Affective states leak into movement execution: Automatic avoidance of threatening stimuli in fear of spider is visible in reach trajectories

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Version of record first published: 07 Mar 2012.

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Affective states leak into movement execution: Automatic avoidance of threatening stimuli in fear of spider is visible in reach trajectories

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Approach-like actions are initiated faster with stimuli of positive valence. Conversely, avoidance-like actions are initiated faster with threatening stimuli of negative valence. We went beyond reaction time measures and investigated whether threatening stimuli also affect the way in which an action is carried out. Participants moved their hand either away from the picture of a spider (avoidance) or they moved their hand toward the picture of a spider (approach). We compared spider-fearful participants to non-anxious participants. When reaching away from the threatening spider picture, spider-fearful participants moved more directly to the target than controls. When reaching toward the threatening spider, spider-fearful participants moved less directly to the target than controls. Some conditions that showed clear differences in movement trajectories between spider-fearful and control participants were devoid of differences in reaction time. The deviation away from threatening stimuli provides evidence for the claim that affective states like fear leak into movement programming and produce deviations away from threatening stimuli in movement execution. Avoidance of threatening stimuli is rapidly integrated into ongoing motor behaviour in order to increase the distance between the participant's body and the threatening stimulus.

Keywords: Affective states; Hand trajectories; Reaching; Spider phobia; Threat.

Emotions are often considered a predisposition toward action (Darwin, 1872; Lang, Bradley, & Cuthbert, 1990; LeDoux, 2000). Two fundamental classes of actions can be distinguished in this context: approach of appetitive, positive stimuli and avoidance of aversive, negative stimuli. To show that negative stimuli automatically elicit avoidance, while positive stimuli automatically elicit approach, Chen and Bargh (1999; see also Solarz, 1960) ran an experiment in which they asked participants to evaluate the valence of a word in terms of "good" or "bad" by pushing or

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pulling a lever. Responses were faster when positive valence was paired with approach-like pulling responses and when negative valence was paired with avoidance-like pushing responses than with the opposite valence–response mapping.

Chen and Bargh's (1999) study has generated a number of follow-up studies that will be presented below. For the purpose of the present study, it is important to note that research on Chen and Bargh's approach–avoidance task is fundamentally about *when* one of two actions is selected. The main dependent variable was reaction time for valence-congruent versus valence-incongruent responses. In addition, a large part of this research used responses that were not aimed at a particular goal. For instance, observers pulled or pushed a lever that was not in close proximity to the stimuli on the computer screen. Here, we present results from a novel paradigm in which we were not primarily interested in *when* an action was executed but in *how* it was executed. The question is whether and how the affective state (fear) before movement execution affects the spatial character-istics of the response. To our knowledge, this is the first study on the influence of affective, and not cognitive, states (see Song & Nakayama, 2009, for a review) on motor execution in choice reaching tasks.

Our question seems relevant in light of two issues that have been investigated in the wake of Chen and Bargh's (1999) study. First, the claim that priming of valence-congruent actions is auto-matic. Chen and Bargh (1999), Experiment 2) changed the task and made the valence of the stimulus word irrelevant. Participants just pushed the lever upon presentation of the word in the first block of trials and pulled it in the second block (or vice versa). Because the compatibility effect per-sisted, the authors concluded that priming of valence-congruent responses is automatic. Subse-quent studies, however, produced inconsistent results (De Houwer, Crombez, Baeyens, & Hermans, 2001; Lavender & Hommel, 2007; Rotteveel & Phaf, 2004), supporting the idea that the conscious processing of the valence of stimuli is a precondition for valence–response congruency effects.

Second, there was a discussion about which motor responses constitute approach and avoid-ance. Chen and Bargh (1999) considered arm flexion and extension as approach and avoidance, respectively, probably because flexion is involved in behaviour such as eating. Rotteveel and Phaf (2004) confirmed that flexion and extension result in valence–response congruency effects even when the movements are not executed toward and away from the body, but vertically up and down. However, subsequent studies showed that the association between a certain motor response and its significance (to approach or avoid) may be highly flexible (Eder & Rothermund, 2008; Eder, Rothermund, & Proctor, 2010; Lavender & Hommel, 2007).

In our experiments, participants saw pictures of an animal in the left and the right hemifield. They had to indicate the position of the target by reaching to a small box below the target (see Figure 1). Participants reached toward a positive butterfly picture in Experiment 1 and toward a negative spider picture in Experiment 2. In addition to the target stimulus, a distractor stimulus was shown in the opposite hemifield. In Experiment 1, the distractor was sometimes a picture of a spider. Therefore, reaching the target meant avoiding the spider. One advantage of reaching movements with the target objects in the close vicinity of the hand is that approach and avoidance are clearly defined and unlikely to undergo cognitive reinterpretation (see Eder & Rothermund, 2008). To the same end, previous studies have used movements very close to the target word (Wentura, Rothermund, & Bak, 2000), an action goal (Lavender & Hommel, 2007), or visual expansion/contraction to mimic approach/avoidance (Rinck & Becker, 2007). Because the spider position varied randomly, there was no fixed motor pattern that could be asso-ciated with approach or avoidance. Further, the task did not involve conscious evaluation of the valence of the stimuli. Observers were asked to perform an object classification task (butterfly vs. other in Experiment 1 and spider vs. other in Experiment 2), which necessitates attention to the category of the animal, not its valence. Any effects

of picture valence may therefore be considered automatic, although alternative explanations are possible (e.g., faking; Langner et al., 2010).

Most importantly, we recorded the trajectories of reaching movements in order to evaluate the effects of stimulus valence on response execution. Specifically, we investigated the efficiency of movements in the presence of threatening (and therefore negative) stimuli. When reaching toward a positive stimulus and thereby avoiding a negative stimulus, reaching movements are expected to be more efficient because the tendency to avoid the stimulus is congruent with the current motor intention. In contrast, when reaching toward a negative stimulus, reaching movements are expected to be less efficient because the goal of the response is in conflict with the automatic tendency to avoid the negative stimulus.

Finally, our study may contribute to the somewhat inconsistent literature on differences between spider-fearful and control participants in implicit tasks. Some studies confirmed differences between spider-fearful and control participants in implicit tasks such as tests of implicit attitudes (Teachman, Gregg, & Woody, 2001) or the approach–avoidance task (Rinck & Becker, 2007). In contrast, other studies failed (de Jong, Van den Hout, Rietbroek, & Huijding, 2003) or found only non-significant differences (Huijding & de Jong, 2005) between spider-fearful and control participants.

EXPERIMENT 1

Method

Participants. Sixteen subclinical spider-fearful (16 females, mean age 21 years, 15 right-handed) and 16 non-anxious (11 females, mean age 23 years, 14 right-handed) participants were selected on the basis of their scores on the French version of the Fear of Spiders Questionnaire (Delroisse & Philippot, 2007). We pre-screened participants with a question from this questionnaire. All participants were psychology students at the

University of Geneva. They were not aware of the selection criteria, questionnaire scores, or experimental hypotheses, had normal or corrected-to-normal vision and were without history of any psychiatric disorders. The study was approved by the local ethics committee.

Apparatus and stimuli. To exclude eye movements as a source of hand trajectory modulation (e.g., Buetti & Kerzel, 2010), we monitored eye movements (EyeLink II, SR-Research, Kanata, Ontario, Canada). The 3D coordinates of manual movements were recorded at a sample frequency of 150 Hz by means of a marker positioned on the nail of the right index finger (CMS20S, zebris Medical GmbH, Isny im Allgäu, Baden-Württemberg, Germany). Reaching responses were performed on a flat screen that was attached to the edge of a table at an angle of about 38 degrees.

The stimulus arrangement was modelled on our previous studies (Buetti & Kerzel, 2008, 2009, Buetti & Kerzel, 2010) because we hoped that its sensitivity to differences in cognitive processing would also carry over to affective processing. Two empty boxes (4.7 cm wide × 3.8 cm high) were displayed on a black background (see Figure 1) separated by a horizontal distance of 2.9 cm (edge-to-edge). Pictures of about 4.5 × 3.6 cm were presented in these placeholders. For each stimulus category (butterfly, spider, beetle, dragonfly), there were 21 different pictures from Rinck, Reinecke, Ellwart, Heuer, and Becker (2005) and various websites. A fixation circle was positioned in the centre between the placeholders. At 4.4 cm below the fixation mark, a small cross was presented to mark the start position of the reaching movement. The targets for the reaching movements were two empty squares (2.2 × 2.2 cm) at 5.1 cm from the start position (centre-to-centre).

Procedure. First, participants completed three questionnaires in French: the Beck Depression Inventory II (BDI-II; Beck, Steer, & Brown, 1996), the State and Trait Anxiety Inventories (STAI; Bruchon-Schweitzer & Paulhan, 1993),
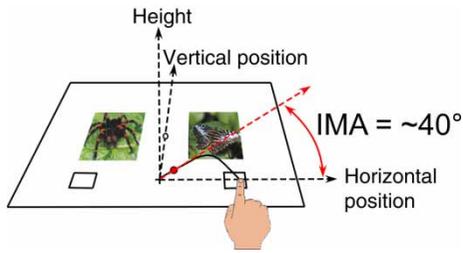
Figure 1. *Side view of the experimental setup (not drawn to scale). In Experiment 1, participants had to reach the square below the butterfly from a central start location (the cross), while in Experiment 2, they had to reach the square below the spider. The unfilled circle between the two pictures was the fixation mark. The filled circle on the movement trajectory indicates the sample that occurred after 1/5 of the overall movement time. The initial movement angle (IMA) was the angle between this point and the axis running from the start location to the final response location. An IMA close to 0° indicates a very direct response toward the correct response location. An IMA of 90° indicates that the initial trajectory was performed perpendicular to the screen surface. Thus, the smaller the IMA, the more direct was the movement.*

and the Fear of Spiders Questionnaire (Delroisse & Philippot, 2007). Second, they did three blocks of 126 trials of the experimental task. Participants were instructed to respond as rapidly as possible without making too many errors. Also, they were asked to maintain fixation on the central circle during the whole trial. When the right index finger was placed on the cross, target (butterfly) and distractor (spider, beetle, or dragonfly) were presented simultaneously after a random interval of between 0.3 and 1.3 s. Then, participants had to lift the index finger from the screen and touch the square below the butterfly picture. The three distractor types had an equal probability of occurrence. Visual feedback was provided after the following errors: RTs shorter than 100 ms or longer than 1 s, hand movements with continuous contact with the screen, loss of the ultrasonic signal, blinking, and saccades larger than 2°. Erroneous trials were repeated (11% of the trials). Third, participants rated the valence of the stimuli. Responses were coded such that −2 corresponds to very unpleasant, −1 to unpleasant, 0 to neutral, 1 to pleasant, and 2 to very pleasant.

Dependent variables and analyses. Offline, we filtered the trajectory data for better precision.

Reaction time (RT; from stimulus onset to movement onset) and movement time (MT; from movement onset to movement offset) were determined using a velocity criterion. Trials in which the endpoint was reached in two or more submovements were discarded (5% of the initially retained trials). Next, we calculated the initial movement angle (IMA). The IMA was the angle between two vectors. The first vector went from the position of the index finger at movement onset to the position of the index finger after 1/5 of the total MT (see Figure 1). The second vector went from the position of the index finger at movement onset to the position of the index finger at movement offset. Thus, the IMA gives information about trajectory deviations in the early segment of the movement and mirrors the motor plan assembled before movement initiation. Small IMAs indicate deviation away (avoidance) of the distractor. Further, we calculated the maximal height and maximal vertical deviation of the trajectory relative to the starting position. These values should not be confounded with the final or average trajectory height or vertical deviation. Finally, leftward movements were flipped so that the horizontal position always went from 0 mm to approximately 51 mm.

Results

Questionnaires. As expected, subclinical spider-fearful and non-anxious participants differed on the Fear of Spiders Questionnaire (mean scores: 5 vs. 1), $t(17.77) = 26.83$, $p < .001$. The two groups of participants did not differ on the BDI (9 vs. 6), $t(30) = 1.57$, $p = .13$. Finally, there was a tendency for a higher state (36 vs. 30) and trait (41 vs. 34) anxiety in spider-fearful than in non-anxious participants, $t(30) = 1.87$, $p = .07$ and $t(30) = 1.93$, $p = .06$.

Evaluation of stimuli. We confirmed that evaluations of spiders were more negative in spider-fearful than in non-anxious subjects (−1.9 vs. −1.2), $t(18.29) = 3.80$, $p < .01$. A mixed-factors analysis of variance (ANOVA) 2 (Groups) × 3 (Distractors) showed that spider-fearful

participants judged all distractors taken together as less pleasant than controls (-0.9 vs. -0.4), $F(1, 30) = 12.58$, $p < .01$. The main effect of Distractor, $F(2, 60) = 75.23$, $p < .001$, revealed that spiders (-1.6) were judged as less pleasant than beetles (-0.6) and dragonflies (0.3). The interaction between Distractor and Group was not significant, $p = .49$, suggesting that spiders were not judged as particularly pleasant by non-anxious participants either. Further, evaluations of

butterflies were equally positive for spider-fearfuls and controls (1.4 for both groups).

Experimental task. Mean RT, IMA, and maximal height are shown in the left column of Figure 2. Mean trajectories are displayed in Figure 3 and 4 (left columns). In preliminary analyses of the data from Experiments 1 and 2, we did not observe evidence of differential processing of negative information in the left or right hemifield
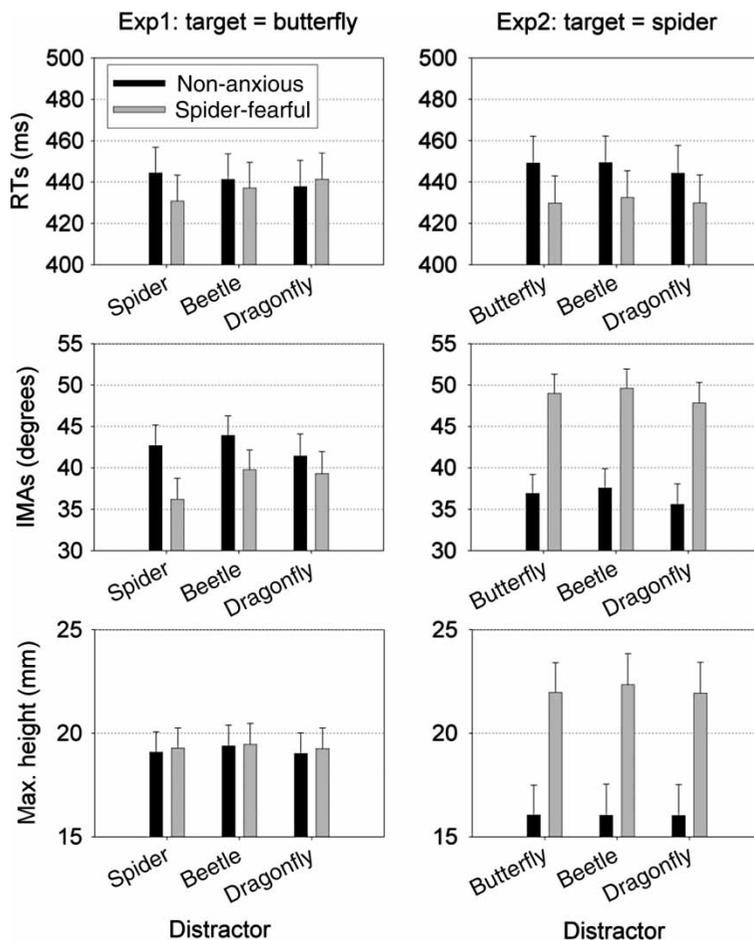
Figure 2. *Results from Experiments 1 and 2 are shown in the left and right column, respectively. In Experiment 1, participants moved toward the butterfly picture and pictures of spiders, beetles, and dragonflies were shown as distractors. In Experiment 2, participants moved toward the spider picture and pictures of butterflies, beetles, and dragonflies were shown as distractors. Mean reaction times (RTs), initial movement angles (IMAs) and the maximal heights of the trajectory are shown. Error bars indicate the between-subject standard error of the mean.*

Figure 3. *The 2D trajectories performed by non-anxious and spider-fearful participants in Experiments 1 and 2. The movement starts at 0 mm horizontally. The midpoint of the target box was at 51 mm horizontally. The height of the trajectory is perpendicular to the screen surface. Averaged movements towards the right are shown. Left movements were mirrored before averaging. To calcula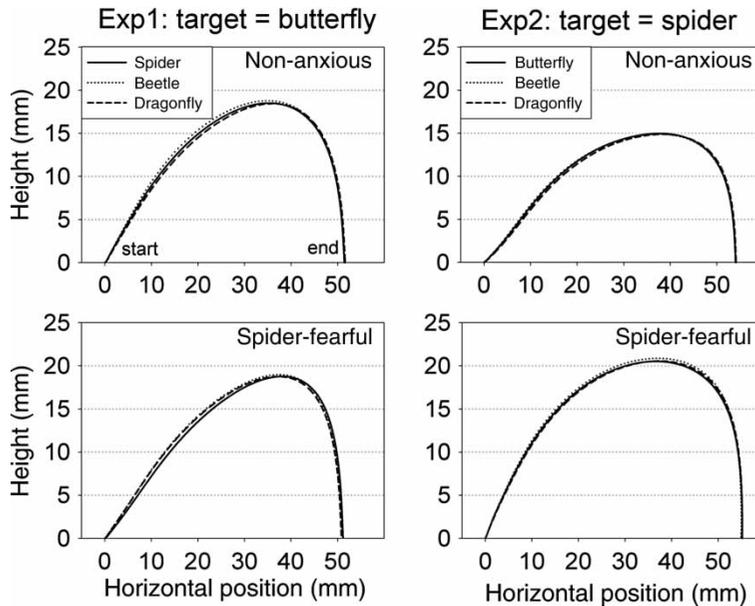te the mean movement trajectory across participants, we resampled the 3D coordinates of movement trajectories so that each trajectory contained 100 samples from movement onset and offset.*

(but see Davidson, Shackman, & Maxwell, 2004; Maxwell & Davidson, 2007). Therefore, we collapsed the data across target position. Also, comparison of the first to the second half of the experiment showed that motor learning did not interfere with the effects of threatening stimuli.

We carried out mixed-factors two-way ANOVAs, 2 (Groups) × 3 (Distractors). To follow-up on significant interactions, we specifically tested for differences between spiders and the other two distractor types. The ANOVA on RTs (see Figure 2) showed that the interaction between
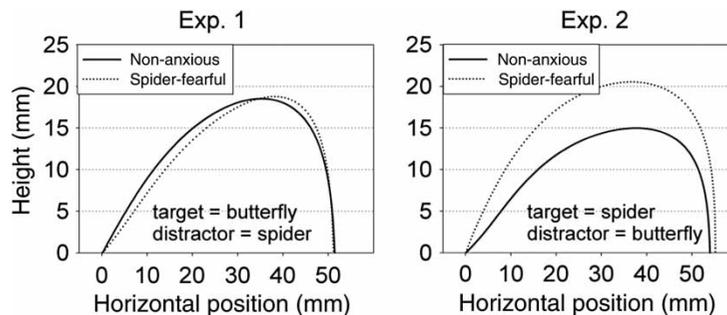
Figure 4. *The mean 2D movement trajectories of non-anxious and spider-fearful participants for visually identical conditions. In the spider/butterfly condition of Experiment 1, participants moved toward a butterfly picture and a spider picture was shown on the other side. In the spider/butterfly condition of Experiment 2, participants moved toward a spider and a butterfly picture was shown on the other side. The trajectories are replotted from Figure 3 to facilitate comparison between groups.*

Distractor and Group was significant, $F(2, 60) = 16.86$, $p < .001$. For control participants, reaction times were *longer* with spider than with dragonfly distractors (445 vs. 438 ms), $t(15) = 3.81$, $p = .002$. For spider-fearful participants, RTs were significantly *faster* for spider (431 ms) than for beetle (437 ms) and dragonfly (441 ms) distractors, ts$(15) > 3.22$, ps $< .006$. Thus, control participants responded more slowly with spider distractors whereas spider-fearful participants responded more rapidly.

The ANOVA on MTs did not reveal any significant effects (ps $> .076$). Mean MTs were 209 and 206 ms for spider-fearful and control participants, respectively.

The ANOVA on IMAs confirmed a main effect of Distractor type, $F(2, 60) = 7.96$, $p < .001$. IMAs were $39°$ with spider distractors, $42°$ with beetle and $40°$ with dragonfly distractors. The interaction between Distractor and Group was significant, $F(2, 60) = 6.52$, $p = .003$. For spider-fearful participants, IMAs with spider distractors ($36°$) were smaller than IMAs with beetle ($40°$) and dragonfly distractors ($39°$), ts$(15) > 3.09$, ps $< .005$. That is, the initial trajectories of spider-fearful participants went more directly toward the butterfly target when a spider was shown on the other side. For control participants, IMAs with spider distractors ($43°$) did not differ from beetle ($44°$) and dragonfly distractors ($41°$), ps $> .13$.

Analysis of the mean maximal height and mean maximal vertical deviation showed no significant effects (ps $> .143$). The mean maximal height was 19 mm and the mean maximal vertical deviation was 13 mm towards the butterfly picture. Inspection of Figure 3 and 4 shows that the differences in the trajectories were rather subtle. For spider-fearful participants, there was a difference between spider distractors and the other distractor types in the initial portion of the trajectory, which is reflected in the IMAs. In the later part of the trajectory, however, no differences were visible, which is reflected in equal maximal heights.

The percentage of choice errors was very low (1.3%) and not analysed any further. Saccade errors occurred on 5% of the trials. For subjects who made saccade errors, saccades went to the butterfly on 57% of trials (not significantly different from 50%) without difference between groups.

Discussion

The results indicated that threat-relevant distractors influenced response initiation and execution. Compared to beetle and dragonfly distractors, RTs were faster with spider distractors for spider-fearful participants, while the opposite was true for control participants. For spider-fearful participants, IMAs were smaller with spider distractors than with beetle or dragonfly distractors. This was not the case for control participants. Overall, responses of spider-fearful participants got more efficient when a spider distractor was presented: Responses were faster and went more directly towards the target. While the modulation of the initial trajectory was significant, inspection of the entire trajectory shows that it was rather subtle.

Faster responses with spider distractors in spider-fearful participants are somewhat at odds with a recent study by Gerdes, Pauli, and Alpers (2009), who found that RTs of spider-fearful participants were delayed when asked to saccade away from spiders, suggesting difficulties in disengaging attention from spider pictures. The discrepancy may be due to a number of reasons. First, it is possible that results observed with saccades do not generalise to manual responses. Second, eye movements had to be inhibited in the present study because of our fixation requirement. Thus, attention was probably also kept at central fixation, thereby suppressing or attenuating attentional engagement and disengagement.

EXPERIMENT 2

We asked participants to approach the location where a spider was presented while a distractor (butterfly, beetle, or dragonfly) was displayed on the opposite location. We expected spider-fearful participants to respond more slowly and to perform less direct responses toward the target to avoid the spider.

Method

The methods were as in Experiment 1 with the following exceptions. Sixteen new subclinical spider-fearful (15 females, mean age 20 years, 15 right-handed) and 16 non-anxious (11 females, mean age 22 years, 16 right-handed) participants took part. Participants were instructed to reach the box below the spider. Thus, the picture of a spider occurred on every trial and the distractor could be the picture of a butterfly, a dragonfly, or a beetle. A total of 13% of the trials had to be repeated and 14% of the initially retained trials were eliminated in the offline analysis, leaving an average of 324 trials per participant.

Results

Questionnaires. Subclinical spider-fearful participants had higher scores on the Fear of Spiders Questionnaire than non-anxious participants (5 vs. 2), $t(30) = 7.24$, $p < .001$. Subclinical spider-fearful participants tended to have higher scores than non-anxious participants on the BDI (11 vs. 8), $t(30) = 1.79$, $p = .083$. However, the two groups did not differ on the state (40 vs. 36) and trait (44 vs. 43) anxiety inventories, $t(30) = 1.01$, $p = .32$, and $t(30) = 0.11$, $p = .91$, respectively.

Evaluation of stimuli. We confirmed that evaluations of spiders were more negative in spider-fearful than in non-anxious subjects (-1.9 vs. -0.6), $t(30) = 9.95$, $p < .001$. The mixed-factors ANOVA, 2 (Groups) $\times$ 3 (Distractors), showed that beetles (-0.5) were judged the least pleasant, followed by dragonflies (0.2) and butterflies (1.2), $F(2, 60) = 152.93$, $p < .001$. All distractors differed from each other, ts$(31) > 7.06$, ps $< .001$. Finally, the interaction between Distractor and Group was significant, $F(2, 60) = 13.51$, $p < .001$; the t-tests indicated that the evaluation of beetles was more negative in spider-fearful than controls (-0.9 vs. -0.1), $t(30) = 3.52$, $p < .01$, but there was no difference between the two groups in the evaluation of dragonflies (0.1 vs. 0.3) or butterflies (1.3 vs.

1.2), $t(30) = 0.88$, $p = .39$ and $t(30) = 1.00$, $p = .32$.

Experimental task. The mixed-factors, two-way ANOVA, 2 (Groups) $\times$ 3 (Distractors), on RTs did not reveal significant effects (ps $> .122$). The mean RT was 439 ms. Another ANOVA on MTs did not yield significant effects either (ps $> .322$). Mean MT was 263 ms.

The ANOVA on the IMAs showed less direct trajectories toward the target in spider-fearful than in control participants (49° vs. 37°), $F(1, 30) = 13.61$, $p < .001$. The main effect of Distractor reached significance, $F(2, 60) = 6.52$, $p = .003$. IMAs were 43° with butterflies, 44° with beetles and 42° with dragonflies.

Analysis of maximal height showed that spider-fearful participants reached higher than control participants (22 vs. 16 mm), $F(1, 30) = 8.44$, $p = .007$. The mean maximal vertical deviation was 5 mm above the start position, but the ANOVA did not reveal any significant effects. The mean trajectories in Figure 3 and 4 show that the differences between spider-fearful and control participants concern both the initial and the later parts of the trajectory. The trajectories of spider-fearful participants are less direct throughout: The initial angle and the height are greater.

Again, the percentage of choice errors was very low (2.6%) and not analysed any further. Saccade errors occurred on 7% of the trials. Saccades went toward the spider on 71% of trials, which is significantly different from 50%, $t(26) = 7.67$, $p < .001$, without differences between groups.

Comparison between experiments. We compared reaching movements with identical stimuli (butterfly and spider), but different targets (butterfly in Experiment 1 and spider in Experiment 2). In Experiment 1, spider-fearful participants showed *smaller* IMAs with butterfly targets and spider distractors. In Experiment 2, spider-fearful participants showed *larger* IMAs with spider targets and butterfly distractors. This pattern is summarised in Figure 4 and suggests that spider-fearful participants deviated away from spider pictures both when avoiding and when approaching a spider.

To confirm this pattern across experiments, we ran a 2 (Experiment) × 2 (Groups) between-subjects ANOVA on the conditions with spiders and butterflies (i.e., the other distractors were excluded from analysis). There were no significant effects in the RT data, $p > .199$. Mean RTs were 438 and 439 ms in Experiments 1 and 2, respectively. For MTs, the main effect of experiment was significant, $F(1, 60) = 20.627$, $p < .001$, showing that MTs were shorter in Experiment 1 than 2 (207 vs. 263 ms). The longer MTs are due to the fact that the hand moved a longer distance when participants moved toward a spider. The length of the vector between onset and offset position was 52 mm in Experiment 1 (butterfly target) and 55 mm in Experiment 2 (spider target), $F(1, 60) = 6.32$, $p = .015$. For IMAs, the interaction between Experiment and Group reached significance, $F(1, 60) = 14.84$, $p < .001$, indicating that IMAs tended to be *smaller* in spider-fearful than control participants when the butterfly was reached and the spider was on the opposite side (36° vs. 43°), $t(30) = 1.83$, $p = .078$, whereas IMAs were *larger* in spider-fearful than control participants when the spider was reached and the butterfly was on the opposite side (49° vs. 37°), $t(30) = 3.7$, $p = .001$. The mean maximal height was higher with spider-fearful than with control participants (18 vs. 21 mm), $F(1, 60) = 6.22$, $p = .015$, but the interaction between Group and Experiment, $F(1, 60) = 5.47$, $p = .023$, showed that maximal height differed between spider-fearful and controls only when participants reached toward the spider in Experiment 2 (22 vs. 16 mm), $t(30) = 2.93$, $p = .006$, but not when they reached toward the butterfly in Experiment 1 (19 vs. 19 mm), $p = .891$. The mean maximal vertical deviation was further above the start position when participants reached a butterfly in Experiment 1 than when they reached a spider in Experiment 2 (13 vs. 5 mm), $F(1, 60) = 140.17$, $p < .001$.

Discussion

When reaching toward a spider, the spatial characteristics of the trajectories differed strongly between spider-fearful and control participants, while the temporal characteristics of the responses were not different. The initial movement segment deviated away from the spider picture in spider-fearful compared to control participants. Also, the height of the trajectory was greater in spider-fearful than control participants. There were no effects of the type of distractor showing that the differences were highly specific to spider stimuli and did not depend on the valence of the distractor. Note that there were large differences in valence between the beetle, dragonfly, and butterfly distractors. Despite the large difference in trajectories between spider-fearful and control participants, there were no effects in the temporal parameters of the action. Somewhat surprisingly, MTs did not differ between spider-fearful and control participants, despite the much longer trajectories (see Figure 4). Inspection of mean velocity during movement execution showed that mean maximal velocity was higher in spider-fearful than control participants (321 vs. 301 mm/s), but a separate ANOVA on velocity did not reveal any significant effects. This is most likely due to the large inter-individual variability in our velocity measures. Thus, the spatial characteristics proved more sensitive in statistical tests than the MT data. Further, fear may have modulated Fitts's law, which states that movement time increases with movement distance (and difficulty). Csatho, Tey, and Davis (2008) showed that this dependency is weakened by fear such that temporal parameters and velocity less reliably reflect differences in spatial distance.

Further, there are some interesting differences between Experiments 1 and 2. Across both groups, MTs were longer because trajectories overshot the required amplitude of 51 mm by 1 mm with butterfly targets and by 4 mm with spider targets. The mean maximal vertical deviation was less positive with spider than with butterfly targets showing that the participants were not as close to the spider target in Experiment 2 compared to the butterfly target in Experiment 1. These results are consistent with the hypothesis of a fear-module (Öhman & Mineka, 2001), according to which all participants

should show some fear of phylogenetically threatening stimuli like spiders. The difference between Experiment 1 and 2 suggests that all participants tried to stay away from spider pictures compared to butterfly pictures.

GENERAL DISCUSSION

We investigated reaching responses toward a positive stimulus (a butterfly) in Experiment 1 and toward a negative stimulus (a spider) in Experiment 2. Subclinical spider-fearful and control participants were compared. Contrary to previous research, we focused on the spatial and not on the temporal characteristics of approach and avoidance movements. An important conclusion of our study is that spatial measures were more sensitive than temporal measures to effects of threat. The distinction between response initiation and execution is therefore of paramount importance, but has been blurred in previous studies by using joystick responses (e.g., Chen & Bargh, 1999; Eder & Klauer, 2009; Eder et al., 2010; Rinck & Becker, 2007). Joysticks determine response time not at movement onset, but when a certain angle is reached (i.e., at some unspecified point during response execution).

Our spatial measures showed that spider-fearful participants automatically avoided threat (i.e., spider pictures) by moving more directly toward the positive butterfly picture in Experiment 1 and by moving less directly toward the negative spider picture in Experiment 2. Notably, there were no differences in response initiation times in Experiment 2. The avoidance of spider distractors observed in Experiment 1 was rather subtle and only concerned the initial part of the trajectory, while the avoidance caused by spider targets was stronger and concerned the entire trajectory. Thus, spider-fearful participants are particularly reluctant to move toward the feared stimulus, a tendency that is consistent with the "behavioural approach task", in which participants are asked to move as closely as possible toward a spider (de Jong, Vorage, & Van den Hout, 2000; Rinck & Becker, 2007; Teachman & Woody, 2003; see

also Rinck, Kwakkenbos, Dotsch, Wigboldus, & Becker, 2010). Typically, spider-fearful participants stay at a larger distance from the spider than control participants. In contrast to the present task, however, the distance in the behavioural approach task is consciously set without time constraint, whereas we observe modulations of speeded, goal-directed actions. According to a previous study (Langner et al., 2010), explicit tasks, such as the behavioural approach task, are more susceptible to hypothesis-guessing than implicit tasks: If asked to fake the behaviour of a spider-fearful person, participants managed to do so in the behavioural approach task, but were less successful in a variant of Chen and Bargh's (1999) approach–avoidance task. Because behaviour in the present task was similarly rapid (MTs of 200 ms) and highly stereotyped across 378 trials, we think it is rather unlikely that observers' conscious beliefs about the typical responses of a spider-fearful or non-anxious participant had an impact on our results. Nonetheless, we admit that further research is needed to rule out this possibility.

We suggest that the affective state before movement initiation influenced the way in which the reaching movement was carried out. The affective state of spider-fearful participants when viewing pictures of spiders "leaked" into response execution or "meddled" (Wentura & Rothermund, 2003) with ongoing motor behaviour. The results suggest that high fear of spiders produced automatic avoidance of spiders, visible as a deviation away from spider pictures. Please note that we only considered trials in which the hand moved "straight" and without submovements from the home position to the target box. Thus, we measured the modulation of responses free of choice or movement errors. The object discrimination task was generally easy and only few errors occurred (less than 3%).

Our finding that hand trajectories deviate away from threatening stimuli may be explained in two different ways. On the first account, certain affective states brought about by positive or negative stimuli are preferentially connected to certain classes of overt behaviour, a view that is

shared by many theorists (Chen & Bargh, 1999; Darwin, 1872; Lang et al., 1990; LeDoux, 2000; Wentura & Rothermund, 2003). In particular, our results favour the hypothesis that the valence of a stimulus automatically activates corresponding motor programmes. In our experiments, valence was irrelevant, yet we found that responses were influenced by the affective content of the pictures. However, this was only true for highly feared objects such as spiders in a population of spider-fearful participants. Other negative stimuli, such as beetles, were not different from neutral (dragonflies) or positive objects (butterflies). Thus, previous failures to observe valence–response congruency may be due to the failure to evoke affective states of sufficient strength. In addition, the results support the idea that the valence–response associations go beyond the association of fixed motor patterns to positive and negative valence. Here, approach and avoidance was defined by a spatial direction and the same motor patterns (i.e., reaching to the left or right) were involved in approach and avoidance of negative stimuli. Our results suggest that avoidance is not only mediated by the activation of certain action types (i.e., arm extension vs. arm contraction) but also by a modulation of goal-directed actions. Avoidance of threatening stimuli is rapidly integrated into ongoing motor behaviour in order to increase the distance between the participant's body and the threatening stimulus.

An alternative hypothesis of our findings, which we will reject, refers to the link between attention and motor behaviour: A robust finding is that pictures of snakes and spiders are detected faster in a visual search array than pictures of flowers or mushrooms (Öhman, Flykt, & Esteves, 2001). Rapid detection of threatening stimuli was found to be enhanced in participants fearful of spiders (Öhman et al., 2001; Rinck et al., 2005), but not necessarily reduced in participants who do not evaluate spiders negatively ("spider experts"; Purkis & Lipp, 2007). Further, fearful participants are more strongly slowed by a feared distractor stimulus when searching for a neutral target (Gerdes, Alpers, & Pauli, 2008; Gerdes et al., 2009; Rinck et al., 2005). Studies measuring

eye movements also suggest that the different search times between fearful and non-fearful participants are mediated by different scan paths (Pflugshaupt et al., 2005; Rinck & Becker, 2006).

Thus, one may speculate that hand movements deviate away from spider pictures because attention was initially drawn toward spiders. There is evidence that movement trajectories deviate away from objects that are attended, but are not the target of an eye (e.g., Sheliga, Riggio, & Rizzolatti, 1994) or hand movement (e.g., Tipper, Howard, & Houghton, 1999; Welsh, Elliott, & Weeks, 1999). However, trajectories of hand movements were found to initially deviate toward the position of a suddenly appearing stimulus (Buetti & Kerzel, 2008, 2009; Scherbaum, Dshemuchadse, Fischer, & Goschke, 2010), even though participants were instructed to move away from it. This finding was interpreted as a reflex-like response toward sudden onsets caused by the automatic capture of attention. Therefore, it seems unlikely that an attention shift toward the spider explains the deviation away from threatening stimuli that we observed in the current study.

REFERENCES

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manuel de l'inventaire de dépression de Beck—2ème édition*. Paris, France: Édition du Centre de Psychologie Appliquée.

Bruchon-Schweitzer, M. L., & Paulhan, I. (1993). *Manuel de l'inventaire d'anxiété état-trait forme Y (STAI-Y)*. Paris, France: Édition du Centre de Psychologie Appliquée.

Buetti, S., & Kerzel, D. (2008). Time course of the Simon effect in pointing movements for horizontal, vertical, and acoustic stimuli: Evidence for a common mechanism underlying the Simon effect. *Acta Psychologica*, 129(3), 420–428.

Buetti, S., & Kerzel, D. (2009). Conflicts during response selection affect response programming: Reactions toward the source of stimulation. *Journal*

of Experimental Psychology: Human Perception and Performance, 35(3), 816–834.

Buetti, S., & Kerzel, D. (2010). Effects of saccades and response type on the Simon effect: If you look at the stimulus, the Simon effect may be gone. *The Quarterly Journal of Experimental Psychology, 63*(11), 2172–2189.

Chen, M., & Bargh, J. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin, 25*(2), 215–224.

Csatho, A., Tey, F., & Davis, G. (2008). Threat perception and targeting: The brainstem–amygdala–cortex alarm system in action? *Cognitive Neuropsychology, 25*(7), 1039–1064.

Darwin, C. (1872). *The expression of the emotions in man and animals*. London, UK: John Murray. (Retrieved from: http://darwin-online.org.uk)

Davidson, R. J., Shackman, A. J., & Maxwell, J. S. (2004). Asymmetries in face and brain related to emotion. *Trends in Cognitive Science, 8*(9), 389–391.

De Houwer, J., Crombez, G., Baeyens, F., & Hermans, D. (2001). On the generality of the affective Simon effect. *Cognition and Emotion, 15*(2), 189–206.

de Jong, P. J., Van den Hout, M. A., Rietbroek, H., & Huijding, J. (2003). Dissociations between implicit and explicit attitudes toward phobic stimuli. *Cognition and Emotion, 27*(4), 521–545.

de Jong, P. J., Vorage, I., & Van den Hout, M. A. (2000). Counterconditioning in the treatment of spider phobia: Effects on disgust, fear and valence. *Behaviour Research and Therapy, 38*(11), 1055–1069.

Delroisse, S., & Philippot, P. (2007). Questionnaire sur la peur des araignées: Validation française du "Fear of Spiders Questionnaire". *Revue Francophone de Clinique Comportementale et Cognitive, 13*, 14–21.

Eder, A. B., & Klauer, K. C. (2009). A common-coding account of the bidirectional evaluation–behavior link. *Journal of Experimental Psychology: General, 138*(2), 218–235.

Eder, A. B., & Rothermund, K. (2008). When do motor behaviors (mis)match affective stimuli? An evaluative coding view of approach and avoidance reactions. *Journal of Experimental Psychology: General, 137*(2), 262–281.

Eder, A. B., Rothermund, K., & Proctor, R. W. (2010). The prepared emotional reflex: Intentional preparation of automatic approach and avoidance tendencies as a means to regulate emotional responding. *Emotion, 10*(4), 593–598.

Gerdes, A. B., Alpers, G. W., & Pauli, P. (2008). When spiders appear suddenly: Spider-phobic patients are distracted by task-irrelevant spiders. *Behaviour Research and Therapy, 46*(2), 174–187.

Gerdes, A. B., Pauli, P., & Alpers, G. W. (2009). Toward and away from spiders: Eye-movements in spider-fearful participants. *Journal of Neural Transmission, 116*(6), 725–733.

Huijding, J., & de Jong, P. J. (2005). A pictorial version of the Extrinsic Affective Simon Task: Sensitivity to generally affective and phobia-relevant stimuli in high and low spider fearful individuals. *Experimental Psychology, 52*(4), 289–295.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*(3), 377–395.

Langner, O., Ouwens, M., Muskens, M., Trumpf, J., Becker, E. S., & Rinck, M. (2010). Faking on direct, indirect, and behavioural measures of spider fear: Can you get away with it? *Cognition and Emotion, 24*(3), 549–558.

Lavender, T. J., & Hommel, B. (2007). Affect and action: Towards an event-coding account. *Cognition and Emotion, 21*(6), 1270–1296.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155–184.

Maxwell, J. S., & Davidson, R. J. (2007). Emotion as motion: Asymmetries in approach and avoidant actions. *Psychological Science, 18*(12), 1113–1119.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*(3), 466–478.

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522.

Pflugshaupt, T., Mosimann, U. P., von Wartburg, R., Schmitt, W., Nyffeler, T., & Muri, R. M. (2005). Hypervigilance-avoidance pattern in spider phobia. *Journal of Anxiety Disorders, 19*(1), 105–116.

Purkis, H. M., & Lipp, O. V. (2007). Automatic attention does not equal automatic fear: Preferential attention without implicit valence. *Emotion, 7*(2), 314–323.

Rinck, M., & Becker, E. S. (2006). Spider fearful individuals attend to threat, then quickly avoid it: Evidence from eye movements. *Journal of Abnormal Psychology, 115*(2), 231–238.

Rinck, M., & Becker, E. S. (2007). Approach and avoidance in fear of spiders. *Journal of Behavior Therapy and Experimental Psychiatry, 38*, 105–120.

Rinck, M., Kwakkenbos, L., Dotsch, R., Wigboldus, D. H. J., & Becker, E. S. (2010). Attentional and behavioural responses of spider fearfuls to virtual spiders. *Cognition and Emotion*, *24*(7), 1199–1206.

Rinck, M., Reinecke, A., Ellwart, T., Heuer, K., & Becker, E. S. (2005). Speeded detection and increased distraction in fear of spiders: Evidence from eye movements. *Journal of Abnormal Psychology*, *114*(2), 235–248.

Rotteveel, M., & Phaf, R. H. (2004). Automatic affective evaluation does not automatically predispose for arm flexion and extension. *Emotion*, *4*(2), 156–172.

Scherbaum, S., Dshemuchadse, M., Fischer, R., & Goschke, T. (2010). How decisions evolve: The temporal dynamics of action selection. *Cognition*, *115*(3), 407–416.

Sheliga, B. M., Riggio, L., & Rizzolatti, G. (1994). Orienting of attention and eye movements. *Experimental Brain Research*, *98*(3), 507–522.

Solarz, A. K. (1960). Latency of instrumental responses as a function of compatibility with the meaning of eliciting verbal signs. *Journal of Experimental Psychology*, *59*, 239–245.

Song, J. H., & Nakayama, K. (2009). Hidden cognitive states revealed in choice reaching tasks. *Trends in Cognitive Sciences*, *13*(8), 360–366.

Teachman, B. A., Gregg, A. P., & Woody, S. R. (2001). Implicit associations for fear-relevant stimuli among individuals with snake and spider fears. *Journal of Abnormal Psychology*, *110*(2), 226–235.

Teachman, B. A., & Woody, S. R. (2003). Automatic processing in spider phobia: Implicit fear associations over the course of treatment. *Journal of Abnormal Psychology*, *112*(1), 100–109.

Tipper, S. P., Howard, L. A., & Houghton, G. (1999). Behavioral consequences of selection form neural population codes. In S. Monsell & J. Driver (Eds.), *Attention and performance XVIII* (pp. 223–245). Cambridge, MA: MIT Press.

Welsh, T. N., Elliott, D., & Weeks, D. J. (1999). Hand deviations toward distractors. Evidence for response competition. *Experimental Brain Research*, *127*(2), 207–212.

Wentura, D., & Rothermund, K. (2003). The "meddling-in" of affective information: A general model of automatic evaluation effects. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion* (pp. 51–86). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: The attention-grabbing power of approach- and avoidance-related social information. *Journal of Personality and Social Psychology*, *78*(6), 1024–1037.