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Postural and eye-blink indices of the defensive startle reflex

Charles H. Hillman[a,*], Elizabeth T. Hsiao-Wecksler[b], Karl S. Rosengren[a,c]

[a] Department of Kinesiology, University of Illinois at Urbana-Champaign, 213 Louise Freer Hall, 906 S. Goodwin Avenue, Urbana, IL 61801, USA
[b] Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
[c] Department of Psychology, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

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Abstract

Postural and eye-blink reactions to acoustic startle probes were examined in 24 volunteers, who completed two blocked conditions (baseline, startle). A postural reaction during the startle condition demonstrated a reflexive movement in the anterior–posterior direction, which was not observed during the baseline condition. This reflexive response was positively associated with the eye-blink reflex, such that larger blink magnitude related to greater posterior movement. These findings were not observed for postural movements in the medial–lateral direction. The results suggest that a measurable postural reaction may be observed following a startling acoustic stimulus, which may reflect generalized bodily flexion associated with a preparatory behavioral response.

Keywords: Posture; Center of pressure; Approach–withdrawal; Avoidance behavior; Eye-blink reflex; Postural sway

Many contemporary theories of emotion (Davidson et al., 1990; Lang, 2000; see Elliot and Covington, 2001 for review) contend that emotion is organized around basic motivational systems. The defensive system, the focus of the current investigation, is responsible for withdrawal or avoidance behavior that is activated in the context of threat and underlies unpleasant reactions (Bradley et al., 2001).

The acoustic startle reflex is considered a primitive defensive reflex to an abrupt sensory event that serves as a behavioral interrupt of ongoing behavior, and may also protect various organs from injury (e.g., the eye-blink; Lang et al., 1997). The neural circuitry of the basic startle reflex involves a subcortical mechanism in which sensory inputs activate nuclei in the reticular formation with outputs to the descending reticulo-spinal tract to the spinal cord (Davis et al., 1982). In threatening or fearful contexts, this reflex is modulated by other brain regions (e.g., the amygdala) and is thought to reflect withdrawal motivation (Lang et al., 1990).

Some of the earliest studies on the defensive startle reflex in humans employed a revolver shot to elicit a response ("the startle pattern"), captured by high-speed film as generalized bodily flexion (Landis and Hunt, 1939). Since that time, researchers have used

* Corresponding author. Tel.: +1-217-244-2663; fax: +1-217-244-7322.
E-mail address: chhillma@uiuc.edu (C.H. Hillman).

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other indices of the human startle reflex including electromyographic (EMG) activity associated with eye closure, neck, shoulder, trunk, and leg flexion, as well as neuroelectric activity. Of these responses, the eye-blink has captured considerable attention due to its sensitivity and slow habituation rate (Stern and Dunham, 1990). Although early research on the startle reflex examined behavioral sequelae, virtually all research since that time has examined electrical activity of the cortical or muscular systems. Given the importance of overt behavior during emotional appraisal in novel environments, this report re-examines behavioral reactions associated with the human defensive startle reflex. Specifically, postural reactions to an acoustic startle probe were investigated. Standing postural reactions, assessed by changes in center of foot pressure (COP), serve as a summary measure of all movements made above the support surface. Postural reactions are dependent upon sensory information (Redfern et al., 2001) and reflect a dynamic coupling of perception and action (Bertenthal et al., 1997). To date, only one study of postural sway has examined overall postural reactions motivated by specific emotional stimuli (Hillman et al., 2004), and no research has assessed postural reactions to abrupt, startling stimuli. Accordingly, we hypothesized that an acoustic startle probe would elicit a defensive whole-body reflexive reaction characterized by bilateral symmetry and rapid anterior movement (indicative of flexion) that would not be observed during a baseline (non-startle) condition. No such reaction was expected in the medial–lateral (ML) direction during either condition (i.e., startle or baseline).

1. Method

1.1. Participants

Twenty-four undergraduate students (12 females, 12 males) from the University of Illinois at Urbana-Champaign participated in this study for extra course credit. Participants ranged from 18 to 24 years (M = 19.7, SD = 1.5) and reported no hearing loss or central nervous system disorders that would affect balance or gait. Informed consent was obtained from all participants.

1.2. Procedure

To measure postural reactions, participants stood in stocking feet on a force platform in their normal, comfortable stance with arms at the side. Sensors were affixed under the left eye to measure the eye-blink response. Headphones were placed on the participants, the lights were dimmed, and they were given a few moments to acclimate to the room. Participants were instructed to stand quietly for the entire length of the trial (40 s). They were told that they would occasionally hear brief noises over the headphones, which should be ignored. One practice startle trial was given. Participants completed two counterbalanced conditions (baseline and startle), each consisting of 11 trials with a brief rest between each trial and a 5-min rest between blocks. During startle trials, participants received one acoustic startle probe. No noise probe was used in baseline trials.

1.3. Stimulus

The startle probe consisted of a 50-ms burst of 95 dB white noise with instantaneous rise time. The startle probe onset, marked on the recordings by a 5-volt signal, was presented between 4 and 8 s following the start of data collection and was counterbalanced within and across participants such that they received an equal number of probes at the 4, 5, 6, 7, and 8 s time points following trial onset. Probes were presented binaurally using calibrated headphones (TDH-49; Telephonics, Huntington, NY).

1.4. Apparatus and response measures

For each 40-s trial, data from the force platform (9281B; Kistler Instruments, Amherst, NY) provided information on the movement of the COP in the anterior–posterior (AP) and medial–lateral (ML) directions. For startle condition trials, COP data were reduced by creating an 11-s epoch of continuous data (from 1-s prior through 10-s after startle probe onset). Data were baseline corrected using mean data from the 1-s period of quiet standing that occurred prior to startle probe onset. For baseline condition trials, an 11-s epoch was created from data during the time period from 5 to 16 s after trial onset. Since the 6-s time point was the average time point in which the startle probe was delivered during the startle condition, the 1-s period from 5 to 6 s was used for mean adjustment for baseline condition trials. Force platform data were sampled at 100 Hz.

These epochs were averaged across all trials for a given condition. For each participant, the averaged data were used to examine COP reaction in the AP and ML directions. Peak amplitudes were measured during the first second following startle probe onset.

Eye-blink responses to the acoustic startle probe were measured by recording EMG activity from the lower arc of the left orbicularis oculi muscle using two adjacent 4 mm Ag–AgCl electrodes. An 8-mm Ag–AgCl electrode placed on the right collarbone served as the ground. Impedance for the electrodes was below 10 kΩ for all participants. EMG data were recorded and analyzed using commercial psychophysiological data acquisition equipment (Neuroscan, Neuro, El Paso, TX). The raw EMG signal was amplified, bandpass filtered from 30 to 500 Hz (24 dB/octave), rectified, and integrated. The eye-blink reaction was sampled at 2000 Hz from 50 ms prior to, and 250 ms after, the onset of the acoustic startle probe. The mean EMG activity from the 50-ms period prior to the onset of the startle probe was used for baseline correction. Peak magnitude was used to assess the eye-blink reaction.

1.5. Statistical analysis

Statistical analyses were performed using SPSS 11.5 (Chicago, IL). Postural reactions during the one-s period after probe onset were examined using three sets of paired samples *t*-tests. Specifically, startle and baseline conditions were compared by examining (1) the anterior peak of the COP response, (2) the posterior peak of the COP response, and (3) an overall peak-to-peak measure that examined the difference between the largest positive and largest negative peaks (i.e., anterior peak + |negative peak|). Correlations were conducted on the COP reaction with the eye-blink response using a two-tailed Pearson correlation coefficient. The alpha level was set at $p = 0.05$ for all statistical tests with a Bonferroni correction factor, such that $p < 0.017$ was necessary to achieve significance. Analyses of the COP reaction in the ML direction were not performed since consistent peak movements were not observed in either condition (see Fig. 1b).

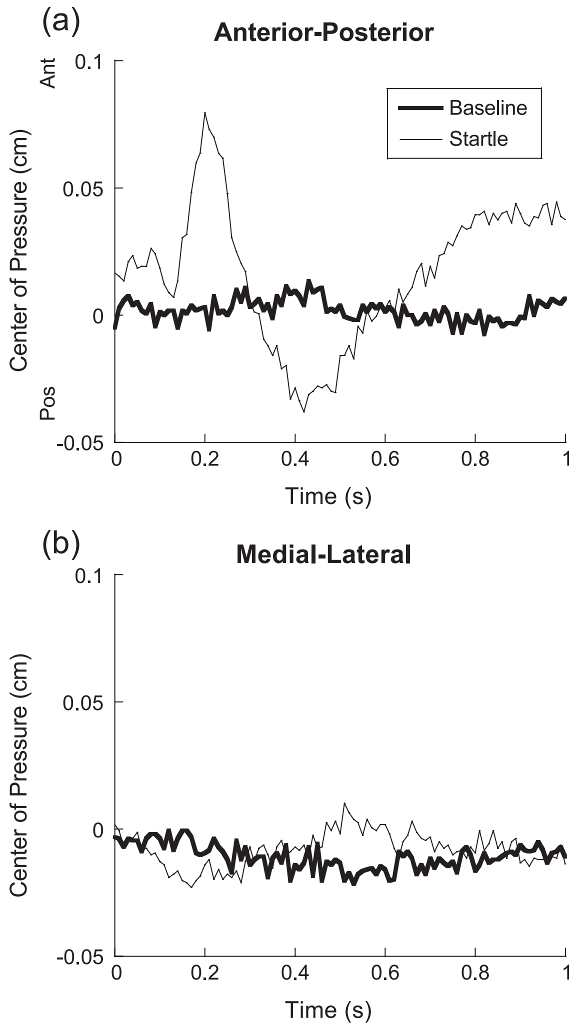

Fig. 1. Ensemble-averaged COP response for baseline and startle trials during the initial 1 s after startle onset. (a) Note the initial anterior movement, followed by a posterior movement, during the startle trials. This behavior is not found in baseline trials. (b) No consistent movements were observed in the ML direction for either trial type.

2. Results

2.1. Startle-COP response

Fig. 1 illustrates the COP reaction in the AP and ML directions. As can be seen in the figure, begin-

Table 1
Means (SE) of peak movement (cm) in the anterior, posterior, and peak-to-peak measures of the COP

Peak	Startle	Baseline
Anterior	0.2 (0.03)	0.09 (0.02)
Posterior	– 0.15 (0.02)	– 0.07 (0.02)
Peak-to-peak	0.34 (0.03)	0.17 (0.01)

ning approximately 100 ms following the startle probe, participants typically exhibited a movement characterized by an initial anterior motion that was followed immediately by a posterior movement (see Table 1 for average peak data). Statistical analysis indicated that the anterior movement, $t(1, 23)=4.7$, $p<0.001$, and posterior movement, $t(1, 23)=2.6$, $p=0.017$, in response to the startle stimulus, were significantly larger than movement during the baseline condition (see Fig. 1a). Further, the peak-to-peak analysis, which examined overall movement to the startle probe by measuring the difference between the peak anterior and posterior movements also exhibited increased postural movement compared to the baseline condition, $t(1, 23)=6.7$, $p<0.001$.

2.2. Startle eye blink reflex

The startle blink reflex was characterized by a mean magnitude of 29.9 μV (SE = 5.5) across all participants. Since the eye-blink reflex was not elicited during the baseline condition, statistical analyses between conditions could not be conducted. However, exploratory analyses using Pearson's correlation coefficients were conducted to determine associations between the magnitude of the blink reflex and the COP reaction in the anterior, posterior, and overall peak-to-peak measures during the startle condition trials. Results revealed a positive association between blink magnitude and the amount of movement in the posterior direction, $r=0.47$, $p=0.02$. A similar trend was noted for the relationship between blink magnitude and the overall peak-to-peak COP response, $r=0.33$, $p=0.11$, and no relationship was observed for the association between blink magnitude and the amount of anterior COP movement ($p=0.72$). In other words, larger startle blink magnitudes were associated with greater movement in the posterior direction, which was further reflected in the overall peak-to-peak COP measure.

3. Discussion

These results suggest that a measurable postural reaction, which is characterized by an initial anterior movement, followed by a posterior one, may be observed in response to an acoustic startle probe, while no consistent COP movement was observed for the baseline condition, or in the ML directions. This AP reaction, could be indicative of reflexive behavior, and may be motivated by the defensive response system.

The findings in the AP direction are consistent with a reflexive reaction, given the fast time course and resolution of the changes in COP movement (i.e., movement in the anterior and posterior directions are completed approximately 500 ms following startle onset). Additionally, the time course of this postural change is inline with other reflexive startle measures, which also have fast time courses such as the eye-blink (30–50 ms; Lang et al., 1990) and forearm (80 ms; Valls-Solé et al., 1999) responses. Further, we have previously demonstrated that emotional reactions elicit postural behavior (Hillman et al., 2004). That study examined postural COP reactions to emotional picture viewing and found that female participants exhibited increased posterior movement to unpleasant pictures depicting scenes of mutilated and disfigured bodies, and threat (Hillman et al., 2004). Considering that the acoustic startle probe may elicit a defensive reaction, the postural responses observed in the current study may be suggestive of generalized postural flexion, and provides support for the notion that emotional reactions prime behavioral action.

The current results provide insight into motivated behavioral reactions to potentially noxious stimuli and suggest that protective postural reflex behavior occurs. These reactions, mediated by a primitive defensive system, may be rooted in neurophysiological brain circuits that underlie defensive motives (Lang et al., 1997). Thus, these findings may provide a new direction for better understanding motivated behavior. Future work should also examine postural reactions during emotional events, including both the motivated defensive and appetitive systems.

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