Gait & Posture 34 (2011) 164–168

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Organization of voluntary stepping in response to emotion-inducing pictures

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ARTICLE INFO

Article history:
Received 18 January 2010
Received in revised form 28 January 2011
Accepted 5 April 2011

Keywords:
Postural control
Emotion
Reaction time
Step initiation

ABSTRACT

The present experiment was conducted to examine the expectation that emotion stimuli influence the initiation and execution of voluntary stepping, a highly coordinated activity involving a sequence of medio-lateral and anterio-posterior weight shifts. Thirty participants made forward (approach) or backward (avoidance) steps on a forceplate in response to the valence of visual stimuli. Posturographic parameters of the steps, related to automatic stimulus evaluation, step initiation and step execution, were determined and analyzed as a function of stimulus valence and stimulus-response mapping. The results revealed marked effects of emotion on the step parameters of interest; unpleasant images caused an initial "freezing" response, and a tendency to move away from the stimuli. Pleasant stimuli, in contrast, were not found to induce approach tendencies. The results demonstrated that affect, especially negative emotions, and whole-body movements such as voluntary stepping are coupled.

1. Introduction

Darwin [1] already proposed a relation between emotional states and postural changes in man and animals. Recent studies using posturographic recordings have indeed found markers of emotion in the posturogram, providing evidence for the notion that emotions are fundamentally dispositions to act (cf. [2]). A number of studies using the quiet stance paradigm have observed reduced sway and increased frequency in the center-of-pressure (COP) fluctuations in response to unpleasant visual stimuli, suggestive of "attentive immobility" or "freezing" [3,4]. Also shifts in the mean position of the COP have been observed in an emotion-eliciting context. Those shifts have been interpreted as involuntary signs of gait initiation, in order to approach or avoid an object or situation with positive or negative valence [2,5,6]. However, to our knowledge, no study to date has directly tested how a step in a particular direction is organized in response to an affective stimulus. The aim of the present study was to examine how the transition from quiet stance to step initiation is influenced by emotion.

We employed a novel adaptation of the affect-compatibility paradigm, which has been extensively used within experimental psychology to study how manual responses are coupled to emotion-eliciting stimuli. The responses typically consist of arm flexions and extensions, which have been interpreted operationally as "approach" (moving toward oneself) and "avoidance" (pushing away from oneself), respectively (e.g., [7–9]). Analyses of the reaction times revealed that arm flexions (extensions) are initiated faster in response to pleasant (unpleasant) visual stimuli than with the converse stimulus-response assignment. These findings have been taken to reflect automatic behavioral tendencies elicited by affective stimuli (e.g., [10]).

However, manual responses might bear little resemblance to real-life approach-avoid behavior, as the physical distance between the self and the emotion-inducing stimulus or object remains unchanged [11]. To this end, we asked our subjects to produce whole body forward ("approach") or backward ("avoidance") steps in response to the valence of visual stimuli. Step initiation from a quiet bipedal standing posture is a highly coordinated activity involving a rapid lateral weight shift to the stance leg (caused by lifting the swing leg), followed by a leg swing and a whole body displacement in the desired direction. A number of studies have investigated the accompanying trace in the COP profile to scrutinize how step initiation is organized [12,13]. For example, it has been found that in order to create enough sideways and forward momentum, humans produce anticipatory postural adjustments (APAs) prior to the actual step. These APAs consist of an initial brief weight shift to the swing leg and a weight shift in the anterior direction, both of which are clearly visible in the COP trace [12]. After the APA the execution of the step proceeds in a highly stereotypic manner [13]. We adopted the whole-body approach-avoidance paradigm to examine whether the time course of affective processing is reflected in the spatio-temporal evolution of the COP.

The question we addressed was whether, and how, the preparation, initiation and execution of voluntary forward or backward steps is influenced by the valence of emotional stimuli. First, we predicted approach tendencies in response to pleasant stimuli, and avoidance tendencies in response to unpleasant

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doi:10.1016/j.gaitpost.2011.04.002

stimuli. We expected these tendencies to show up in the time to initiate a step (reaction time; RT), with faster RTs for the pleasant/approach and unpleasant/avoid arrangement than for the converse arrangement. This prediction can be considered to close the empirical gap between studies that observed approach-avoidance tendencies in the quiet stance paradigm [2,5,6] and studies that found evidence of such tendencies in the pattern of manual response times [7–10]. Second, we predicted an initial freezing reaction in response to highly unpleasant stimuli. This freezing response was thought to occur fast and automatically upon stimulus presentation, as a prelude of overt defensive behavior, at least with respect to potentially threatening stimuli. Even though evidence of freezing has been found during quiet stance [3,4,14], it has never been investigated whether affect-induced freezing precedes stepping in a particular direction. Third, we examined whether other phases of the step, namely the execution of the movement and the APAs, would be sensitive to the affective content of the stimuli. Studies examining post-decision motoric processes of arm movements in response to affective stimuli have yielded inconsistent results [15,16], and our paradigm allows us to examine whether affect has an influence on the execution of the steps.

2. Methods

2.1. Participants

30 healthy undergraduate students (16 females; mean age 22.3 years) volunteered to participate in the experiment. All participants gave their written informed consent prior to the experiment. The study was approved by the local Ethics Committee.

2.2. Procedure

Participants stood on a custom made strain gauge force plate (dimensions: 1 m × 1 m; sampling frequency: 100 Hz; resolution: 0.28 N/bit; resonance frequency: 30 Hz), viewing a 17-in. monitor 1 m in front of them on which images were displayed. The stimuli (24 pleasant and 24 unpleasant images[1]; randomly presented) were adopted from the International Affective Picture System (IAPS) [17], a commonly used database for emotion research containing validated pictures with affective content. Each stimulus was shown for 5 s (4–6 s variable inter-trial interval to prevent anticipation) during which the screen went black. The images were presented in fully random order. Participants received 6 practice trials (3 pleasant, 3 unpleasant images). After the experiment we obtained valence and arousal ratings of the pictures, using the Self-Assessment Manikin (e.g., [2]).

Participants were instructed to stand still and adopt a slightly splayed foot stance, and to await the arrival of the stimulus. As soon as the visual stimulus appeared they had to make a fluent step with their right leg followed by their left leg in either the anterior direction (approach) or the posterior direction (withdrawal) in response to the valence of the image, and to remain stationary until the stimulus disappeared. During the inter-trial interval participants had to step back to their starting position and await the next trial. The center of pressure changes accompanying each step were recorded in the x-direction (medio-lateral) and y-direction (anterio-posterior). Recording started 2 s prior to each stimulus and stopped at stimulus offset. In the affect-congruent condition (performed by half the participants) an approach step was linked to a pleasant image, and a withdrawal step to an unpleasant image. In the affect-incongruent condition (performed by the other half) this mapping was reversed. Speed and accuracy were emphasized. We chose to adopt a between-subjects design (with mapping as between-subjects variable) rather than a within-subjects design, as the latter would have entailed switching the instructions halfway the experiment, which might have induced additional switch costs (cf. [18]).

2.3. Data analysis

Following the IAPS instruction manual [2] we scored the valence and arousal ratings such that 9 represents a high rating on each dimension (i.e., pleasant, high arousal), and 1 represents a low rating on each dimension (i.e., unpleasant, low arousal), to obtain mean ratings for the picture categories.

The COP time series were filtered using a 5-point moving average. From these time series we calculated a number of spatial and temporal parameters that characterize various phases of the steps, related to (a) the initial automatic reaction to the stimulus, (b) the initiation of the step, and (c) the execution of the step.

Ad (a). We tested whether early (and presumably, automatic) visual processing of the affective material would manifest itself as early involuntary changes in the COP. To this end, we determined from the first 400 ms post stimulus the length of the sway path of the COP time series, which is indicative of the total amount of body sway, and hence of immobility or “freezing” (cf. [3,4]).

Ad (b). We determined the time it took to organize and commence the step, i.e., the reaction time. Calculation of RT was based on a velocity criterion. We reasoned that step initiation would become manifest as a marked increase in the velocity of the COP, following a period of more or less quiet stance. We differentiated the COP trajectory with respect to time, and we determined the moment at which the tangential velocity exceeded the threshold of 15 cm/s, which we took as our measure of RT. In addition, we calculated the amount of initial COP displacement along the AP-axis of the force plate opposite the required direction of the step. Initial COP displacement was calculated by subtracting the pre-stimulus stance position in the AP-direction from the extreme posterior (in the case of approach) or anterior (in the case of withdrawal) position of the COP (cf. Landmark 2 in Fig. 2 of [19]).

Ad (c). Execution of the step was studied by examining step size (the distance between the initial stance position prior to step initiation and the final stance position) and the movement time (the time difference between the reaction time and the first instance in the AP time series when the final stance position was reached).

These measures are illustrated in Fig. 1, where we plotted (a) the displacement in the ML-direction, (b) the displacement in the AP-direction, (c) the COP in the AP-ML plane, and (d) the velocity profile, of a representative forward step. Note that the velocity profile consists of three peaks that are associated with distinct phases in the step, namely (1) a lateral displacement of the COP, caused by a rapid weight shift to the (left) stance leg, (2) a forward displacement of the COP, corresponding to a forward propulsion of the body center of mass (COM), and (3) stabilization of the body in its new position and counteracting the inevitable overshoot of the COM. Steps in the backward direction yield nearly identical COP profiles.

Trials at which (a) the RT was outside the range of 200 ms and 2000 ms, (b) a step was made in the wrong direction, (c) a step was made with the left foot, or (d) there was considerable pre-stimulus COP movement (i.e., when the velocity of the COP exceeded 10 cm/s in the 500 to 0 ms pre-stimulus window) were counted as errors and were not analyzed further.

2.4. Statistics

The gait parameters and the valence and arousal ratings were entered into separate ANOVAs with mapping (affect-congruent vs. affect-incongruent) as between-subjects factors, and valence (pleasant vs. unpleasant pictures) as within-subjects factor. Follow-up analyses were done using a t-test. For all analyses we adopted a p-value of .05.

3. Results

In total, 63 trials (4.4%) were counted as errors, based on the criteria described above.

3.1. Picture ratings

The ANOVA performed on the valence ratings revealed a main effect of valence, $F(1,\ 28) = 1059.61$, $p < .001$. Pleasant images received higher valence scores than unpleasant ones (6.2 vs. 1.7, respectively). Also, pleasant images received lower arousal scores than unpleasant ones (3.2 vs. 4.6, respectively), $F(1,\ 28) = 62.56$, $p < .001$. No effects involving mapping were significant. Over all trials, valence and arousal ratings were moderately correlated ($r = -.39$, $p < .01$), indicating that unpleasant images were also high in arousal.

3.2. Posturograhy: automatic stimulus evaluation

The sway path length in the initial 400-ms post-stimulus interval was shorter with the unpleasant images than with the pleasant images (8.5 mm vs. 9.4 mm), $F(1, 28) = 10.62$, $p < .01$. No effects involving mapping were significant.

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[1] International Affective Picture System catalog numbers for pictures used in this study were as follows: pleasant (pictures showing wild life, children, and smiling people): 1440, 1441, 1463, 1603, 1710, 1750, 1920, 2050, 2057, 2080, 2165, 2224, 2311, 4250, 4574, 4599, 5001, 5623, 5833, 7325, 8120, 8350, 8470, 8496; unpleasant (pictures showing scenes of fear, anger, mutilation, and disgust): 1050, 1111, 1201, 1280, 1525, 3016, 3030, 3068, 3181, 3220, 6242, 6313, 6370, 6510, 6570, 8485, 9300, 9301, 9405, 9561, 9571, 9592, 9900, 9910.

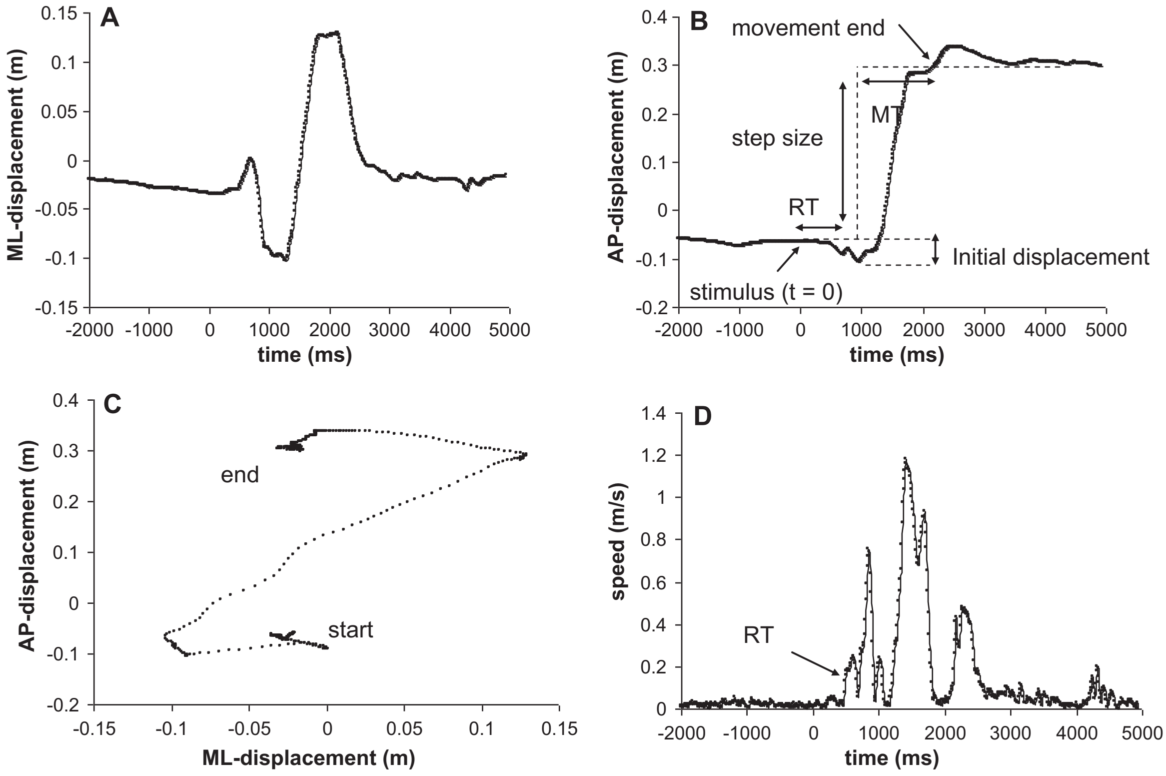

Fig. 1. Representative time series of a step in the anterior direction. Panel A: displacement in the ML-direction; panel B: displacement in the AP-direction; panel C: top view of the COP in the AP–ML plane; panel D: the velocity profile. Step parameters are depicted in panel B (see text for details). The stimulus appears at time $t = 0$ and disappears after 5 s.

3.3. Posturograhy: step initiation

Analysis of the RTs revealed a main effect of valence, $F(1, 28) = 23.45$, $p < .01$, and an interaction of valence and mapping, $F(1, 28) = 6.15$, $p < .05$. These effects were due to relatively long RTs in the condition where subjects in the incongruent group had to respond to unpleasant images, that is, by taking a forward step (Fig. 2). The difference in RT between congruent and incongruent steps was not significant for backward steps ($t < 1$), whereas it was significant for forward steps, $t(28) = 2.243$, $p < .05$.

APAs were only affected by step direction as evidenced by the significant mapping by valence interaction, $F(1, 28) = 446.99$, $p < .001$. Forward steps were preceded by an initial posterior displacement of the COP of 29.4 mm on average, whereas backward steps were preceded by a 43.0-mm initial anterior displacement, regardless of valence and mapping.

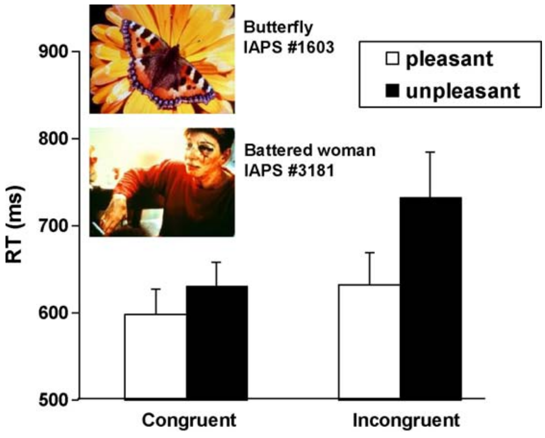

Fig. 2. Mean RT in ms separate for the two mappings (affect-congruent and affect-incongruent) and the two picture categories (pleasant and unpleasant). Error bars indicate standard errors of the mean. Also shown is an example of a pleasant picture (top) and an unpleasant picture (bottom) from the IAPS set used.

3.4. Posturograhy: step execution

Analysis of the step sizes only revealed an interaction of mapping and valence, $F(1, 28) = 9.00$, $p < .01$. Participants produced forward steps with an amplitude of 344 mm on average, and backward steps with an amplitude of 327 mm. For the movement times no effects were significant. The average MT was 1848 ms.

3.5. Correlation between sway path length and initiation time

Given that both the sway path length and the initiation times were influenced by picture valence, we decided to explore whether these measures were statistically related. To this end, we correlated overall sway path length and initiation time, separately for pleasant and unpleasant picture categories. This correlation was significant both for the pleasant and unpleasant pictures ($r = -.568$, $p < .01$; $r = -.573$, $p < .01$, respectively). These correlations indicate that subjects who show reduced body sway directly after stimulus presentation take more time to initiate a step (see Fig. 3).

Partial correlations controlling for mapping yielded nearly identical values ($r = -.560$ and $r = -.578$, respectively), indicating that the correlation between sway path length and initiation times was not modulated by the instruction to perform a congruent or incongruent stepping response.

As a control, we performed the same analysis, but now correlating the sway path length 0–400 ms prior to the stimulus with the initiation times. The same correlations were low and non-significant (r's .175 and .064, respectively), indicating that the relation between body sway and step initiation was evoked by stimulus presentation and not simply an effect of body sway in general.

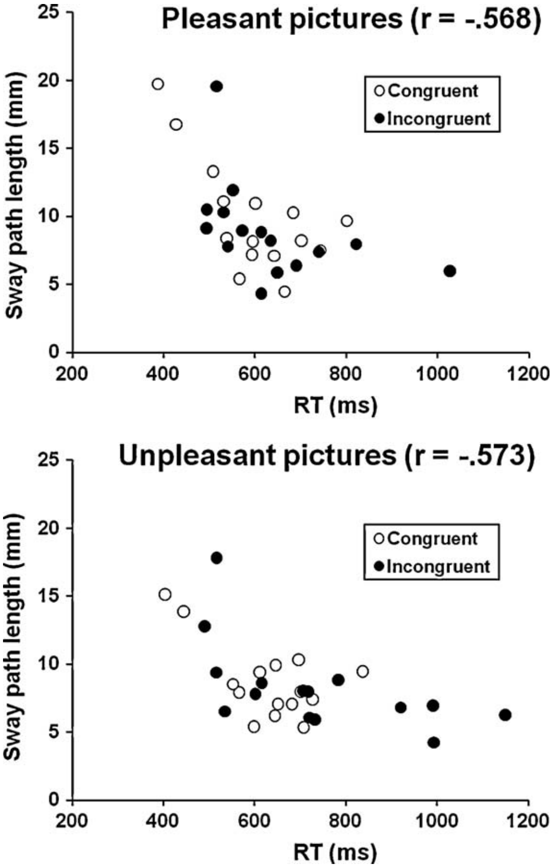

Fig. 3. Scattergrams displaying RTs plotted against sway path length, separately for the two picture categories (pleasant and unpleasant). Each dot shows an individual's mean score for the two variables.

4. Discussion

We examined whether, and how, the preparation, initiation, and execution of voluntary forward or backward steps were influenced by the valence of emotional stimuli. Based on findings in the emotion and motor control literature (e.g., [2–6,9,12,13]) we formulated a number of predictions regarding posturographic markers of emotion, which were largely supported. First, we found evidence for an initial "freezing" response with unpleasant images. Potentially threatening stimuli are thought to be processed in a fast and automatic fashion, resulting in behavior changes such as heart rate deceleration and attentive immobility [3,4,14,20]. In our experiment this immobility became manifest as shorter sway path length. It has been proposed that potentially threatening stimuli cause a temporary increase in awareness, leading to a shift in more conscious motor control which, in turn, results in reduced body sway (cf. [21]). This hypothesis was also put forward in another study [22], where it was found that maintaining balance at an elevated surface height not only caused an increase in the frequency of postural adjustments (indicative of postural stiffening), but also more conscious postural control, thereby interfering with automatic control processes.

Second, we found that unpleasant images induced a tendency to initiate a backward step (avoidance), as evidenced by elevated RTs in the condition where participants had to produce an (incongruent) forward step in response to an unpleasant picture. Thus, in order to approach unpleasant or threatening pictures, participants had to override strong avoidance dispositions, which was time consuming. However, the mapping effect was only significant for forward steps, but not for backward steps. This suggests that approach tendencies (primed by pleasant pictures) and avoidance tendencies (primed by unpleasant pictures) are not simply opposites and that the unpleasant-avoidance coupling was stronger than the pleasant-approach coupling. This asymmetry has also been noted in theoretical accounts (e.g., [23]), as well as brain imaging studies [24] of the human defensive and appetitive motivation system. In a similar vein, it has been found that postural adjustments during quiet standing are especially sensitive to unpleasant stimuli. A study found evidence of avoidance tendencies in response to unpleasant images, and little evidence of approach with pleasant images [2]. In addition, effects of immobility ("freezing") are typically found with unpleasant pictures [4], although perhaps surprisingly that study also found evidence of freezing with affiliative stimuli (babies and smiling people).

Third, we found that parameters of step execution (step size and movement times) were unaffected by mapping and valence. For the step size only a difference between forward and backward steps was found. This indicates that once a step has been selected and initiated, the subsequent unfolding of the steps proceeds in a highly stereotypic manner.

Finally, we found that postural immobility (assessed using sway path length) prior to the execution of the step was highly correlated with the step initiation times, meaning that subjects showing initial immobility also took more time to start moving. It could be argued that this is a trivial finding; after all, subjects who are not standing still (perhaps because they are excited or have consumed coffee) are also likely to produce speeded responses. However, postural immobility prior to the stimulus was uncorrelated with RTs. In other words, the correlation only emerged in response to the visual stimuli. This suggests that immobility is not a short-lived and transient phenomenon, but may negatively affect subsequent movement initiation. However, movement initiation (but not sway path length) was additionally affected by the instructions, as evidenced by delayed step initiations in the (incongruent) approach-to-unpleasant pictures. Our data thus suggest that delayed stepping may partly be explained by prior postural immobility, and partly by stimulus-response (in)compatibility.

Although the present study mainly focused on the valence of the picture categories, emotion eliciting images such as used in the IAPS induce numerous behavioral and physiological changes that we did not control for. For example, one study [20] found that passive viewing of IAPS pictures resulted in changes in heart rate, skin conductance, and facial muscle activity. In addition, unpleasant images may induce a sense of surprise, heightened awareness [20], and they are difficult to attentionally disengage from [25]. With respect to posture, it has been shown that arousal (e.g., [26]) and attentional focus (e.g., [27]) impact on the regulation of balance. The latter study found that an external focus of attention during quiet stance caused greater postural stiffening. In the present study we did not control for these variables, and they undoubtedly form part and parcel of the full emotional response. In fact, we found a modest correlation between subjective valence and arousal ratings, which has been observed before with the IAPS [23]. On the other hand, subjects in our study were explicitly asked to categorize the images based on their valence, and to select and initiate a step based on that characteristic. The pattern of results clearly demonstrated that valence affected pre-step postural immobility, and that step initiation times were additionally affected by the instructions. Moreover, the pattern of RTs was consistent with previous studies using manual responses.

Our findings underscore the notion that the human postural control system is coupled to neural structures that process affect. Candidate neural structures are the parabrachial nucleus, which acts as a "site of convergence" for vestibular information and afferent processing [28–30] and the midcingulate cortex, a pivotal node of interaction between negative emotions and motor signals that trigger defensive responses [31].

In sum, we found that emotion eliciting visual material had marked effects on the organization of voluntary forward and backward steps. Our posturographic results obtained with unpleasant images seemed to follow a bi-phasic pattern: First highly unpleasant stimuli seemed to cause a brief initial orienting stage, characterized by cardiac deceleration, bodily immobility, greater skin conductance, heightened awareness, and enhanced information processing. This stage is followed by a stage of defensive action, characterized by increased metabolic activity and the preparation, selection, and action initiation. As far as we know, our study is the first to demonstrate signatures of these two stages and their interrelationship within posturographic activity obtained in a single experiment, thus demonstrating that posturographic measures obtained during quiet standing and voluntary whole-body displacements may provide insight into the affect-balance interface.

Acknowledgments

We thank Karin Roelofs and Muriel Hagenaars for helpful discussions on an earlier version of this draft.

Conflict of interest: There are no commercial relationships of the authors which may lead to a conflict of interests, whether financial or personal, with third parties or persons.

References

[1] Darwin C. The expression of emotion in man and animals. London: Murray; 1872.
[2] Hillman CH, Rosengren KS, Smith DP. Emotion and motivated behavior: postural adjustments to affective picture viewing. Biol Psychol 2004;66:51–62.
[3] Azevedo TM, Volchan E, Imbiriba LA, Rodrigues EC, Oliviera JM, Oliviera LF, et al. A freezing-like posture to pictures of mutilation. Psychophysiology 2005;42:255–60.
[4] Facchinetti LD, Imbiriba LA, Azevedo TM, Vargas CD, Volchan E. Postural modulation induced by pictures depicting prosocial or dangerous contexts. Neurosci Lett 2005;410:52–6.
[5] Maki BE, McIlroy WE. Influence of arousal and attention on the control of postural sway. J Vestib Res 1996;6:53–9.
[6] Carpenter MG, Frank JS, Silcher CP. Surface height effects on postural control: a hypothesis for a stiffness strategy for stance. J Vestib Res 1999;9:277–86.
[7] Chen M, Bargh JA. Consequences of automatic evaluation: immediate behavioural predispositions to approach or avoid the stimulus. Pers Soc Psychol Bull 1999;25:215–23.
[8] Markman AB, Brendl CM. Constraining theories of embodied cognition. Psychol Sci 2005;16:6–10.
[9] Duckworth KL, Bargh JA, Garcia M, Chaiken S. The automatic evaluation of novel stimuli. Psychol Sci 2002;13:513–9.
[10] Alexopoulos T, Ric F. The evaluation-behavior link: direct and beyond valence. J Exp Soc Psychol 2007;43:1010–6.
[11] Koch S, Holland RW, Hengstler M, Van Knippenberg A. Body locomotion as a regulatory process. Psychol Sci 2009;20:549–50.
[12] MacKinnon CD, Bissig D, Chiusano J, Miller E, Rudnick L, Jager C, et al. Preparation of anticipatory postural adjustments prior to stepping. J Neurophysiol 2007;97:4368–79.
[13] Liu W, McIntire K, Kim SH, Zhang J, Dascalos S, Lyons KE, et al. Bilateral subthalamic stimulation improves gait initiation in patients with Parkinson's disease. Gait Posture 2006;23:492–8.
[14] Stins JF, Beek PJ. Effects of affective picture viewing on postural control. BMC Neurosci 2007;8:83.
[15] Puca RM, Rinkenauer G, Breidenstein C. Individual differences in approach and avoidance movements: how the avoidance motive influences response force. J Pers 2006;74:979–1014.
[16] van Peer JM, Roelofs K, Rotteveel M, van Dijk JG, Spinhoven PH, Ridderinkhof KR. The effects of cortisol administration on approach-avoidance behavior: an event-related potential study. Biol Psychol 2007;76:135–46.
[17] Lang PJ, Bradley MM, Cuthbert BN. International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-6. Gainesville, FL: University of Florida; 2005.
[18] Lavender T, Hommel B. Affect and action: towards an event-coding account. Cogn Emotion 2007;21:1270–96.
[19] Hass CJ, Waddell DE, Wolf SL, Juncos JL, Gregor RJ. Gait initiation in older adults with postural instability. Clin Biomech 2008;23:743–53.
[20] Sanchez-Navarro JP, Martinez-Selva JM, Roman F. Uncovering the relationship between defence and orienting in emotion: cardiac reactivity to unpleasant pictures. Int J Psychophysiol 2006;61:34–46.
[21] Vuillerme N, Nafati G. How attentional focus on body sway affects postural control during quiet standing. Psychol Res 2007;71:192–200.
[22] Huffman JL, Horslen BC, Carpenter MG, Adkin AL. Does increased postural threat lead to more conscious control of posture? Gait Posture 2009;30: 528–32.
[23] Bradley MM, Codispoti M, Cuthbert BN, Lang PJ. Emotion and motivation I: defensive and appetitive reactions in picture processing. Emotion 2001;1:276–98.
[24] Roelofs K, Minelli A, Mars RB, Van Peer J, Toni I. On the neural control of social emotional behavior. SCAN 2009;4:50–8.
[25] Koster EHW, Crombez G, Verschuere B, De Houwer J. Selective attention to threat in the dot probe paradigm: differentiating vigilance and difficulty to disengage. Behav Res Ther 2004;42:1183–92.
[26] Brown LA, Polych MA, Doan JB. The effect of anxiety on the regulation of upright standing among younger and older adults. Gait Posture 2006;24:397–405.
[27] McNevin NH, Wulf G. Attentional focus on supra-postural tasks affects postural control. Hum Mov Sci 2002;21:187–202.
[28] Balaban CD. Neural substrates linking balance control and anxiety. Physiol Behav 2002;77:469–75.
[29] Balaban CD, Thayer JF. Neurological bases for balance-anxiety links. J Anxiety Disord 2001;15:53–79.
[30] Stins JF, Ledebt A, Emck C, van Dokkum EH, Beek PJ. Patterns of postural sway in high anxious children. Behav Brain Funct 2009;5:42.
[31] Pereira MG, de Oliveira L, Erthal FS, Joffily M, Mocaiber IF, Volchan E, et al. Emotion affects action: midcingulate cortex as a pivotal node of interaction between negative emotion and motor signals. Cogn Affect Behav Neurosci 2010;10:94–106.