero (Figure 5). Therefore, SCR was presumably not sensitive enough to differentiate between individuals with different preliminary fear levels.

Exploratory Analyses

Contrary to the results reported by Olatunji et al. (2009) – and contrary to our hypothesis – there was no change of disgust over time. Again, a potential explanation is that the stimuli were overall not strong enough. Apart from this, disgust ratings were constantly higher than fear ratings. In line with that observation, past research has repeatedly shown that disgust is closely associated with spider fear and it has been suggested that there is a functional linkage between disgust and fear (Smits, Telch, & Randall, 2002). This relationship has been attributed to the beforehand mentioned evolutionary factors (Öhman & Mineka, 2001). Spiders have been associated with disease by our ancestors and as a protective mechanism they therefore evoke fear as well as disgust in humans (Smits et al., 2002). The claim that spider fearful individuals predominantly experience fear and less strongly disgust in response to spider images (Sawchuk et al., 2002) has not been supported by the present results. Thus, the main

implication is that disgust is indeed a highly relevant concept in spider phobia and that its patterns in ET should be more closely observed in future studies. Specifically, disgust and fear should be assessed by use of similar scales to achieve comparability (i.e. assess both ratings in response to each image presentation).

Finally, the results of the remaining exploratory analyses did not underlie any directional hypothesis. Importantly, the highly significant increase of exhaustion over time was expectable but should still be considered in the planning of future studies. For example, time of breaks can be prolonged or pre-determined, and cognitive relaxation during breaks can actively be promoted. The former intervention may avoid subjects from skipping breaks to finish the experiment early, and the latter may decrease exhaustion. The interventions could however promote boredom, which significantly increased over time, too. Boredom might be naturally reduced by an increase in heterogeneity of the database. The repetitive task will, however, always stimulate some level of boredom. Importantly, catch trials controlled – at least to some degree – for the potential confounding of boredom and exhaustion. The catch trials prohibited random and strategic answering and facilitated the exclusion of subjects whose responses were presumably confounded by boredom or exhaustion.

Limitations

This study represents a first attempt in the implementation of a validated spider database and in the development of a computer assisted (adaptive) exposure paradigm. Some limitations of the study (random presentation of stimuli, wording of question assessing fear, timing of pre-post questionnaires) have already been mentioned above. In addition, the following limitations could be addressed in future research. Firstly, the database was tested with respect to its effects on spider-fearful individuals. A validated image database that can be applied in different studies and paradigms should incorporate an equal number of images of each fear level. This is because for an adaptive treatment paradigm, images of all fear levels must be available to flexibly adapt the strength of the stimulus to the subject's fear level. As can be seen in figure 2, fear ratings were unevenly distributed. Specifically, the frequency of fear ratings was low in the range of 1 – 49 and 80 – 99. The most frequently chosen fear rating was zero and the mean fear rating was only slightly above 50. Thus, the database should be supplemented with novel images and its fear inducing quality should be validated.

Secondly, the time span between pre-questionnaire, experiment, and post-questionnaires should have been standardized. The FSQ comprises numerous questions

regarding how the subject would respond or feel if a spider appeared in the room “now” (at the time of answering the questionnaire). Because the post-questionnaire was administered right after the experiment, it is likely that subjects were still emotionally aroused – especially with regard to spider content – and gave higher ratings than they would have done later. In addition, the FSQ contains the statement “At present, I often think about spiders”, which will be rated high by any spider-fearful person who signed up for a spider-related study. Thus, post-questionnaire ratings were probably confounded by agitation and emotional arousal. Differences in time span between pre-questionnaire and experiment are less likely to have affected the results but to avoid confound, pre- and post-measures should have been employed ideally within the same time course before and after the experiment.

Thirdly, the distribution of gender was highly skewed in the sample, which questions generalisability. Indeed, with regard to lifetime-prevalence, significant gender differences are reported for specific phobias (i.e. spider phobia) as well as spider fear: women are about twice as often affected (10.3%) than men (4.9%; Alonso et al., 2004; Oosterink et al., 2009). Thus, the large number of females in the sample represents a trend that has been observed in the population. However, to make inferences on the population and to develop an exposure paradigm suitable for the population, future samples should more strongly mirror the actual gender distribution. This would facilitate analyses of gender differences in spider fear which is relevant according to Oosterink et al. (2009) who reported that spider phobic women give significantly higher fear ratings than spider phobic men. In addition, the samples of future studies should resemble the population also in other aspects – we consider as relevant, for example, age and education.

Fourthly, outlier treatment in the analysis of SCR data can be discussed. In the present analysis, outliers of beta values were not removed from the analyses for two reasons. More than half of the SCR data had been removed due to insufficient signal quality before the analysis. Therefore, additional rejection of outliers was considered excessive. In addition, the assessment of SCR actually aims at the observation of deviations from the baseline and the paradigm aimed at the elicitation of such deviations. Thus, in view of the fact that SCR data had been cleaned before the analysis, the outliers were regarded as responses to the experimental procedure and therefore relevant for analysis. However, it is arguable that the rejection of more than 40 percent of data is erroneous and that the pre-processing of SCR data should be re-examined. The high number of negative beta values in the data supports

this line of reasoning. Negative beta values are unlikely the result of a stronger relaxation in comparison to the baseline but instead the result of spontaneous fluctuations. Thus, pre-processing should be re-evaluated and based on the outcome, outlier treatment should again be discussed.

Fifthly, the linear mixed model which was employed with the aim to predict fear ratings from beta values (research question 2) was applied with *order* as a random effect. The variable was entered to account for repeated measures within individuals. As stimuli were presented to the subjects in random order, the variable does not capture the respective image that matches the data but only the order of stimuli presentation per individual. It would have been sensible to replace the variable *order* in the linear mixed model by another (non-categorical) variable which captures the identity of the images. Such a variable would be suitable to account for repeated measures within individuals and it would add information to the prediction of fear ratings. In addition, it would facilitate the analysis of the impact specific stimuli have on subjects. This novel variable should thus also be employed as feature in machine learning models. Fifthly, the identification of predictors of subjective fear has been part of an exploratory analysis. To draw sensible conclusions, the results should be validated and extended in future studies.

Despite these limitations, the results suggest several theoretical and practical implications. It becomes clear that SCR patterns are affected by repeated exposure to spider images and that SCR is a relevant but no stand-alone predictor of fear. The results also reveal that subjective fear can be predicted (from the mean fear rating), which is an important insight for the further development for an adaptive exposure paradigm. In addition, the results show that the present database does have a fear relevance for spider fearful individuals. As mentioned above, potentially valuable changes that should be made to the database and to the setup can be derived from the present results. Therefore, the study was highly successful with regard to the aim to deliver insights which aid in the development of more advanced studies.

Future Directions

Much work remains to be done before a full understanding of the mechanisms underlying exposure therapy in spider fearful individuals is achieved. This study represents the groundwork in a long-term project. Therefore, many factors could be named with regard to future research: Aside from the above-mentioned aspects, three more shall be introduced

here. Firstly, the application of pre- and post-questionnaires could be improved in the future. In the current study, the pre-questionnaire was administered online prior to the experiment and the time period from the pre-assessment to the experiment was not controlled for. By contrast, the post-questionnaire was administered immediately after the final relaxation period, thus right after the experiment. As the experimental procedure took about 90 minutes, the post-questionnaire might have been completed inattentively by the subjects. To reduce the risk of confounding questionnaire scores by lack of motivation, the pre- and post-questionnaires might be administered in standardized time-periods before and after the experiment.

Secondly, the present results demonstrate that fear ratings as well as SCR are relevant measures in the exposure therapy approach. Fear ratings clearly distinguished high- from low-fearful individuals and SCR showed a habituation effect in response to exposure. In terms of future research, it would be useful to extend the current findings by examining the combination of these patters: Do subjective fear and especially SCR habituate (differentially) in low- and high-fearful individuals? In addition, the sample split (between low- and high fearful individuals) was accomplished with the sample median FSQ-score as critical value. With reference to the significant treatment effect in SAS scores and the lack of a treatment effect in FSQ-scores, it would additionally be interesting to explore the same questions after a sample split using the median SAS-score of the sample. Importantly, results of the third research question support the usage of FSQ-scores as inclusion criteria for future studies, as these differentiate between different levels of spider fearfulness between individuals.

Our results regarding the habituation of fear differ from previous studies. Together with other inconsistencies in the literature, this result indicates that comparability between different studies is difficult due to differences in paradigms and variables assessed. Our finding reinforces the claim that there has been much variability in previous exposure paradigms and that the development of an overarching quantitative framework might facilitate the integration of results from different exposure settings and paradigms.

Conclusion

The present study demonstrates that image-based and computer assisted ET can induce treatment effects in spider-fearful individuals and that subjective fear in response to exposure can be predicted from mean fear rating and SCR. However, it has become clear that the

development of a validated database of fear-relevant images for flexible use in research and practice requires acquisition and analysis of much more data to evaluate the effect of specific images on different individuals. Similarly, the development of a uniform and adaptive ET paradigm, which ideally involves an adaptive presentation of images, requires a more detailed understanding of the predictors of fear and their mechanisms. The present study sets the groundwork for such developments: the preliminary database has proved fear-relevant and specific implications for future adjustments were extracted; effects of the exposure treatment were found for SCR an SAS scores; two sensible predictors of subjective fear (mean fear rating; SCR) were identified and linear as well as non-linear machine learning techniques were recognised as useful tools for the prediction of fear rating data. Thus, the results provide an important insight into the mechanisms of spider fear in response to image-based exposure treatment and implement the groundwork for future studies advancing the adaptive ET paradigm. Overall, the present study contributed to the development of a promising treatment for spider phobia which may encourage affected individuals to seek and complete treatment and which can be applied as standardized procedure in future research.

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Appendix 1

Table 3

Classification of Images in the Database According to Six Criteria

Criterium	Classification	n
Spider in picture	no spider	9
	Spider	162
	painted spider	4
Environment	not applicable	6
	nature	107
	civilization	46
	human contact	16
Texture	not applicable	10
	smooth	85
	hairy	80
Origin	not applicable	12
	exotic	105
	native in Austria	58
Subjective size	not applicable	9
	small	42
	middle	88
	large	36
Perspective	not applicable	9
	from side	58
	from top/all legs visible	108

Note. All spider-related images in the database (*N* = 175) were classified in each category.

Appendix 2

Table 4

Results of Each Tests of Normality Conducted Prior to the Analyses

Research Question	Variable	Shapiro – Wilk test		
		Statistic	df	Sig.
1 a	Mean fear rating per subject	0.989	50	.140
	Mean beta value per subject	0.973	28	< .000
	FSQ difference scores	0.987	50	.850
	SAS difference scores	0.968	50	.184
	Fear break 1	0.898	50	< .000
	Fear break 2	0.923	50	.003
	Fear break 3	0.902	50	< .000
	Fear break 4	0.888	50	< .000
1 b	Fear ratings $_{\text{paired differences}}$	0.940	866	< .000
3	Beta values $_{\text{low-fearful individuals}}$	0.963	14	.746
	Beta values $_{\text{high-fearful individuals}}$	0.799	13	.005
	Fear $_{\text{low-fearful individuals}}$	0.877	25	.005
	Fear $_{\text{high-fearful individuals}}$	0.935	24	.120
Exploratory analyses	Disgust break 1	0.946	50	.022
	Disgust break 2	0.924	50	.003
	Disgust break 3	0.943	50	.017
	Disgust break 4	0.935	50	.008
	Boredom break 1	0.862	50	< .000
	Boredom break 2	0.849	50	< .000
	Boredom break 3	0.906	50	.001
	Boredom break 4	0.888	50	.001
	Agitation break 1	0.954	50	.048
	Agitation break 2	0.935	50	.008
	Agitation break 3	0.951	50	.036
	Agitation break 4	0.958	50	.066

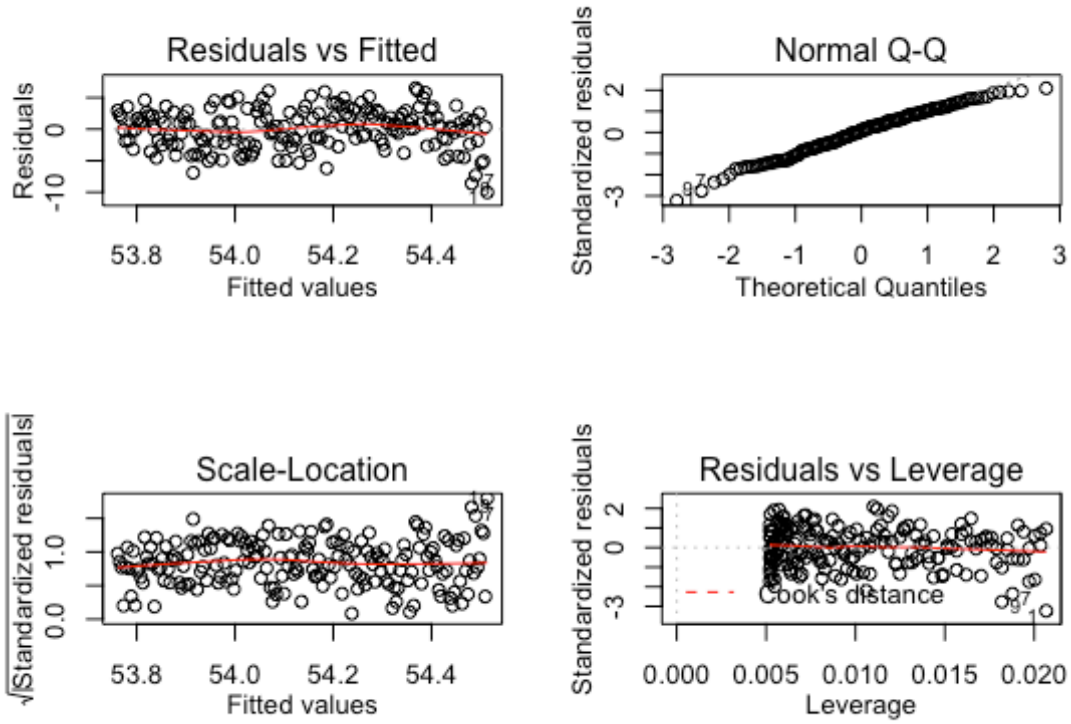
Table 4 (continued)

	Exhaustion break 1	0.892	50	< .000
Exploratory	Exhaustion break 2	0.927	50	.004
Analyses	Exhaustion break 3	0.949	50	.030
	Exhaustion break 4	0.959	50	.073

Appendix 3

Figure 9

Residual Plots Inspected to Assess the Assumptions of the Simple Linear Regression Model with Fear Rating as Dependent Variable

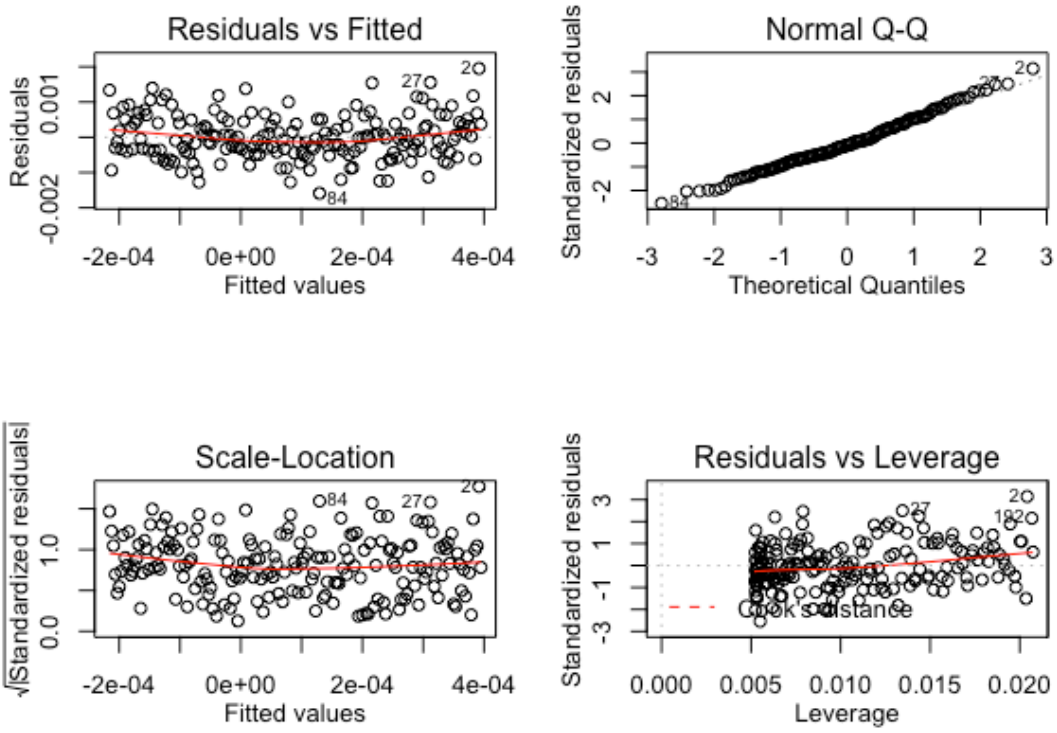


Note. Based on the *Residuals vs Fitted* plot, the assumption of linearity of the relationship between trial and fear rating can be accepted. Based on the *Normal Q-Q* plot, the assumption of normal distribution of the residuals can be accepted. Based on the *Scale-Location* plot, the assumption of homogeneity of variances was accepted. The *Residuals vs Leverage* plot suggests that there are outliers. The outlier treatment has been discussed above.

Appendix 4

Figure 10

Residual Plots Inspected to Assess the Assumptions of the Simple Linear Regression Model with Beta Value as Dependent Variable



Note. Based on the *Residuals vs Fitted* plot, the assumption of linearity of the relationship between trial and beta value can be accepted. Based on the *Normal Q-Q* plot, the assumption of normal distribution of the residuals can be accepted. Based on the *Scale-Location* plot, the assumption of homogeneity of variances was accepted. The *Residuals vs Leverage* plot suggests that there are outliers. The outlier treatment has been discussed above.

Appendix 5

Table 5

Results of the Paired t-Tests Assessing General Habituation Effects in FSQ and SAS Scores

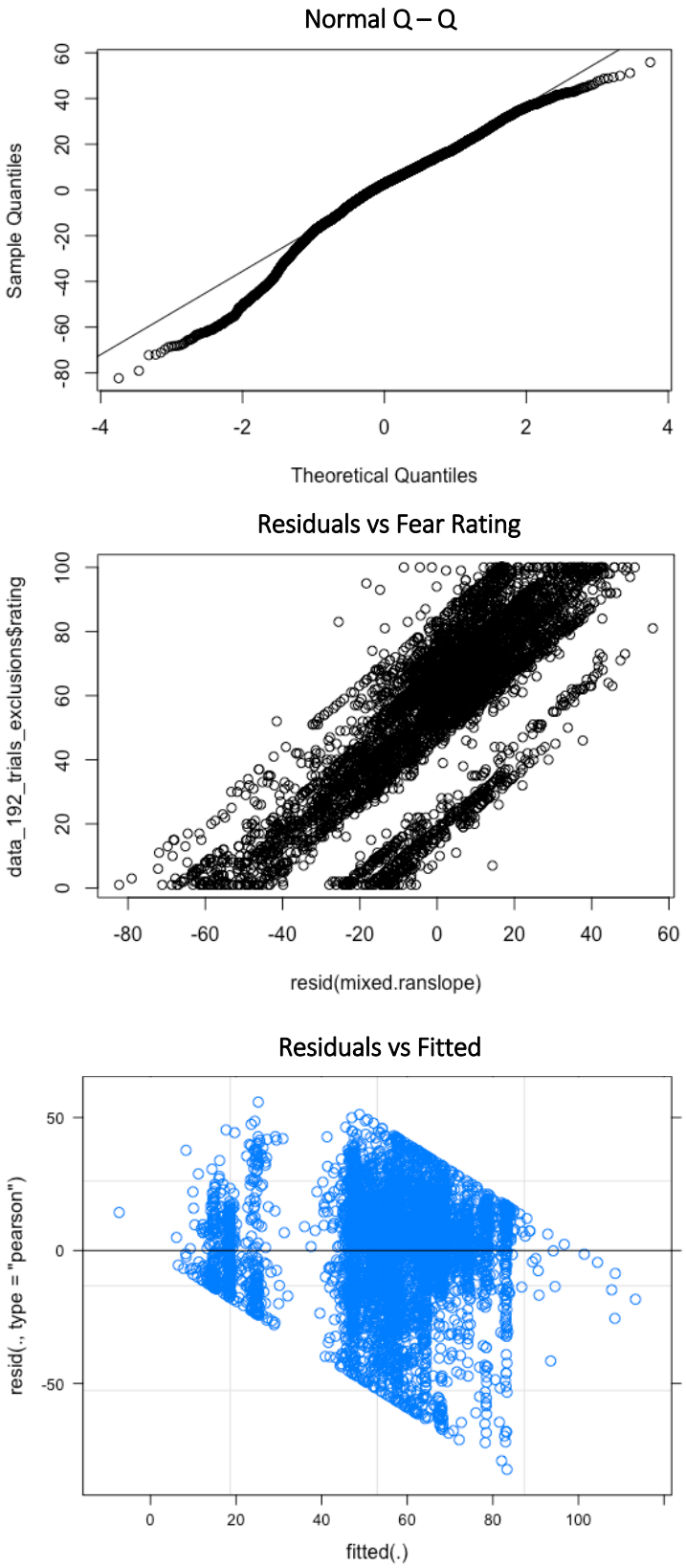
Variable	Pre-questionnaire		Post-questionnaire		t(50)	*p*	$p_{Holm\text{-}Bonferroni}$	Cohen's *d*	95% CI
	M	*SD*	*M*	*SD*					
FSQ	56.02	17.65	52.20	23.77	-1.88	.06	.13	-0.16	[-0.33, 0.01]
SAS	17.44	3.69	14.92	4.91	-5.92	.00	.00	-0.53	[-0.72, -0.34]

Note. It was corrected for multiple comparisons by use of the Holm-Bonferroni correction ($p_{Holm\text{-}Bonferroni}$).

Appendix 6

Figure 11

Residual Plots of the Variables Applied in the Random Slope Random Intercept Model

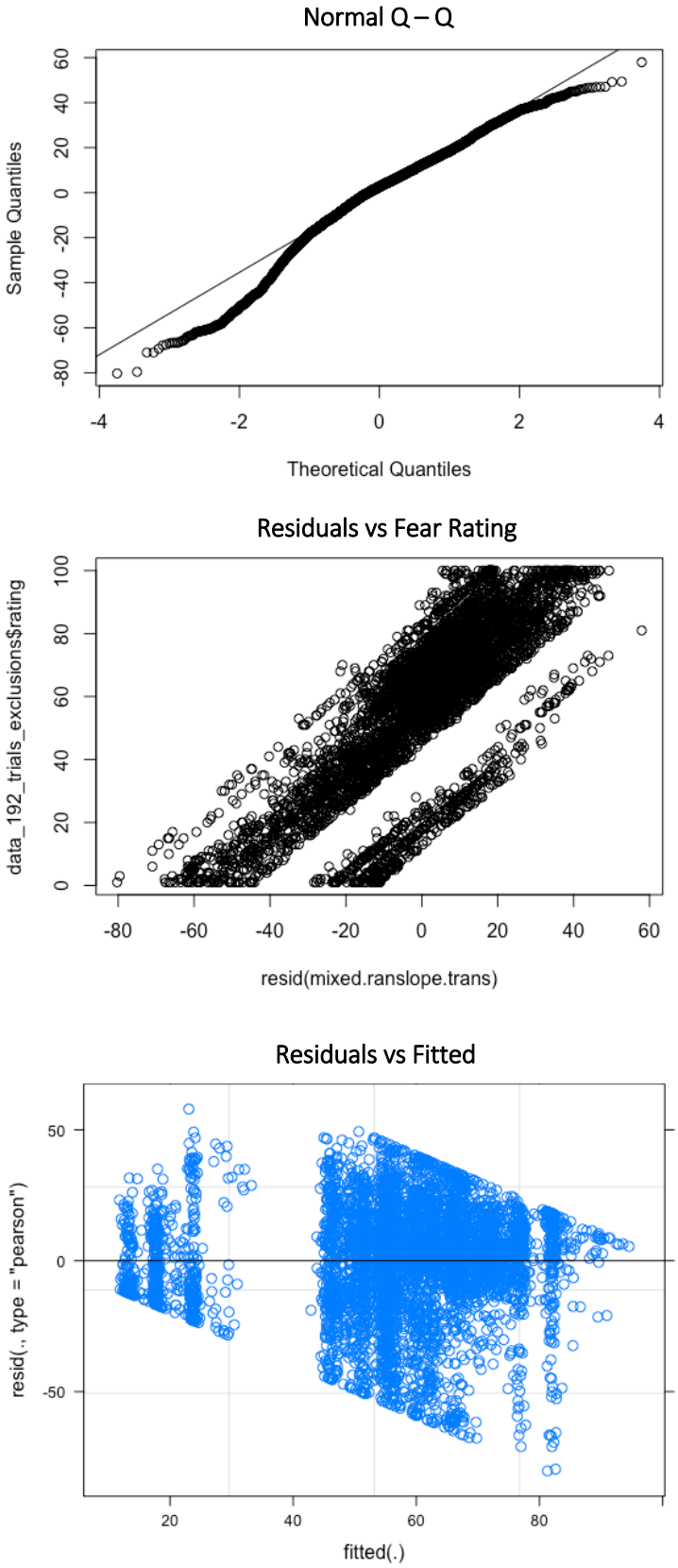


Note. Based on the *Normal Q-Q* plot it was assumed that the residuals were approximately normally distributed. The *Residuals vs Fear Rating* plot displays the violation of the assumption of linearity (there should be no pattern). The *Residuals vs Fitted* plot indicates that the assumption of homoscedastic is violated (there should be no pattern).

Appendix 7

Figure 12

Residual Plots of the Variables Applied in the Random Slope Random Intercept Model After log(x) Transformation of Beta Values



Note. Based on the *Normal Q-Q* plot it was assumed that the residuals were approximately normally distributed. The *Residuals vs Fear Rating* plot displays the violation of the assumption of linearity (there should be no pattern). The *Residuals vs Fitted* plot indicates that the assumption of homoscedastic is violated (there should be no pattern).

Appendix 8

Table 6

Research Question 3: Descriptive Data of SCR and Fear Ratings per Group.

	Fear of spiders	*n*	*M*	*SD*	*Mdn*	min	max
SCR	low	15	-0.000261	0.000774	-0.0000562	-0.00201	0.00137
	high	14	0.000499	0.00110	-0.0000247	-0.000690	0.00262
Fear rating	low	26	49.7	16.0	55.7	13.2	68.6
	high	25	58.7	17.4	60.1	14.5	83.7

Appendix 9

Etwa ein Fünftel der europäischen Bevölkerung hat Angst vor Spinnen und in vielen Fällen beeinträchtigt der daraus resultierende Stress den Alltag. Die meist angewandte Behandlungsoption, die Expositionstherapie (ET), weist hohe Abbruchraten und eine große Variationsbreite in der Praxis auf und ist daher suboptimal. Daher streben wir die Entwicklung eines effizienten computergestützten ET-Paradigmas an, das eine Anpassung der Stimuli (Bilder) an das jeweilige Angstniveau der Individuen beinhaltet. Das Angstniveau könnte z.B. durch physiologische Erregung oder subjektive Angst operationalisiert werden. Die vorliegende Studie legt den Grundstein für eine solche Entwicklung. Wir setzten Personen mit Spinnenangst (N = 51) einer neuen Datenbank mit spinnenbezogenen Bildern aus und erhoben deren subjektive Angst und den Hautleitwert für jeden Stimulus. Die Behandlungseffekte wurden zusätzlich mittels standardisierter Prä- und Post-Fragebögen (Spinnenangst-Fragebogen; Spinnenangst-Screening, SAS) und durch wiederholte Erhebung der Variablen Angst und Ekel untersucht. Die Ergebnisse zeigten Gewöhnungseffekte für SCR und für SAS. Außerdem wurden Hautleitwert und mittleres Angstniveau mittels linearer sowie nichtlinearer maschineller Lernmodelle (regularised linear least absolute shrinkage and selection operator regression; ensemble of randomized trees analyses) als Prädiktoren der subjektiven Angst identifiziert. Drittens berichteten Personen mit starker Spinnenangst signifikant höhere Angstniveaus als Reaktion auf die Exposition als Personen mit geringer Spinnenangst. Dies bestätigte, dass die neu entwickelte Datenbank in der Zielgruppe Angst auslöst. Darüber hinaus wurde gezeigt, dass Veränderungen des Hautleitwertes eine Voraussagekraft in Bezug auf die subjektive Angst haben, dass aber weitere und möglicherweise präzisere Prädiktoren erforscht werden sollten, um schließlich ein adaptives ET-Paradigma zu entwickeln. Am wichtigsten ist, dass die Studie grundlegende Einblicke in die Mechanismen, die Spinnenangst zugrunde liegen, lieferte und die Generierung von Forschungsfragen für die nachfolgende Studien initiierte.

Keywords: computergestützte bildbasierte Expositionstherapie, Spinnenangst, Spinnenphobie, elektrodermale Aktivität