Gait & Posture 41 (2015) 159–163

Contents lists available at ScienceDirect

Gait & Posture

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

Biomechanical organization of gait initiation depends on the timing of affective processing

John F. Stins *, Linda M.A. van Gelder, Laura M. Oudenhoven, Peter J. Beek

MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 21 September 2013
Received in revised form 16 September 2014
Accepted 24 September 2014

Keywords:
Gait initiation
Emotion
Center-of-pressure
Balance

ABSTRACT

Gait initiation (GI) from a quiet bipedal posture has been shown to be influenced by the emotional state of the actor. The literature suggests that the biomechanical organization of forward GI is facilitated when pleasant pictures are shown, as compared to unpleasant pictures. However, there are inconsistencies in the literature, which could be due to the neural dynamics of affective processing. This study aimed to test this hypothesis, using a paradigm whereby participants initiated a step as soon as they saw an affective picture (i.e., onset), or as soon as the picture disappeared from the screen (i.e., offset). Pictures were a priori categorized as pleasant or unpleasant, and could also vary in their arousing properties. We analyzed center-of-pressure and center-of-gravity dynamics as a function of emotional content. We found that gait was initiated faster with pleasant images at onset, and faster with unpleasant images at offset. Also, with offset GI the peak velocity of the COG was reduced, and subjects took smaller steps, with unpleasant images relative to pleasant images. The results are discussed in terms of current knowledge regarding temporal processing of emotions, and its effects on GI.

1. Introduction

Gait initiation (GI) from a quiet bipedal posture entails destabilizing postural equilibrium and propelling the body center of gravity (COG) forward. This highly coordinated activity involves lifting the swing leg (resulting in a rapid lateral weight shift), swinging the leg forward, and using the stance leg to create sufficient forward momentum. Analysis of COG and center-of-pressure (COP) dynamics has been employed to quantify key biomechanical parameters that constrain the step [1].

Recent studies investigated whether the control of GI is influenced by emotion. Posturographic studies have revealed that potent emotional triggers may activate innate behavioral tendencies, such as freeze, fight, or flight responses [2–4]. These responses may play into the neural control of balance, where they become visible as automatic postural adjustments. Recent studies [5–7] found that it took longer to initiate a forward step toward an unpleasant picture than toward a pleasant one, suggesting that it took longer to override the automatic avoidance tendency with unpleasant pictures. These results support the 'motivational direction hypothesis', which states that pleasant/desirable items trigger approach behavior, whereas unpleasant items prime avoidance behavior (see also [8]). Evidence for this hypothesis has been found in manual choice reaction time studies (e.g. [9]). Another study [10], however, found that highly arousing unpleasant pictures speeded up reaction time. They also found effects of emotional valence and arousal on other biomechanical features of the step, such as the anticipatory postural adjustments (APA) and step velocity. Findings were explained in terms of the arousing properties of unpleasant items.

It is unclear why some studies [5–7] found facilitation of forward steps toward pleasant pictures (compared to unpleasant items), whereas another study [10] found facilitation for unpleasant pictures. Reading of the literature reveals a subtle, but potentially crucial methodological difference: In earlier studies [5–7] participants had to initiate a step as soon as they saw and mentally classified the picture. In the divergent study [10] participants had to watch the picture for its entire duration (2–4 s), and initiate a step as soon as the picture disappeared, i.e., at stimulus offset. This could prove to be a key factor, since neural processing of affective proceeds via a highly stereotypical sequence of information processing 'stages', during which the stimulus is evaluated and endowed with meaning. The time course

* Corresponding author at: MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, van der Boechorststraat 9, 1081 BT, Amsterdam, The Netherlands. Tel.: +31 (0)20 5988543.
E-mail address: j.stins@fbw.vu.nl (J.F. Stins).

http://dx.doi.org/10.1016/j.gaitpost.2014.09.020
0966-6362/

of affective processing is paralleled in physiological responses [8]. Moreover, especially unpleasant and threatening items may induce a short orienting phase during which the organism is immobile and hypervigilant, followed by selection of overt action. Hence, the manner in which a step is selected and organized may crucially depend on where along this neural chain of events the motor program for GI is activated.

We directly compared GI in response to the onset vs. offset of affective stimuli, and tested whether the biomechanical organization of GI depends on this factor. We predicted facilitation of GI for pleasant items in the onset condition (relative to unpleasant items) and facilitation of GI for unpleasant items in the offset condition. We further expected effects of emotion to become manifest in the APA and step size. We additionally assessed whether COG velocity provides information on how affective information processing couples to GI. Only one study [7] analyzed COG dynamics of GI in response to affective visual stimuli, but they did not vary arousal levels (a potentially crucial stimulus variable [10]). To this end, we tested the factorial combination of valence (pleasant/unpleasant) and arousal (high arousal vs. low arousal) of the affective content of the pictures.

2. Methods

2.1. Participants

Twenty-seven healthy individuals (11 males, 16 females; *M* age = 28.7 y, SD = 14.0) participated. None of the participants had lower extremity injuries that could hamper task performance. The local ethics committee approved the experiment. The participants signed an informed consent form prior to testing.

2.2. Material and methods

Posturographic data were recorded using a custom-made strain gauge force plate (1 m $\times$ 1 m; sampling frequency: 100 Hz). The force plate consisted of eight force sensors; four measuring forces in the *z* direction, and two each for the *x* and *y* directions. These signals were converted to forces (Fx, Fy, Fz) from which moments were (Mx, My, Mz) calculated. Mx and My were then used to calculate the point of application of the vertical force on the support surface (e.g. [11]). Pictures were shown on a 17-inch monitor, positioned at eye height 1.5 m in front of the participant.

The stimuli included photographs from the International Affective Picture System (IAPS [12]). The IAPS is a database of affective pictures with normative subjective scores for each picture on two continuous dimensions: valence (pleasant vs. unpleasant) and arousal (high arousing vs. low arousing). We selected 25 pictures, representing 5 affective categories: (1) High arousal, pleasant (HA-P; erotica), (2) Low arousal, pleasant (LA-P; children and animals), (3) High arousal, unpleasant (HA-U; attack and mutilation), (4) Low arousal, unpleasant (LA-U; contamination and famine), and (5) neutral (NEU; faces and abstract shapes) (see Appendix). Subjective valence and arousal were rated for each picture using the 9-point Likert version of the self-assessment manikin (SAM), with higher scores indicating positive (pleasant) valence and more arousal.

2.3. Procedure

At the beginning of each trial the participants stood still at one of the corners of the force plate, facing the monitor, which was positioned near the opposing corner. The pictures displayed on the monitor served as a cue for step initiation. Participants had to initiate and execute a step with their right leg in the direction of the monitor, diagonally across the plate, and stand still in this new position.[1] No instructions regarding step length and step velocity were given. We also presented 5 catch trials (a red cross), which signaled that participants had to refrain from stepping.

The timing of stimulus events was as follows. First, a black screen was presented for a variable 3–5 s duration, during which participants stood still. Next, an IAPS picture was shown for a variable 3–5 s duration. Participants in the *onset* condition had to initiate a step as soon as the picture appeared, whereas in the *offset* condition they had to initiate a step as soon as the picture disappeared from the screen. Next, a 4 s black screen was presented. Note that during this interval participants in the onset condition have already executed the step and stand in their new position, whereas those in the offset condition are still in the process of stepping. Finally, a 3-s message appeared on the screen with the words 'STEP BACK', during which participants assumed their initial position.

Participants were tested in both conditions (counterbalanced). During each condition the same 25 IAPS were shown, albeit in a different (randomized) order, plus the 5 catch trials. At the end of the experiment participants rated each picture.

Prior to each condition (onset and offset) there were 10 practice trials, showing pictures from each of the 5 picture categories plus 2 catch trials. These trials were not further analyzed.

2.4. Data reduction

The *x-y* COP time-series were rotated by 45° (due to the diagonal arrangement of the measurement setup), yielding a new time series involving an anterior–posterior (AP) component corresponding to the progression axis of the step, and a mediolateral (ML) component corresponding to sideways excursions. In addition, we calculated the instantaneous acceleration of the COG in the AP-direction by dividing the ground reaction forces by the subject's mass. We analyzed the following GI parameters:

Reaction time: the time interval between t0 (stimulus onset, or stimulus offset) and the first discernible change in COG displacement. Step initiation was defined as the moment at which the acceleration of the COG trace in the anterior direction exceeded 4 times the standard deviation of the COG trace recorded in the 1-s quiet stance time window preceding the GI cue.

APA amplitude: the distance between the COP at t0 and the maximum posterior displacement of the COP.

APA velocity: the average velocity of the posterior COP shift (cf. [10]).

Swing heel-off time (HO): the moment where the APA ends and the execution phase starts. We calculated the time difference between t0 and the moment where the vertical impulse peaked downwards (cf. [13]). Vertical impulse was calculated by integrating the vertical ground reaction force, after subtraction of the subjects body weight.

Peak velocity of the COG trace: Through simple integration of the COG acceleration trace we obtained the COG AP velocity [7,14]. Note that this procedure only yields amplitude information about the COG acceleration; not its directional position (see also [15]). The maximal excursion of this signal following GI corresponded to the peak velocity.

Step size: the distance along the AP-axis between the COP of the initial stance position prior to step initiation and the final stance position.

A COP trace of a representative step in shown in Fig. 1.

[1] This diagonal arrangment was chosen so as to prevent constraints on step length and step velocity that could be induced by the margins of the force plate.