Interpretative bias in spider phobia: Perception and information processing of ambiguous schematic stimuli

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Abstract

This study investigates the interpretative bias in spider phobia with respect to rapid visuomotor processing. We compared perception, evaluation, and visuomotor processing of ambiguous schematic stimuli between spider-fearful and control participants. Stimuli were produced by gradually morphing schematic flowers into spiders. Participants rated these stimuli related to their perceptual appearance and to their feelings of valence, disgust, and arousal. Also, they responded to the same stimuli within a response priming paradigm that measures rapid motor activation. Spider-fearful individuals showed an interpretative bias (i.e., ambiguous stimuli were perceived as more similar to spiders) and rated spider-like stimuli as more unpleasant, disgusting, and arousing. However, we observed no differences between spider-fearful and control participants in priming effects for ambiguous stimuli. For non-ambiguous stimuli, we observed a similar enhancement for phobic pictures as has been reported previously for natural images. We discuss our findings with respect to the visual representation of morphed stimuli and to perceptual learning processes.

Keywords: spider phobia, interpretative bias, priming, morphed schematic pictures, perceptual learning

Introduction

The fast detection and reaction to fear-relevant situations and stimuli in our environment is one of the most important and evolutionary significant tasks of the human visual and motor system. However, which situations and stimuli are regarded as fear-relevant is not at all universal. Different individuals strongly differ in their evaluations with respect to fear relevance. This is most evident when considering individuals with anxiety disorders such as social or specific phobias.

Indeed, individuals with specific phobias by definition suffer from a "marked and persistent fear that is excessive or unreasonable, cued by the presence or anticipation of a specific object or situation" (Diagnostic criteria for specific phobia, DSM-IV-TR, APA, 2000, pp. 449-450). In other words, they evaluate specific situations (e.g., heights, plane rides) or stimuli (e.g., spiders, snakes, dogs, or blood) as strongly threatening that are not necessarily regarded as such by other non-anxious individuals. Additionally, a large number of studies has demonstrated that individuals with social phobia – which are fearful of "social or performance situations in which embarrassment may occur" (DSM-IV-TR, APA, 2000, pp. 450) – tend to interpret even typical social situations as potentially threatening (e.g., Amir, Foa, & Coles, 1998; de Jong, Merckelbach, Bögels, & Kindt, 1998; Mellings & Alden, 2000; Voncken, Bögels, & Vries, 2003; Wells, Clark, & Ahmad, 1998; for a review see Heinrichs & Hofmann, 2001). However, this misinterpretation, or interpretative bias, is promoted by the fact that social situations are often ambiguous. So the question arises whether such bias is also present in individuals with specific phobias directed to situations or stimuli that are less inherently ambiguous?

This question can be evaluated by considering, for example, individuals with spider phobia. In contrast to other persons – that are encountered in social situations – spiders do not exhibit much behavior that might be (mis)interpreted by humans. Furthermore, the potential ambiguity of the fear-relevant stimuli can be further reduced by using static visual stimuli, as in previous studies on information processing in individuals with specific phobias (e.g., Haberkamp, Schmidt, & Schmidt, 2013; Öhman, Flykt, & Esteves, 2001). An observed interpretative bias in individuals with spider phobia for static visual stimuli cannot be based on a bias in the interpretation of (ambiguous) behavior but has to be based on a more fundamental bias in the interpretation of visual features of the stimuli.[1] Is there any evidence for such a fundamental bias in information processing in individuals with spider phobia?

Becker and Rinck (2004) presented spider-fearful participants and non-anxious control participants with a stream of scrambled pictures interspersed by short 14 ms presentations of photographs of spiders, beetles, or butterflies. Spider-fearful participants more often reported that they have seen a spider or a beetle – which was also rated as being aversive. Thus, spider-fearful participants seem to have a more liberal criterion when classifying perceptually similar animals as fear-relevant compared to non-anxious individuals. Kolassa et al. (2007) presented participants with spider phobia or social phobia, spider aficionados, or non-anxious control participants with schematic stimuli (i.e., line drawings) that morphed from flower into spider pictures in 7 steps. Again, participants with spider phobia more often reported that these ambiguous stimuli (i.e., those in-between flowers and spiders) resembled a spider compared to all other groups.

This fundamental bias in the perceptual interpretation of static visual information prompts the question whether information processing on the visuomotor level would also be different for ambiguous stimuli between spider-fearful participants and non-anxious participants. This cannot be taken for granted

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[1] Note that individuals with social phobia did not show any interpretative bias in the judgment of ambiguous (static) images of facial expressions (for a review see Staugaard, 2010).

because, for example, dissociations between (slow) perception and (fast) motor responses have been reported frequently. For example, the effects of masked primes can be dramatically different in perception and visuomotor priming: invisible primes can produce strong priming effects (e.g., Kiesel, Kunde, Pohl, Berner, & Hoffmann, 2009; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003).

With respect to non-ambiguous and natural fear-relevant stimuli, numerous studies demonstrated that information processing (i.e., detection and classification) is enhanced in the general population (Fox et al., 2000; Lipp & Waters, 2007; Öhman et al., 2001; Williams, Moss, Bradshaw, & Mattingley, 2005; but see Tipples, Young, Quinlan, Broks, & Ellis, 2002). This effect is even more pronounced in individuals with specific phobias (e.g. Haberkamp & Schmidt, 2014; Haberkamp et al., 2013; Lipp & Waters, 2007; Öhman et al., 2001; for a review see Yiend, 2010) and with other anxiety disorders (e.g., social anxiety, Eastwood et al., 2005; Gilboa-Schechtman, Foa, & Amir, 1999).

In two recent studies, we investigated rapid information processing by using natural images of neutral, fear-relevant, and phobic stimuli (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013). We found that spider-fearful participants responded faster to phobic target pictures of spiders compared to fear-relevant snakes and neutral flowers and mushrooms. Additionally, spider-fearful participants responded faster to spider targets compared to a non-anxious control group. Finally, phobic spider primes elicited larger priming effects in the spider-fearful group compared to fear-relevant and neutral primes and compared to the control group (Haberkamp et al., 2013). For blood-injury-injection-fearful participants, we observed the same data pattern although that phobia has features that clearly distinguish it from other specific phobias (e.g., experience of nausea and fainting in phobic situations). Fearful participants responded faster to target pictures of small injuries compared to neutral targets and compared to a non-anxious control group. Also, phobic primes elicited larger priming effects compared to neutral primes (Schmidt & Haberkamp, 2014).

We concluded that phobic natural images lead to rapid information processing in fearful individuals. Our findings are in line with other studies in the image processing literature which show that despite their visual complexity, the categorization of natural images is remarkably fast (e.g., Bacon-Macé, Kirchner, Fabre-Thorpe, & Thorpe, 2007; Schmidt & Schmidt, 2009). How can this rapid processing of natural images be explained?

VanRullen (2009) suggested a process of “hardwired” binding of features to which a person is frequently exposed as a result of perceptual learning. For example, if a person is frequently exposed to spiders, this might induce enhancements in the functional properties of the cortical arrays involved in spider detection and recognition. In individuals with spider phobia, these learning processes are presumably stronger because spiders have strong emotional significance and thus attract more attention (Haberkamp et al., 2013).

However, to investigate information processing for ambiguous stimuli, natural images pose problems that schematic pictures do not. Schematic pictures lend themselves much more easily to controlled variations in the level of ambiguity (e.g., by morphing stimuli between a schematic flower and spider, see below) because they are restricted to the variation of shape information. This ambiguity is much less restrained in the case of natural images where typically shape, color, and texture information are combined. Because of this combination the range of potential stimuli is much larger compared to schematic pictures. Consequently, there is a risk that differences in information processing are driven by shape, color, or texture information that is specific for the tested exemplars. At the same time, schematic stimuli should still contain the most relevant “hardwired” key (shape) features of the natural images (i.e., spider body and legs). As a consequence, information processing can be measured over this range of different ambiguity levels and compared for individuals with specific phobia and non-anxious controls. Finally, by using schematic stimuli, it is possible to compare information processing of phobic stimuli to that of stimuli which are perceptually very similar – in contrast to a comparison to the processing of very distinct natural images of butterflies, mushrooms, and flowers.

Here, we use stimuli that were designed to investigate “the role of the Gestalt of a spider as one of the fear-inducing properties that might induce fear in spider phobic subjects” (Kolassa et al., 2007; p. 2). Spiders are reduced to their key features and then morphed by a gradual shift of their contours into schematic flowers (Fig. 1, lower panel).[2] The morphing manipulations by Kolassa et al. (2006, 2007) allow us to investigate the influence of slight perceptual stimulus changes on rapid information processing and on measures of perceptual interpretation and emotional significance, and follow these influences over different levels of stimulus ambiguity. By using a response priming paradigm, we can tie in with our earlier results on phobic natural images (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013). Also, our study is related to research on morphed emotional face stimuli in the general population (e.g., Duval, Moser, Huppert, & Simons, 2013; Haberman & Whitney, 2007; Schweinberger, Burton, & Kelly, 1999) as well as in clinical and subclinical samples (e.g., Averbeck, Bobin, Evans & Shergill, 2012; Heuer, Lange, Isaac, Rinck, & Becker, 2010; Joormann & Gotlib, 2006). To the best of our knowledge, the effect of ambiguous schematic stimuli in phobic participants was never before tested with respect to rapid information processing.

The present study

We use a response priming paradigm that taps into the earliest stages of observable behavior (Klotz & Neumann, 1999; Klotz & Wolff, 1995; Vorberg et al., 2003; also cf. Schmidt, Haberkamp, & Schmidt, 2011). The paradigm was successfully applied in recent studies on information processing in individuals with specific phobias (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013). In response priming, participants have to classify target stimuli into different response categories (e.g., spider versus flower) by performing a speeded motor response. The target stimulus (e.g., spider) is preceded by a prime stimulus triggering either the same response as the target (consistent prime; e.g., spider) or the opposite response (inconsistent prime; e.g., flower). Consistent primes speed responses to the target, inconsistent primes slow down responses and increase error rates. This response priming effect increases with increasing stimulus-onset asynchrony (SOA) between prime and target for SOAs up to approximately 100 ms (Vorberg et al., 2003). While response compatibility paradigms have been used before to study processing advantages for fear-relevant material, response priming has special properties that have not yet been demonstrated for other paradigms. Many studies have confirmed that primes directly initiate the specific motor responses assigned to them – an effect clearly discernible in the time-course of lateralized readiness potentials and overt pointing movements (e.g., Leuthold & Kopp, 1998; Schmidt, 2002). Therefore, response priming effects are directly related to the visuomotor processes triggered by visual stimuli, and sensitive to differences in visuomotor processing.

In the current experiment, one group of spider-fearful participants and one control group with no fear of spiders responded to schematic pictures of flowers, spiders and morphed in-between pictures with respect to their perceptual similarity to a spider versus a flower (*perceptual rating task*), with respect to the dimensions of valence, arousal, disgust (*emotional rating task*), and in a response priming experiment (*priming task*). Schematic spiders and spider-like morphed pictures were assumed to be *fear-relevant* to non-anxious participants, but *phobic* to spider-fearful participants. Schematic flowers and flower-like morphed pictures were assumed to be *neutral* for the two groups.

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[2] Thanks to Iris-Tatjana Kolassa for kindly providing us with the original stimuli from Kolassa et al. (2006, 2007).

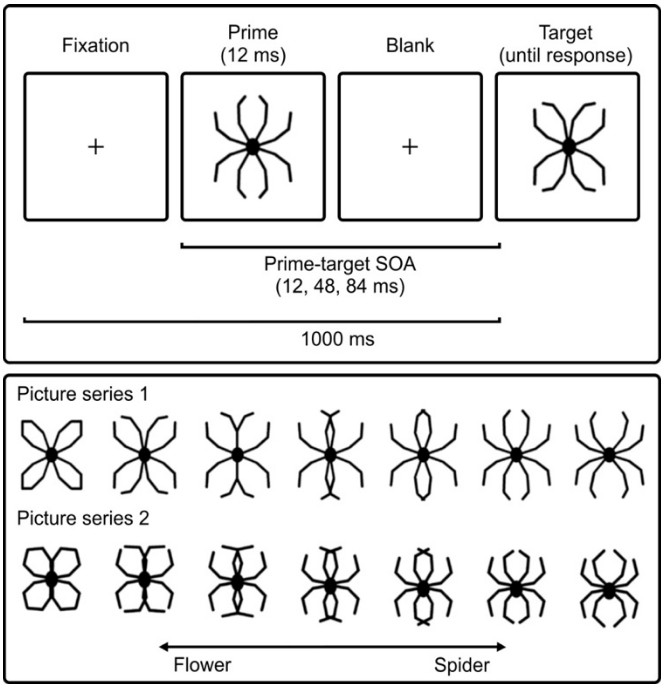

Figure 1. Procedure and stimuli. Upper panel: Primes and targets were presented in the sequence displayed. Lower panel: In each block, primes and targets were either drawn from picture series 1 or 2. The prime was any of the seven pictures; the target was either the second picture ("flower") or the second-to-last picture ("spider") in the respective series.

Based on the results of Kolassa et al. (2007), we hypothesize that the perception of ambiguous morphed stimuli will be biased towards spiders in the group of spider-fearful participants (i.e., in the *perceptual rating task* spider-fearful participants will more often classify ambiguous schematic pictures as spiders). Furthermore, we assume that schematic pictures of spider and spider-like stimuli will be rated as being more unpleasant, arousing, and disgusting by spider-fearful participants – in contrast to flower and flower-like schematic pictures and compared to the non-anxious control group (*emotional rating task*). Finally, we expect to observe response priming effects for both non-ambiguous schematic flower and spider pictures (*priming task*). As a new finding, these priming effects should level off with increasing ambiguity of the primes. More specifically, we expect that phobia-relevant pictures (i.e., spider-like morphed pictures) will be preferentially processed by spider-fearful participants; resulting in enhanced visuomotor processing of these pictures (1) in comparison to the visuomotor processing of neutral pictures (i.e. flower-like morphed pictures), and (2) compared to the visuomotor processing of fear-relevant spider-like pictures in the non-anxious control group. Based on our previous research (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013), this enhanced processing should be evident in larger response priming effects for phobia-relevant compared to neutral primes in the spider-fearful group as well as faster responses to phobia-relevant targets compared to neutral targets (within-group comparison). Also, we expect that priming effects elicited by phobia-relevant primes in the spider-fearful group will be larger compared to priming effects elicited by fear-relevant primes in the non-anxious control group as well as responses towards phobia-relevant targets in the spider-fearful group will be faster compared to responses towards fear-relevant targets in the control group (between-groups comparison).

In sum, we want to investigate the question to what extent ambiguous stimuli influence rapid information processing as measured by response priming effects. In other words, to what extent will an ambiguous prime that is rated as more spider-like (Kolassa et al., 2007) will be preferentially processed by the visual system? Finally, we are interested in whether this effect would be further enhanced in spider-fearful individuals as suggested by previous findings with non-ambiguous phobic stimuli that were preferentially processed by fearful individuals (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013).

Methods

Participants. Nineteen participants, all students from the University of Kaiserslautern, took part in the study. All of them were naïve to the purpose of the study. Nine of them reported that they were highly afraid of spiders (8 women, 1 man; age range 19-30 years), the other ten were not afraid of spiders and participated as control participants (4 women, 6 men; age range 18-33 years). Before the start of the experiment, we invited people which described themselves as highly afraid of spiders or not afraid of spiders at all.

Table 1. Means (SDs) and *t*-Tests for difference scores of spider-fearful and control participants in the two spider questionnaires (German version of the "Spider Questionnaire" SPQ; Hamm, 2006; German questionnaire "Fragebogen zur Angst vor Spinnen" FAS; Rinck et al., 2002), in the BDI (Beck et al., 1961) and for age.

	Spider-fear	Control	t (17)	*p*
Measure				
SPQ	20.78 (3.49)	2.70 (1.83)	-14.36	*p* < .001
FAS	70.44 (17.02)	2.90 (3.87)	-11.64*	*p* < .001
BDI	3.44 (2.30)	3.20 (1.93)	-0.25	*ns*
Age	22.11 (3.48)	22.70 (4.14)	0.33	*ns*

Note: *ns* = non significant; SPQ = Spider Questionnaire; FAS = Fragebogen zur Angst vor Spinnen; BDI = Beck Depression Inventory. *degrees of freedom adjusted due to unequal variance.

Consecutively, all of these potential participants were screened with objective tests to confirm (or refute) their subjective appreciations (Table 1). For this purpose, two spider questionnaires were applied (German version of the "Spider Questionnaire" SPQ; Hamm, 2006; original version by Klorman, Weerts, Hastings, Melamed, & Lang, 1974; German questionnaire "Fragebogen zur Angst vor Spinnen" FAS; Rinck et al., 2002; original version by Szymanski & O'Donohue, 1995).

All participants in the spider-fearful group had to score above 75th percentile in the spider questionnaire SPQ.[3] Control participants had to score below 25th percentile in the SPQ to exclude spider-fearful individuals in the control group.[4] Also, all participants completed the Beck-Depressions-Inventar (German version of the "Beck Depression Inventory" BDI; Hautzinger, Bailer, Worall, & Keller, 1995; original version by Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The data of participants having a BDI score above 18, indicating a clinical relevant depression, were excluded from the analysis. The two criteria excluded four participants in the group of spider-fearful participants (already excluded from the nine participants mentioned above); two for scoring too low in the SPQ and two for scoring above 18 in the BDI. The remaining nine spider-fearful and ten control participants scored significantly different in the spider questionnaires, but did not differ in mean BDI values or age (Table 1).

Additionally, all spider-fearful participants were tested for specific anxiety disorders using a structured diagnostic interview ("Diagnostic Interview for Psychological Symptoms (DIPS)"; Schneider & Margraf, 2006), based on the DSM-IV-TR (APA, 2000). Seven participants met at least five criteria for specific spider phobia, the other two participants met three criteria. The criterion that was not satisfied in most cases (criterion E) states that the individual's fear, anxiety, or avoidance causes significant distress or significant interference in the person's day-to-day life. For this reason, we will refer to these participants as "fearful" instead of "phobic".

All participants had normal or corrected-to-normal visual acuity and received payment of €6 per hour. All of them gave informed consent and were treated in accordance with the ethical guidelines of the American Psychological Association. The study was approved by the Ethical Committee of the Faculty of Social Sciences (University of Kaiserslautern).

Apparatus. The participants were seated in a dimly lit room in front of a color cathode-ray monitor (1280 × 1024 pixels, retrace rate 85 Hz) at a viewing distance of approximately 70 cm.

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[3] Note that one spider-fearful female participant scored on the 75th percentile. All other spider-fearful participants scored above the 85th percentile.

[4] Note that all control participants scored on the 20th percentile and below.

Stimuli and Procedure. Stimuli were two series of schematic flower/spider pictures from Kolassa et al. (2007). We did not include a third series of stimuli because it was perceptually very similar to one of the other series. Both series contained seven pictures that stepwise morphed a schematic flower into a schematic spider. This was achieved by shifting the angles of the closed contours of the flower petals such that they transformed into open contours resembling spider legs (Fig. 1, lower panel). The picture size varied between 3.03° x 3.36° of visual angle (flower) and 3.52° x 4.26° (spider) in series 1, and 2.95° x 3.03° (flower) and 2.95° x 3.85° cm (spider) in series 2 (1 cm ≈ 0.82° of visual angle). The contours of the schematic pictures were presented in black (0.13 cd/m²) against a white background (60.00 cd/m^2).

Priming task. Primes consisted of all 7 pictures of picture series 1 and 2, respectively (cf. Fig. 1, lower panel) and targets of pictures 2 and 6, respectively.[5] Each trial started with the appearance of the central fixation point (Fig. 1, upper panel). After a varying delay (between 916 to 988 ms), the prime was displayed for 12 ms either above or below the fixation point at 3.97°. Subsequently, the target was presented at the same position at prime-target SOAs of 12, 47, or 82 ms and remained on screen until the participant's response. The participants performed speeded keypress responses to classify the targets as quickly as possible by pressing the left button for flowers or the right button for spiders (or vice versa). In each trial, the prime was consistent, indifferent or inconsistent with the target – accordingly, we expected the prime to speed up, to not affect, or to slow down the motor response to the target. In each block, prime and target pictures were pseudo-randomly drawn from one of the seven prime or one of the two target pictures within the picture series. All stimulus combinations of prime, target, and prime-target SOA within one picture series occurred equiprobably and pseudo-randomly in a repeated measures design.

Each participant performed three separate sessions; the assignment of left and right response keys was counterbalanced across participants. Participants received summary feedback on the speed and correctness of their responses after each block. Each participant performed three 1-hour sessions with 1,344 trials each, composed of one practice block followed by 42 blocks of 32 trials. Participants were debriefed after the final session and received an explanation of the experiment.

Perceptual rating task. After the first session of the priming task, participants were asked to evaluate the prime pictures with respect to their perceptual appearance. Primes were presented one-by-one in a random order and on the same position and formatting as in the priming task. The rating involved a seven-point rating scale that was presented below the picture. The participants' task was to rate the presented picture according to its similarity to a flower or a spider by pressing keyboard buttons 1 ("The picture *very much* looks like a flower"), 2 ("The picture *somewhat* looks like a flower"), 3 ("The picture *slightly* looks like a flower"), 4 ("The picture *neither* looks like a flower *nor* like a spider"), 5 ("The picture *slightly* looks like a spider"), 6 ("The picture *somewhat* looks like a spider") to 7 ("The picture *very much* looks like a spider").

We decided to use a seven-point rating scale in contrast to three categories ("flower", "neither/nor", "spider") employed by Kolassa et al. (2007). A participant who is uncertain whether an ambiguous stimulus resembles a spider or a flower and is only provided with three response categories faces a difficult decision. She either gives the (incorrect) impression that she has no preference ("neither/nor") or the (incorrect) impression that she has a strong preference for either spider or flower. This might lead to an underestimation of the variance in participants'

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[5] We chose these targets over the least ambiguous pictures 1 and 7 because picture 1 (flower) in each condition consisted of closed shapes (the petals of the schematic flower) so that participants would have been able to base their responses on a superficial feature-based classification of closed (flower) versus open (spider) shapes. This would have most likely also eliminated any differences in response time effects based on differences in perceptual interpretation or emotional significance of the stimuli.

perceptual interpretations and, as a result, to a potential overestimation of potential perceptual biases (cf. Alwin & Krosnick, 1991). At the same time, presenting participants with rating scales much beyond 7 response options might overstrain them (Miller, 1956). Also, the seven-point rating scale conforms with the number of the morphed stimuli so that we could (de-)validate the rather artificial order defined by Kolassa et al. (2007) through the gradual changes in the angles of the closed contours of the flower petals. Finally, we matched the seven-point perceptual rating scale to the seven-point emotional rating scale (i.e., valence, arousal, and disgust), allowing for intuitive comparisons between the results in both ratings.

Emotional rating task. After the third session of the priming task, participants were asked to evaluate the prime pictures with respect to the induced emotional response. Primes were presented one-by-one in a random order and on the same position and formatting as in the priming task. The rating involved three dimensions (valence, arousal, and disgust) on a seven-point rating scale presented below the picture. Scales were coded so that high scores reflect high arousal and disgust, respectively. In the valence ratings, higher scores represent positive emotions towards the picture and lower scores reflect negative emotions. Again, participants rated the presented picture by pressing keyboard buttons 1 to 7.

Data treatment and statistical methods. Practice blocks were not analyzed. The data of one spider-fearful participant were excluded because her mean response times (*M* = 811.81 ms) deviated more than 2 *SD*s from the overall mean (*M* = 454.15 ms, *SD* = 174.58 ms). A single session of one participant was lost due to technical failure (1.75% of trials). Finally, trials were eliminated if response times were shorter than 100 ms or longer than 1,000 ms (0.60% of trials).

The overall error rate was about 3.81% of all trials. Error trials were not included in the response time analyses. Repeated-measures analyses of variance (rmANOVAs) were performed separately for response times and error rates with Huynh-Feldt-corrected *p* values. Error rates were arcsine transformed to comply with ANOVA requirements. We report *F* values with subscripts indicating the respective effect (e.g., $F_{P \times T}$ for the interaction of prime and target, i.e., the priming effect). Additionally, we report the effect size η^2 (cf. Levine & Hullett, 2002) in which 0.01 reflects a small, 0.059 reflects a medium, and 0.138 reflects a large effect (Cohen, 1988).

Results

Perceptual rating task

For results see Figure 2. The perceptual score was submitted as dependent variable to a univariate ANOVA with factors of group (*G*; control, spider fear), series (*SE*; morphed picture series 1, 2), and prime (*P;* morphed pictures 1 to 7). Both groups delivered the highest scores for spider pictures and the lowest score for flower pictures [$F_P(6,238) = 193.32$, $p < .001$] and this effect increased/decreased monotonically with morphing. Scores were generally higher in picture series 2 compared to series 1 [$F_{SE}(1,238) = 5.64$, $p = .018$], especially for

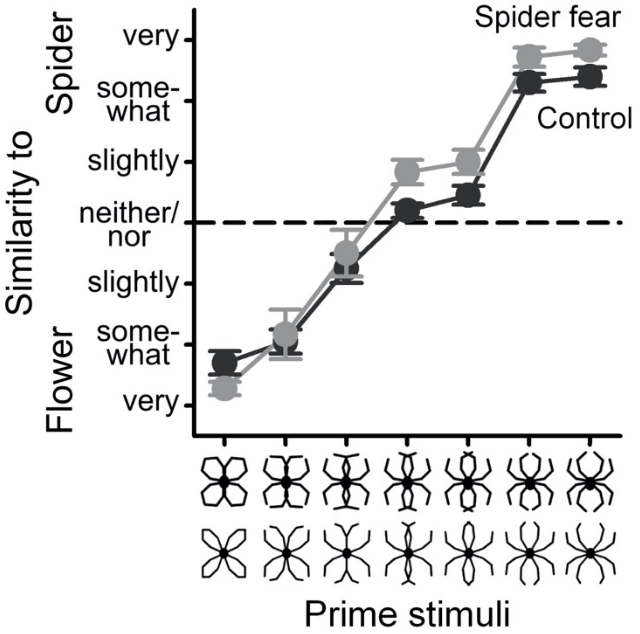

Figure 2. Participants' mean scores for the perceptual rating of the prime pictures (perceptual appearance) separately for each group and across picture series. The seven-point rating scale was coded such that higher scores reflect higher similarity of the stimulus to a spider, and lower scores reflect higher similarity to a flower. Error bars denote standard errors of the mean.

pictures 2 to 4 [$F_{SExP}(6,238) = 4.52$, $p < .001$]. As expected, the groups differed significantly regarding their classification. Spider-fearful participants achieved higher overall scores [$F_G(1,238) = 6.80$, $p = .010$], reflecting that they more often perceived a higher similarity of the pictures to a spider than to a flower. We found no interaction of group and prime, meaning that this effect was not limited to specific pictures.

Emotional rating task

For results of control participants (valence [*M* = 3.21, *SD* = 0.97], arousal [*M* = 0.18, *SD* = 0.51], and disgust [*M* = 0.18, *SD* = 0.54]) and spider-fearful participants (valence [*M* = 2.60, *SD* = 1.74], arousal [*M* = 1.68, *SD* = 1.74], and disgust [*M* = 1.67, *SD* = 1.92]) see Figure 3. All scores were submitted as dependent variables to multivariate ANOVAs with the same factors as in the perceptual rating task. As expected, the groups differed significantly regarding their evaluations. For all three scores, we obtained a main effect of group [all $F_G(1,238) > 16.64$, all $p < .001$], prime [all $F_P(6,238) > 34.78$, all $p < .001$], and an interaction of both factors [all $F_{GxP}(6,238) > 24.24$, all $p < .001$]. Thus, spider-fearful participants rated spider pictures more aversive on all three dimensions as compared to flower pictures or control participants. This effect monotonically increased/decreased with morphing. Control participants on the other hand, did not rate any of the pictures as particularly positive or negative, disgusting, or arousing.

Finally, we obtained effects of picture series for disgust scores [$F_G(1,238) = 6.98$, $p = .009$] and by trend for arousal scores [$F_G(1,238) = 3.70$, $p = .056$], reflecting that the pictures of series 2 were rated more negative on these dimensions by all participants. However, there were no interactions between picture series and other factors.

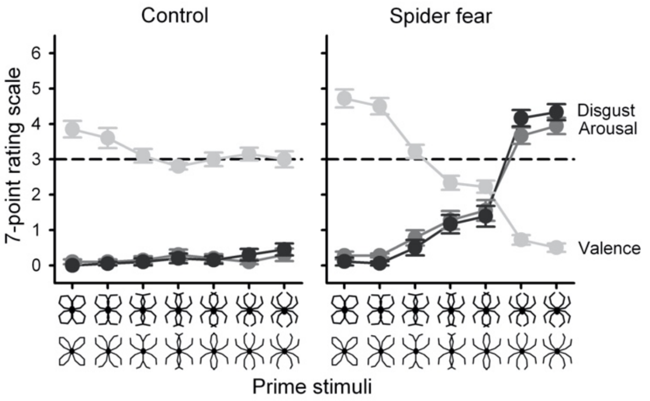

Figure 3. Participants' mean scores for the emotional rating of the prime pictures (valence, arousal, and disgust) separately for each group and across picture series. The seven-point rating scale was coded such that higher scores reflect more positive emotions (valence) or higher arousal and disgust towards the stimulus, respectively. Error bars denote standard errors of the mean.

To test whether the emotional ratings of spider-fearful participants were driven by their perception of ambiguous stimuli as more spider-like, we calculated Pearson product-moment correlations between the different emotional rating results and the perceptual rating results across all pictures. Indeed, we obtained strong correlations supporting that claim (Table 2). Note that although correlations are also significant for control participants, correlations in the spider-fearful group were substantially higher.

Table 2. Correlation coefficients and *p*-values for the Pearson product-moment correlations between the different emotional ratings and the perceptual ratings across all pictures separately for both groups.

	Spider-fear		*Control*	
	Pearson's r	*p*	*Pearson's r*	*p*
Emotional rating				
Valence	.872	*p* < .001	.298	*p* < .001
Arousal	.778	*p* < .001	.153	*p* = .070
Disgust	.782	*p* < .001	.279	*p* = .001

Priming task: overall results

We performed a fully-factorial rmANOVA with the between-factor of group (*G*; control, spider fear), and within-factors of series (*SE*; morphed picture series 1, 2), target (*T;* flower, spider), prime (*P;* morphed pictures 1 to 7), and SOA (*S;* 12, 48, 84 ms). This analysis allows analyzing our results with respect to priming effects, effects of the picture series, and target effects for spider-fearful and control participants.

Influence of the primes on priming effects. Response priming effects are defined as the difference between the responses to the flower and spider targets as a function of the morphed primes (Fig. 4). Most importantly, priming effects depended strongly on the morphed primes, in response times [$F_{TxP}(6,102) = 278.95$, $p < .001$, $\eta^2 = 0.258$] as well as error rates [$F_{TxP}(6,102) = 50.15$, $p < .001$, $\eta^2 = 0.394$]. Responses to the flower targets were fastest and most accurate when following the flower prime but increasingly slower and erroneous when the prime morphed into a spider. Equivalently, responses to the spider targets were fastest and most accurate following the spider prime but increasingly slower and erroneous when the prime morphed into a flower. These changes in response times and error rates followed a linear trend [$F_{TxP}(1,17) = 427.00$, $p < .001$, $\eta^2 = 0.246$; $F_{TxP}(1,17) = 68.41$, $p < .001$, $\eta^2 = 0.397$, respectively], suggesting that priming effects linearly increased/decreased with morphing. Moreover, priming effects increased strongly with SOA in response times [$F_{TxPxS}(12,204) = 65.56$, $p < .001$, $\eta^2 = 0.083$] as well as in error rates [$F_{TxPxS}(12,204) = 15.59$, $p < .001$, $\eta^2 = 0.164$] (cf. Schmidt et al., 2011; Vorberg et al., 2003).

Importantly, overall priming effects in response times and error rates were not different between spider-fearful and control participants [$F_{GxTxP}(6,102) = 0.42$, $p = .683$, $\eta^2 = 0.001$; $F_{GxTxP}(6,102) = 0.14$, $p = .867$, $\eta^2 = 0.002$]. This shows that the differences between groups in the perceptual and emotional ratings of ambiguous stimuli did not translate to differences in priming effects.

To test whether our results are in line with previous reports of enhanced information processing for non-ambiguous natural stimuli (e.g., Haberkamp et al., 2013), we calculated rmANOVAs including only the most discernible primes (i.e., the morphed pictures 1 and 7). To allow for a meaningful analysis, we defined a new within-factor consistency (*C*, consistent, inconsistent), coding whether the target was in the same category (flower, spider) as the prime or not. A significant effect of consistency corresponds to a significant priming effect. Indeed, we observed a three-way interaction of group, prime, and consistency in response times [$F_{GxPxC}(1,17) = 6.55$, $p = .020$, $\eta^2 = 0.011$] but not in error rates. Specifically, priming was larger for spiders compared to flowers in spider-fearful participants, and vice versa in control participants, replicating our previous findings (Haberkamp et al., 2013). There was no further modulation of this group effect by the factors of morphed picture series or SOA.

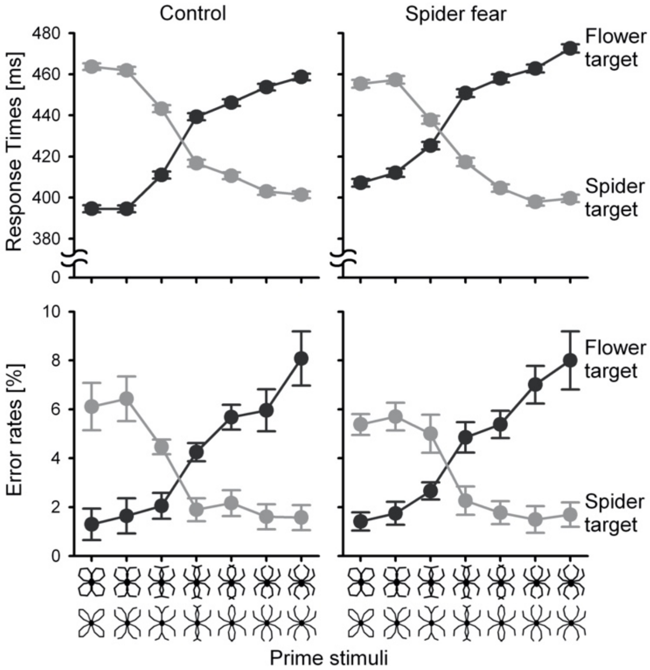

Figure 4. Upper panels: Response times to spider and flower targets as a function of prime picture. Response times are shown separately for each group and across picture series and SOA. Although the SOA is strongly modulating the priming effects, it has only a prototypical influence on the effects. Lower panels: Error rates, displayed equivalently to response times. In all panels, error bars denote standard errors of the mean with pure intersubject variance removed (Cousineau, 2005).

Influence of the targets on overall response times. In the overall analysis (rmANOVA), it was also found that responses were faster to spider targets [$F_T(1,17) = 5.81$, $p = .028$, $\eta^2 = 0.011$] compared to flower targets. Because responses to spider targets were also more accurate [$F_T(1,17) = 4.78$, $p = .043$, $\eta^2 = 0.033$], this was not a result of speed-accuracy trade-off. Interestingly, we also observed differences for response times to spider and flower targets between the groups [$F_{GxT}(1,17) = 5.87$, $p = .027$, $\eta^2 = 0.037$] (Fig. 5): spider-fearful participants responded faster (but not more accurate) to spider targets [$M = 423.81$ ms, $SD = 102.26$] compared to flower targets [$M = 440.63$ ms, $SD = 105.97$]. This was not the case for control participants (spider targets [$M = 428.13$ ms, $SD = 98.90$], flower targets [$M = 427.67$ ms, $SD = 102.28$]). Again, this replicates previous findings with non-ambiguous natural stimuli (Haberkamp et al., 2013).

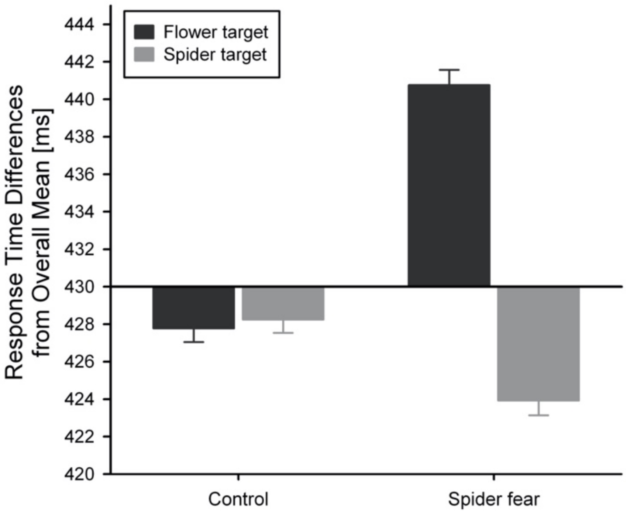

Figure 5. Response times to spider and flower targets, separately for each group and across picture series and SOA. Response times are shown relative to the grand average response time of 430 ms. Error bars denote standard errors of the mean.

Influence of the picture series on results. Unexpectedly, we observed different results for picture series 1 and 2 in the two rating tasks. Thus, we also included this factor in the analyses of priming and target effects (rmANOVA) and found that it had a strong influence on overall results. In series 2, responses were generally faster [$F_{SE}(1,17) = 44.25$, $p < .001$, $\eta^2 = 0.020$] and error rates were by trend lower [$F_{SE}(1,17) = 4.37$, $p = .052$, $\eta^2 = 0.006$]. Also, priming effects in series 2 compared to series 1 were stronger in response times [$F_{SExTxP}(6,102) = 4.91$, $p < .001$, $\eta^2 = 0.003$] and by trend in error rates [$F_{SExTxP}(6,102) = 2.18$, $p = .051$, $\eta^2 = 0.011$]. Furthermore, the target effects (i.e., the faster and more accurate responses to spider targets) were stronger in series 2 in response times [$F_{SExT}(1,17) = 11.27$, $p = .004$, $\eta^2 = 0.037$] but stronger in series 1 in error rates [$F_{SExT}(1,17) = 18.06$, $p = .001$, $\eta^2 = 0.037$]. With no a-priori hypotheses concerning the different picture series, we are not able to interpret the observed differences. However, we might speculate that they arise from differences in the energy of spatial frequencies, for example, in contrast energy at midrange spatial frequencies for which humans are most sensitive (Cole & Wilkins, 2013; Delplanque, N'diaye, Scherer, & Grandjean, 2007).

Discussion

We studied perception, evaluation, and visuomotor processing of ambiguous schematic stimuli in spider-fearful and control participants. Compared to control participants, spider-fearful participants showed a general perceptual interpretative bias to perceive schematic pictures as more similar to a spider (Becker & Rinck, 2004) and evaluated spider-like pictures as more negative, disgusting, and arousing. Finally, spider-fearful participants responded faster to spider targets, and showed larger priming effects for spider primes – however, compared to control participants they did not show stronger priming effects for ambiguous prime stimuli.

Rating Tasks

Based on the results of Kolassa et al. (2007) as well as the findings from Becker and Rinck (2004), we expected an interpretative bias in spider-fearful participants. Specifically, spider-fearful participants should classify ambiguous schematic pictures as more similar to spiders compared to flowers.

Indeed, although we did use a different number of response categories, spider-fearful participants compared to non-anxious control participants more often classified all schematic stimuli as resembling spiders, replicating the general interpretative bias reported by Becker and Rinck (2004). However, spider-fearful participants did not specifically classify the ambiguous pictures 2 to 6 as more similar to spiders. Thus, we did not replicate the findings by Kolassa et al. (2007) for ambiguous schematic stimuli.

Still, the rather artificial order of the morphed stimuli defined by Kolassa et al. (2007) is reflected in the subjective percepts of these stimuli. For example, picture 3 of prime condition 2 (cf. Fig. 1, lower panel) might also have passed as being more spider- than flower-like but was rated according to the suggested order. This suggests that the principles by which the morphed stimuli were constructed might be similar to the principles by which the visual system extrapolates stages between the schematic spider and flower stimuli (*causal history*; cf. Leyton, 1989). With respect to the emotional ratings, we assumed that an interpretative bias for ambiguous stimuli in the spider-fearful group would also lead to more negative evaluations of these stimuli. Indeed, spider-fearful participants rated spider and spider-like stimuli as being more unpleasant, arousing, and disgusting compared to the flower and flower-like stimuli (within group comparison) as well as compared to the ratings of the spider and spider-like stimuli by the non-anxious control group (between groups comparison).

The results of both rating tasks validated the schematic picture stimuli by showing that they were able to induce an interpretative bias in spider-fearful participants and that they were emotionally relevant (i.e., phobic) to these participants. Both findings suggest that we also might find differences in information processing for these stimuli within and between groups.

Response Priming Task

Overall, we found robust response priming effects in the two groups for all primes as well as for the most discernible primes (i.e., the least ambiguous pictures of spiders and flowers). In general, inconsistent compared to consistent primes slowed down response times and increased error rates. These priming effects increased with prime-target SOA. As expected, priming effects levelled off with increasing ambiguity of the stimuli. This again shows that the representation of the morphed stimuli in the visual system is based on the same rotation transformations that were used to construct the stimuli. Our results are also in line with previous reports of decreasing similarity judgements and slower response times in same-different tasks with increasing transformational distance between two objects (e.g., increasing angular departure; e.g., Shepard & Cooper, 1982).

In the following, we focus on differences in visuomotor processing within each group of spider-fearful and non-anxious control participants that might show up in the overall response times (reflecting processing aspects of the target) as well as in the magnitude of priming effects (reflecting processing aspects of the prime) (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013).

In the control group, we found no systematic differences in the responses towards the two different targets (spider or flower). Thus, even though spiders are often assumed to be fear-relevant for non-anxious individuals, this was not reflected in our results. This is consistent with the fact that control participants rated the spider pictures as only slightly negative, arousing, and disgusting (Fig. 3). First, these findings are also in accordance with previous response priming results on fear-relevant natural images (Haberkamp & Schmidt, 2014; Haberkamp et al., 2013). Second, they are in accordance with the findings by Tipples et al. (2002) who did not observe any biases for threatening stimuli in non-anxious individuals in a visual search task (but see Fox et al., 2000; Lipp & Waters, 2007; Öhman et al., 2001; Williams et al., 2005).

Importantly, spider-fearful participants showed a different result pattern. Firstly, they responded more rapidly to spider targets as compared to flower targets. In turn, the fast responses to spider targets affected the size of the priming effect which led to larger priming effects in cases where the target was preceded by a spider prime and to smaller priming effects in cases where the target was preceded by a flower prime. In other words, if the prime was a clearly discernible spider picture, a subsequent spider target led to faster responses due to (1) the consistency of prime and target, and (2) the aversiveness of the target. In contrast, when the prime was a clearly discernible flower picture, priming effects were reduced because responses to the spider target were still relatively fast, even though the target was inconsistent to the prime (cf. Haberkamp et al., 2013). Thus, our results show that in spider-fearful participants spider targets and spider primes lead to faster responses and larger priming effects, respectively. Nevertheless, the observed pattern of results was restricted to trials in which the primes were clearly discernible and did not translate to trials with ambiguous primes. Although priming effects increased monotonically with decreasing ambiguity of the primes and spider-fearful participants rated ambiguous stimuli as being more spider-like and therefore more unpleasant, we observed no interaction effect between prime, target and group. This might be due to two reasons. First, the physical variations in the most ambiguous stimuli might have been too small, resulting in only small changes in the observed priming effects. Consequently, to detect differences between the two groups, we would need higher statistical power. Second, enhanced information processing of phobic stimuli in fearful participants might be based on perceptual learning processes: stimuli to which a person is frequently exposed are processed via ‘hardwired’ binding of features which in turn accelerates processing of these stimuli (cf. VanRullen, 2009). Thus, ambiguous stimuli might just not share enough ‘hardwired’ features with previously experienced phobic spider stimuli to be subject to enhanced information processing.

Note also that overall effects sizes related to within-group and between-group comparisons are only moderate. The results are thereby noticeably different to our findings in an earlier response priming study with natural images of spiders and flowers that produced large effect sizes for differences between spider-fearful and non-anxious control participants (Haberkamp et al., 2013). It is reasonable to presume that this difference in results is a consequence of the applied stimuli. Thus, natural images – which are of much higher ecological validity compared to schematic pictures – are stronger in eliciting emotional responses in spider-fearful participants. As a consequence, accompanying enhancements in information processing might be stronger for natural images compared to schematic pictures.

To sum up, we found that spider-fearful participants showed an interpretative bias in the classification of ambiguous schematic stimuli. Also, they rated spider-like stimuli as more unpleasant, disgusting, and arousing. Finally, these stimuli were processed more rapidly compared to flower-like stimuli, and more rapidly compared to the same stimuli in the control group. But how are all these results related and what are the underlying mechanisms of this enhancement?

We suggest that our findings can be explained in terms of perceptual learning processes. Perceptual learning can occur each time a person identifies an object. Usually, in object recognition elementary features (e.g., shape, color) must be bound into objects; for example, eight black pins and a black oval body may be bound into the silhouette of a spider. According to many authors, this process requires attentional resources and should therefore be time-consuming (e.g., Treisman, 1996). Contradicting this view, VanRullen (2009) pointed out that this notion is in conflict with the remarkable speed of object categorization responses in natural scenes and suggests a process of ‘hardwired’ feature binding as a consequence of perceptual learning. For example, if a person is frequently exposed to spiders, this might induce enhancements in the functional properties of the cortical arrays involved in spider detection and recognition. If the person additionally perceives spiders as threatening like our spider-fearful participants, this process might be further strengthened by attentional biases (i.e., attention is automatically and involuntarily drawn towards the phobic stimuli; Yiend, 2010). In other words, the participants’ fear of spiders leads to an intensified monitoring of the environment, especially in critical surroundings like the attic or the basement. That behavior increases the probability to detect and attend spiders. Additionally, it is plausible that ambiguous stimuli are more frequently classified as spiders because this strategy helps to avoid the feared animal. Thus, the negative emotionality towards spiders and the interpretative bias enhances perceptual learning processes and these processes modulate the processing hardware concerned with that stimulus class and enables enhanced information processing of those stimuli (cf. Haberkamp et al., 2013).

Limitations

Even though we found evidence for enhanced information processing of phobic schematic pictures, the current study has specific limitations.

First, in contrast to Kolassa et al. (2007) neither spider aficionados nor a second experimental group (e.g., individuals with social phobia) took part in the experiment. The inclusion of spider aficionados might have been of further interest for a decided analysis whether perceptual learning processes indeed play a role for enhanced information processing or whether the effect is primarily driven by the emotionality of the ambiguous stimuli. Including a second experimental group of fearful individuals (e.g., individuals with social phobia) would have ruled out the possibility that the fear-relevant pictures of spiders enhance information processing in individuals with anxiety disorders per se. Yet, recent literature suggests that attentional biases and enhanced information processing in spider-fearful individuals are restricted to the phobic spider stimuli (Haberkamp et al., 2013; Öhman, et al., 2001; Soares, Esteves, Lundqvist, & Öhman, 2009). This is in contrast to, for example, individuals with blood-injury-injection phobia (Armstrong, Hemminger, & Olatunji, 2013).

Second, we specifically recruited participants with a known fear of spiders (experimental group) and with no fear of spiders (control group). However, the experimenter emphasized before the diagnostic and rating sessions that we were interested in the subjective attitudes of our participants towards spiders and flowers and that, for example, even individuals with no specific fear of spiders might feel negative emotions towards these animals. Also, our diagnostic procedure corresponds to the study design of recent studies with spider-fearful individuals (e.g., Becker & Rinck, 2004; Haberkamp et al., 2013; Lipp & Waters, 2007).

Third, the use of schematic stimuli might be problematic as illustrated by earlier research on face processing using schematic face stimuli (e.g., “smileys” and “grumpys”). It was demonstrated that differences in the processing of schematic faces might be due to low-level differences rather than differences in the displayed emotions (e.g., Coelho et al., 2010; Becker et al., 2011; Horstmann, 2007; Horstmann & Bauland, 2006; Schmidt & Schmidt, 2013; Stein & Sterzer, 2012). Although these results suggest that it is not possible to eliminate the influence of low-level stimulus characteristics just by using schematic stimuli, the perceptual differences between stimuli in the current study are rather small. Also, the rather artificial stimulus order by Kolassa et al. (2006, 2007) was reflected in the emotional ratings, the perceptual ratings, as well as in the response priming tasks. Thus, we can conclude that low-level differences did not bias the current results.

Summary

In our study, we investigated the influence of morphed spider and flower pictures on perception, emotion, and rapid information processing in spider-fearful participants compared to non-anxious control participants. By employing a perceptual and emotional rating scale and comparing all pictures in their ability to drive priming effects, we validated the effectiveness and order of the morphed stimulus sets. The latter finding also suggests the representation of the morphed stimuli in the visual system is based on the same rotation transformations that were used to construct the stimuli. In accordance with Kolassa et al. (2006, 2007), we also found an interpretative bias in spider-fearful individuals that also rated spider-like stimuli as more unpleasant, disgusting, and arousing compared. Finally, spider-like stimuli were processed more rapidly compared to flower-like stimuli as well as compared to the same stimuli in the control group. This was reflected in accelerated responses towards spider targets and larger priming effects elicited by spider primes. However, we did not observe different priming effects between groups for ambiguous primes. We suggest that our results can be explained in terms of perceptual learning, just as earlier findings with natural images (Haberkamp et al., 2013).

Author note

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Reference

Alwin, D.F., & Krosnick, J.A. (1991). The Reliability of Survey Attitude Measurement The Influence of Question and Respondent Attributes. *Sociological Methods & Research*, *20*(1), 139-181. http://dx.doi.org/10.1177/0049124191020001005

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders, 4th edn. Text Revision (DSM-IV-TR).* Washington, D.C.: American Psychiatric Association.

Amir, N., Foa, E.B., & Coles, M.E. (1998). Automatic activation and strategic avoidance of threat-relevant information in social phobia. *Journal of abnormal psychology*, *107*(2), 285. http://dx.doi.org/10.1017/S0033291711001413

Armstrong, T., Hemminger, A., & Olatunji, B.O. (2013). Attentional bias in injection phobia: overt components, time course, and relation to behavior. *Behaviour Research and Therapy, 51,* 266–273. http://dx.doi.org/10.1016/j.brat.2013.02.008

Averbeck, B.B., Bobin, T., Evans, S., & Shergill, S.S. (2011). Emotion recognition and oxytocin in patients with schizophrenia. *Psychological Medicine*, *42*, 1-9. http://dx.doi.org/10.1017/S0033291711001413

Bacon-Macé, N., Kirchner, H., Fabre-Thorpe, M., & Thorpe, S.J. (2007). Effects of task requirements on rapid natural scene processing: From common sensory encoding to distinct decisional mechanisms. *Journal of Experimental Psychology. Human Perception and Performance, 33,* 1013–1026. http://dx.doi.org/10.1037/0096-1523.33.5.1013.

Beck, A.T., Ward, C.H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An Inventory for Measuring Depression. *Archives of General Psychiatry, 4,* 53-63.

Becker, D.V., Anderson, U.S., Mortensen, C.R., Neufeld, S.L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General, 140,* 637-659. http://dx.doi.org/10.1037/a0024060

Becker, E., & Rinck, M. (2004). Sensitivity and response bias in fear of spiders. *Cognition and Emotion, 18(7),* 961-976. http://dx.doi.org/10.1080/02699930341000329

Coelho, C.M., Cloete, S., & Wallis, G. (2010). The face-in-the-crowd effect: When angry faces are just cross(es). *Journal of Vision, 10,* 1-14. 10. http://dx.doi.org/1167/10.1.7

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.) Hillsdale, NJ: Lawrence Erlbaum Associates.

Cole, G. G., & Wilkins, A. J. (2013). Fear of holes. *Psychological Science*. doi: 10.1177/0956797613484937.

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorials in Quantitative Methods for Psychology, 1,* 42-45.

de Jong, P. J., Merckelbach, H., Bögels, S., & Kindt, M. (1998). Illusory correlation and social anxiety. *Behaviour research and therapy*, *36*(11), 1063-1073. http://dx.doi.org/10.1016/S0005-7967(98)00099-0

Delplanque, S., N'diaye, K., Scherer, K., & Grandjean, D. (2007). Spatial frequencies or emotional effects?: A systematic measure of spatial frequencies for IAPS pictures by a discrete wavelet analysis. *Journal of Neuroscience Methods*, *165*(1), 144-150.

Duval, E. R., Moser, J. S., Huppert, J. D., & Simons, R. F. (2013). What's in a face? The late positive potential reflects the level of facial affect expression. *Journal of Psychophysiology*, *27*(1), 27. http://dx.doi.org/10.1027/0269-8803/a000083

Eastwood, J., Smilek, D., Oakman, J., Farvolden, P., van Ameringen, M., Mancini, C., & Merikle, P. (2005). Individuals with social phobias are biased to become aware of negative faces. *Visual Cognition, 12,* 159–179. http://dx.doi.org/10.1080/13506280444000175

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion, 14*(1), 61–92. http://dx.doi.org/10.1080/026999300378996

Gilboa-Schechtman, E., Foa, E. B., & Amir, N. (1999). Attentional biases for facial expressions in social phobia: The face-in-the-crowd paradigm. *Cognition and Emotion, 13*(3), 305–318. http://dx.doi.org/10.1080/026999399379294

Haberkamp, A., Schmidt, F., & Schmidt, T. (2013). Rapid visuomotor processing of phobic images in spider-and snake-fearful participants. *Acta psychologica*, *144*(2), 232-242. http://dx.doi.org/10.1016/j.actpsy.2013.07.001

Haberkamp, A., & Schmidt, T. (2014). Enhanced visuomotor processing of phobic images in blood-injury-injection fear. *Journal of anxiety disorders, 28,* 291–300. http://dx.doi.org/10.1016/j.janxdis.2014.02.001

Haberman, J., & Whitney, D. (2007). Rapid extraction of mean emotion and gender from sets of faces. *Current Biology*, *17*(17), R751-R753. http://dx.doi.org/10.1016/j.cub.2007.06.039

Hamm, A. (2006). *Spezifische Phobien.* Göttingen: Hogrefe.

Hautzinger, M., Bailer, M., Worall, H., & Keller, F. (1994). Beck-Depressions-Inventar (BDI). Bearbeitung der deutschen Ausgabe. Testhandbuch. *Bern: Huber*.

Heinrichs, N., & Hofmann, S.G. (2001). Information processing in social phobia: A critical review. *Clinical psychology review*, *21*(5), 751-770. http://dx.doi.org/10.1016/S0272-7358(00)00067-2

Heuer, K., Lange, W. G., Isaac, L., Rinck, M., & Becker, E. S. (2010). Morphed emotional faces: emotion detection and misinterpretation in social anxiety. *Journal of behavior therapy and experimental psychiatry*, *41*(4), 418-425. http://dx.doi.org/10.1016/j.jbtep.2010.04.005

Horstmann, G. (2007). Preattentive face processing: What do visual search experiments with schematic faces tell us? *Visual Cognition, 15,* 799–833. http://dx.doi.org/10.1080/13506280600892798

Horstmann, G., & Bauland, A. (2006). Search asymmetries with real faces: Testing the anger-superiority effect. *Emotion, 6(2),* 193-207. http://dx.doi.org/10.1037/1528-3542.6.2.193

Joormann, J., & Gotlib, I.H. (2006). Is this happiness I see? Biases in the identification of emotional facial expressions in depression and social phobia. *Journal of abnormal psychology*, *115*(4), 705. http://dx.doi.org/10.1037/0021-843X.115.4.705

Kiesel, A., Kunde, W., Pohl, C., Berner, M. P., & Hoffmann, J. (2009). Playing chess unconsciously. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), 292-298.

Kirchner, H., & Thorpe, S.J. (2006). Ultra-rapid object detection with saccadic eye movements: Visual processing speed revisited. *Vision Research, 46,* 1762–1776. http://dx.doi.org/10.1016/j.visres.2005.10.002.

Klorman, R., Weerts, T.C., Hastings, J.E., Melamed, B.G., & Lang, P.J. (1974). Psychometric description of some specific fear questionnaires. *Behavior Therapy, 5,* 401-409. http://dx.doi.org/10.1016/S0005-7894(74)80008-0

Klotz, W., & Neumann, O. (1999). Motor activation without conscious discrimination in metacontrast masking. *Journal of*

Experimental Psychology. Human Perception and Performance, 25, 976–992. http://dx.doi.org/10.1037/0096-1523.25.4.976.

Klotz, W., & Wolff, P. (1995). The effect of a masked stimulus on the response to the masking stimulus. *Psychological Research, 58,* 92–101. http://dx.doi.org/10.1007/BF00571098.

Kolassa, I.T., Buchmann, A., Lauche, R., Kolassa, S., Partchev, I., Miltner, W.H., & Musial, F. (2007). Spider phobics more easily see a spider in morphed schematic pictures. *Behavioral and Brain Functions*, *3*, 59. http://dx.doi.org/10.1186/1744-9081-3-59

Kolassa, I.T., Musial, F., Kolassa, S., & Miltner, W.H. (2006). Event-related potentials when identifying or color-naming threatening schematic stimuli in spider phobic and non-phobic individuals. *BMC psychiatry, 6*(1), 38. http://dx.doi.org/10.1186/1471-244X-6-38

Leuthold, H., & Kopp, B. (1998).Mechanisms of priming by masked stimuli: Inferences from event-related brain potentials. *Psychological Science, 9,* 263–269. http://dx.doi.org/10.1111/1467-9280.00053.

Levine, T.R., & Hullet, C.R. (2002). Eta squared, partial eta squared, and misreporting of effect sizes in communication research. *Human Communication Research, 28*, 612–625. http://dx.doi.org/10.1111/j.1468-2958.2002.tb00828.x

Leyton, M. (1989). Inferring causal history from shape. *Cognitive Science*, *13*, 357-387.

Lipp, O., & Waters, A.M. (2007). When danger lurks in the background: Attentional capture by animal fear-relevant distractors is specific and selectively enhanced by animal fear. *Emotion, 7,* 192–200. http://dx.doi.org/10.1037/1528-3542.7.1.192.

Mellings, T., & Alden, L.E. (2000). Cognitive processes in social anxiety: The effects of self-focus, rumination and anticipatory processing. *Behaviour Research and Therapy*, *38*(3), 243-257. http://dx.doi.org/10.1016/S0005-7967(99)00040-6

Miller, G.A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological review*, *63*(2), 81. http://dx.doi.org/10.1037/h0043158

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology. General, 130,* 466–478. http://dx.doi.org/10.1037/AXJ96-3445.130.3.466.

Rinck, M., Bundschuh, S., Engler, S., Müller, A., Wissmann, J., Ellwart, T., & Becker, E.S. (2002). Reliabilität und Validität dreier Instrumente zur Messung von Angst vor Spinnen. *Diagnostica, 48,* 141-149. http://dx.doi.org/10.1026//0012-1924.48.3.141

Schmidt, F., Haberkamp, A. & Schmidt, T. (2011). Do's and dont's in response priming research. *Advances in Cognitive Psychology, 7*, 120–131. http://dx.doi.org/10.2478/v10053-008-0092-2

Schmidt, T. (2002). The finger in flight: Real-time motor control by visually masked color stimuli. *Psychological Science, 13,* 112-118. http://dx.doi.org/10.1111/1467-9280.00421

Schmidt, F. & Schmidt, T. (2013). No difference in flanker effects for sad and happy schematic faces: A parametric study of temporal parameters. *Visual Cognition, 21,* 382- 398. http://dx.doi.org/10.1080/13506285.2013.793221

Schmidt, T., & Schmidt, F. (2009). Processing of natural images is feedforward: A simple behavioral test. *Attention, Perception, & Psychophysics, 71,* 594-606. http://dx.doi.org/10.3758/APP.71.3.594

Schneider, S. & Margraf, J. (2006). *DIPS – Diagnostisches Interview bei psychischen Störungen.* (3. Aufl.). Heidelberg: Springer.

Schweinberger, S.R., Burton, A.M., & Kelly, S.W. (1999). Asymmetric dependencies in perceiving identity and emotion:

Experiments with morphed faces. *Perception & Psychophysics*, *61*(6), 1102-1115.

Shepard, R., & Cooper, L. (1982). *Mental images and their transformations.* Cambridge, MA: MIT Press.

Soares, S.C., Esteves, F., Lundqvist, D., & Öhman, A. (2009). Some animal specific fears are more specific than others: Evidence from attention and emotion measures. *Behaviour Research and Therapy, 47(12),* 1032–1042. http://dx.doi.org/10.1016/j.brat.2009.07.022

Szymanski, J., & O'Donohue, W. (1995). Fear of Spiders Questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry, 26,* 31–34.

Stein, T., & Sterzer, P. (2012). Not just another face in the crowd: Detecting emotional schematic faces during Continuous Flash Suppression. *Emotion, 12,* 988-996. http://dx.doi.org/10.1037/a0026944

Tipples, J., Young, A.W., Quinlan, P., Broks, P., & Ellis, A.W. (2002). Searching for threat. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 55,* 1007–1026. http://dx.doi.org/10.1080/02724980143000659.

Treisman, A. (1996). The binding problem. *Current Opinion in Neurobiology, 6,* 171–178. http://dx.doi.org/10.1016/S0959-4388(96)80070-5.

VanRullen, R. (2009). Binding hardwired versus on-demand feature. *Visual Cognition, 17,* 103–119. http://dx.doi.org/10.1080/13506280802196451.

Voncken, M.J., Bögels, S.M., & de Vries, K. (2003). Interpretation and judgmental biases in social phobia. *Behaviour Research and Therapy*, *41*(12), 1481-1488. http://dx.doi.org/10.1016/S0005-7967(03)00143-8

Vorberg, D., Mattler, U., Heinecke, A., Schmidt, T., & Schwarzbach, J. (2003). Different time courses for visual perception and action priming. *Proceedings of the National Academy of Sciences (USA), 100,* 6275–6280. http://dx.doi.org/10.1073/pnas.0931489100

Wells, A., Clark, D.M., & Ahmad, S. (1998). How do I look with my minds eye: Perspective taking in social phobic imagery. *Behaviour Research and Therapy*, *36*(6), 631-634. http://dx.doi.org/10.1016/S0005-7967(98)00037-0

Williams, M., Moss, S., Bradshaw, J., & Mattingley, J. (2005). Look at me, I'm smiling: Visual search for threatening and nonthreatening facial expressions. *Visual Cognition, 12,* 29–50. http://dx.doi.org/10.1080/13506280444000193.

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition & Emotion, 24,* 3–47. http://dx.doi.org/10.1080/02699930903205698.