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**Title:** Interaction between emotion and postural control associated with forward or backward step initiation.

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**Abstract:**

This study investigated the impact of emotion-eliciting images on anticipatory postural adjustments (APAs) associated to forward or backward step initiation. Eighteen healthy young women initiated the two kinds of steps in two conditions: 1) if they judged the image as pleasant or unpleasant, respectively (i.e. congruent condition) and 2) if they judged the image as unpleasant or pleasant, respectively (i.e. incongruent condition). Nine participants performed the congruent condition first while the others performed it in second. The results show that the emotional effect (i.e. the difference between the congruent and incongruent conditions) on APAs associated to forward step only differs according to the axis (anterior-posterior, medio-lateral) that is considered, suggesting a specific emotional component of postural stability.

**Second title:** emotion and step initiation

**Keywords:** emotion, postural control, step initiation

**Titre** : Interactions entre émotion et contrôle postural associé à l'initiation d'un simple pas vers l'avant ou vers l'arrière.

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### **Résumé**

Cette étude analyse l'impact d'images émotionnelles sur les Ajustements Posturaux Anticipés (APAs) associés à l'initiation du Simple Pas vers l'avant ou vers l'arrière. Dix huit jeunes femmes saines initiaient ces deux types de simples pas dans deux conditions : 1) si elles jugeaient l'image plaisante ou déplaisante, respectivement (i.e. condition congruente) et 2) si elles jugeaient l'image déplaisante ou plaisante, respectivement (i.e. condition non congruente). Neuf participantes réalisaient la condition congruente en premier lieu alors que les 9 autres réalisaient cette condition en second lieu. Les résultats montrent que l'effet des émotions (différence entre les conditions congruente et non congruente) sur les APAs associés aux simples pas vers l'avant uniquement, diffèrent suivant l'axe considéré (antéro-postérieur, médio-latéral), suggérant une composante émotionnelle spécifique du contrôle postural médio-latéral.

**Titre courant** : Emotion et initiation du simple pas.

**Mots clefs** : Emotion, contrôle postural, initiation du simple pas, APA.

## 1. Introduction

Gait initiation, i.e. the transition between quiet standing posture and the gait pattern, involved a complex posture-movement coordination called Anticipatory Postural Adjustments (APAs). APAs consist in a stereotyped sequence of postural shifts along both the Anterior-Posterior (AP) and Medio-Lateral (ML) axes (Brenière, Do & Bouisset, 1987; Elble, Moody, Leffler & Sinha, 1994; Jian, Winter, Ishac & Gilchrist, 1993). Whereas APAs along the AP axis reflect the creation of the necessary conditions for progression (Brenière *et al.*, 1987), APAs along the ML axis deal with the lateral stability (Lyon & Day, 1997; McIllroy & Maki, 1999; Yiou & Do, 2010). It has been demonstrated that APAs associated to gait initiation were highly adaptable according to the task requirements, such as the gait velocity reached at the end of the first step (Brenière *et al.*, 1987) or the initial postural configuration (Couillandre, Maton & Brenière, 2000).

Recent studies have integrated the emotional dimension of gait initiation (Gélat, Coudrat & Le Pellec, 2011; Naugle, Hass, Joyner, Coombes & Janelle, 2011; Stins & Beek, 2011; Yiou, Gendre, Deroche & Le Bozec, 2014). In all these previous studies, gait or single step initiation is defined as a whole body movement allowing the decrease or the increase of the distance between the self (the body) and the emotional stimulus location. More precisely, in line with the conceptualization of approach/avoidance movement proposed by Eder and Rothermund (2008), the initiation of forward or backward step following the onset or the offset of emotional visual information is conceptualized as an approach or an avoidance movement, respectively. According to the biphasic theory of emotion (Lang, Bradley & Cuthbert, 1997), approach and avoidance behaviours are primed by appetitive and defensive motivational systems triggering by the view of pleasant and unpleasant stimuli, respectively. From this motivational direction hypothesis, a congruency effect is analysed, i.e. a difference between two conditions: congruent (CO), i.e. approach/avoidance behaviours associated to

pleasant/unpleasant stimuli, respectively, and incongruent (IC), i.e. approach/avoidance behaviours associated to unpleasant/pleasant stimuli, respectively (Bamford & Ward, 2008; Chen & Bargh, 1999; Duckworth, Bargh, Garcia & Chaiken, 2002). As an example, reaction time was reported to be shorter in the CO than the IC condition of upper limb movements (Chen & Bargh, 1999; Duckworth *et al.*, 2002).

Interestingly, a similar congruency effect was observed during gait initiation. Indeed, it has been reported that the initiation of forward gait (i.e. approach) was slower (longer reaction time) and weaker (lower APAs amplitude) with unpleasant images (i.e. IC condition) than with pleasant images (i.e. CO condition) (e.g. Gélat *et al.*, 2011; Naugle *et al.*, 2011). Importantly, the congruency effect on reaction time was observed for forward step (i.e. approach movement) but not for backward step (i.e. avoidance movement) (Stins & Beek, 2011; Yiou *et al.*, 2014).

The aim of the present study was to analyse the impact of emotion on AP and ML APAs associated to forward and backward step initiation by considering the order with which the CO/IC conditions were performed. Indeed, Gélat *et al.* (2011) demonstrated that the congruency effect observed on AP APAs amplitude disappeared when the previous trial was IC. This result arose from the fact that AP APAs amplitude in current IC trials was enhanced when the previous trial was IC, as compared to CO. It has been suggested that this interaction (current trial x previous trial) effect, which is similar to the Gratton effect originally observed on reaction time during button press tasks (e.g. Gratton, Coles & Donchin, 1992; Etkin, Egner, Peraza, Kandel & Hirsch, 2006), accounted for an up-regulation in cognitive control, which is triggering by an immediately prior IC trial, in order to improve the conflict resolution on the next IC trial (e.g., Botvinick, Braver, Barch, Carter & Cohen, 2001; Gélat *et al.*, 2011). However, it is important to note that this interaction effect was specific to AP

APAs amplitude as no interaction effect was observed on reaction time, suggesting that AP APAs amplitude were prioritized at the expense of its time of release (Gélat *et al.*, 2011).

We used a paradigm similar to that used by previous studies (e.g. Stins & Beek, 2011; Yiou *et al.*, 2014), in which participants performed a congruent (approach/pleasant, avoid/unpleasant) and an incongruent (approach/unpleasant, avoid/pleasant) condition. The participants were divided into two groups: the group A, for which participants performed the CO condition followed by the IC one, and the group B, for which participants performed the IC condition followed by the CO one. We expected a congruency effect on both AP and ML APAs, i.e. greater APAs amplitude for pleasant (CO) than unpleasant (IC) images. Moreover, we hypothesized an interaction between the congruency effect and the order in which the CO/IC bloc is performed on AP and ML APAs.

## **2. Materials and methods**

### *2.1. Participants*

Eighteen young women adults (age  $22 \pm 6$  years) recruited from various scientific departments of the Paris West Nanterre University participated in this study with their informed consent. All were right handed and indicated they preferentially used their right foot to initiate gait. They reported normal or corrected-to-normal vision and any lower extremity injuries in the previous 2 years. The local Ethics Committee approved the study.

### *2.2. Experimental protocol*

Participants stood at the centre of a force platform (AMTI 120 X 60 cm) placed 1.75 metre in front of a white wall of the laboratory on which emotion eliciting images (95 cm x 160 cm) were presented. The positioning of the feet allowed the single step (forward, backward) to be performed on the platform and was marked to be used by the participants in all trials. Twenty height pleasant (P) and unpleasant (U) images (14 P and 14 U) were presented during two

experimental conditions. In the congruent condition (CO), participants have to initiate a Forward (FS) or a Backward (BS) single Step with the right foot if they judged the image as pleasant or unpleasant, respectively. In the incongruent condition (IC), the given instruction was opposed: participants have to initiate a FS or a BS with the right foot if they judged the image as unpleasant or pleasant, respectively. In each condition, 7 P and 7 U images were presented in a randomised order. Thus, FS and BS were performed in pleasant (7 trials each) and unpleasant (7 trials each) conditions. Moreover, participants were divided into two groups: the A group (nine participants) performed the CO condition first, whereas the B group (nine participants) performed the IC condition first. Prior to experimental conditions, participants were familiarized with the protocol by performing a training session in which they viewed four images (two pleasant and two unpleasant).

Images were selected from the International Affective Picture System (IAPS) according to their normative ratings for female participants (Lang, Bradley & Cuthbert, 2005). Valence of P and U images were significantly different ( $P = 7.3$ ,  $U = 1.5$ ), whereas arousal were similar ( $P = 6.3$ ,  $U = 6.5$ )<sup>1</sup>.

SuperLab Pro v.2 soft © was used to control the visual stimuli presentation of each trial which began with a 1-s blank, followed by a 2-s image and a 5-s blank (Figure 1). Participants were instructed to 1) look at the picture for the entire time it was on the wall (i.e. 2-s) and 2) initiating a FS or a BS with the right foot without any temporal pressure after image extinction. No instruction was given on the movement speed. Immediately following the completion of all trials, a computerized 9-point version of the self-assessment manikin (SAM) (Lang, 1980) was used to obtain subjective ratings of valence and arousal of all images viewed during the conditions.

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<sup>1</sup> IAPS numbers were: *pleasant*, 1710, 2050, 2160, 2209, 2216, 2303, 4640, 4659, 5929, 8080, 8200, 8210, 8370, 8496; *unpleasant*, 2276, 2800, 3015, 3110, 3230, 3530, 6313, 6350, 6415, 6570, 9140, 9421, 9635.1, 9910.

\*\*\*\* Insert Figure 1 here \*\*\*\*

### *2.3. Data recordings*

All signals from the force platform were recorded at 1000 Hz for 8 s and synchronized with the images presentation procedure. These signals were filtered with a 10 Hz low-pass, fourth order, zero-lag Butterworth filter. Coordinates of CP on the AP ( $y_P$ ) and the ML ( $x_P$ ) axes were calculated from ground reaction forces and moments. As the step initiation movement was analysed on the AP (Y) and ML (X) directions, the displacement of CP on these directions was derived to obtain the CP velocities ( $y'_P$ ,  $x'_P$ ). The body's CM acceleration ( $y''_G$ ) was obtained from Newton's law and the CM velocity ( $y'_G$ ) was calculated from simple integration, by posing that  $y''_G$  and  $y'_G$  equalled zero at the onset of postural modifications.

### *2.4. Experimental variables*

#### *2.4.1 Initial balance conditions*

As the initial posture depends on the intended gait velocity (e.g. Lepers & Brenière, 1995), the postural phase prior to image offset was analysed in order to ensure that participants began the movement in a similar postural configuration. According to Hillman, Rosengren & Smith (2004), the postural phase prior to image offset was divided into 3 phases, lasting 1-s each: the first phase with no image, the second and the third phases in front of a pleasant or an unpleasant image (Figure 1). Initial balance conditions of participants during these 3 phases were assessed from mean values of  $x_P$  and  $y_P$ , which were expressed as a percentage of the base of support's dimensions.

#### *2.4.2 Single step initiation movement*



The main experimental variables were common to both AP and ML axes but their computation differed according to the axis (AP versus ML) that is concerned (see Figure 2).

- The onset of postural modifications on AP ( $t_{0y}$ ) and ML ( $t_{0x}$ ) axes were defined as 1) the time at which 5% of the first peak of  $y'P$  during backward (for forward step) or forward (for backward step) shift of CP was reached (i.e.  $t_{0y}$ ) and 2) the time at which 5% of the first peak of  $x'P$  during lateral shift of CP was reached (i.e.  $t_{0x}$ ), respectively.
- The Movement Initiation Time on AP (MIT<sub>y</sub>) or ML (MIT<sub>x</sub>) axes corresponded to the time delay between image offset and  $t_{0y}$  or  $t_{0x}$ , respectively.
- APAs duration corresponded to 1) on the AP axis: the time delay from  $t_{0y}$  to the time the first peak of backward shift of CP was reached (i.e. the time at which  $y'P$  returns to the 0 value) and 2) on the ML axis: the time delay from  $t_{0x}$  to the time the peak of initial lateral shift of  $xP$  was reached.
- APAs amplitude was assessed 1) on the AP axis: from both the surface of the CP shift, i.e. the magnitude of the time integral of backward shift of CP at 100, 200 and 300 ms after  $t_{0y}$ , i.e. around the end of the AP APAs, and from the CM velocity on the AP axis at these times and 2) on the ML axis: from the magnitude of the lateral excursion of CP at the end of the ML APAs.
- At the end of the step, the peak value of CM velocity (peak velocity) and the time for reaching this peak (time to peak) were used for index of the overall movement performance.

\*\*\*\* Insert Figure 2 here \*\*\*\*

#### *2.4. Statistical analysis*

Analyses were performed using Statistica 7.1 software for Windows (StatSoft, Inc, Tulsa, USA). Initial balance conditions were analysed separately on each axis using a three-way analysis of variance (ANOVA) with repeated measures on the last three factors [group (2: A, B) x phase (3: 1, 2, 3) x image (2: pleasant, unpleasant)]. Movement Initiation Times were analysed using a 3-way ANOVA with repeated measures on the last two factors [group (2) x axis (2) x image (2)]. All other variables were analysed using a 2-way ANOVA with repeated measures on the last factor [group (2) x image (2)]. Forward and backward single steps were analysed separately. Post hoc analyses were conducted using the Tukey test. All significance thresholds were set at  $p < 0.05$ . Effect sizes were calculated as partial eta-squared ( $\eta_p^2$ ) to estimate the meaningfulness of significant findings.

### **3. Results**

#### *3.1. Pictures ratings*

The 2-way ANOVA performed on the ratings of self-reported valence (SAM procedure) revealed no interaction (group x image) and no main effect of group ( $p > 0.05$ ). However, the effect of image was significant ( $p < 0.0001$ ). According to normative valence ratings (IAPS), post-hoc test demonstrated that valence of pleasant images ( $7.7 \pm 0.1$ ) was significantly higher ( $p < 0.0001$ ) than that of unpleasant ones ( $1.6 \pm 0.1$ ).

For the ratings of self-reported arousal (SAM procedure), the 2-way ANOVA showed neither interaction nor main effect ( $p > 0.05$ ). According to normative arousal ratings (IAPS), pleasant images ( $5.5 \pm 0.4$ ) were rated as equally ( $p > 0.05$ ) arousing than were unpleasant ones ( $6.1 \pm 0.6$ ).

#### *3.2. Initial balance conditions*

The CP position was situated more forward and to the stance limb between phase 1 and phase 3, regardless of the emotional image.

The 3-way ANOVA performed on each axis showed only a main effect of phase (on the AP axis:  $F_{2,32} = 3.52$ ,  $p = 0.04$ ,  $\eta_p^2 = 0.180$ ; on the ML axis:  $F_{2,32} = 5.97$ ,  $p = 0.006$ ,  $\eta_p^2 = 0.272$ ). *Post hoc* tests showed a significant increase in the mean position of the coordinate of the CP during the phase 3 on the AP and ML axes ( $43.00 \pm 1.16$  % and  $51.33 \pm 0.17$  %, respectively) compared with the phase 1 ( $42.67 \pm 1.19$  % and  $49.32 \pm 0.68$  %, respectively), regardless of the emotional picture (pleasant, unpleasant) that is presented. Moreover, as no difference was found between pleasant and unpleasant image in the phase 3, all the participants began the movement in a similar initial postural configuration.

### *3.3 Movement initiation time (MIT)*

The results of the 3-way ANOVA (group  $\times$  image  $\times$  axis) performed on MIT data showed only a significant main effect of axis ( $F_{1,16} = 10.70$ ,  $p = 0.005$ ,  $\eta_p^2 = 0.401$ ). These results demonstrated that MIT was longer in the AP ( $1346 \pm 27$  ms) than in the ML ( $1272 \pm 21$  ms) axis.

### *3.4 Spatiotemporal parameters of the backward step initiation (BS)*

For BS, the 2-way ANOVA (group  $\times$  image) showed no interaction neither main effect for all dependent variables of the backward step initiation process ( $p > 0.05$ ). The results of BS are not detailed in order to not overload the present paper.

### *3.5 Spatiotemporal parameters of the forward step initiation (FS)*

For FS, the results of the statistical analysis depended on the axis that is considered.

#### *3.5.1. FS: results obtained on the anterior-posterior (AP, y) axis (table 1)*

Whereas APAs duration was similar in the pleasant and unpleasant contexts in both groups, APAs amplitude was higher in the pleasant than in the unpleasant trials, for the group B only.

Regarding APAs duration, the 2-way ANOVA (group x image) did not show any significant interaction or main effect ( $p > 0.05$ ). Mean values were approximately 300 ms whatever the image (pleasant, unpleasant) and the group (A, B) (Table 1). However, the 2-way ANOVA revealed a significant interaction (group x image) effect for all the dependent variables that reflect APAs amplitude on the AP axis (Table 1): for time integral of CP shift at 100 ms ( $F_{1,16} = 7.38, p = 0.015, \eta_p^2 = 0.315$ ) up to 300 ms ( $F_{1,16} = 5.26, p = 0.036, \eta_p^2 = 0.247$ ) from t0y, and for velocity of CM at 100 ms ( $F_{1,16} = 6.04, p = 0.026, \eta_p^2 = 0.274$ ) up to 300 ms ( $F_{1,16} = 7.56, p = 0.014, \eta_p^2 = 0.321$ ) from t0y. Post-hoc tests highlighted that the time integral of backward shift and the CM velocity at 200 ms after t0y was higher in pleasant ( $0.175 \pm 0.022$  cm.s, and  $0.0194 \pm 0.002$  cm.s, respectively) than unpleasant ( $0.135 \pm 0.023$  cm.s and  $0.0141 \pm 0.003$  cm.s, respectively) trials for the B group only (Figure 3a).

### 3.5.2. FS: results obtained on the medio-lateral (ML, x) axis (Table 1)

Whereas APAs duration was similar in the pleasant and unpleasant contexts in both groups, APAs amplitude was higher the pleasant than in the unpleasant trials, regardless of the group. The 2-way ANOVA (group x image) did not show any significant interaction or main effect ( $p > 0.05$ ) for the APAs duration on the ML axis. Mean values were approximately 300 ms whatever the image (pleasant, unpleasant) and the group (A, B) (Table 1). In contrast to the AP axis, the 2-way ANOVA (group x image) showed only a significant main effect of image on the ML APAs amplitude ( $F_{1,16} = 6.68, p = 0.02, \eta_p^2 = 0.294$ ). The magnitude of the lateral excursion of CP at the end of the APAs was higher in pleasant ( $4.24 \pm 0.35$  cm) than unpleasant ( $3.79 \pm 0.32$  cm) trials, regardless of the group (Figure 3b).

### 3.5.3. FS: overall movement performance (Table 1)

At the end of the step, the 2-way ANOVA showed no interaction (group x image) neither main effect ( $p > 0.05$ ) for all the dependent variables that reflect the overall movement

performance. Peak velocity and the time to peak were similar between pleasant ( $0.411 \pm 0.013 \text{ m}\cdot\text{s}^{-1}$  and  $1127 \pm 28 \text{ s}$ , respectively) and unpleasant ( $0.400 \pm 0.016 \text{ m}\cdot\text{s}^{-1}$  and  $1183 \pm 47 \text{ s}$ , respectively) trials, regardless of the group (Table 1).

\*\*\*\* Insert Table 1 here \*\*\*\*

\*\*\*\* Insert Figure 3 here \*\*\*\*

## DISCUSSION

The aim of the present study was to analyse the impact of pleasant or unpleasant emotional state, induced by the view of a 2-s emotional image, on the biomechanical organization of forward or backward step initiation. Two original aspects of the present study need to be pointed out: 1) the dynamic modulation of emotional processing was taken into account by considering the order in which the CO/IC sequence was performed (group A, group B) and 2) the biomechanical organisation of step initiation was analysed along both the AP and the ML axes in order to investigate how emotional state impacts the two main functions of APAs, i.e. the forward disequilibrium (i.e. APAs along the AP axis) and the lateral stability (i.e. APAs along the ML axis). According to our hypothesis, a congruency effect was found on AP and ML APAs. The results showed that APAs amplitude along both axes was greater in the CO (pleasant) than the IC (unpleasant) conditions for forward step only. These results suggested a facilitating effect of pleasant emotion on both functions of APAs. Moreover, we found an interaction between the congruency effect and the order in which the CO/IC bloc was performed for AP APAs but not for ML APAs. Regarding the AP axis, greater APAs were observed in the CO (pleasant) than in the IC (unpleasant) condition only when the IC condition was performed first (group B). In contrast, regarding the ML axis, greater APAs were observed in the CO (pleasant) than in the IC (unpleasant) context for both groups, i.e.

regardless of the order in which the CO/IC sequence was performed. The present discussion followed the three main parts of the step initiation process that were analysed, i.e. the initial balance conditions, the movement initiation time and the spatio-temporal parameters of AP and ML APAs.

#### *Emotional effect on the initial balance conditions*

Several studies showed that the view of pleasant and unpleasant pictures impacted postural control during quiet standing posture (e.g. Azevedo *et al.*, 2005; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Hillman *et al.*, 2004; Stins & Beek, 2007). For example, Hillman *et al.* (2004) showed that women exhibited a backward shift of CP in front of unpleasant images, lasting 6-s each, indicating a backward body inclination. This pattern was in agreement with the biphasic theory of emotion as it directly reflects the fundamental unpleasant/avoidance coupling (Lang *et al.*, 1997). In the present study, no avoidance tendencies were found in the unpleasant context during quiet standing posture as no main effect of image on the mean value of yP during postural phases was observed. In contrast, the mean value of yP during the third postural phase (end of the postural phase with an emotional image) was higher than in the first phase (i.e. control) (see Figure 1), indicating a forward body leaning before the onset of the step initiation process, even when the emotional image was unpleasant. A similar forward shift in the AP coordinates of the CP during the static period before fast gait and step initiations in neutral conditions has been previously reported (Dietrich, Brenière & Do, 1994; Lepers & Brenière, 1995). This motor strategy has been interpreted as a part of the anticipatory movements (Dietrich *et al.*, 1994) in order to encourage gravity's action and increase the speed of the forward-falling body (Lepers & Brenière, 1995). Thus, during the postural phase of the present study, it could be stated that

participants anticipated the forthcoming movement, regardless of the emotional state, as if the priority was given to the initiation of the single step while standing.

#### *Emotional effect on the movement initiation time*

In the present study, no main effect of image was observed on the Movement Initiation Time on both axes (MIT<sub>y</sub> and MIT<sub>x</sub>). It was about 1.3 s regardless of the pleasant or the unpleasant image. These results were in line with previous studies which showed that the effect of emotional valence on reaction time disappeared 1) when forward gait was initiated at image offset (following a 3-5 s duration of an emotional image viewing), compared to image onset (Stins *et al.*, 2015), and 2) when the imperative “go” stimulus appeared 3 s after image onset (long condition), compared with when it appeared at only 500 ms after image onset (short condition) (Gélat & Ferrel Chapus, 2015). It has been suggested that the long-time available for affective processing in the offset (Stins, van Gelder, Oudenhoven & Beek, 2015) and in the long condition (Gélat & Ferrel-Chapus, 2015) would have allowed the implementation of emotion regulation processes (Stins *et al.*, 2015; Gélat & Ferrel Chapus, 2015), even if the kind of process is not yet consensual (see Stins *et al.*, 2015 and Gélat & Ferrel Chapus, 2015 for more detailed). In the present study, as step was initiated at image offset and 2 s after its appearance, it could be assumed that similar emotion regulation processes would have been implemented.

#### *Emotional effect on the spatio-temporal parameters of AP and ML APAs*

The results obtained on APAs amplitude suggested a facilitating effect of pleasant emotion on both functions of APAs associated to forward step initiation. ML APAs amplitude in both groups and AP APAs amplitude in the group B only were greater in the congruent (pleasant) versus incongruent (unpleasant) conditions. These results extended those obtained in the

studies of Gélat *et al.* (2011) and Naugle *et al.* (2011) to forward step initiation. In line with the biphasic theory of emotion (Lang *et al.*, 1997), the weaker forward motor response in the incongruent (unpleasant) condition probably accounted for a directional conflict between the avoidance tendencies primed by the aversive stimulus and the approach component of the goal directed movement, i.e. forward step initiation.

Moreover, this result was not found for the group A as no difference was observed between pleasant and unpleasant images on the AP APAs amplitude for this group. First, this result suggested that the order with which the CO/IC bloc was performed is a crucial determinant when studying the impact of emotion on a goal directed movement. Secondly, this result could stem from a dynamic modulation of emotional processing (Okon-Singer, Lichtenstein-Vidne & Cohen, 2013). Indeed, it has been demonstrated that reactions to emotional stimuli depend on attention and its executive network that is involved in functions such as resolving conflict (e.g. Etkin *et al.*, 2006; Gratton *et al.*, 1992). For example, during a typical button press task, it has been demonstrated that the congruency effect (reaction time difference between CO and IC trials) was smaller if the previous trial was IC than if it was CO (Etkin *et al.*, 2006). A similar result has been found during forward gait initiation but for APAs amplitude only (Gélat *et al.*, 2011). In line with the cognitive control theory (Botvinick *et al.*, 2001), the disappearance of the congruency effect when the previous trial was IC has been interpreted as resulting from an up-regulation in cognitive control, i.e. the activation of a high conflict resolution, during the previous IC trial that benefited to the conflict resolution on the next IC trial. In the present study, the disappearance of the congruency effect observed on AP APAs amplitude for the group A only might stem from a similar dynamic modulation of emotional processing.

However, as this result was only observed for AP APAs, it could be stated that the forward disequilibrium (AP APAs) was prioritized at the expense of lateral stability (ML APAs). This



was probably due to the directional component of AP APAs that matches with that of the approach-avoidance tendencies induced by the view of pleasant-unpleasant images. Moreover, the fact that the congruency effect on ML APAs amplitude was not impacted by the order in which the CO/IC bloc was performed suggesting a specific impact of emotion on lateral stability. The specific impact of emotion on ML postural control has been already highlighted during quiet standing posture (Azevedo *et al.*, 2005; Facchinetti *et al.*, 2006; Hilliard *et al.*, 2008; Maki, Holliday & Toppa, 1994). For example, the viewing of highly unpleasant images (mutilation) increased the frequency of CP oscillations on the ML axis but not on the AP one (Azevedo *et al.*, 2005). This pattern reflected a freezing-like behaviour associated with highly unpleasant images (Azevedo *et al.*, 2005; Bradley, 2009; Fanselow, 1994).

Furthermore, the beneficial effect of pleasant emotion during forward step initiation was only transient as peak velocity and time to peak at the end of the step did not depend on the emotional context (pleasant versus unpleasant). These results were in agreement with those obtained in the study of Gélat *et al.* (2011).

Lastly, in line with previous studies that focused on the relationship between emotion and backward step (Stins & Beek, 2011; Yiou *et al.*, 2014), no effect of image neither interaction between image and group was found on the spatio-temporal parameters related to backward step initiation. These results indicated that the performance of the motor response in the incongruent condition (avoidance/pleasant) was as efficient as that obtained in the congruent condition (avoidance/unpleasant), while the arousal of pleasant images was rated as strong as that of unpleasant one. As it was stressed by Stins & Beek (2011), approach and avoidance tendencies during whole body movement such as step initiation are not simply opposite and that the unpleasant/avoidance coupling was stronger than the pleasant/avoidance one.

In conclusion, the present findings provide original evidence that both the forward disequilibrium and the lateral stability associated to forward step initiation in young healthy adults may be decreased when they were associated to emotional conflict resolution (unpleasant condition). In incongruent (IC) condition, as compared to congruent (CO) one, reduced amplitude of APAs along both the AP and ML axes appeared to result from the emotional significance that participants conferred to the required motor action, i.e., a whole body approach towards an unpleasant stimulus. The weaker motor response in the IC condition likely reflected the implementation of a defensive response, avoidance or freezing like behaviour, as previously reported in standing humans viewing mutilation images (e.g. Azevedo *et al.*, 2005; Facchinetti *et al.*, 2006, Hillman *et al.*, 2004). Moreover, the results also showed that the emotional impact on forward disequilibrium only could disappear according to the dynamic modulation of emotional processing, suggesting a specific emotional component of the two functions of APAs. Finally, this emotional effect seems asymmetric as no emotional impact was found on backward step initiation.

As the present study focused only on early postural modifications associated to step initiation, no data was obtained during subsequent steps. Thus, it would be interesting in a future work to investigate the relationship between emotion and gait by using a paradigm including several steps such as gait initiation.

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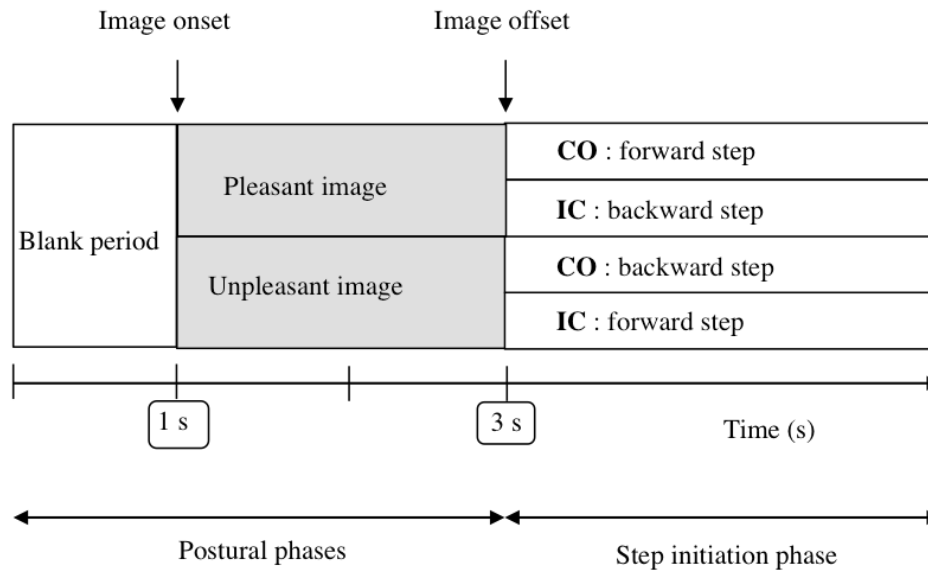


Figure 1: Schematic representation of the time course of a trial. CO, IC: congruent and incongruent conditions, respectively.

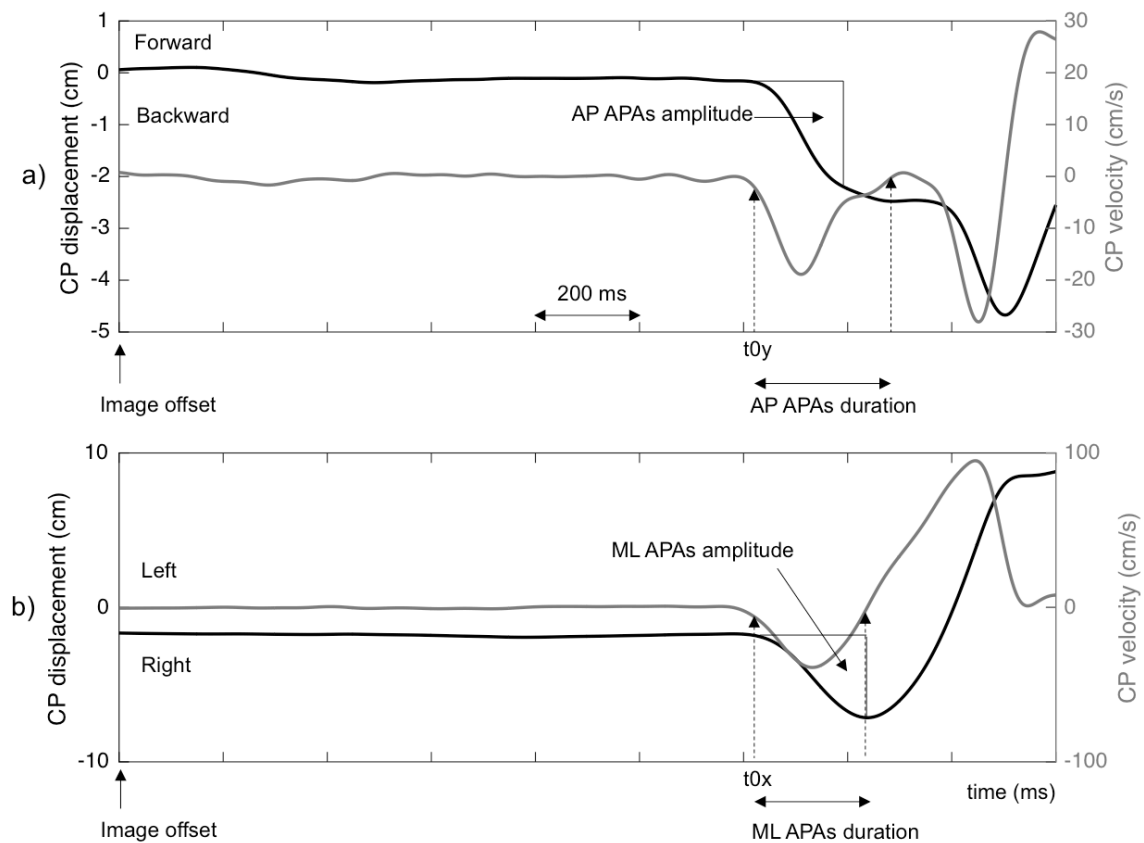


Figure 2: Typical biomechanical traces (one trial with one representative participant) associated with Forward Step initiation at image (pleasant) offset (CO condition), along the AP (a) and ML (b) axes. (a) CP displacement and velocity along the AP axis;  $t_{0y}$ : onset of AP postural modifications; AP APAs amplitude: magnitude of the time integral of backward shift of CP at 200 ms from  $t_{0y}$ . (b) CP displacement and velocity along the ML axis;  $t_{0x}$ : onset of ML postural modifications; ML APAs amplitude: magnitude of the lateral excursion of CP at the end of the ML APAs.



**Table 1:** Main spatio-temporal parameters on the anterior-posterior (AP) and mediolateral (ML) axis of the forward single step initiation according to the group (A, B) and the emotional condition (pleasant, unpleasant). Values are mean  $\pm$  SD. MIT: Movement Initiation Time; APAs amplitude on the AP axis was characterized with the magnitude of the time integral of backward shift of CP at 200 ms after the onset of postural modifications; (1) and (2): *p* values of the main effect of image and the interaction (group  $\times$  image) effect, respectively.

	Group A		Group B		ANOVA results	
	Pleasant	Unpleasant	Pleasant	Unpleasant	(1)	(2)
<b>MIT (ms)</b>						
AP axis	1383 $\pm$ 41	1365 $\pm$ 49	1296 $\pm$ 41	1341 $\pm$ 49	0.963	0.156
ML axis	1300 $\pm$ 35	1235 $\pm$ 33	1257 $\pm$ 35	1300 $\pm$ 35		
<b>APAs duration (ms)</b>						
AP axis	282 $\pm$ 21	287 $\pm$ 31	315 $\pm$ 21	365 $\pm$ 31	0.539	0.708
ML axis	317 $\pm$ 16	337 $\pm$ 22	294 $\pm$ 16	328 $\pm$ 22	0.068	0.629
<b>APAs amplitude</b>						
AP axis (cm.s)	0.106 $\pm$ 0.022	0.124 $\pm$ 0.023	0.175 $\pm$ 0.02	0.135 $\pm$ 0.023	0.275	**
ML axis (cm)	3.83 $\pm$ 0.49	3.44 $\pm$ 0.45	4.65 $\pm$ 0.49	4.15 $\pm$ 0.45	*	0.738
<b>Overall Movement</b>						
Peak velocity (m.s <sup>-1</sup> )	0.393 $\pm$ 0.018	0.388 $\pm$ 0.023	0.428 $\pm$ 0.018	0.412 $\pm$ 0.023	0.277	0.570
Time of the peak (ms)	1181 $\pm$ 39	1169 $\pm$ 66	1073 $\pm$ 39	1197 $\pm$ 66	0.129	0.069

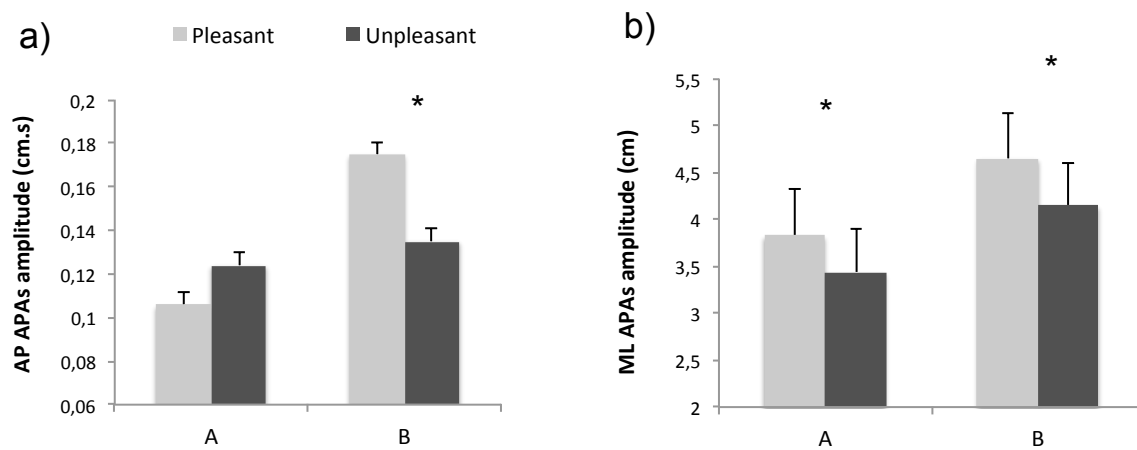


Figure 3. Mean values (and standard error) of APAs amplitude across the emotional image (pleasant, unpleasant) and group (A, B) along (a) the AP axis, i.e. the magnitude of time integral of backward shift of CP at 200 ms after the onset of postural modification, and (b) the ML axis, i.e. the magnitude of the lateral excursion of CP at the end of the ML APAs.

\* Significant ( $p < 0.05$ ) difference between emotional image.