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Back off! The effect of emotion on backward step initiation

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ABSTRACT

The distance regulation (DR) hypothesis states that actors are inclined to increase their distance from an unpleasant stimulus. The current study investigated the relation between emotion and its effect on the control of backward step initiation, which constitutes an avoidance-like behavior. Participants stepped backward on a force plate in response to neutral, high-arousing pleasant and high-arousing unpleasant visual emotional stimuli. Gait initiation parameters and the results of an exploratory analysis of postural sway were compared across the emotion categories using significance testing and Bayesian statistics. Evidence was found that gait initiation parameters were largely unaffected by emotional conditions. In contrast, the exploratory analysis of postural immobility showed a significant effect: highly arousing stimuli (pleasant and unpleasant) resulted in more postural sway immediately preceding gait initiation compared to neutral stimuli. This suggests that arousal, rather than valence, affects pre-step sway. These results contradict the DR hypothesis, since avoidance gait-initiation in response to unpleasant stimuli was no different compared to pleasant stimuli.

1. Introduction

A core aspect of emotions is that they mobilize energy and direct behavior to attain a certain goal. Arguably the most basic motivational systems are reflected in approach and avoidance behaviors (e.g., Vernazza-Martin, Longuet, Damry, Chamot, & Dru, 2015). These directional motivations manifest themselves in goal-directed motor behaviors, such as whole body displacement. For example, a desirable object in the immediate vicinity might induce forward leaning and/or initiation of forward locomotion, in order to decrease the distance between the self and the object. Many studies (see below) have found a clear link between emotions and whole body directional behaviors. In the literature three paradigms are often used: quiet standing (e.g., Horslen & Carpenter, 2011), initiation of a single step in a particular direction (Stins & Beek, 2011), and locomotion (Naugle, Joyner, Hass, & Janelle, 2010). In general, pleasant items tend to facilitate forward body displacements ('approach'), whereas unpleasant items tend to facilitate backward body displacements ('avoidance')[1] but also sometimes postural 'freezing', i.e., immobility (e.g. Azevedo et al., 2005). In the current experiment we adopt the second paradigm, i.e. initiation of a step in a particular direction. This paradigm allows for recording the kinematic profile of directional movements in response to an affective stimulus, and thus for a rich characterization of how such movements are organized in space and time (e.g., Gélat, Coudrat, & Le Pellec, 2011; Naugle et al., 2010; Roelofs, Hagenaars, & Stins, 2010). As such, the paradigm provides an interesting merger between the field of experimental psychology and biomechanics.

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[1] A notable exception is anger; this unpleasant affective state tends to facilitate approach, arguably in order to confront an opponent (e.g., Carver & Harmon-Jones, 2009).

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Even though the coupling between emotion and whole-body displacement is not disputed, several theoretical perspectives exist that attempt to explain the nature of this relationship. Beatty, Cranley, Carnaby, and Janelle (2016) identified five different theoretical frameworks to explain how emotional states affect the initiation of goal directed movements. One of the key findings of their meta-analysis was that there was empirical evidence for most of these frameworks, but with different effect sizes. The authors made several recommendations for empirical and conceptual future research. For present purposes we focus on one of the frameworks thus identified, namely the Distance Regulation (DR) perspective. This perspective states that the change in physical proximity of the actor to the outside world underwrites approach and avoidance behavior (e.g., Markman & Brendl, 2005), and we aim to test a specific prediction derived from this perspective. Approach is defined as a decrease in distance between the actor and the stimulus, while avoidance is defined as an increase in distance. Beatty et al. (2016) framed it thus: 'the real (or perceived) distance, and subsequent distance change of an individual relative to the locus of emotional stimuli influences motor behavior.'(p. 238). An obvious prediction of the DR perspective would be that pleasant (appetitive) stimuli motivate a decrease in distance, whereas unpleasant stimuli motivate an increase in distance. The gait initiation paradigm, whereby participants physically increase or decrease the distance between themselves and the stimulus, therefore seems ideally suited to test specific predictions derived from the DR perspective.

Some studies have directly contrasted approach and avoidance related movement patterns within the same design (e.g. Stins et al., 2011; Yiou, Gendre, Deroche, & Le Bozec, 2014), while others have studied only forward (i.e., approach) gait initiation (e.g. Stins, van Gelder, Oudenhoven, & Beek, 2015a; Stins, Van Gelder, Oudenhoven, & Beek, 2015b) with affective stimuli. Even though humans typically move forward when approaching a desirable item or attractive person, the reverse situation, i.e., moving backward so as to avoid something unpleasant or unattractive, has not been sufficiently studied. We know of four studies that not only included a condition involving forward stepping but also a condition involving backward stepping in response to emotion-eliciting images. We will discuss all four below, focusing specifically on the subset of data relating to backward gait initiation (GI). To anticipate, results involving forward GI tend to show the effects in the expected direction, i.e., facilitation of forward GI with pleasant compared to unpleasant items, but the reverse pattern with backward GI is not so clear cut and therefore deserves further study.

The first study to adopt forward and backward GI with emotional pictures was conducted by Stins and Beek (2011), who used pleasant and unpleasant images adopted from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Participants were tested in either the congruent condition (step forward when seeing a pleasant picture; step backward when seeing an unpleasant picture) or the incongruent condition (step forward when seeing an unpleasant picture, step backward when seeing a pleasant picture). Thus, when a picture was shown, participants had to categorize it as pleasant or unpleasant, and respond according to the instructions. When analyzing forward and backward stepping separately, the authors found clear effects of emotion on the efficiency with which forward gait was initiated, but no effects when backward GI was considered. That is, backward GI was equally fast with pleasant and unpleasant pictures. Stins et al. (2011) performed a similar experiment but with happy and angry faces. In the congruent blocks, participants had to step forward when categorizing a face as being happy and backward when categorizing it as being angry. In the incongruent blocks, this mapping was reversed. Similar to Stins and Beek (2011), no effect of emotion on reaction time was found when only backward steps were considered; RTs were equally fast in response to both types of facial expressions. A third study was done by Yiou et al. (2014). Participants had to first mentally classify a picture as either pleasant or unpleasant. Then, according to instructions and emotion, they had to step forward with either the preferred leg or (in another condition) the non-preferred leg. In other conditions participants had to select a leg and step in the backward direction. All participants performed both the congruent (forward-pleasant) and incongruent (forward-unpleasant) conditions. Looking at the subset of data involving backward stepping, Yiou et al. (2014) found no effects of emotion on the time to initiate a step in the required direction. The only kinematic parameter that showed a significant effect in backward stepping was the center of mass velocity at the time of swing foot-off: the velocity was lower in response to pleasant compared to neutral pictures. In a fourth study by Stins, Lobel, Roelofs, and Beek (2014) instructions were to step forward or backward depending on the gender of a face (which could be either happy or angry). Again, the authors found no effect of emotion on backward stepping; in this study also forward GI was unaffected by the emotional expression. However, it is important to note that the emotion of the stimuli was task-irrelevant, as participants had to base their response (forward or backward stepping) on the gender.

The general picture that emerges from these studies is that the effects of emotion are more prominent for forward stepping than for backward stepping. This asymmetry deserves further investigation since it is unclear why DR would hold only for approach-like behaviors (easier GI toward pleasant compared to unpleasant stimuli), but not for avoidance-like behaviors (backward GI). The observation that forward and backward stepping in response to affective stimuli yields asymmetric behavioral patterns could be due to various factors. For example, there could be an inherent asymmetry in the motor control of forward vs. backward stepping, independent of emotion. This asymmetry is in fact evident in the respective kinematic profiles of the step patterns of the studies described previously. To illustrate, Stins and Beek (2011) found that forward steps were larger compared to backward steps, regardless of the emotional content of the stimulus. In addition, Stins et al. (2011) found that participants stepped backward faster compared to forward, again regardless of emotional content. Both the peak velocity and the movement times were faster in backward stepping. Furthermore, Stins et al. (2014) found that participants made a larger step forward than backward, regardless of the emotional content of the stimuli. From a more psychological perspective, it has also been suggested that backward stepping is less automatized than forward stepping since visual guidance is mostly absent in backward stepping (Stins et al., 2011). This may induce the need for additional cognitive effort to parameterize the step, making the step less automatized compared to forward stepping.

However, at this stage it is premature to conclude that emotion does not affect backward stepping for the following two reasons. First, in all previous studies participants had to mentally classify the stimulus before initiating a step, since their response depended on the (emotional) content of the stimulus. This setup may impose additional constraints on the working memory of participants, thereby potentially obscuring subtle biomechanical markers of avoidance tendencies in backward stepping. Note that in three recent experiments (Bouman, Stins, & Beek, 2015; Naugle, Hass, Joyner, Coombes, & Janelle, 2011; Stins et al., 2015a, 2015b) the response choice element was removed; subjects always had to step forward with the same leg. Interestingly, all three experiments found clear evidence for effects of emotion pictures on the control of forward GI, but the overall pattern of results is somewhat complicated because the effects were modulated by viewing duration. Second, the previous studies failed to reject the null-hypothesis (i.e., $p > 0.05$) when only backward stepping was considered. However, the absence of a significant effect cannot be taken to imply the presence of a (true) null effect. In fact, other statistical procedures (Bayesian statistics; see below) need to be adopted in order to draw such a conclusion. Therefore, there is as of yet no solid statistical evidence that backward stepping is unaffected by emotion.

In the current experiment we addressed both these issues. First, we tested backward stepping in isolation, thereby excluding the decision-making component: participants had to step backward in response to all (emotion-eliciting) stimuli. Second, we performed not only null-hypothesis significance testing, but also Bayesian statistics to specifically test the evidence in favor of the null-hypothesis (for details, see Dienes, 2014), i.e., no difference between emotion categories on parameters of backward GI. If we indeed find that emotion does not affect backward GI, as has been suggested by previous studies, this will strengthen the notion that there is an asymmetry in whole-body movement regarding approach and avoidance motivations, which would be difficult to reconcile with a literal reading of the DR perspective.

2. Method

2.1. Participants

Thirty individuals (16 females; *Mean age* = 23.6 yrs., *SD* = 3.3) participated in the experiment. All participants were screened for injuries of the lower extremities or difficulties with stepping due to another cause. The local ethics committee approved of the experimental protocol before it was conducted. Informed consent was obtained from all individual participants included in the study.

2.2. Materials and methods

Posturographic data were recorded using a custom-made 1 m × 1 m strain gauge force plate (sampling frequency: 100 Hz), which was rotated 45 degrees to ensure that participants had sufficient room to execute a step backwards, that is, diagonally across the force plate. Forces were recorded with eight sensors embedded in the plate; four measuring forces in the z direction, and two sensors for the x and y directions, respectively. The data from these sensors were converted to the total force in three directions (Fx, Fy, and Fz), from which moments (Mx, My, Mz) were calculated. The Center of Pressure (COP) was then calculated using the Mx and My vectors. The COP represents the point of application of the ground reaction force (for details see Brenière, Cuong Do, & Bouisset, 1987).

Images were shown on a 55-inch monitor placed 30 cm in front of the participant at eye-level. The image size was 32 × 43 cm, so that it was completely visible while standing close to the screen. Image onset and offset were detected by a photodiode attached to the monitor, which was not visible to the participant, and was synchronized with the force plate recording. The stimuli were chosen from the IAPS (Lang et al., 2005). Only high-arousal pictures were used since previous research showed that especially these pictures have discernible impact on gait initiation (Stins et al., 2015a, 2015b). Three picture categories were used: (1) erotica (high arousal pleasant), (2) mutilation (high arousal unpleasant), and (3) neutral. Twenty unique pictures were chosen from each picture category.[2] Note that the erotica and mutilation pictures in the present experiment were also used in at least three previous GI studies (Bouman et al., 2015; Naugle et al., 2011; Stins et al., 2015a, 2015b). At the end of the experiment, the participants filled out the 9-point Self-Assessment Manikin (SAM), rating each image on valence and arousal, with higher scores meaning more pleasant and more arousing ratings.

2.3. Procedure

After having signed the informed consent form, participants stepped onto the force plate. They were instructed to touch a piece of white tape, which was attached to the force plate in the corner closest to the monitor, with their toes, to ensure that all participants started in the same initial position. From this position, participants had to initiate a step backwards towards the opposite corner, which was thus furthest away from the monitor. A 5-min practice session preceded the experiment.

At the start of each trial, an on-screen message instructed the participants to stand with their feet shoulder-width apart and to look at the fixation cross. The fixation cross remained visible on screen for three seconds, after which one of the IAPS images appeared. The duration of the image varied randomly between 2 and 4 s, so that participants could not anticipate the timing of the disappearance of the image. Participants had to stand still during the image presentation and had to initiate a step backward as soon as the image disappeared from screen. No instructions on step length and speed were given. All steps were initiated with the right leg and after stepping participants had to wait for a message to appear on screen, after which they resumed their original position and awaited a new trial. The cue for GI was the offset (i.e., disappearance) of the stimulus. At each trial, participants likely loaded and parameterized the relevant motor program for backward GI, awaiting picture offset. Our paradigm involving at least 2 s viewing

[2] IAPS pictures for each picture category: *Neutral:* 2038, 2102, 2104, 2190, 2200, 2210, 2270, 2305, 2440, 7004, 7006, 7010, 7025, 7035, 7041, 7050, 7410, 7705. Catch: 7150, 2215. *Erotica:* 4001, 4607, 4608, 4609, 4611, 4625, 4643, 4645, 4649, 4651, 4653, 4658, 4659, 4660, 4670, 4680, 4683, 4687. Catch: 4694, 4002. *Mutilation:* 3000, 3010, 3016, 3017, 3030, 3051, 3060, 3061, 3062, 3068, 3069, 3071, 3080, 3100, 3130, 3150, 3170, 3400. Catch: 3063, 3064.

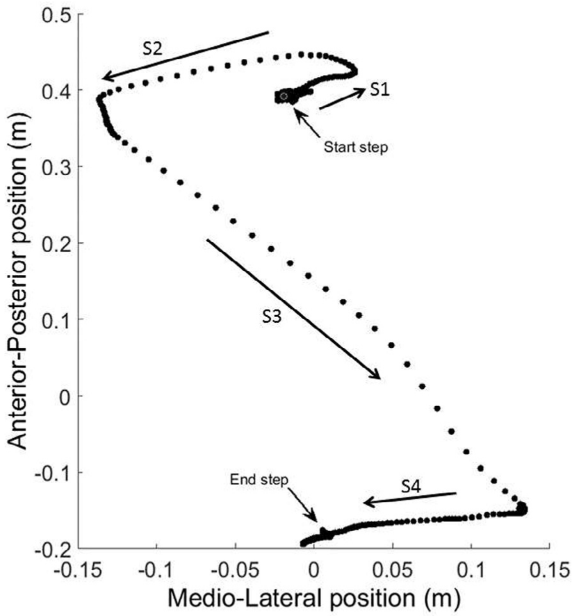

Fig. 1. Graphic representation of the COP trace of a representative backward step. The COP trace consists of four sections; S1 involves building up of momentum in order to accelerate the body center of mass sideways and backward. S2 is the weight shift period during which body weight is transferred to the (left) stance leg (yielding a single support phase), hence a lateral displacement of the COP. The abrupt change in the COP trace, where S2 ends and S3 begins, corresponds to the phase during which the (right) swing leg moves backward, and then lands behind the body but is still unloaded. During S3 the (left) stance leg becomes unloaded and the right (now posterior) leg becomes loaded, so that the body center of mass makes a rapid and large posterior shift. S3 thus involves a double support phase (both feet temporarily loaded). During the change from S3 to S4 there is again a single support phase but now for the right leg. Finally, during S4 the left leg is again positioned adjacent to the right leg; the COP moves sideways and comes to a halt somewhere between the feet.

duration allows us to assess whether emotional content interfered with this process of parameterization and execution of the motor program, as evidenced by the COP profile. This paradigm has been used in previous research (Bouman et al., 2015; Naugle et al., 2011; Stins et al., 2015a, 2015b), all involving forward GI.

All 60 IAPS images were presented in random order, with a break of a self-chosen length after every 20 trials. Within each block of 20 trials, two catch trials were added which consisted of a big red cross appearing directly after picture offset, and requiring no step. This ensured that participants were paying attention to the task. In total, 18 steps were recorded within each of the three picture categories.

Finally, participants filled out the SAM scale for all 60 images. The images were shown in random order on a monitor and participants used paper and pencil for ratings.

2.4. Data reduction

The COP data and the force plate data were rotated by 45 degrees (due to the rotation of the force plate; see Stins et al., 2015a, 2015b), generating a new time-series with the anterior-posterior (AP) COP component in the direction of the screen and the medio-lateral (ML) COP component representing sideways movement. The data were filtered using a 5-point moving average. Fig. 1 shows a representative COP trace of a backward step and an explanation of the key events. The overall shape of the trace is similar to earlier studies reporting backward GI (e.g., Stins et al., 2011). Given that the COP traces of forward and backward GI are comparable (yet flipped along the horizontal axis) this indicates that the steps are biomechanically comparable, so that we can accurately compute GI parameters in a similar way as with forward GI. The following GI parameters were analyzed:

2.4.1. Reaction time

The reaction time was determined as the time interval between picture offset (cue for GI) and the time at which the force in the anterior direction exceeded 5 N (cf. Bouman et al., 2015).

2.4.2. APA amplitude

The anticipatory postural adjustment (APA) is the first period within the unfolding of the GI. The shape and timing profile of the APA represents the build-up of momentum, in order to accelerate the body in the required (backward) direction at a certain velocity (Lepers & Brenière, 1995). The measure used in the present study was the magnitude of displacement in AP-direction between the initial position of the COP and the most anterior and lateral displacement of the COP in the direction of the right leg. This period within GI has is labelled 'S1' in Fig. 1; cf. Naugle et al. (2011).

2.4.3. Peak velocity

Maximum velocity of the COP during the step within S3. Velocity was determined by numerical differentiation of the COP trace in the AP-ML plane. In general, peak velocity will be reached when the swing and the stance leg are both on the plate and when the largest weight shift occurs.

2.4.4. Step length

The difference along the AP-axis between the initial position of the COP and the final position after completing the step.

2.4.5. Postural sway

In addition to parameters related to step execution, the data also allowed us to investigate whether postural sway is affected by emotional cues. There is evidence from the quiet standing literature that emotional pictures (especially unpleasant ones) can induce a temporary reduction in sway (e.g. Azevedo et al., 2005; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Roelofs et al., 2010), which has been related to a 'freezing response'. There is also evidence that a brief postural immobility phase accompanies the gait initiation profile (e.g. Stins et al., 2011). In addition, previous research has found that emotional content affects COP-trajectories prior to execution of a forward step (Fawver, Beatty, Naugle, Hass, & Janelle, 2015). It could be the case that our mutilation stimuli not only induce motivational tendencies to step backwards, but also postural immobility. Since we did not know in advance which sections of the COP trajectory would be sensitive to emotion, we decided to adopt an exploratory analysis (cf. Wagenmakers, Wetzels, Borsboom, Van der Maas, & Kievit, 2012), and focus on three sections in the trajectory that might potentially reveal emotion-induced postural immobility.

We focused on three time windows: 1) 0–200 ms after stimulus onset; 2) −200 ms to 0 before stimulus offset; 3) 0–200 ms after stimulus offset. These time windows were chosen to include the whole trial of viewing and responding to the emotional images. The length of these windows was chosen on the basis of our consideration to reject RTs that were below 200 ms. By choosing the time window of 200 ms, we ensured that postural activity related to step initiation would not interfere with our measure of postural immobility. For each of these time windows (thus consisting of 20 COP samples) we calculated the integrated length of the COP path, i.e., sway path length. Small values of this measure correspond to immobility and may be indicative of automatic and fast postural adjustments.

2.5. Statistical analysis

Four dependent GI variables (RT, APA, peak velocity, and step length) were analyzed in IBM SPSS (version 23) using a 3-way (emotion: neutral, pleasant, unpleasant) multivariate repeated measures analysis of variance (RM MANOVA) to control for type-I error, since these dependent measures are potentially related (see Naugle et al., 2011; Stins et al., 2015a, 2015b). Follow-up analyses of the four dependent variables were performed using separate one-way repeated measures analyses of variance (RM ANOVAs). The three postural sway measures are likely unrelated to gait initiation and, in addition, they represent the same measure (sway) under different conditions (time and emotion). Sway path length was therefore analyzed using a separate 3 (time: onset, pre-offset, post-offset) × 3 (emotion: neutral, pleasant, unpleasant) RM ANOVA.

Greenhouse-Geisser correction was used if the assumption of sphericity was violated. Significant effects were examined using post hoc paired samples *t*-tests with Bonferroni correction. Separate ANOVAs (emotion: neutral, pleasant, unpleasant) were performed on both the arousal and valence SAM scores. Alpha was set to 0.05.

Both partial eta squared (η_p^2) and generalized eta squared (η_G^2) are reported as measure of effect size since they are differentially affected by study design (see Bakeman (2005), Olejnik and Algina (2003), and Lakens (2013) for details on theory and calculation). For the post hoc paired-samples *t*-tests, both Hedges' $g_{average}$ (g_{av}) and a common language (CL) effect size are reported (see Lakens (2013) for details and calculation). The CL effect size is a percentage that represents the probability, after controlling for individual differences, that a given person scores higher in one condition compared to the other.

Since previous research did not find effects of emotion on backward GI, Bayesian comparisons of means were performed using JASP (Version 0.7.5; cf. Love et al., 2015; Morey & Rouder, 2015; Rouder, Speckman, Sun, Morey, & Iverson, 2009) to test whether the data support the null-hypothesis. This analysis can be used to calculate so-called Bayes factors (BF), which quantify the relative evidence for the null hypothesis vis-à-vis the alternative hypothesis. For more information on Bayesian analysis see Dienes (2014) and Jarosz and Wiley (2014). The default Cauchy prior width of 0.707 was used to calculate the BF_{01} for each comparison. The BF_{01} indicates how much more likely the data support the null-hypothesis (no difference between the two means) compared to the alternative hypothesis. BF_{10} is simply $1/BF_{01}$. BF smaller than 3 is treated as inconclusive evidence, BF between 3 and 10 as moderate evidence, while BF higher than 10 is seen as strong evidence.

3. Results

We removed 7.2% (117 out of 1620) of the trials due to excessive postural movement before the cue for GI, i.e., picture offset (8), stepping with the left leg (12), stepping too soon (RT < 200 ms) (55), stepping too late (RT > 1000 ms) (28), and an atypical APA profile based on visual inspection (14).

Table 1
Mean valence and arousal SAM scores (mean + SD) for all emotion categories.

Category	Valence	Arousal
Neutral	5.16 (0.22)	1.65 (0.63)
Erotica	6.06 (0.85)	4.34 (1.52)
Mutilation	2.17 (0.96)	6.17 (1.64)

3.1. SAM

SAM scores are reported in Table 1. The pattern of valence scores was as expected and differed across all three categories, with erotica being scored as more pleasant compared to neutral ($t(29) = 5.66, p < 0.001$, Hedges $g_{av} = 1.41$, CL = 85%) and mutilation ($t(29) = 15.14, p < 0.001$, Hedges $g_{av} = 4.18$, CL = 99%). Mutilation was scored as more unpleasant compared to neutral ($t(29) = 16.51, p < 0.001$, Hedges $g_{av} = 4.20$, CL = 99%).

With respect to arousal, both erotica and mutilation were scored as more arousing compared to neutral images ($t(29) = 11.26$, $p < 0.001$, Hedges $g_{av} = 2.25$, CL = 98% and $t(29) = 15.87$, $p < 0.001$, Hedges $g_{av} = 3.56$, CL = 99%, respectively). Additionally, mutilation was scored as more arousing compared to erotica ($t(29) = 5.95$, $p < 0.001$, Hedges $g_{av} = 1.13$, CL = 86%). The arousal and valence scores had a similar pattern as those reported by Yiou et al. (2014) and Bouman et al. (2015), and confirmed their affective characteristics.

3.2. Gait initiation parameters

Using Pillai's trace, the RM MANOVA was significant for the GI parameters ($V = 0.97$, $F(3,27) = 378.2$, $p < 0.001$) and, more importantly, the interaction between GI parameters and emotion ($V = 0.50$, $F(6, 24) = 3.99$, $p < 0.005$), meaning that the effect of emotion on the GI parameters differed between the four parameters. The separate ANOVAs for the four gait initiation parameters of interest are described below. All means are reported in Table 2 and shown in Fig. 2. The BFs for all pair-wise contrasts are reported in Table 3.

3.2.1. Reaction time

RT data is shown in Fig. 2a. The ANOVA showed no significant effect of emotion category on RT ($F(2, 58) = 0.16$, $p = 0.85$). The Bayesian analysis comparing the RT in response to neutral, erotica and mutilation images, yielded moderate evidence (see Table 3; all $BF_{01} > 4.3$) supporting the null-hypothesis, meaning that the data showed evidence for the absence of a significant difference in reaction time across the various emotion categories.

3.2.2. Anticipatory postural adjustment

APA data is shown in Fig. 2b. The ANOVA showed no significant effect of emotion category on APA either ($F(2, 58) = 0.10$, $p = 0.91$). Bayesian analysis again showed moderate evidence (all $BF_{01} > 4.7$) in support of the null-hypothesis. The data indicated that the APA was not different for the different emotion categories.

3.2.3. Peak velocity

Peak velocity data is shown in Fig. 2c. Peak velocity showed no significant effect of emotion category ($F(1.58, 45.82)) = 0.91$, $p = 0.39$). Bayesian analyses showed that the comparison between neutral images and both erotica and mutilation images did not yield any evidence for either hypothesis ($BF_{01} < 3$), meaning that the data are inconclusive. However, there was moderate evidence ($BF_{01} = 4.8$) for the absence of a difference between the peak velocity to erotica and mutilation images.

3.2.4. Step length

Step length data is shown in Fig. 2d. There was a marginally significant effect of emotion category on step length ($F(1.20, 34.73) = 3.65$, $p = 0.057$, $\eta_p^2 = 0.11$, $\eta_G^2 = 0.059$). Since both the uncorrected F-test ($F(2, 58) = 3.65$, $p < 0.05$) and the multivariate

Table 2
Mean (+SD) for all dependent variables in response to neutral, erotica, and mutilation stimuli.

	Neutral	Erotica	Mutilation
RT (ms)	434 (106)	430 (129)	428 (113)
APA (cm)	3.77 (1.72)	3.78 (1.66)	3.75 (1.60)
Peak velocity (m/s)	2.20 (0.87)	2.23 (0.91)	2.24 (0.87)
Step length (cm)	46.48 (12.82)	47.13 (13.00)	47.63 (11.82)
Sway 200 ms onset (mm)	6.88 (1.08)	6.89 (1.08)	6.96 (1.30)
Sway 200 ms pre-offset (mm)	6.81 (1.19)	6.79 (1.12)	6.76 (1.19)
Sway 200 ms post-offset (mm)	8.25 (2.16)	9.18 (3.01)	9.09 (2.77)

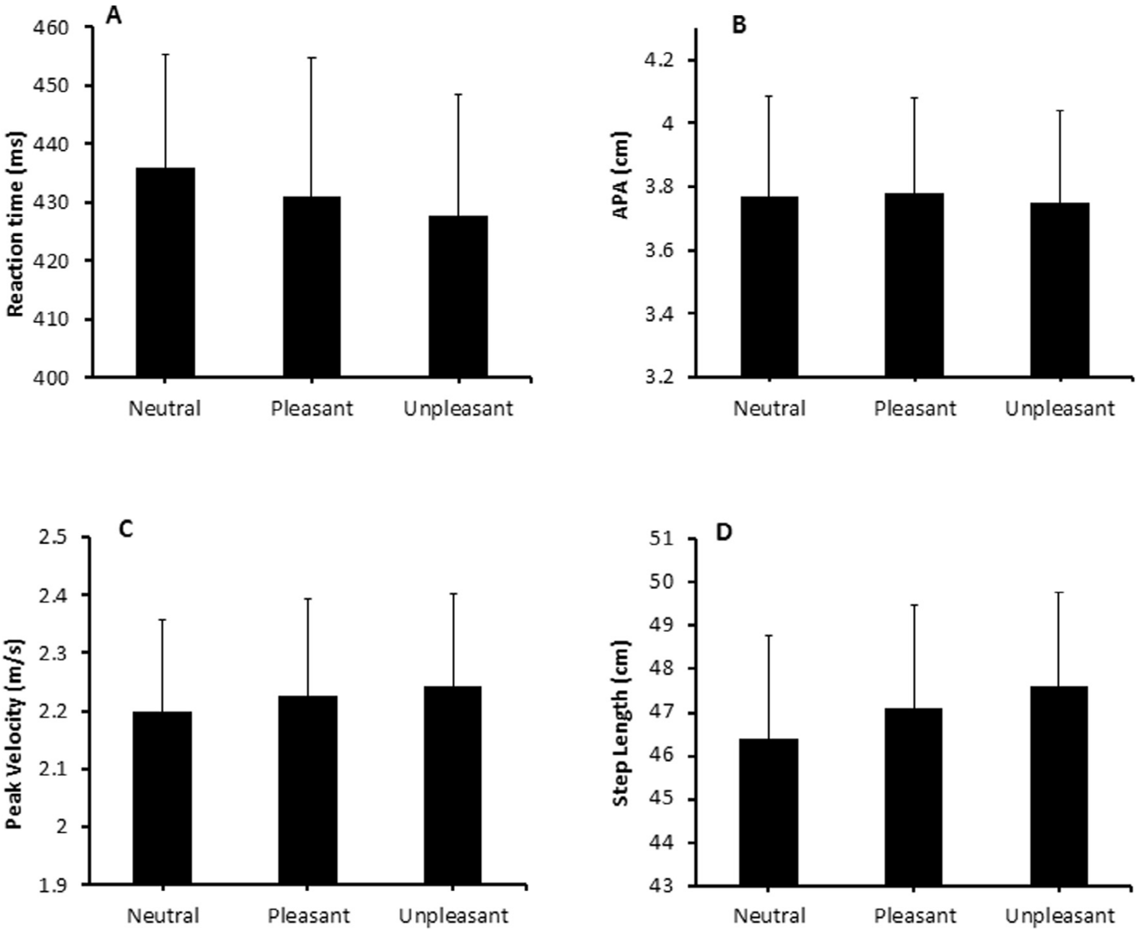

Fig. 2. Four GI parameters (mean ± SE) for neutral, pleasant and unpleasant conditions; (a) reaction time; (b) amplitude of the anticipatory postural adjustment; (c) peak velocity; (d) step length.

Table 3
Bayes factors (BF_{01}) for stimuli-comparisons of gait initiation (GI) parameters and sway path length.

	Neutral–Erotica	Neutral–Mutilation	Erotica-Mutilation
GI parameters			
Reaction Time	4.9	4.3	5.0
APA	5.1	4.9	4.7
Peak Velocity	2.7	2.4	4.8
Step length	0.05[a]	0.5[b]	3.4
Sway path length			
Onset	5.1	4.1	4.3
Pre-Offset	5.1	4.2	4.7
Post-Offset	0.3[c]	0.2[d]	5.0

[a] BF_{10} is equal to 21.5.
[b] BF_{10} is equal to 2.1.
[c] BF_{10} is equal to 3.7.
[d] BF_{10} is equal to 5.3.

tests were significant (e.g. Pillai's Trace: $V = 0.39$, $F(2, 28) = 8.80$, $p < 0.01$), it can be concluded that there were significant differences in step length between the emotion categories to perform pairwise comparisons (cf. Field, 2013, p. 563).

The pairwise comparisons showed no significant effect in step length for either the comparison between neutral and mutilation pictures ($t(29) = -2.37$, $p = 0.025$, which is larger than the Bonferroni-corrected alpha = 0.017) or the comparison between erotica and mutilation pictures ($t(29) = -0.95$, $p = 0.35$). The results only showed a significant difference in step length between neutral and erotica pictures ($t(29) = -3.47$, $p < 0.01$, Hedges $g_{av} = 0.049$, CL = 74%), with participants taking a somewhat larger backward step in response to erotic pictures compared to neutral pictures. This significant difference in step length between neutral

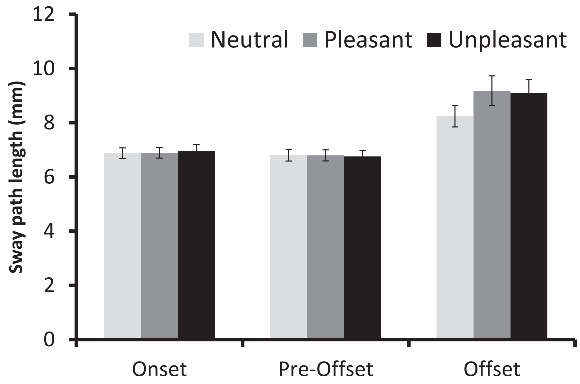

Fig. 3. Sway path length (mean ± SE) for neutral, pleasant and unpleasant conditions calculated over 200 ms at stimulus onset, pre-offset and post-offset.

and erotica pictures was supported by the Bayesian analysis of this comparison ($BF_{01} = 0.05$, $BF_{10} = 21.5$), which yielded strong evidence for a difference between the two conditions. The Bayesian analysis for the step length in the erotica and mutilation condition indicated moderate evidence ($BF_{01} = 3.4$) in support of the null-hypothesis. Finally, the evidence for a difference between the neutral and mutilation condition was inconclusive ($BF_{01} = 0.5$, $BF_{10} = 2.1$).

3.3. Sway path length

The three sway path lengths were compared using a 3 × 3 RM ANOVA, which yielded a significant effect for emotion ($F(2,58) = 3.72$, $p < 0.05$, $\eta_p^2 = 0.11$, $\eta_G^2 = 0.014$), indicating that different emotion categories resulted in differing sway path length values, regardless of when the sway was measured.

A significant effect of the time within the trial when the sway was measured was also found ($F(1.03, 29.90) = 30.42$, $p < 0.001$, $\eta_p^2 = 0.51$, $\eta_G^2 = 0.39$). Looking at Fig. 3, it seems evident that this significant result was driven by the increase in sway measured post-offset compared to the sway measured at onset and pre-offset, which likely showed adherence of the participants to the instructions, i.e., initiate a step.

Finally, a significant interaction was found between emotional category and time at which the sway was measured ($F(2.36,68.49) = 4.55$, $p < 0.01$, $\eta_p^2 = 0.14$, $\eta_G^2 = 0.027$), indicating that for the three different times at which sway was measured, emotion affected sway differentially.

The differences between the emotion categories within each sway time were investigated with separate post hoc paired samples *t*-tests. All means are reported in Table 2 and shown in Fig. 3. The BFs for all pair-wise contrasts are reported in Table 3.

3.3.1. Sway path length 200 ms after onset

There was no significant difference in sway path length in the first 200 ms after picture onset between the three emotion categories. The differences between neutral and erotica pictures ($t(29) = -0.096$, $p = 0.92$), between neutral and mutilation pictures ($t(29) = -0.71$, $p = 0.48$), and between erotica and mutilation pictures ($t(29) = -0.61$, $p = 0.54$) were not significant. Looking at the BF for all three comparisons (all $BF_{01} > 4.1$), the data showed moderate evidence in favor of the null-hypothesis, i.e. evidence in support of equality in sway for all three emotion categories.

3.3.2. Sway path length 200 ms before offset

No significant difference in sway path length was found 200 ms before offset between the three emotion categories. The difference between neutral and erotica pictures ($t(29) = 0.20$, $p = 0.84$), the difference between neutral and mutilation pictures ($t(29) = 0.68$, $p = 0.50$), and the difference between erotica and mutilation pictures ($t(29) = 0.43$, $p = 0.67$) were all non-significant. The BF showed moderate evidence in support of the null-hypotheses (all $BF_{01} > 4.2$).

3.3.3. Sway path length 200 ms after offset

A significant effect of emotion category on the sway path length 200 ms after the picture offset was found. The pairwise comparisons showed a significant difference in sway after the neutral compared to erotica pictures ($t(29) = -2.66$, $p < 0.05$, Hedges $g_{av} = 0.34$, CL = 69%), and compared to mutilation pictures ($t(29) = -2.83$, $p < 0.01$, Hedges $g_{av} = 0.33$, CL = 70%) with both mutilation and erotica eliciting a higher sway path length, and thus more sway. No significant difference was found between the erotica and mutilation conditions ($t(29) = 0.27$, $p = 0.79$). The BF supported these conclusions, in that both comparisons with the neutral condition have a BF_{10} above 3.7, showing moderate support in favor of a difference in sway between the neutral condition and the both erotica and mutilation conditions. In addition, the BF_{01} for the comparison between erotica and mutilation was 5.0, indicating moderate evidence in favor of no difference in post-offset sway between these two conditions.[3]

[3] As an additional check we calculated sway in the 200 ms preceding stimulus onset. As expected, postural immobility was identical across the three conditions, with

4. Discussion

The aim of this study was to examine whether the organization of backward stepping would be affected by emotional content of affective pictures. The theoretical goal was to study avoidance behavior in isolation, and thereby test the DR hypothesis. A step in the backward direction results in an immediate increase in the distance between the actor and the emotion eliciting (i.e., potentially harmful) stimulus, thereby reducing the possibility of adverse consequences. According to the DR hypothesis, it would be easier to organize a step in the backward direction in response to unpleasant/threatening stimuli compared to other (neutral or positive) items. However, like previous studies including backward stepping, the results showed very little effect of emotional content on the gait initiation parameters of the backward step. The absence of a significant effects of emotion was evidenced by non-significant *p*-values. In addition, adding a new dimension compared to previous studies, Bayes Factors were calculated, which provided evidence for the null-hypothesis in almost all conditions.

Emotional content of the stimuli affected neither the RT nor the APA of the backward step. Both GI parameters revealed moderate evidence in favor of no difference between the emotional conditions. The evidence for the difference in peak velocity between the neutral and two emotional conditions was inconclusive. However, there was moderate evidence for similar peak velocities in the erotica and mutilation conditions. Finally, step length showed moderate evidence for a similar step length in the erotica and mutilation conditions as well, but inconclusive evidence for the difference between the neutral and mutilation condition. However, there was strong evidence for a larger step length in response to erotic compared to neutral stimuli, which was the only significant effect of emotion on backward gait initiation parameters. At present we have no explanation for this finding but it could reflect feelings of embarrassment, with a tendency to physically distance one-self from such pictures, despite their positive hedonic value. More generally, caution should be exercised in interpreting these results, as demand characteristics (especially after extended viewing) will likely also play a role.

The exploratory analysis of the sway path length in various places in the COP trace revealed differential effects of the experimental conditions on sway. Overall, there was more body sway after picture offset (which was the cue for the participant to initiate their step) compared to both picture onset and pre-offset. This likely shows adherence of the participants to the instructions: "Do not move as long as the picture is on the screen, initiate your step when the picture disappears." This increase in sway after offset does not reflect gait initiation, because early (impossibly fast) RTs below 200ms were excluded from further analysis. This general increase in sway after the cue is most likely to reflect the response to the cue (the disappearance) and the preparation for movement before the GI.

Emotion only showed a differential effect on postural immobility after offset. Moderate evidence was found that participants exhibited more postural movement after seeing erotic and mutilation pictures compared to neutral pictures. This effect was not due to movement initiation, because (1) all trials with fast RTs were removed (RT $<$ 200 ms), and (2) RT did not show differences between the different emotion categories. An explanation could be that erotic and mutilation pictures caused a higher incentive to start moving (arousal was significantly higher for both categories compared to neutral pictures), increasing the amount of body sway, possibly as a precursor to actual step execution.

Similar to earlier studies on backward GI and emotion, but in contrast to the expectation based on the DR perspective, the current results did not show a pronounced effect of (unpleasant) emotion on backward gait initiation, with the exception of taking a larger step backward in response to an erotic picture compared to a neutral picture. Yiou et al. (2014) found that the velocity at the time of swing foot-off was lower when seeing a pleasant picture compared to a neutral picture. These two results are the only ones within the literature that reflected an effect of emotion on backward stepping in isolation.

Our data are consistent with other studies that included backward stepping, which found no evidence for an effect of emotion on backward gait initiation. However, previous studies did not confirm the null-hypothesis. By using Bayesian statistics in the current study, we have shown evidence that emotion indeed hardly affects backward stepping. This points to a fundamental asymmetry between emotion-cued forward and backward GI since forward GI studies generally show an effect of emotion (i.e., Stins & Beek, 2011). There may be various reasons for the lack of GI findings and the effect of emotion on sway after the cue in the current experiment. It could be that emotions affect backward stepping in a different way compared to forward stepping. It seems that step initiation and execution are barely changed in response to emotional items (as shown by the negative results found by Stins and Beek (2011), Stins et al. (2011, 2014), Yiou et al. (2014) and the current experiment). However, in the brief time period between the cue and movement onset, the current data point to an effect of arousal. This pre-step sway has not been investigated in previous studies that included backward GI. Future research needs to determine whether emotion affects sway before backward step initiation.

Notable is that none of the GI or sway parameters revealed a difference between the erotic and mutilation conditions. Indeed, in all dependent variables the Bayes Factors pointed to moderate evidence in favor of the null-hypothesis (see Table 3). This is an interesting finding given the expectation that mutilation stimuli were to have a greater effect on GI compared to erotic stimuli, based on the overarching hypothesis that backward stepping represents an avoidance behavioral response, aimed at avoiding unpleasant items and events. However, the only differences that were found (in step length and pre-step sway at offset) were between neutral and high-arousal pleasant and unpleasant stimuli. In other words, arousing stimuli, regardless of valence, had a greater effect on step length and pre-step sway than neutral stimuli. A comparable pattern has been found in previous gait initiation and quiet standing research (Bouman et al., 2015; Horslen & Carpenter, 2011). Both Bouman et al. (2015) and Horslen and Carpenter (2011) found that

(*footnote continued*)
a sway path length of 6.7 mm on average.

there was no difference in respectively forward GI and postural sway between high-arousal pleasant and high-arousal unpleasant stimuli. Combined with the current results, this seems to suggest that differences in arousal (neutral vs. high-arousal stimuli) are stronger predictors of gait initiation and postural sway than differences in valence (pleasant or unpleasant). However, more research is needed to investigate the respective roles of valence and arousal on motivational direction, systematically varying these two core emotion dimensions. Relatedly, it could be argued that the stimuli chosen (all high arousal) might induce conflicting response tendencies and unexpected demand characteristics. For example, erotica might also induce feelings of embarrassment, and mutilation images might also induce empathy. We note that in our previous experiment (Stins et al., 2015a, 2015b), where we employed a largely overlapping stimulus set, we found clear effects of picture category on forward GI. In general, the choice of an appropriate stimulus set to induce behavioral tendencies is the corner stone of these types of experiment and requires careful consideration.

It is difficult to reconcile the findings of the current experiment with the DR hypothesis. The findings seem to suggest that backward stepping GI parameters are largely unaffected by emotional stimuli, whereas the DR hypothesis would predict that participants should be inclined to increase the distance between themselves and unpleasant stimuli. An explanation for this lack of findings could reside in the offset-paradigm, since participants did not respond to the unpleasant image per se, but to its disappearance (which could be interpreted as a pleasant event). Indeed, previous research has shown that differences exist in forward GI when directly comparing the onset- and offset-paradigm (Stins et al., 2015a, 2015b). However, this explanation does not seem likely since previous research not using the offset-paradigm (Stins & Beek, 2011; Stins et al., 2011, 2014; Yiou et al., 2014) also reported negligible effects of emotion on backward stepping. Also, it might be argued that backward stepping may not be an ideal response set to study avoidance motivation. Typical avoidance reactions (e.g., flight from imminent danger) might involve triggering and execution of a motor program consisting of turning the whole body and then running away. If it is the case that a single backward step is only loosely coupled to avoidance motivations, this might explain the lack of significant findings. But given that many earlier studies had added a condition involving backward stepping, we deemed it worthwhile to scrutinize how this movement pattern is coupled to affective stimuli, and thereby inform future experiments involving emotion-induced GI.

Since our analysis of postural immobility was exploratory, the interpretation of these results must be done with caution (see Wagenmakers et al., 2012). We would therefore like to suggest ideas for future research in which the role of postural immobility can be investigated. One research domain where sway (reduction) is important concerns studies on the fear response known as 'freeze'. Physiological parameters that indicate freezing behavior are bradycardia (slowing of the heart rate), an overall reduction in movement, and increased muscle tonus (Hagenaars, Oitzl, & Roelofs, 2014). Studies within the whole-body movement paradigm discussed by Hagenaars et al. (2014) mainly report data of participants standing still on a force platform, without having to perform a postural task, except looking at images or clips on a screen. In those studies, it has often been found that unpleasant images or clips cause a freeze-like response. Our data suggest the opposite of a freeze response, with high-arousing unpleasant (and pleasant) images causing an increase in postural sway, i.e., the converse of freeze. It could be that the freezing response is mainly present in the quiet standing paradigm, and not in the GI paradigm. This could be due to participants having to execute a postural motor program (GI), instead of standing quietly during picture viewing. Alternatively, it could be that freeze is not an isolated event, localized within a narrow time bin, but that it instead influences various stages of motor parameterization. Future research could analyze freeze-like behavior within the GI paradigm in more detail. Hagenaars et al. (2014) suggest that postural immobility effects alone should be interpreted with caution, since these could reflect a response to arousing or novel stimuli, instead of the freeze response. It is therefore important to also monitor heart rate and muscle activity, in addition to motor output, to obtain a more complete picture of the hypothesized freezing response. Likewise, postural responses to emotion might be modulated by excessive trait anxiety, such as in PTSD (e.g., Fragkaki, Roelofs, Stins, Jongedijk, & Hagenaars, 2017) but to our knowledge our participants did not suffer from such a condition.

In conclusion, the current experiment has shown evidence that backward gait initiation is unaffected by emotional content. However, these data point toward increased postural sway just before gait initiation, where participants showed increased postural movement following erotic and mutilation images compared to neutral images. Hence, despite the absence of an effect of emotion on the control of backward GI, we did observe pre-step postural activity to the emotional images, which shows that the images have the potential to affect our postural behavior, possibly mediated by arousal and not valence.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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