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Aversive Life Events Enhance Human Freezing Responses

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In the present study, we investigated the effect of prior aversive life events on freezing-like responses. Fifty healthy females were presented neutral, pleasant, and unpleasant images from the International Affective Picture System while standing on a stabilometric platform and wearing a polar band to assess body sway and heart rate. In the total sample, only unpleasant pictures elicited reduced body sway and reduced heart rate (freezing). Moreover, participants who had experienced 1 or more aversive life events showed greater reductions in heart rate for unpleasant versus pleasant pictures than those who had experienced no such event. In addition, relative to no-event participants, single-event participants showed reduced body sway to unpleasant pictures, while multiple-event participants showed reduced body sway in response to all picture categories. These results indicate that aversive life events affect automatic freezing responses and may indicate the cumulative effect of multiple trauma. The experimental paradigm presented is a promising method to study freezing as a primary defense response in trauma-related disorders.

Keywords: freezing, immobility, trauma, posturography, anxiety

Fast emotional reactions and action tendencies in response to threat, like fight and flight responses, serve survival purposes. Aversive stimuli do indeed invoke individuals' automatic avoidance tendencies, whereas people tend to approach appetitive stimuli (e.g., Chen & Bargh, 1999). However, animal studies have shown a third behavioral response that may occur in situations of acute threat: freezing. Blanchard, Griebel, and Blanchard (2001) described freezing as a defense response that takes place when threat is closer and no escape route is available. They hereby made a distinction between freezing and the cessation of ongoing activity that occurs in the orienting (or *risk-assessment*) phase. Freezing is thought to serve survival purposes in that it optimizes attentional processes and prepares the organism for action (Lang, Bradley, & Cuthbert, 1997). It is reflected in physiological parameters like reduced heart rate (fear bradycardia), and reduced mobility (Fanselow, 1984; Vianna & Carrive, 2005). Indeed, threat cues activate defensive neural circuits that facilitate threat processing, preparing the animal for overt defense behavior (LeDoux, 1996).

Freezing has been studied extensively in animals and is used as a main outcome measure in many animal studies (e.g., Kalin, Shelton, Rickman, & Davidson, 1998). Freezing is relatively ignored in humans though, despite the fact that other automatic responses to threat like avoidance (flight) are important in the development and maintenance of anxiety disorders (Brewin & Holmes, 2003). Like fight and flight behavior, freezing may have consequences for the processing of threat-related information and may similarly contribute to the development or maintenance of psychopathology. The effect of threat-related immobility in humans has been examined in only a very few studies. Clinical studies (e.g., Bovin, Jager-Hyman, Gold, Marx, & Sloan, 2008) have indeed shown an association with posttraumatic stress disorder (PTSD) development, and experimental studies have suggested a link with the development of intrusive images (Hagenaars, Brewin, van Minnen, Holmes, & Hoogduin, 2010; Hagenaars, van Minnen, Holmes, Brewin, & Hoogduin, 2008). However, all these studies have concerned subjective, retrospective reports of immobility or immobility manipulations that were designed to mimic freezing.

Spontaneous defense reactions can be elicited by an affective picture viewing paradigm. Affective picture viewing has been suggested to mimic the situation of an animal that encounters threat (Lang et al, 1997). That is, the participant is oriented toward the (threatening) sensory input and automatically prepares for action. Affective picture viewing could therefore be an effective way to study freezing responses in humans. Bradley, Codispoti, Cuthbert, and Lang (2001) indeed found that watching aversive

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pictures evoked strong physiological reactions, negative affect, and arousal. Pictures of mutilation and death seemed to evoke the greatest response. These were included in an elegant study by Azevedo et al. (2005) who used a stabilometric platform to objectively assess body sway and observed freezing (reduced body sway and bradycardia) in response to mutilation but not neutral and sports pictures. Only very few other researchers have used a stabilometric platform to quantify postural freezing, but all have found associations between posture and either anxiety or threatening stimuli (Carpenter, Frank, Adkin, Paton, & Allum, 2004; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Lopes et al., 2009; Roelofs, Hagenaars, & Stins, 2010; Stins & Beek, 2007).

Early traumatic life events have been shown to be associated with long-lasting physiological alterations in emotional expression, including changes in freezing responses. Animal studies indeed showed that rats that were previously exposed to stress exhibited impaired reversal of freezing (Koseki et al., 2009) or increased freezing in contextual fear conditioning (Imanaka, Morinobu, Toki, & Yamawaki, 2006). Early multiple postnatal stresses (e.g., separation from the nest for the first 14 postnatal days) also increased freezing behavior in adulthood in rats (Sanders & Knoepfler, 2008). In addition, some animal studies indicate different effects of single versus multiple trauma. For example, multiple stressful events (shock) were associated with enhanced fear learning, whereas one event was not (Rau & Fanselow, 2009). There are some indications that early aversive events affect automatic stress responses in humans as well, such as blunted cortisol responses to a psychosocial stress task (Elzinga et al., 2008). Furthermore, the consequences of experiencing single or multiple traumas have been found to be different. For example, persons with multiple traumas showed more interpersonal dependency (Allen & Lauterbach, 2007) and higher levels of dissociation and shame (Hagenaars, Fisch, & van Minnen, in press) than those who experienced a single trauma. Increased frequency of aversive life events also seems to be associated with decreased coping abilities in response to current threat (Boscarino & Adams, 2009). In addition, there are some indications that trauma affects motor responses, with increased trauma frequency being associated with more severe motor dysfunctions in conversion disorder (Roelofs, Keijsers, Hoogduin, Näring, & Moene, 2002). Repeated or sustained life stress is suggested to lead to increased sensitization of the neuroendocrine stress response (Santa Ana et al., 2006). We hypothesized that this may be reflected in enhanced defense responses like freezing. Therefore, in the present study, we examined the effect of prior aversive events and traumas on freezing responses to affective pictures using a passive affective picture viewing task.

The first aim was to test whether reductions in body sway and heart rate (freezing) previously found in men (Azevedo et al., 2005) would also be present in women in response to unpleasant pictures. In addition, and most important, we aimed to examine whether aversive life events would modulate freezing responses. Our expectation, based on animal studies, was that freezing would be enhanced in individuals who had experienced trauma, especially in those who had experienced multiple events.

Method

Participants

A total of 50 right-handed, female students participated in the present study. They were recruited at Leiden University and VU University Amsterdam and received course credits or cash for their participation. Women were selected in order to check whether the effects of Azevedo et al. (2005), who used male participants only, would also apply to female participants. In addition, because this was the first study to address trauma effects on body sway, the selection of a maximally homogeneous group was preferred. Vision was normal or corrected to normal in all participants. Age ranged from 18 to 30 years, with a mean age of 20.6 years (SD = 2.25). The study was approved by the local ethics committee, and all participants gave written informed consent.

Apparatus and Material

Body sway. Center of pressure (COP) excursions in anterior–posterior (AP) and mediolateral (ML) directions were recorded with a custom-made 1 m × 1 m stabilometric platform at a sample frequency of 100 Hz.

Heart rate. Heart rate was recorded with a polar band (heart rate telemetry). The polar band was placed at the height of the sternum. The signal was converted to beats per minute (BPM) with LabVIEW (National Instruments Corp., Austin, TX).

Pictorial stimuli. Three sets of stimuli were selected from the International Affective Picture System[1] (IAPS; Center for the Study of Emotion and Attention, 1999). The first set comprised 20 pictures of neutral objects. The second set comprised 20 pleasant pictures. Pictures of sports were selected for this category in order to facilitate comparisons across studies and because arousal ratings of these pictures were similar to those in the unpleasant category (Azevedo et al., 2005). The third set consisted of 20 unpleasant pictures depicting mutilated bodies and corpses.

Stimuli were presented full screen at eye height on a 17-inch-high (431.8-mm) adjustable computer screen, approximately 1 m in front of the participant with a visual angle (height × width in degrees) of 15.5° × 10.8°.

Valence, arousal, and subjective immobility. Subjective valence and arousal were rated using the 9-point Likert scale of the IAPS rating system, with higher scores indicating negative valence and more arousal. In addition, participants were asked to rate the degree of immobility that each picture elicited on a similar scale, with higher scores indicating more subjective feelings of paralysis.

Aversive life events. We assessed aversive life events and traumatic experiences with the Negative Life Experiences and Trauma Questionnaire (NLETQ; Engelhard, van den Hout, Kindt, Arntz, & Schouten, 2003). The NLETQ consists of 24 items describing various events (e.g., sexual and physical assault, serious

[1] IAPS catalog numbers for pictures used in this study are Neutral: 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7031, 7035, 7040, 7050, 7052, 7060, 7080, 7090, 7150, 7175, 7211; Pleasant: 8021, 8032, 8034, 8040, 8041, 8090, 8161, 8186, 8190, 8192, 8200, 8210, 8300, 8370, 8400, 8460, 8465, 8467, 8470, 8620; and Unpleasant: 3000, 3010, 3030, 3051, 3053, 3060, 3061, 3062, 3063, 3064, 3069, 3080, 3100, 3102, 3110, 3130, 3140, 3150, 3261, 3400.

accidents, death of a loved one) and one open-ended item ("other, namely") for unlisted events (Morgan & Janoff-Bulman, 1994). Participants have to indicate whether they have experienced the event and if so how many times. For the present study, participants were categorized in one of three groups: those who never experienced an aversive event ($n = 15$), those who experienced a single event ($n = 17$), and those who experienced multiple events ($n = 15$). The occurrence of the different events in both latter groups is listed in Table 1.

State anxiety. State anxiety was assessed with the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lusshene, Vagg, & Jacobs, 1983). Participants respond to 20 self-report items (using a scale ranging from 1 to 4) to indicate how anxious they feel at the moment.

Procedure

Prior to testing, participants attached the polar band, after which they sat down and watched a 4-min neutral film scene to make them feel at ease and normalize heart rate. They were then asked to step onto the middle of the stabilometric platform and watch the monitor, on which the instructions were displayed. Participants were instructed to remove their shoes and to stand upright with their feet approximately 30 cm apart and their arms hanging relaxed along the trunk of their body. They had to watch the sequences of images on the monitor while standing still. The actual experiment was preceded by a brief practice trial in which letters were presented.

The actual experiment consisted of a passive viewing task, with blocked presentation of the 20 pictures in each category (neutral, pleasant, and unpleasant). Pictures were presented for 3 s each, without between-picture interval, resulting in a total duration of 60 s (20 pictures × 3 sec) per set. The presentation of these affective sets was randomized, as well as the pictures within each set. A 5-s black screen followed by a 2-s white fixation cross was presented between the sets. The experiment took place in a dimly lit room. The total viewing time was 4 min 21 s (60 s practice + 201 s picture viewing). After the posturographic assessment, participants sat down to complete stimulus ratings and the NLETQ, which they could do at their own pace.

Table 1
Occurrence of Aversive Events (NLETQ) in the Two Event Groups

Aversive events	No. of aversive events experienced: Single ($n = 17$)	Multiple ($n = 15$)
Life-threatening illness	1	2
Divorce	4	5
Childhood sexual abuse	—	1
Childhood physical abuse	—	—
Childhood emotional abuse	—	2
Severe accident	1	—
Miscarriage	—	1
Abortion	1	—
Sexual assault (no rape) by a known person	—	2
Sexual assault (no rape) by an unknown person	—	3
Rape by a known person	—	—
Rape by an unknown person	—	—
Physical assault by a known person	—	1
Physical assault by an unknown person	—	—
Death of a close friend	4	7
Death of a partner	—	—
Death of a sibling	1	—
Death of a parent	—	1
Death of a child	—	—
Life-threatening illness of a parent, sibling or partner	2	4
Being fired	—	—
End of a long-lasting relationship	2	9
Becoming bankrupt or being sued	—	—
Fire or disaster	1	1
Other event, namely	—	3

Note. NLETQ = Negative Life Experiences and Trauma Questionnaire.

Posturographic and Statistical Analyses

Reduced body sway and heart rate deceleration were used to define freezing. Posturographic analyses were performed with MATLAB (MathWorks, Natick, MA). The x and y time series were low-pass filtered with a second-order Butterworth filter with a cutoff frequency of 10 Hz. For each picture, the mean position (M) in anterior–posterior direction (COP AP) and mediolateral direction (COP ML) were calculated. Postural immobility was defined as the standard deviation of the COP in anterior–posterior and mediolateral directions, with lower scores indicating increased immobility. For clarity, the standard deviation in anterior–posterior direction is referred to as *AP sway* and the standard deviation in mediolateral direction as *ML sway*. The mean heart rate in beats per minute (BPM) was determined for the three emotion blocks separately.

Separate repeated-measures (rm) analyses of variance (ANOVA rm) and multiple analyses of variance (MANOVA rm) were used to analyze picture ratings, postural measures (AP sway and ML sway), and heart rate with emotion (neutral, pleasant, unpleasant) as a within-subjects factor. To optimally control for the effects of arousal, we used pleasant–unpleasant contrasts to subsequently test the modulating effects of aversive life events (categorized as 0, 1, and >1) on freezing. Three participants were removed from the analyses because of extensive movements (Z scores > 4 on the posturographic measure).[2] Tests were two tailed or one tailed (for some specified hypotheses), with the significance level set at .05.

Results

Posturography

The overall MANOVA rm model including AP sway and ML sway showed a significant main effect of emotion, $F(4, 43) = 4.72$, $p = .003$, $\eta_p^2 = .31$; (see Figure 1). Univariate tests yielded a significant emotion effect for AP sway, $F(1, 46) = 4.71$, $p = .035$, $\eta_p^2 = .09$, and ML sway, $F(1, 46) = 14.06$, $p < .001$, $\eta_p^2 = .23$. Post hoc comparisons demonstrated a significant effect of

[2] Excluded participants did not differ from the rest of the sample with respect to age or subjective valence, arousal, or immobility ratings (all ps > .34).

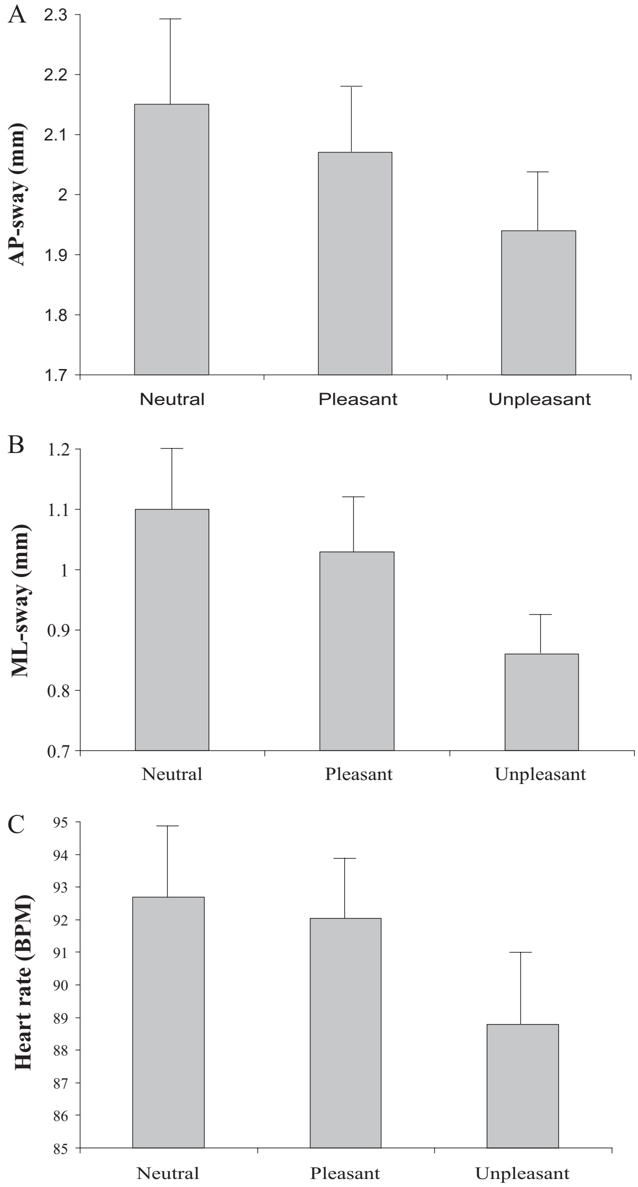

Figure 1. Panel A. Mean (standard error of the mean [SEM]) anterior–posterior standard deviations (AP sway) of the center of pressure (COP) in millimeters for neutral, pleasant, and unpleasant pictures in the total sample. AP sway was significantly reduced for unpleasant relative to neutral pictures. Panel B. Mean (SEM) mediolateral standard deviations (ML sway) of the COP in millimeters for neutral, pleasant, and unpleasant pictures in the total sample. ML sway was significantly reduced for unpleasant relative to neutral and pleasant pictures. Panel C. Mean (SEM) heart rate responses (in beats per minute) to neutral, pleasant, and unpleasant pictures in the total sample. Heart rate is significantly reduced for unpleasant relative to neutral and pleasant pictures.

unpleasant versus neutral for both AP sway and ML sway (p = .035 and $p < .001$ respectively). The effect of unpleasant versus pleasant was significant for ML sway (p = .001) but not for AP sway (p = .29). There were no differences between neutral and pleasant pictures for AP sway and ML sway (both *p*s > .05).

Heart Rate

ANOVA rm yielded a significant main effect for emotion, $F(2, 45) = 14.84$, $p < .001$, $\eta_p^2 = .40$; (see Figure 1 and Table 2 for means). Post hoc comparisons showed a significant heart rate reduction in response to unpleasant compared with neutral ($p <$ .001) and pleasant ($p < .001$) pictures (see Figure 1). There were no differences in heart rate responses to neutral and pleasant pictures (p = .44).

Aversive Life Events

To test whether aversive life events modulate the emotion effect on freezing, we conducted 2 × 3 MANOVA rm analyses with emotion (pleasant, unpleasant) as the within-subjects factor and group (categorized as 0, 1, and >1 aversive event) as the between-subjects factor. The overall model showed a significant Emotion × Group interaction, ($F(4, 88) = 4.15$, $p = .02$, $\eta_p^2 = .16$. Univariate tests with AP sway as a dependent variable revealed a significant Emotion × Group interaction, $F(2, 44) = 3.61$, $p = .035$, $\eta_p^2 =$ .14, indicating that the pleasant–unpleasant contrast was different for each group. Post hoc analyses showed that single-event participants showed greater AP sway reduction for unpleasant versus pleasant pictures than those with no events, $t(30) = -2.16$, $p =$ .02 (one-tailed). Pleasant–unpleasant AP sway reductions were not different for the no-event versus the multiple-event group, $t(28) =$ -0.30, $p = .39$ (one-tailed).

The absence of a difference in pleasant–unpleasant AP-sway reduction between the no-event and multiple-event group was not anticipated, so we tested whether this could result from a floor effect of body sway in the most severe (>1 event) group. We therefore additionally analyzed the absolute magnitude of AP sway for the specific stimulus categories. These analyses revealed significant differences between those with no events and those with multiple events in response to all picture categories (neutral: $p =$ .010; pleasant: $p = .037$; unpleasant: $p = .043$), indicating overall reduced AP body sway, which was not affected by picture category (see Figure 2). On the other hand, relative to those with no events, single-event participants showed reduced AP sway in response to unpleasant pictures ($p = .049$) but not to neutral ($p = .47$) or pleasant ($p = .73$) pictures, indicating specific reduced AP body sway in response to unpleasant pictures. The Emotion × Group interaction was not significant in the univariate tests with ML sway as the dependent variable, $F(2, 44) = 0.86$, $p = .43$, $\eta_p^2 = .04$.

Similar ANOVA rm analyses for heart rate again showed a significant Emotion × Group interaction, $F(2, 44) = 3.90$, $p = .03$ (one-tailed), $\eta_p^2 = .15$. Post hoc analyses showed that participants with a single event, $t(30) = -1.73$, $p = .047$ (one-tailed), and those with multiple events, $t(28) = -2.06$, $p = .024$ (one-tailed), showed greater heart rate reductions for unpleasant versus pleasant pictures, relative to those with no events. Interestingly, visual inspection of Figure 2, Panel C, suggested that heart rate was generally increased in multiple-event participants. This overall higher heart rate level was significant compared with that of single-event participants ($p = .03$), but not with that of no-event participants ($p = .20$).

Group differences in body sway were found on objective measures only. There was no significant Emotion × Group interaction for subjective immobility ratings, $F(2, 44) = 2.10$, $p = .28$

Table 2
Posturographic and Heart Rate Data (N = 47)

	Images					
	Neutral		Pleasant		Unpleasant	
Data	*M*	*SD*	*M*	*SD*	*M*	*SD*
Anterior–posterior sway (SD in mm)	2.15	0.90	2.06	0.75	1.94	0.67
Mediolateral sway (SD in mm)	1.11	0.61	1.03	0.54	0.86	0.38
Heart rate (beats per min)	92.69	13.47	92.03	14.00	88.80	13.45

Note. mm = millimeters.

(one-tailed), $\eta_p^2 = .03$. Also, an ANOVA yielded no significant differences in STAI among the three event groups, $F(2, 44) = 0.82$, $p = .45$, $\eta_p^2 = .03$, indicating that the findings could not be the result of differences in anxiety.

Subjective Picture Ratings

ANOVA rm analyses showed a significant effect of emotion on valence ratings, $F(2, 45) = 470.93$, $p < .001$, $\eta_p^2 = .91$. Post hoc comparisons showed significant differences between all emotion categories (all *p*s < .001), with pleasant pictures rated most positive and unpleasant most negative ($M = 4.06$, $SD = 1.28$; $M = 2.93$, $SD = 1.01$; and $M = 8.56$, $SD = 0.51$ for neutral, pleasant, and unpleasant images, respectively). Arousal ratings also differed significantly, $F(2, 45) = 329{,}72$, $p < .001$, $\eta_p^2 = .88$, with post hoc comparisons indicating significant differences between all emotion categories (all *p*s <.001), with the neutral pictures rated as least and the unpleasant pictures as most arousing ($M = 1.99$, $SD = 1.21$; $M = 4.68$, $SD = 1.82$; and $M = 7.37$, $SD = 1.63$ for neutral, pleasant, and unpleasant, respectively).

Finally, immobility ratings differed significantly, $F(2, 45) = 441.89$, $p < .001$, $\eta_p^2 = .91$, with post hoc comparisons showing significant differences between all emotion categories (all *p*s < .001). Subjective immobility was highest in response to the unpleasant relative to the neutral and pleasant pictures ($M = 1.38$, $SD = 0.75$; $M = 1.86$, $SD = 1.16$; $M = 6.90$, $SD = 1.57$ for neutral, pleasant, and unpleasant, respectively).

Discussion

The present study showed that freezing-like responses (indicated by reduced body sway and heart rate deceleration) could indeed be elicited in women by having them view aversive pictures. That is, for the total sample, we found heart rate deceleration and reduced body sway (decreases in ML and AP standard deviation of postural sway) in response to unpleasant (mutilation) pictures only. Subjective ratings of immobility indicated that overall, participants felt immobilized when viewing unpleasant but not neutral or pleasant pictures. These findings are in line with other studies (e.g., Azevedo et al., 2005), suggesting that passive picture viewing is indeed an adequate way to elicit human defensive reactions similar to the freeze–fight–flight response sequence in animals (Lang et al., 1997).

The main finding concerned the modulating effect of aversive life event experience on freezing responses. That is, participants who had experienced a single or multiple aversive events showed greater heart rate deceleration in response to unpleasant versus pleasant pictures than those who had experienced no such events. Multiple-event participants showed this enhanced freezing response in addition to an overall increased heart rate. Interestingly, this might be in line with PTSD phenomenology, consisting of stimulus-specific fear responses in addition to overall hypervigilance (American Psychiatric Association, 2000). Note that differences in heart rate and body sway among those with no, a single, and multiple aversive events were directly the result of experiencing these events, as groups did not differ in state anxiety.

The experience of aversive life events also affected body sway, with reduced anterior–posterior body sway in response to unpleasant versus pleasant pictures for the single-trauma group but not for the no-event group. This is the first study in which freezing (operationalized by heart rate deceleration and body sway reduction) has been shown to be enhanced by the experience of aversive events. Thus far, only animal studies have indicated the effect of early life stress on freezing behavior (e.g., Imanaka et al., 2006). The fact that this was found on objective measures only emphasizes the importance of objective measurement in the assessment of automatic defense responses. Note that group differences in pleasant–unpleasant reductions in body sway were found in the AP and not in the ML direction. In that direction, all groups showed pleasant–unpleasant reductions in body sway. Possibly, the AP direction is most sensitive to trauma-related fight–flight or approach–avoidance responses, and as a consequence, preparation of these responses is most clearly reflected in this direction. More research is needed, though, to distinguish between directional reductions in body sway.

Although remarkable at first, the absence of a significant difference in AP body sway for pleasant versus unpleasant pictures between participants with no aversive events and those with multiple aversive events could be explained by the fact that multiple-event participants showed overall reduced body sway in response to all picture categories (neutral, pleasant, and unpleasant). In contrast, single event participants showed decreased body sway in response to unpleasant pictures only. Possibly, a single aversive life event leads to specific fear conditioning associated with negative stimuli (specific freezing), whereas generalized effects and additional self-regulatory disturbances can be observed after multiple events (Cloitre, Stolbach, & Herman, 2009). In terms of classical conditioning, generalization of the fear response may have occurred, with formerly non-threat-related stimuli also evoking freezing. Speculatively, our data may also support the notion that cumulative trauma causes fundamental changes in an individ-

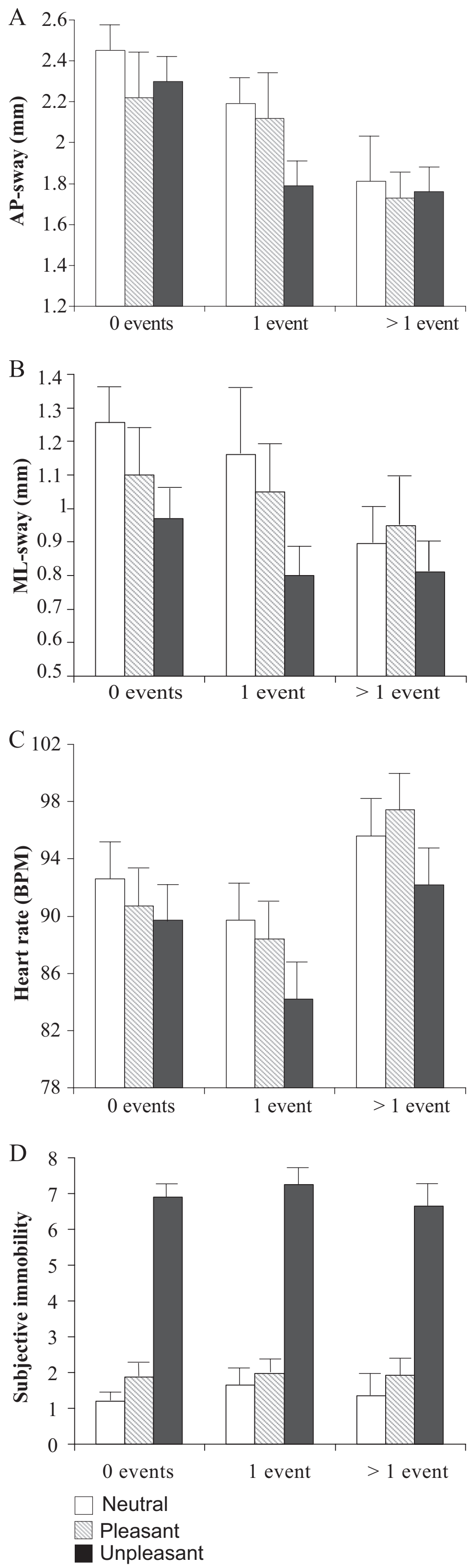

Figure 2. Panel A. Mean (standard error of the mean [SEM]) anterior–posterior standard deviations (AP sway) of the center of pressure (COP) in millimeters (mm) for neutral, pleasant, and unpleasant pictures in participants who had experienced no, a single, or multiple aversive life events. AP sway was significantly reduced in single-event participants relative to those with no events in response to unpleasant but not to neutral or pleasant pictures. AP sway was significantly reduced in multiple-event participants relative to those with no events in response to all picture categories. Panel B. Mean (SEM) mediolateral standard deviations (ML sway) of the COP in millimeters for neutral, pleasant, and unpleasant pictures in participants who had experienced no, a single, or multiple aversive life events. There was no interaction between picture category and aversive life events. Panel C. Mean (SEM) heart rate (beats per minute [BPM]) for neutral, pleasant, and unpleasant pictures in participants who had experienced no, a single, or multiple aversive life events. Pleasant–unpleasant reductions were significantly larger for participants who experienced a single or multiple events, relative to those with no events. Panel D. Mean (SEM) subjective immobility ratings for neutral, pleasant, and unpleasant pictures in participants who had experienced no, a single, or multiple aversive life events. There was no interaction between picture category and aversive life events.

ual's personality (Allen & Lauterbach, 2007), including changes in automatic defense behaviors. Note that Lopes et al. (2009) also found an overall decrease in body sway, associated with anticipatory anxiety, in patients with panic disorder relative to healthy controls. However, these panic-disorder patients also showed reduced body sway in response to the baseline in which they watched a gray screen. In order to compare our data with theirs, we also calculated body sway during the gray-screen periods (i.e., between the picture blocks) for the three trauma groups. Interestingly, there were no differences among participants with no, single, or multiple events for "baseline" AP-sway (all $ps > .39$) and ML sway (all $ps > .59$). Thus, overall immobility in our multiple-event participants was triggered by stimulus presentation, whereas the panic disorder patients in the study by Lopes et al. (2009) showed non-task-related overall immobility. These differences may reflect distinct fear processing for panic disorder and trauma-related disorders, for example, generalization of fear associations to nonthreatening stimuli versus anticipatory anxiety. For now, our data seem to indicate enhanced freezing in response to unpleasant stimuli as a result of trauma (possibly in a dose–response relation) and additional overall motion inhibition in response to all stimuli after cumulative traumas.

In the total sample, AP reductions in body sway were somewhat (although nonsignificantly) reduced in response to the pleasant pictures as well (see Figure 1), which seems remarkable at first sight. Reduced body sway in response to pleasant pictures has been found previously (Facchinetti et al., 2006), although while participants were viewing "social-bonding" pictures like babies and happy families. The authors of that study reasoned that these pictures evoke selective immobility responses to attachment stimuli. Possibly, the mechanisms are even broader than that. That is, reduced body sway has been proposed to be associated with enhanced perceptual intake and to serve attentional processes (Dault, Frank, & Allard, 2001; Stins, Roerdink, & Beek, in press). It is indeed known that not stimulus valence per se but also stimulus relevance may lead to enhanced attentional processes, and orienting can be affected by both valence and arousal (Williams, Mathews, & MacLeod, 1996; Yiend, 2010). Similarly, any emotional stimulus may trigger risk assessment behavior in order to allow individuals to detect and analyze possible threat (Blanchard, Griebel, Pobbe, & Blanchard, 2011). Note that heart rate was not decreased in response to pleasant pictures; thus, reduced body sway in response to pleasant pictures may reflect pure attentional processes rather than freezing. Freezing is a defense response associated with changes not only in perceptual and attentional processes but also in autonomic physical processes (like bradycardia, increased muscle tonus, and cutaneous vasoconstriction) that enhance action preparation (Vianna & Carrive, 2005). Moreover, reductions in body sway for pleasant pictures were found in AP direction only; body sway in ML direction was still reduced for unpleasant versus pleasant pictures, suggesting indeed that the AP reductions in body sway for pleasant pictures reflect a purely attentive process without need to prepare for fight or flight.

The present study has some limitations. First, only female participants were included, and organization of posture might be different in males. For example, Hillman, Rosengren, and Smith (2004) found increased postural displacement in posterior and anterior direction for men and women, respectively, in response to unpleasant pictures. Future studies should address possible gender differences in motor defense responses. Also, subjective arousal ratings in our study were higher for unpleasant than for pleasant pictures, although both were rated as more arousing than the neutral pictures. This is in contrast with the findings of Azevedo et al. (2005) and the official IAPS ratings (Center for the Study of Emotion and Attention, 1999); although using the same pictures that we used here, neither found differences in arousal levels in response to viewing the sports pictures versus viewing the mutilation pictures. Note, however, that differences in arousal are not likely to explain our findings, as freezing (reduced heart rate and body sway) in the total sample was found for unpleasant pictures only; pleasant pictures did not evoke heart rate reductions, an essential component of freezing. However, given that body sway is a newly used measure and that we do not know whether heart rate and body sway are similarly sensitive to arousal affects, future studies should also include "milder" unpleasant pictures, like threatening animals and pointed guns in order to match arousal levels with the pleasant pictures because mutilated bodies are extremely arousing and therefore their effect is difficult to match. Finally, we need to emphasize that the present study addressed defensive freezing behavior. Theoretically, some models distinguish freezing from tonic immobility, with tonic immobility, or "death feigning" taking place after contact with the predator, when fight, flight, or freezing are no longer options that increase survival chances (Eilam, 2005; Marx, Forsyth, Gallup, Fusé, & Lexingon, 2008). Human retrospective studies have found peritraumatic tonic immobility to be associated with later impairment like posttraumatic stress disorder (Bovin et al., 2008; Galliano, Noble, Puechl, & Travis, 1993; Heidt, Marx, & Forsyth, 2005). The distinction between freezing and tonic immobility is an interesting one that merits further investigation with longitudinal designs. The impact of freezing and tonic immobility responses also should be investigated in terms of later psychopathology.

In conclusion, spontaneous freezing-like reactions can indeed be elicited in humans by a passive viewing task, indicating parallel defense processes in animals and humans and underlining the importance of animal models for investigating (pathological) anxiety in humans. Moreover, aversive life events were shown to affect spontaneous freezing responses. Freezing is of great importance, as it has been linked to the etiology of psychiatric disorders like PTSD and conversion disorder. The present approach seems a promising way to objectify freezing and explore freezing mechanisms in such trauma-related disorders.

References

Allen, B., & Lauterbach, D. (2007). Personality characteristics of adult survivors of childhood trauma. *Journal of Traumatic Stress, 20,* 587–595. doi:10.1002/jts.20195

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

Azevedo, T. M., Volchan, E., Imbiriba, L. A., Rodrigues, E. C., Oliveira, J. M., Oliveira, L. F., . . . Vargas, C. D. (2005). A freezing-like posture to pictures of mutilation. *Psychophysiology, 42,* 255–260. doi:10.1111/j.1469-8986.2005.00287.x

Blanchard, D. C., Griebel, G., & Blanchard, R. J. (2001). Mouse defensive behaviors: Pharmacological and behavioral assays for anxiety and panic. *Neuroscience and Biobehavioral Reviews, 25,* 205–218. doi:10.1016/S0149-7634(01)00009-4

Blanchard, D. C., Griebel, G., Pobbe, R., & Blanchard, R. J. (2011). Risk assessment as an evolved threat detection and analysis process. *Neuroscience and Biobehavioral Reviews, 35,* 991–998. doi:10.1016/j.neubiorev.2010.10.016

Boscarino, J. A., & Adams, R. E. (2009). PTSD onset and course following the World Trade Center disaster: Findings and implications for future research. *Social Psychiatry and Psychiatric Epidemiology, 44,* 887–898. doi:10.1007/s00127-009-0011-y

Bovin, M. J., Jager-Hyman, S., Gold, S. D., Marx, B. P., & Sloan, D. M. (2008). Tonic immobility mediates the influence of peritraumatic fear and perceived inescapability on posttraumatic stress symptom severity among sexual assault survivors. *Journal of Traumatic Stress, 21,* 402–409. doi:10.1002/jts.20354

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation: I. Defensive and appetitive reactions in picture processing. *Emotion, 1,* 276–298. doi:10.1037/1528-3542.1.3.276

Brewin, C. R., & Holmes, E. A. (2003). Psychological theories of posttraumatic stress disorder. *Clinical Psychology Review, 23,* 339–376. doi:10.1016/S0272-7358(03)00033-3

Carpenter, M. G., Frank, J. S., Adkin, A. L., Paton, A., & Allum, J. H. J. (2004). Influence on postural anxiety on postural reactions to multidirectional surface rotations. *Journal of Neurophysiology, 92,* 3255–3264. doi:10.1152/jn.01139.2003

Center for the Study of Emotion and Attention, National Institute of Mental Health. (1999). *The International Affective Picture System.* Gainesville, FL: University of Florida.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin, 25,* 215–224. doi:10.1177/0146167299025002007

Cloitre, M., Stolbach, B. C., & Herman, J. L. (2009). A developmental approach to complex PTSD: Childhood and adult cumulative trauma as predictors of symptom complexity. *Journal of Traumatic Stress, 22,* 399–408. doi:10.1002/jts.20444

Dault, M. C., Frank, J. S., & Allard, F. (2001). Influence of a visuo-spatial, verbal, and central executive working memory task on postural control. *Gait and Posture, 14,* 110–116. doi:10.1016/S0966-6362(01)00113-8

Eilam, D. (2005). Die hard: A blend of freezing and fleeing as a dynamic defense: Implications for the control of defensive behavior. *Neuroscience and Biobehavioral Reviews, 29,* 1181–1191. doi:10.1016/j.neubiorev.2005.03.027

Elzinga, B. M., Roelofs, K., Tollenaar, M. S., Bakvis, P., Van Pelt, J., &

Spinhoven, P. (2008). Diminished cortisol responses to psychosocial stress associated with lifetime adverse events: A study among healthy young subjects. *Psychoneuroendocrinology, 33,* 227–237. doi:10.1016/j.psyneuen.2007.11.004

Engelhard, I. M., van den Hout, M. A., Kindt, M., Arntz, A., & Schouten, E. (2003). Peritraumatic dissociation and posttraumatic stress after pregnancy loss: A prospective study. *Behaviour Research and Therapy, 41,* 67–78. doi:10.1016/S0005-7967(01)00130-9

Facchinetti, L. D., Imbiriba, L. A., Azevedo, T. M., Vargas, C. D., & Volchan, E. (2006). Postural modulation induced by pictures depicting prosocial or dangerous contexts. *Neuroscience Letters, 410,* 52–56. doi:10.1016/j.neulet.2006.09.063

Fanselow, M. S. (1984). Shock-induced analgesia on the formalin test: Effects of shock severity, naloxone, hypophysectomy, and associative variables. *Behavioral Neuroscience, 98,* 79–95. doi:10.1037/0735-7044.98.1.79

Galliano, G., Noble, L. M., Puechl, C., & Travis, L. A. (1993). Victim reactions during rape/sexual assault: A preliminary study of the immobility response and its correlates. *Journal of Interpersonal Violence, 8,* 109–114. doi:10.1177/088626093008001008

Hagenaars, M. A., Brewin, C. R., van Minnen, A., Holmes, E. A., & Hoogduin, C. A. L. (2010). Intrusive images and thoughts after an aversive film. *Memory, 18,* 76–84. doi:10.1080/09658210903476522

Hagenaars, M. A., Fisch, I., & van Minnen, A. (in press). The effect of trauma onset and frequency on PTSD-associated symptoms. *Journal of Affective Disorders.*

Hagenaars, M. A., van Minnen, A., Holmes, E. A., Brewin, C. R., & Hoogduin, C. A. L. (2008). The effect of hypnotically induced somatoform dissociation on development of intrusions after an aversive film: An experimental study. *Cognition and Emotion, 22,* 944–963. doi:10.1080/02699930701575151

Heidt, J. M., Marx, B. P., & Forsyth, J. P. (2005). Tonic immobility and childhood sexual abuse: A preliminary report evaluating the sequela of rape-induced paralysis. *Behaviour Research and Therapy, 43,* 1157–1171. doi:10.1016/j.brat.2004.08.005

Hillman, C. H., Rosengren, K. S., & Smith, D. P. (2004). Emotion and motivated behavior: Postural adjustments to affective picture viewing. *Biological Psychology, 66,* 51–62. doi:10.1016/j.biopsycho.2003.07.005

Imanaka, A., Morinobu, S., Toki, S., & Yamawaki, S. (2006). Importance of early environment in the development of post-traumatic stress disorder-like behaviors. *Behavioural Brain Research, 173,* 129–137. doi:10.1016/j.bbr.2006.06.012

Kalin, N. H., Shelton, S. E., Rickman, M., & Davidson, R. J. (1998). Individual differences in freezing and cortisol in infant and mother rhesus monkeys. *Behavioral Neuroscience, 112,* 251–254. doi:10.1037/0735-7044.112.1.251

Koseki, H., Matsumoto, M., Togashi, H., Miura, Y., Fukushima, K., & Yoshioka, M. (2009). Alteration of synaptic transmission in the hippocampal-mPFC pathway during extinction trials of context-dependent fear memory in juvenile rat stress models. *Synapse, 63,* 805–813. doi:10.1002/syn.20657

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Hillsdale, NJ: Erlbaum.

LeDoux, J. (1996). *The emotional brain.* New York, NY: Simon & Schuster.

Lopes, F. L., Azevedo, T. M., Imbiriba, L. A., Freire, R. C., Valenca, A. M., Caldirola, D., . . . Nardi, A. E. (2009). Freezing reaction in panic disorder patients associated with anticipatory anxiety. *Depression and Anxiety, 26,* 917–921. doi:10.1002/da.20593

Marx, B. P., Forsyth, J. P., Gallup, G. G., Fusé, T., & Lexingon, J. M. (2008). Tonic immobility as an evolved predator defense: Implications for sexual assault survivors. *Clinical Psychology: Science and Practice, 15,* 74–90. doi:10.1111/j.1468-2850.2008.00112.x

Morgan, H. J., & Janoff-Bulman, R. (1994). Positive and negative self-complexity: Patterns of adjustment following traumatic versus non-traumatic life experiences. *Journal of Social and Clinical Psychology, 13,* 63–85. doi:10.1521/jscp.1994.13.1.63

Rau, V., & Fanselow, M. S. (2009). Exposure to a stressor produces a long-lasting enhancement for fear learning in rats. *Stress: The International Journal on the Biology of Stress, 12,* 125–133. doi:10.1080/10253890802137320

Roelofs, K., Hagenaars, M. A., & Stins, J. (2010). Facing freeze: Social threat induces bodily freeze in humans. *Psychological Science, 21,* 1575–1581. doi:10.1177/0956797610384746

Roelofs, K., Keijsers, G. P. J., Hoogduin, K. A. L., Näring, G. W. B., & Moene, F. C. (2002). Childhood abuse in patients with conversion disorder. *The American Journal of Psychiatry, 159,* 1908–1913. doi:10.1176/appi.ajp.159.11.1908

Sanders, B. J., & Knoepfler, J. (2008). Neonatal handling increases cardiovascular reactivity to contextual fear conditioning in borderline hypertensive rats (BHR). *Physiology & Behavior, 95,* 72–76. doi:10.1016/j.physbeh.2008.04.021

Santa Ana, E. J., Saladin, M. E., Back, S. E., Waldrop, A. E., Spratt, E. G., McRae, A. L., . . . Brady, K. T. (2006). PTSD and the HPA axis: Differences in response to the cold pressor task among individuals with child vs. adult trauma. *Psychoneuroendocrinology, 31,* 501–509. doi:10.1016/j.psyneuen.2005.11.009

Spielberger, C. D., Gorsuch, R. I., Lusshene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State–Trait Anxiety Inventory: Form Y.* Palo Alto, CA: Consulting Psychologists Press.

Stins, J. F., & Beek, P. J. (2007). Effects of affective picture viewing on postural control. *BMC Neuroscience, 8,* 83–90. doi:10.1186/1471-2202-8-83

Stins, J. F., Roerdink, M., & Beek, P. J. (2011). To freeze or not to freeze? Affective and cognitive perturbations have markedly different effects on postural control. *Human Movement Science, 30,* 190–202. doi:10.1016/j.humov.2010.05.013

Vianna, D. M. L., & Carrive, P. (2005). Changes in cutaneous and body temperature during and after conditioned fear to context in the rat. *European Journal of Neuroscience, 21,* 2505–2512. doi:10.1111/j.1460-9568.2005.04073.x

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120,* 3–24. doi:10.1037/0033-2909.120.1.3

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

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