Psychophysiology, •• (2014), ••–••. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/psyp.12386

Seated movement indexes emotion and its regulation in posttraumatic stress disorder

STEVEN H. WOODWARD,[a] ASHLEY A. SHURICK,[b] JENNIFER ALVAREZ,[c] JANICE KUO,[d] YULIANA NONYIEVA,[e] JENS BLECHERT,[f] KATERI McRAE,[g] AND JAMES J. GROSS[b]

[a]National Center for PTSD, Dissemination and Training Division, VA Palo Alto Health Care System, Palo Alto, California, USA
[b]Department of Psychology, Stanford University, Stanford, California, USA
[c]Trauma Recovery Programs, VA Palo Alto Health Care System, Palo Alto, California, USA
[d]Psychology Department, Ryerson University, Toronto, Ontario, Canada
[e]Palo Alto University, Palo Alto, California, USA
[f]Division of Clinical Psychology, Psychotherapy, and Health Psychology, Department of Psychology, University of Salzburg, Salzburg, Austria
[g]Department of Psychology, University of Denver, Denver, Colorado, USA

Abstract

This paper reports the results of a study that administered an emotion regulation task to Operation Enduring Freedom/ Operation Iraqi Freedom veterans diagnosed with posttraumatic stress disorder (27) and to healthy controls (23). Seated movement and postural responses were transduced with a sensitive accelerometer attached to the underside of a low-mass cantilevered chair. Consistent with prior studies in which subjects stood on force plates, aversive photographs induced attenuation of nondirectional movement in patients and controls. Regarding seated postural responses, controls leaned towards neutral photographs and away from aversive ones, while participants with PTSD did the opposite. Regulation had no impact on seated movement but was associated with a seated postural withdrawal from the computer screen.

Descriptors: PTSD, Stress, Traumatic, Emotion, Movement, Posture

In nature, adaptive motor behaviors are the dispositive outcomes of perceptual, emotional, and cognitive processes. In high-threat situations, these motor behaviors may take the form of "fight–flight" or, alternatively, movement suppression (i.e., "freezing"), a fear system output elicited at lower levels of threat acuity (Lang, Davis, & Ohman, 2000). Movement responses are rarely assessed in studies of perception, emotion, and cognition. In fact, movements must be suppressed in studies utilizing MRI, positron emission tomography, magnetoencephalography, and, to a lesser extent, EEG. Responses contaminated by movements are usually discarded. Among the conventional modalities of psychophysiology, only the electrocardiogram (ECG) is easily recorded in the moving person. This general limitation does not apply to studies employing technologies of balance and gait assessment to examine movement and postural responses to provocative stimuli.

The authors wish to acknowledge N. J. Arsenault, Sean Pereira, J. Gauthier, & T. Bredesen for assistance with data collection and data analysis. We are especially indebted to Tyson Holmes for his guidance regarding the statistical challenges posed by our experimental design. We are also grateful for the useful comments provided by Lisa McTeague. Finally, we are grateful for the support of the patients and staff of the Men's Trauma Recovery Program, VA Palo Alto Health Care System.

Address correspondence to: Steven H. Woodward, Ph.D., NCPTSD, VA Palo Alto HCS, 3801 Miranda Ave., Palo Alto, CA 94304, USA. E-mail: Steve.woodward@va.gov

Postural sway is defined as movement of the standing body around the center of gravity in response to vestibular stimulation. Azevedo et al. (2005) investigated whether mutilation photographs would attenuate body sway consistent with movement suppression. Subjects stood on a force plate and viewed images depicting mutilation-related, neutral, or positive content. Body sway was significantly reduced for mutilation blocks relative to positive and neutral blocks. Stins and Beek (2007) observed similar attenuation of body sway in response to disgust imagery. In the model articulated by Lang et al. (2000), movement suppression in response to aversive stimuli evidences an adaptation to avoid detection by a distant predator (see also Fanselow, 1994), and is supported by the conditions of "the human laboratory participant [who] . . . like the freezing rat . . . is immobile, vigilant, with easy escape blocked" (p. 149).

While postural sway can be conceptualized as variation around the center of gravity when standing, posture refers to the target position itself. A link between posture and emotion was noted by Darwin (1872) and is reflected in our common usage of phrases such as "leaning towards" and "leaning away" to describe cognitive and motivational phenomena. A number of recent studies have addressed this association, again assessing subjects standing on force plates. Hillman, Rosengren, and Smith (2004) found that female but not male subjects leaned away or "withdrew" from aversive photographs. Furthermore, mean stimulus-induced lean for all stimulus categories was net "away" with no postural approach observed. Perakakis, Idrissi, Vila, & Ivanov (2012) also observed a withdrawal postural response to be induced by both aversive and pleasant photographs. In contrast, using a Wii Balance Board, Eerland, Guadalupe, Franken, and Zwaan (2012) found that pleasant photographs induced postural approach, but unpleasant photographs failed to induce postural withdrawal. Neither Azevedo et al. (2005) nor Stins and Beek (2007) observed modulation of posture by aversive images.

Standing posture, as opposed to sway, may not vary systematically in response to aversive and appetitive stimuli as it is subject to reflexes aimed at remaining upright. Postural adjustments induced by stimulation must engender compensatory movements. A forward (approach) movement of the body must be quickly countered or a forward step will result (hence, sway) or be compensated for by a rearward movement of the lower torso with articulation at the waist. Either compensation could lead to ambiguous recordings on a force plate. We reasoned that the postural responses of seated participants could be measured free of contamination by antigravity reflexes with a sufficiently sensitive apparatus. We predicted, extrapolating from the framework provided by Lang et al. (2000), that nonpostural agitation-like movements would be suppressed by aversive stimuli. We predicted seated postural responses would evidence fundamental approach/avoidance components of motivated behavior. We predicted that movement and postural responses, like other manifestations of motivated behavior, would be sensitive to efforts by participants to regulate their emotions. We also predicted that aversive stimulus-induced movement and postural responses would distinguish persons with posttraumatic stress disorder (PTSD), considered by many to be a disorder of central fear systems and their regulation (Etkin & Wager, 2007; Pitman et al., 2012; Shin & Liberzon, 2009).

The data presented below were collected as part of a laboratory study of emotion regulation in U.S. military combat veterans with and without PTSD. PTSD is a psychiatric condition associated with exposure to one or more extreme stressors, such as military combat. It is characterized by intrusive, imaginal re-experiencing of the event(s), avoidance of internal and external reminders, tonic and episodic hyperarousal, and functional impairment. An emotion regulation framework seems an heuristic approach to PTSD (cf. Cavanagh, Fitzgerald, & Urry, 2014). A companion paper, Woodward et al. (in press), describes our observations of corrugator electromyogram (EMG), the late positive potential (LPP), and the ECG, recorded from the same sample of PTSD patients and controls engaged in an emotion regulation task. That paper reported expected effects of stimulus aversiveness, but few effects of regulation and no diagnosis by regulation interactions on EMG, LPP, or ECG.

Method

Participants

The final sample consisted of 27 veterans with PTSD and 23 controls, all right-handed males. Participants provided written informed consent to undergo the following experimental procedures approved by the Stanford/VA Palo Alto HCS Institutional Review Board. Screening exclusion criteria were current medical illness, history of head injury inducing loss of consciousness longer than 30 min, current substance abuse/dependence, psychotic disorder, mania, current medication on benzodiazepines, beta-blockers, antipsychotics, blood thinners, thyroid hormone-influencing agents, diabetic medications, or anticonvulsants. Inclusion criteria were male gender, age between 19 and 46 years, and right-handedness. Participants underwent structured interviews using the Structured Clinical Interview for the DSM-IV (SCID) and the Clinician-Administered PTSD Scale (CAPS). The original sample included 29 Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) combat veterans recruited from among inpatients of the Men's Trauma Recovery Program at the VA Palo Alto Health Care System and 25 age-matched healthy controls recruited via advertisements on craigslist (an online advertising service). PTSD-positive participants met criteria for current PTSD related to traumas sustained during their military deployments in Iraq and/or Afghanistan. Seventy-one percent of the PTSD participants also met DSM-IV criteria for major depressive disorder or mood disorder NOS (not otherwise specified); 71% met criteria for alcohol dependence; 64% met criteria for dependence on at least one nonalcohol substance. Fifty-seven percent of the PTSD participants were prescribed a sedative/hypnotic, 50% an antidepressant, 11% a mood stabilizer, 11% an opiate receptor blocker, and 4% an atypical antipsychotic. Healthy controls were free of lifetime PTSD, and endorsed few or no PTSD Category A qualifying events. Healthy controls were also free of current or recurrent major depression, panic disorder, agoraphobia, social phobia, simple phobia, or obsessive-compulsive disorder. A single past episode of a major depressive disorder without recurrence was admissible. No healthy controls were taking psychotropic medication.

Table 1. *Psychometrics Characterizing the PTSD and Healthy Control Participants*

	Healthy controls		PTSD			
	Mean	*SD*	Mean	*SD*	*t*	*p*
Age	27.5	6.6	29.5	5.8	1.15	.26
CES	0	0	30.8	6.9	16.0	< .001
BDI	2.3	3.0	29.4	15.0	7.1	< .001
BAI	1.8	2.1	21.0	12.5	6.1	< .001

Note. CES = Combat Exposure Scale; BDI = Beck Depression Inventory–II; BAI = Beck Anxiety Inventory.

Two participants (one PTSD, one healthy control) were identified as cardiac response outliers and one (PTSD) as a movement outlier and excluded. (Outlier status was triggered when more than 30% of change scores across all conditions and time intervals were outside the envelope defined by two sample standard deviations above and below the sample mean of corresponding values. Movement response outliers were excluded from this sample to create equivalent samples across this report and its companion paper.) One additional control was lost due to a recording failure. Additional sample characteristics are presented in Table 1.

Procedure

Participants underwent the application of electrodes for recording of corrugator EMG, EEG (Cz and Pz), and ECG. Participants were seated in a Poang model chair (Ikea, Inc.) to the underside of which was attached a sensitive, low-noise, single-axis, force-balance accelerometer with a bandwidth of 0–60 Hz, range of ±2 g, spot noise < 5 mg/Hz ^ .5 (Sprengnether, Inc.[1]). Because this chair is

1. Accelerometers are no longer available from Sprengnether, Inc.; however, equivalent measurements should be achievable with high-quality accelerometers such as the Silicon Designs Model 2210 2g or Memsic CXL TG-Series 2g.

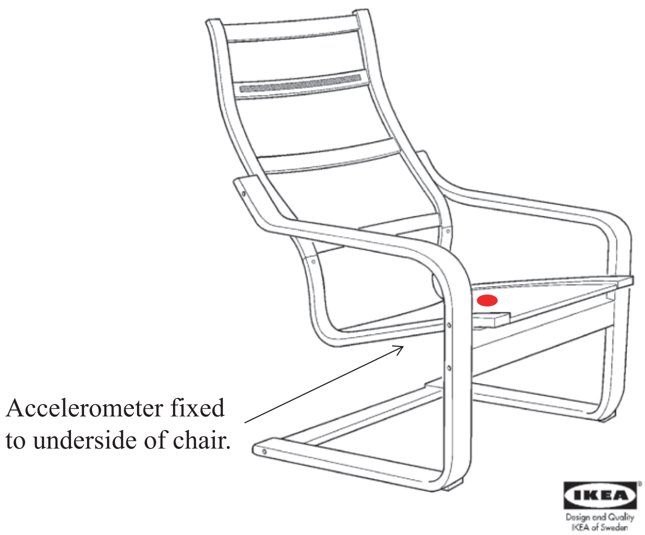

Figure 1. Drawing of a Poang (Ikea, Inc.) model chair (minus cushions) indicating the location of the accelerometer.

low in mass and uses a sprung-cantilevered design (see Figure 1), it flexed in response to participants' movements and postural responses in the fore-aft axis relative to the display. The chair has a preset "bias" (~22 degrees of recline for a 75-kg person) yielding a nonzero set point (corresponding to ~73% of gravitational acceleration), facilitating the interpretation of postural adjustments as towards or away from the display. A 75-kg person deflected the chair seat ~4 cm or ~5.6 degrees. Sensitivity was 0.0659 volts/degree or 865 bits/degree. As wired, movements toward the screen reduced tilt and yielded less negative values, while movements away from the screen yielded more negative values. The system could reliably sense changes in seat inclination associated with isolated head movements ~2 inches towards or away from the screen. That should not be taken to imply that head movements accounted for the small seat movements transduced, though that is a possibility. The measurement apparatus could not transduce sway as defined in a standing person. The chair used was strongly reclining and removed any vestibular challenge. As with posture, it is not possible to precisely specify the sources of the nondirection movement responses without additional sensors, for example, EMG or accelerometry from specific regions of the body, which we elected not to collect for this study in which minimizing burden was a priority. Participants were seated directly in front of and approximately 36 inches (91.4 cm) from the 19-inch (48.4 cm, diagonal measure) display and were video-recorded throughout testing.

Stimuli, Trials, and Blocks

The experimental design is summarized in Figure 2. Photographs containing aversive or neutral content were presented for 10 s each. Aversive stimuli included 48 photographs containing Iraq and Afghanistan conflict-related content. In light of the recency of combat trauma and the severity of current PTSD in the veteran subsample, the OEF/OIF-related images were only moderately explicit in their military content, with one half containing only tangential content (e.g., American flag burnings, anti-American protests). An additional 24 negative and 24 neutral photographs were chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008).[2] Each photograph was preceded by a 2-s fixation cross followed by the appearance of a colored frame at the borders of the screen. The color of the frame

2. IAPS aversive: 1300, 2053, 3030, 3051, 3100, 3102, 3110, 3120, 3140, 3170, 3180, 3350, 6360, 6550, 8230, 9240, 9250, 9140, 9300, 9410, 9571, 9800, 9810, 9921; mean valence: 2.07; *SD*: 0.50; mean arousal: 6.29; *SD*: 0.56. IAPS neutral: 2560, 5250, 5533, 5700, 5731, 5800, 5992, 6150, 7080, 7092, 7100, 7140, 7170, 7207, 7233, 7284, 7286, 7500, 7550, 7820, 7830, 8250, 8280, 8300; mean valence: 5.78; *SD*: 0.70; mean arousal: 3.72; *SD*: 1.02.

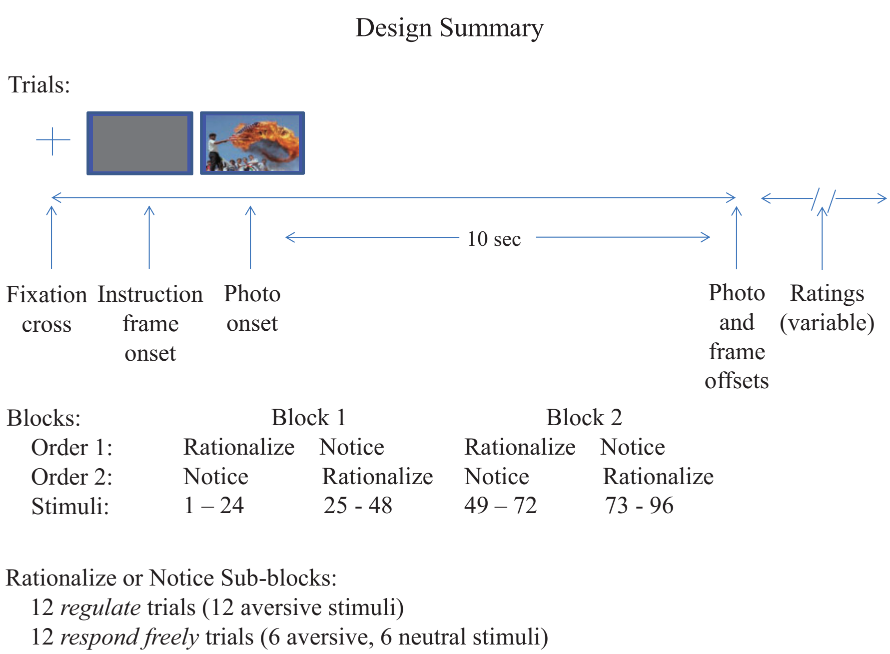

Figure 2. Design summary presenting trial structure, block/strategy counterbalancing across replicate blocks, and subblock trial composition.

cued the participant to regulate their emotional response to the subsequent photograph using the *rationalize* strategy (blue), the *notice* strategy (purple), or instead to *respond freely* (green). On rationalize trials, participants were instructed to "think of something to tell yourself that helps you feel less negative about the photo." On notice trials, participants were instructed to ". . . notice your beating heart and your angry or fearful thoughts, and do not resist these reactions in any way . . . let the emotion flow over you like a wave." After the colored frame was presented for 2 s, the stimulus photograph appeared within it, the frame remaining in place for the duration of the photograph. Each trial was followed by a response-terminated period during which participants answered the question, "How negative do you feel?" using a scale of 1 to 9 with text anchors at 1 (*not at all*), 5 (*somewhat*), and 9 (*very much*).

Verbal instructions were followed by two self-paced, eight-trial practice series, one for each emotion regulation strategy. The first four trials of each series were experimenter guided; the second four were performed with the experimenter out of the room. Participants were then presented with the 96 photographs in two fully replicated blocks of 48 trials. Within each block, rationalize and notice trials were segregated to separate subblocks of 24 trials. Each of these subblocks contained 12 regulate trials and 12 respond freely trials, pseudorandomly ordered. All regulate trials presented aversive content. Respond freely trials were divided equally between aversive and neutral content. The regulation strategy exercised first was counterbalanced across participants (order factor).

Data Analyses

The voltage output of the accelerometer was digitized (along with psychophysiological measures) at 600 Hz. One data channel was used to record square-wave pulses synchronized with image onsets enabling offline extraction of 22-s epochs of trialwise data. To quantify seated movement, accelerometer voltage was filtered to a 2–28 Hz bandwidth, rectified and integrated over a 2,000-ms time constant, and averaged per second. To quantify seated posture, accelerometer voltage output filtered to a 0–28 Hz bandwidth was averaged per second. Values for the last 1-s interval prior to stimulus onset served as baseline values and were subtracted from poststimulus values to yield change scores. There were no effects of group, regulation, or aversiveness on prestimulus values of seated movement. (Baseline values of seated posture were uninformative as they were confounded with participant weight.)

Statistical analyses employed linear mixed modeling (SAS v9.2) to accommodate moderate imbalance in the order factor (29 vs 21). The random effect was participant nested in diagnosis and order. Temporal variations movement and posture were modeled as first-order autoregressive processes. Preliminary analyses included diagnosis and order (of regulation strategy) as between-subjects factors, and block, regulation (yes/no), strategy, and time as within-subjects factors. In preliminary analyses, it was determined that strategy was associated with no main effects and no interactions with diagnosis or regulation. Accordingly, strategy was collapsed and responses averaged across rationalize and notice trials. Responses to aversive photographs on respond freely trials contributed to both aversiveness and regulation contrasts. The order factor was modeled to avoid misallocation of variance to diagnosis, but will not be further discussed as participants were assigned to order groups at random and the strategy factor was collapsed.

Results

Aversiveness Contrast

As is evident in Table 2a, aversive photographs induced higher levels of negative affect than neutral photographs on uninstructed trials (5.0 vs. 1.4; $F(1,92) = 682.0$, $p < .001$). There was a Block × Aversiveness interaction, $F(1,92) = 9.0$, $p = .003$, in which negative affect ratings of aversive but not neutral photographs increased significantly from block 1 to block 2 (aversive: 4.7 to 5.4; $F(1,92) = 12.6$, $p < .001$; neutral: 1.5 to 1.4; $F(1,92) = 0.48$, $p = .49$). Negative affect ratings were higher overall in block 2 (3.1 vs. 3.4; $F(1,46) = 4.11$, $p = .05$). PTSD participants reported more photograph-induced negative affect than controls (3.7 vs. 2.7; $F(1,46) = 13.0$, $p < .001$); however, this held only for aversive photographs (5.8 vs. 4.2; $F(1,92) = 27.7$, $p < .001$) and not neutral ones (1.6 vs. 1.2; $F(1,92) = 1.43$, $p = .24$; Diagnosis × Aversiveness interaction, $F(1,46) = 26.7$, $p < .001$).

On uninstructed respond freely trials, seated body movement decreased near-monotonically over the response interval (main effect of time: $F(9,1638) = 4.97$, $p < .001$). The main effect of aversiveness was not significant, $F(1,92) = 1.14$, $p = .29$; however, there was Aversiveness × Time interaction, $F(9,1638) = 2.72$, $p = .004$, as movement following aversive photographs was significantly reduced relative to movement following neutral photographs at seconds 5 and 6 of the response interval and tended to be lower at time points after second = 1 (see Figure 3).

As shown in Figure 4, on respond freely trials, seated postural responses exhibited a diagnosis by aversiveness interaction, $F(1,92) = 8.70$, $p = .004$. Controls leaned towards neutral photographs and away from aversive photographs. In contrast, PTSD participants leaned towards aversive photographs and away from neutral ones.

Regulation Contrast

Presented in Table 2b, negative affect ratings following aversive photographs exhibited a Block × Regulation interaction, $F(1,92) = 5.8$, $p = .018$, in which regulation moderated negative affect only in block 2 (block 2: 4.9 vs. 5.4; $F(1,92) = 10.04$, $p = .002$; block 1: 4.7 vs. 4.7; $F(1,92) = 0.03$, $p = .87$). The main effect was also significant (least squares means: 5.0 vs. 4.8; $F(1,92) = 4.68$, $p = .033$). Negative affect ratings were also higher overall in block 2 (5.2 vs. 4.7; $F(1,46) = 25.59$, $p < .001$). PTSD participants endorsed more poststimulus negative affect overall than healthy controls (5.7 vs. 4.1; $F(1,46) = 12.44$, $p = .001$), but the Diagnosis × Regulation interaction did not approach significance, $F(1,92) = 0.02$, $p = .88$.

Table 2. *Photograph-Induced Negative Affect Ratings by Contrast*

		Block 1		Block 2	
		Mean	*SE*	Mean	*SE*
a. Valence contrast					
Control	Neutral	1.3	0.3	1.2	0.3
Control	Aversive	3.8	0.3	4.6	0.3
PTSD	Neutral	1.7	0.2	1.5	0.2
PTSD	Aversive	5.5	0.2	6.1	0.2
b. Regulation contrast					
Control	Respond freely	3.8	0.4	4.6	0.4
Control	Regulate	3.9	0.4	4.1	0.4
PTSD	Respond freely	5.5	0.3	6.1	0.3
PTSD	Regulate	5.5	0.3	5.8	0.3

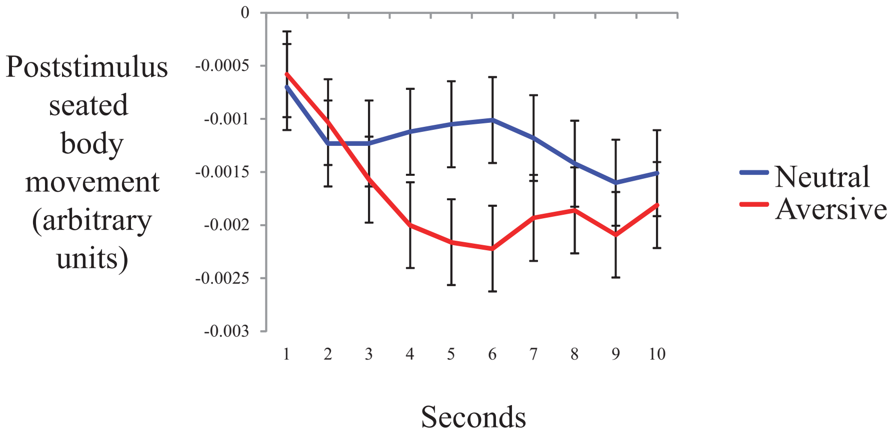

Figure 3. Aversiveness × Time interaction on seated nondirectional movement responses. Nondirectional movement was quantified via rectification/integration of the filtered (2–28 Hz) accelerometer voltage output (per second) and presented here relative to a 1-s prestimulus baseline. Hence, nondirectional movement was reduced during stimuli relative to baseline, especially during aversive stimuli.

Seated movement was not influenced by regulation, exhibiting only an effect of time, $F(9,1638) = 13.76$, $p < .001$.

In the regulation contrast, seated postural responses exhibited a main effect of diagnosis, $F(1,46) = 4.94$, $p = .031$; Diagnosis × Time interaction, $F(4,1638) = 2.05$, $p = .031$, as controls leaned away from the display after photograph onsets while PTSD participants did not (see Figure 5). Regulation of emotion by the two strategies employed was also associated with postural withdrawal, $F(1,92) = 6.61$, $p = .011$; see Figure 6). There was no Diagnosis × Regulation interaction, $F(1,92) = 1.44$, $p = .23$; Diagnosis × Regulation × Time interaction: $F(9,1638) = 1.06$, $p = .39$. Seated postural responses also exhibited a main effect of time as participants leaned slightly away from the display over the first half of the response period, $F(9,1638) = 2.79$, $p = .001$.

Discussion

An accelerometric measure of nondirectional seated movement was sensitive to the aversiveness of photographic stimuli. The attenuation of nondirectional movement following aversive images seen here was consistent with observations of attenuated sway in standing subjects reported by both Azevedo et al. (2005) and Stins and Beek (2007). As noted, the measurement apparatus employed did not transduce sway as defined in a standing person. The chair used was strongly reclining and removed any vestibular challenge. In fact, it is not possible to specify the sources of the nondirection movement responses. In aggregate, the observations from both standing subjects and these seated subjects are compatible with the framework proposed by Fanselow (1994) and Lang et al. (2000) in which movement suppression is posited to be an early, low-threshold output of the central fear system.

Unlike studies measuring standing participants, this study observed both approach- and avoidance-like seated postural responses. On uninstructed trials, healthy controls leaned towards neutral photographs and away from aversive ones. Hence, the directionalities of controls' responses were broadly consistent with the conventional approach/avoidance dimensions of emotion and motivation. While it is plausible, as suggested in the introduction,

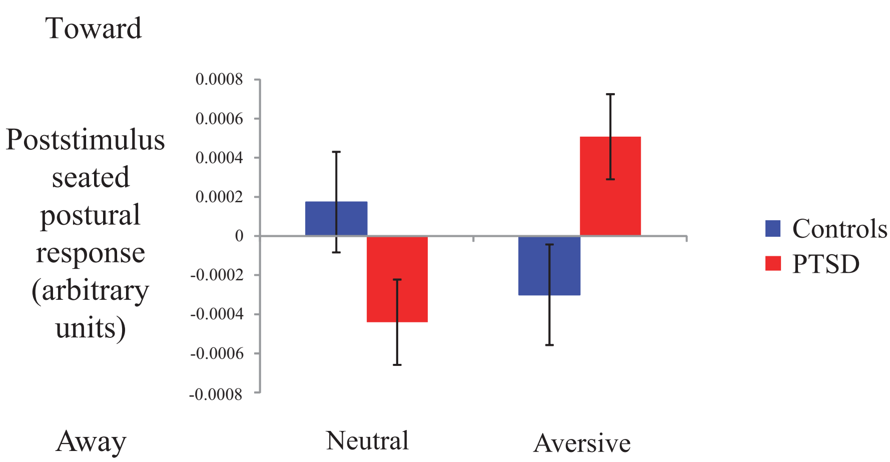

Figure 4. Diagnosis × Aversiveness interaction on seated postural responses. Posture was quantified as the per-second mean of the accelerometer output. The accelerometers used were DC-coupled so that they responded not only to brief movements but also to constant changes in sensor orientation re the force vector of gravity. Within the 10-s response period, controls leaned slightly towards neutral stimuli (relative to a 1-s prestimulus baseline) and away from aversive stimuli. PTSD participants did the opposite.

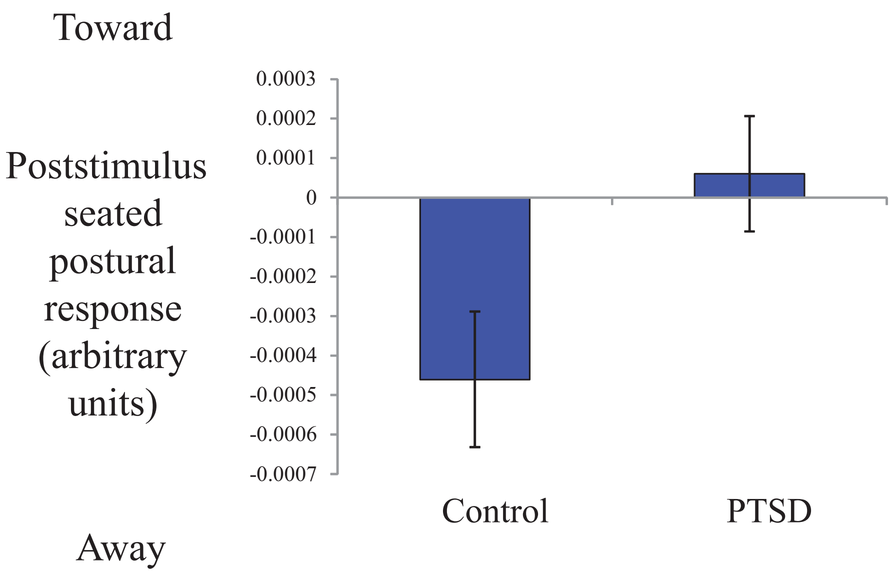

Figure 5. Main effect of diagnosis on seated postural responses on regulation trials. Controls but not PTSD participants leaned away from aversive photographs when instructed to regulate their responses to them.

that seated postural responses better reflect motivational phenomena because they are uncontaminated by balance-maintenance reflexes, studies that obtain both standing and seated postural responses will be necessary to confirm this hypothesis.

Of the objective measures employed in this study, only seated postural withdrawal was associated with efforts to regulate emotion using the collapsed rationalize/notice strategies. It is noteworthy that “distancing,” a subtype of cognitive reappraisal, has been recently shown to be more effective than another subtype, “reinterpretation” (Denny & Ochsner, 2014). Both the rationalize and notice strategies may be compatible with distancing as the notice instruction focused participants’ attention on their internal milieu and away from the photographs. It may be of interest to determine whether instructions to upregulate appetitive responses induce postural approach in normals and differential postural responses in mood-disordered groups.

Like the measures reported in the companion paper, seated postural responses did not disclose objectively measurable differences between PTSD patients and controls as they executed volitional emotion regulation strategies. This was the case despite the fact that controls and PTSD patients exhibited differential postural responses on uninstructed trials, and regulation was associated with postural withdrawal across groups. As noted in the companion paper, the absence of significant differences in instructed emotion regulation between PTSD patients and controls may be attributable to the fact that the former were engaged in an intensive treatment

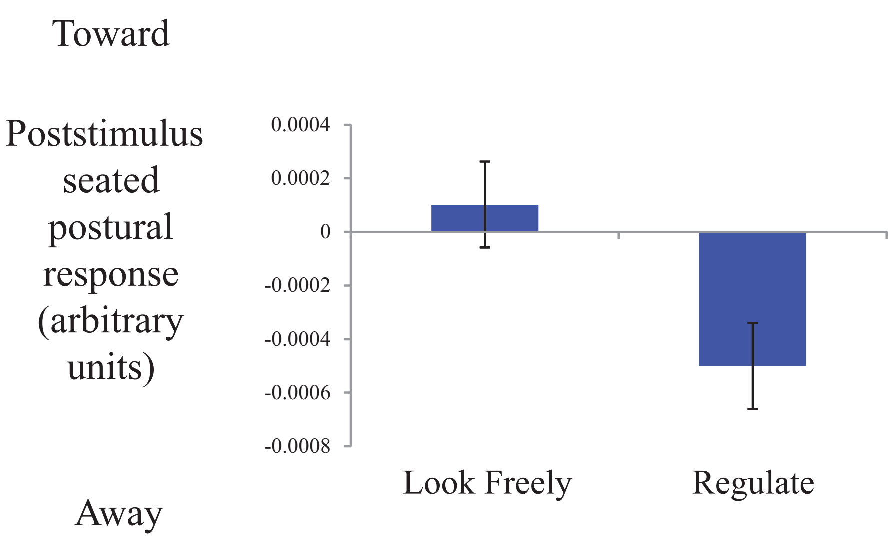

Figure 6. Main effect of regulation on seated postural responses. Across groups, instructions to regulate emotional responses to aversive photographs were associated with leaning away from the display.

program in which emotion regulation skills were taught. Also potentially relevant are gender differences in the neurobehavioral processes underlying emotion regulation (cf. McRae, Ochsner, Mauss, Gabrielli, & Gross, 2008). Future studies should include PTSD samples not receiving treatment and participants of both genders.

While the observed tendency of PTSD participants to lean towards aversive photographs appears broadly inconsistent with the avoidance symptoms codified in DSM-5, it is broadly consistent with studies quantifying gaze in PTSD. These studies have typically found evidence of increased attention to aversive and trauma-relevant images in PTSD samples (Armstrong, Bilsky, Zhao, & Olatunji, 2013; Beevers, Lee, Wells, Ellis, & Telch, 2011; Bryant, Harvey, Gordon, & Barry, 1995; Felmingham, Rennie, Manor, & Bryant, 2011; Kimble, Fleming, Bandy, Kim, & Zambetti, 2010; Thomas, Goegan, Newman, Arndt, & Sears, 2013). Future studies could combine postural and eye tracking indices to examine their interrelationship. It is possible that these two indices provide additive information regarding abnormal approach motivation to aversive stimuli in PTSD. Alternatively, if shown to be highly convergent with eye movements, postural responses could provide a less technically demanding, objective measure of this phenotype. Also noteworthy in this context is the task employed by Fleurkens, Rinck, and van Minnen (2014), which tests whether trauma-related image content interferes preferentially with the initiation of a flexor (approach) versus an extensor (withdrawal) movement of the arm/wrist cued by a neutral stimulus. Unlike the above tasks, which might be construed as isolating attentional phenomena, it has provided evidence consistent with increased avoidance in PTSD.

Participants were stereotypically quiescent and oriented toward the display during testing. Therefore, we believe that transducing seat position changes as described captured a large portion of the informative body movement manifested by participants; however, this supposition could be tested with higher precision. Situating the chair on a sufficiently large force plate would allow for transduction of movements in lateral and anterior-posterior axes. Including transduction of a purely vertical force vector, perhaps combined with EMG in relevant muscle groups, could discriminate anterior-posterior from vertical postural adjustments, either of which could result in changes in seat position. Assuming head position relative to stimulation is a critical output of seated postural responses, additional information could be provided by directly sensing of the position of the head relative to the display; cf. http://www.plesseysemiconductors.com/epic-plessey-semiconductors.php; http://apdm.com/Wearable-Sensors/inertial-sensors.

It is important to note an additional limitation of this study, which is that the design did not distinguish responses to trauma-related versus generic aversive stimuli. Though functional imaging studies have shown that the patterns of brain activation induced in persons with PTSD by trauma-related versus generic aversive stimuli are similar (Bremner et al., 1999; Gold et al., 2011; Phan, Britton, Taylor, Fig, & Liberzon, 2006; Shin et al., 1997, 2004), the regulation of emotions elicited by these two classes of stimuli could be divergent.

In summary, seated movement and postural responses to provocative stimuli may provide novel insights into normal and abnormal affective behavior at relatively low cost. The observation of what appears to be clearly abnormal postural responses to aversive stimuli in PTSD may represent a step in the development of laboratory measures supporting the application of an emotion regulation framework to that disorder. At the same time, many questions remain as to the precise sources of these movement responses and their optimal measurement.

References

Armstrong, T., Bilsky, S. A., Zhao, M., & Olatunji, B. O. (2013). Dwelling on potential threat cues: An eye movement marker for combat-related PTSD. *Depression and Anxiety*, *30*, 497–502.

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.

Beevers, C. G., Lee, H. J., Wells, T. T., Ellis, A. J., & Telch, M. J. (2011). Association of predeployment gaze bias for emotion stimuli with later symptoms of PTSD and depression in soldiers deployed in Iraq. *American Journal of Psychiatry*, *168*, 735–741.

Bremner, J. D., Staib, L. H., Kaloupek, D., Southwick, S. M., Soufer, R., & Charney, D. S. (1999). Neural correlates of exposure to traumatic pictures and sound in Vietnam combat veterans with and without posttraumatic stress disorder: A positron emission tomography study. *Biological Psychiatry*, *45*, 806–816.

Bryant, R. A., Harvey, A. G., Gordon, E., & Barry, R. J. (1995). Eye movement and electrodermal responses to threat stimuli in post-traumatic stress disorder. *International Journal of Psychophysiology*, *20*, 209–213.

Cavanagh, S. R., Fitzgerald, E. J., & Urry, H. L. (2014). Emotion reactivity and regulation are associated with psychological functioning following the 2011 earthquake, tsunami, and nuclear crisis in Japan. *Emotion*, *14*, 235–240.

Darwin, C. (1872). *The expression of the emotions in man and animals*. London, UK: John Murray.

Denny, B. T., & Ochsner, K. N. (2014). Behavioral effects of longitudinal training in cognitive reappraisal. *Emotion*, *14*, 425–433.

Eerland, A., Guadalupe, T. M., Franken, I. H., & Zwaan, R. A. 2012. Posture as index for approach-avoidance behavior. *PLOS ONE*, *7*, e31291.

Etkin, A., & Wager, T. D. (2007). Functional neuroimaging of anxiety: A meta-analysis of emotional processing in PTSD, social anxiety disorder, and specific phobia. *American Journal of Psychiatry*, *164*, 1476–1488.

Fanselow, M. (1994). Neural organization of the defensive behavior system responsible for fear. *Psychonomic Bulletin & Review*, *1*, 429–438.

Felmingham, K. L., Rennie, C., Manor, B., & Bryant, R. A. (2011). Eye tracking and physiological reactivity to threatening stimuli in posttraumatic stress disorder. *Journal of Anxiety Disorders*, *25*, 668–673.

Fleurkens, P., Rinck, M., & van Minnen, A. (2014). Implicit and explicit avoidance in sexual trauma victims suffering from posttraumatic stress disorder: A pilot study. *European Journal of Psychotraumatology*, *5*. doi: 10.3402/ejpt.v5.21359

Gold, A. L., Shin, L. M., Orr, S. P., Carson, M. A., Rauch, S. L., Macklin, M. L., . . . Pitman, R. K. (2011). Decreased regional cerebral blood flow in medial prefrontal cortex during trauma-unrelated stressful imagery in Vietnam veterans with post-traumatic stress disorder. *Psychological Medicine*, *41*, 1–10.

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.

Kimble, M. O., Fleming, K., Bandy, C., Kim, J., & Zambetti, A. (2010). Eye tracking and visual attention to threating stimuli in veterans of the Iraq war. *Journal of Anxiety Disorders*, *24*, 293–299.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. 2008. International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report No. A-8. University of Florida, Gainsville, FL.

Lang, P. J., Davis, M., & Ohman, A. (2000). Fear and anxiety: Animal models and human cognitive psychophysiology. *Journal of Affective Disorders*, *61*, 137–159.

McRae, K., Ochsner, K. N., Mauss, I., Gabrielli, J. D., & Gross, J. J. (2008). Gender difference in emotion regulation: An fMRI study of cognitive reappraisal. *Group Processes and Intergroup Relations*, *11*, 143–162.

Perakakis, P. E., Idrissi, S., Vila, J., & Ivanov, P. (2012). Dynamical patterns of human postural responses to emotional stimuli. *Psychophysiology*, *49*, 1225–1229.

Phan, K. L., Britton, J. C., Taylor, S. F., Fig, L. M., & Liberzon, I. (2006). Corticolimbic blood flow during nontraumatic emotional processing in posttraumatic stress disorder. *Archives of General Psychiatry*, *63*, 184–192.

Pitman, R. K., Rasmusson, A. M., Koenen, K. C., Shin, L. M., Orr, S. P., Gilbertson, M.W., . . . Liberzon, I. (2012). Biological studies of post-traumatic stress disorder. *Nature Reviews Neuroscience*, *13*, 769–787.

Shin, L. M., & Liberzon, I. (2009). The neurocircuitry of fear, stress, and anxiety disorders. *Neuropsychopharmacology*, *35*, 169–191.

Shin, L. M., McNally, R. J., Kosslyn, S. M., Thompson, W. L., Rauch, S. L., Alpert, N. M., . . . Pitman, R.K. (1997). A positron emission tomographic study of symptom provocation in PTSD. *Annals of New York Academy of Sciences*, *821*, 521–523.

Shin, L. M., Orr, S. P., Carson, M. A., Rauch, S. L., Macklin, M. L., Lasko, N. B., . . . Pitman, R. K. (2004). Regional cerebral blood flow in the amygdala and medial prefrontal cortex during traumatic imagery in male and female Vietnam veterans with PTSD. *Archives of General Psychiatry*, *61*, 168–176.

Stins, J. F., & Beek, P. J. (2007). Effects of affective picture viewing on postural control. *BMC Neuroscience*, *8*, 83.

Thomas, C. L., Goegan, L. D., Newman, K. R., Arndt, J. E., & Sears, C. R. (2013). Attention to threat images in individuals with clinical and sub-threshold symptoms of post-traumatic stress disorder. *Journal of Anxiety Disorders*, *27*, 447–455.

Woodward, S. H., Shurick, A. A., Alvarez, J., Kuo, J., Nonyieva, Y., Blechert, J., . . . Gross, J. J. (in press). A psychophysiological investigation of emotion regulation in chronic severe posttraumatic stress disorder. *Psychophysiology*.

(Received July 3, 2014; Accepted October 26, 2014)