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Is Step Initiation in Response to Facial Expressions Modulated by Lateralized Auditory Cues?

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Objective: The left and right hemispheres of the brain play differential roles in emotion processing, grounded in hemispheric asymmetry. Literature suggests an involvement of the left hemisphere (cortex) for approach motivation and an involvement of the right hemisphere for avoidance motivation. We tested whether we could directly prime approach–avoidance tendencies by selectively activating the left or right hemisphere. We did this by presenting a monoaural cue, consisting of a brief tone presented to the left or right ear, preceding a visual cue to approach or avoid a facial stimulus. ***Method:*** Participants ($N = 52$) stood on a force plate and performed a single step forward or backward in response to the valence of a facial stimulus, displaying an emotion. Each stimulus was preceded by a brief acoustic cue randomly presented to either ear, assumed to selectively activate the contralateral hemisphere. We recorded the center of pressure, from which we derived reaction times, defined as the transition from quiet standing to step initiation. ***Results:*** The tone had no effect on the speed of gait initiation. However, the tone induced a brief postural shift in the same direction as ear stimulated. We also observed an interaction between gender of the visual stimulus and the emotion displayed. ***Conclusions:*** We failed to observe an effect of ear (hemisphere) stimulated on the time to initiate a step toward or away from a facial expression. This finding is at odds with a comparable study that did find priming effects in a comparable language categorization task. The results are discussed in terms of the hemispheric specialization of approach–avoidance tendencies and methods to selectively prime either hemisphere.

Public Significance Statement
Emotional responses are orchestrated by centers throughout the brain. The left and right halves of the human brain play different roles in emotions. The time to start moving (taking a step) in response to something pleasant or unpleasant reveals the workings of these emotion centers. We tried to directly influence the left and right halves of the brain with a tone to study its effects on emotion.

Keywords: emotion, postural control, step initiation, approach–avoidance, hemispheric asymmetry

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Is emotion processing lateralized in the brain? This seemingly simple question has still not been answered in a satisfactory manner, despite decades of research. As pointed out by numerous researchers (e.g., LeDoux & Brown, 2017; Palomero-Gallagher & Amunts, 2022), emotion processing is instantiated in various neural (cortical and subcortical) circuits, encompassing the amygdala, the hippocampus, the thalamus, and cortical areas, especially the prefrontal cortex, and of course dense interconnections among these networks. For present purposes, we will not focus on a specific brain network but instead highlight the fact that the left and right halves of the brain seem to play a different role in emotions. That is, emotion processing seems to be lateralized, and the left or right hemisphere seems to be dominant for various emotions. We first present a brief overview of the literature and then formulate our hypothesis as regards emotion-elicited motor responses consisting of approach versus avoidance movements of the body and the putative role of the left/right hemisphere.

Initial studies, done mainly with brain-damaged patients, suggested that *all* emotions are lateralized to the right hemisphere, with the left hemisphere subserving more regulatory functions (e.g., Borod et al., 1998; Robinson & Price, 1982; see Gainotti, 2023, for a historical treatment of these asymmetries). An alternative account posits that emotions are lateralized according to their valence, with a processing preference of the right hemisphere for unpleasant emotions and a left hemisphere preference for pleasant emotions (e.g., Jansari et al., 2000). Evidence for this idea is often based on methods involving the presentation of affective stimuli and then studying lateralized neural responses, such as left–right asymmetries in frontal electroencephalography (e.g., Meyer et al., 2014). More contemporary thinking has seen a shift toward a conceptualization of brain asymmetries in terms of motivational tendencies, namely adaptive behavioral responses, instead of the valence of a particular emotion. Indeed, there is evidence that the right hemisphere favors withdrawal/avoidance behaviors, whereas the left hemisphere favors approach-related behaviors (e.g., Adolph et al., 2017; Harmon-Jones, 2004).

A relatively novel and unexplored method to study hemispheric differences in emotion processing involves trying to selectively influence the state of activation of either hemisphere and then measuring the ensuing neuroaffective response. The left/right hemisphere can be selectively primed by presenting lateralized stimuli that are (initially) processed in one hemisphere but not the other. This paradigm capitalizes on the well-known organization of the central nervous system, where sensory input is often routed to the contralateral hemisphere for further processing. A few studies have adopted this paradigm. For example, Alves et al. (2009) briefly presented emotional facial expression in the left or right visual field, so that the visual input only reached the contralateral visual hemisphere. Using this divided visual field technique, the results revealed a processing advantage for expressions of happy and fearful faces when presented in the left visual field (hence the right hemisphere). More recently, Blom et al. (2020) did a comparable study using chimeric faces, where one half of the face (along the vertical midline) displays a different emotional expression than the alternate half. The results again revealed a left visual field bias for emotions. This paradigm involving lateralized stimulus presentation can also be employed using auditory stimuli because—similar to visual processing—input to one ear is preferentially analyzed in the contralateral hemisphere. For example, Komeilipoor et al. (2013) presented (nonverbal) emotional sounds to either ear and then stimulated the left or right primary motor cortex using transcranial magnetic stimulation. The excitability of the corticospinal motor tract was assessed by the amplitude of the motor-evoked potentials. The results revealed that unpleasant sounds yielded higher excitability of the left cortex, whereas pleasant sounds yielded higher excitability of the right cortex. These findings seem to be at odds with the literature, but it should be pointed out that the effect only pertained to the primary motor cortex, which constitutes a small section of the entire cortex.

Another paradigm to prime the hemisphere involves bodily/motoric interventions. Harmon-Jones (2006) asked participants to perform unimanual contractions with the left or right hand by squeezing a ball. First, as expected, left-hand contractions induced greater right frontal activity (electroencephalography α suppression), whereas the reverse was the case for right-hand contractions. Interestingly, it was found that right-hand contractions (activating the left hemisphere) induced greater approach emotion than contractions with the left hand. Price and Harmon-Jones (2011) used an innovative paradigm in which participants were asked to either lean backward in a reclining chair, to lean forward while seated, or to sit upright. When leaning forward (which could be considered a full-body “approach” state), there was greater relative left frontal cortical activity compared to the two other body postures. This was taken as further evidence that the motivational direction of emotions (i.e., approach–avoidance) by virtue of body posture is coupled to asymmetrical cortical activity. See also Harmon-Jones and Gable (2018) for an overview of asymmetrical cortical (especially frontal) activity and approach/withdrawal motivation.

In the current experiment, we took an innovative study by Fetterman et al. (2013) as our starting point. They tested whether selective auditory priming of either hemisphere using a brief tone could be used to induce a specific emotion-related motivational state. More specifically, they tested whether stimulating the left ear (right hemisphere) could prime the avoidance-related system and whether stimulating the right ear (left hemisphere) could prime the approach-related system. Indeed, using a task in which verbs had to be classified as approach-related actions or as avoidance-related actions, it was found that the speed of categorization was affected by ear/hemisphere stimulated, such that priming the left (“approach”) or right (“avoidance”) hemisphere speeded up responding to words belonging to that same category. The authors concluded that priming of either hemisphere by means of a monoaural cue facilitated cognitive accessibility to specific approach/avoidance-related concepts, which again underscores the lateralization of motivational representations.

To our knowledge, this is the only study using a neutral stimulus (tone) to test specific predictions from the cerebral asymmetry model of emotion processing. A potential limitation of this study is that task execution relies heavily on the left hemisphere as it required reading and classifying purely verbal material, which tends to be strongly lateralized to the language centers of the left hemisphere. As a result, it is difficult to assess how robust this priming methodology is to assess the cerebral asymmetry of motivational tendencies. We reasoned that a paradigm involving viewing of facial expressions, combined with a whole-body approach avoidance task, could be used as a further test of the hypothesized cerebral asymmetry of emotion processing. In addition, it allows us to test how robust this auditory priming methodology is, that is, whether it will replicate in our design. If found to be robust, auditory priming could potentially be used in future studies as an easy and reliable method to bring either hemisphere in a certain affective state and test its behavioral sequelae. In our paradigm, participants are instructed to make a single step in the forward direction (“approach”) or backward direction (“avoidance”) in response to the valence of a facial expression or the valence of an affective photograph. This paradigm has been used in various studies (see, e.g., Coudrat et al., 2017; Gélat et al., 2011; Naugle et al., 2011; Stins et al., 2011), often giving rise to the so-called affective compatibility effect, namely faster responding when stimulus valence and step direction are congruent. Most studies found that effects of emotion are observed in the early biomechanical phases of gait initiation, such as weight shifts, whereas the actual unfolding of the step seems to proceed in an automatic fashion. Likewise, Ellmers et al. (2020) found that participants who experienced fear of falling due to standing on a height exhibited abberant anticipatory postural adjustments (APA) when initiating gait.

We decided to adopt a modified version of the affective compatibility task by presenting a lateralized tone on each trial before the imperative stimulus. This allows us to test two main predictions. The first prediction is that presentation of a tone to the left ear facilitates processing of negative facial emotional expressions (arguably processed in the right hemisphere) compared to positive ones. Priming of the right ear would yield the opposite pattern. The second prediction is that presentation of a tone to the left ear will prime the avoidance system and hence facilitate the initiation of a step in the backward direction compared to a step in the forward direction. Priming of the right ear would likewise yield the opposite pattern.

We have three additional predictions. First, we expect an overall affective compatibility effect: faster forward response initiation to pleasant faces and faster backward response initiation to unpleasant faces, compared to the alternate pairings. This would constitute the classical approach–avoidance (AA) effect. Second, we predict that stimulation of the left/right ear will yield a brief postural movement deflection toward the ipsilateral side. Some studies (e.g., Russolo, 2002) found that an unpredictable monoaural cue induced a reflex-like postural adjustment. Third, we explored whether the facial emotional expressions combined with the gender (male/female) of the visual stimulus yield a processing advantage. As a case in point, Stins et al. (2014) observed faster responding to angry male faces and happy female faces (compared to alternate combinations) in a comparable step initiation study.

Method

Participants

Fifty-two individuals (32 females; M_{age} = 22.9 years) participated in the experiment. None of the participants had neurological conditions that prevented them from performing the task. The local ethics committee approved of the experimental protocol before it was conducted. Informed consent was obtained from all participants. The participants either received a congruent or incongruent instruction (described in the following section). After the experiment, we asked participants to fill out a brief questionnaire outlining their sex, age, body weight, and self-assessed leg preference. Characteristics of the sample are presented in Table 1.

Materials and Method

We used a custom-made 1 m × 1 m strain gauge force plate to record the center-of-pressure (COP) trajectories. Sampling frequency was 1,000 Hz. The plate consists of eight force sensors: four measuring forces in the z direction (one in each corner) and two sensors for the x and y directions (embedded in the four sides of the plate). Prior to the experiment, we calibrated the plate with a set of weights. Both the raw force traces of the eight channels, the summed forces in the three directions, and the COP time series (in the anteroposterior [AP] and mediolateral [ML] directions) were stored for further analysis. In the geometric center of the plate, we had attached small pieces of white tape, which marked the starting position from which each step should be performed.

A 55-in. monitor (Philips) was positioned 1 m in front of the participant at eye level and was used to display the stimuli. The images consisted of happy or angry faces (male and female) and were adopted from the Radboud Faces Database (Langner et al., 2010). The facial expressions were performed by models who were specifically trained to display a number of expressions. The gaze direction was always frontal. The total stimulus set consisted of 20 unique male angry faces, 20 unique male happy faces, 19 unique female angry faces, and 19 unique female happy faces. One of the female angry faces and one of the female happy faces were presented twice. The image size was 64 × 48 cm, so that it was completely visible while standing close to the screen.

We used a small photodiode attached to the monitor to synchronize stimulus events with the force plate recordings. The data from this light sensor and the force plate were fed into an analog-to-digital converter, which then fed the data to the measurement computer.

Auditory stimuli were presented via a headphone (Sony) that was worn throughout the experiment. The stimulus consisted of a 500 ms tone (a Windows XP Ringout tone) that was randomly presented to the left or right ear. In an earlier stage of the study, we had contacted the first author (A.K.F.) of Fetterman et al.'s (2013) article, who kindly agreed to share the original

Table 1
Sample Characteristics of the Participants, Separate for the Groups Who Received the Congruent and Incongruent Instructions

Instruction	Sample	Age (year) + *SD*	Weight (kg) + *SD*	Leg preference
Congruent	11 M/15 F	22.5 (1.9)	71.5 (12.6)	4 L/21 R/1 B
Incongruent	10 M/16 F	23.3 (2.6)	71.3 (12.4)	3 L/22 R/1 B

Note. Shown are the sex (male [M]/female [F]), age, body weight, and leg preference (left [L], right [R], or both [B]). Age of one participant was not recorded. Body weight was based on self report, as was leg preference. Independent t tests revealed no significant difference between the groups in terms of age and weight. The large majority reported a right leg preference, as is consistent with the overall population.

auditory stimulus file with us so that we had identical pitch and duration.

Procedure

Participants performed a number of stepping movements on the plate upon presentation of the visual stimulus. More specifically, the emotion in the face had to be coupled to a step in a particular direction, namely forward or backward. Following convention in the approach–avoidance literature, we label forward steps to a happy face and backward steps away from an angry face as *congruent*. Conversely, forward steps to an angry face and backward steps away from a happy face are labeled *incongruent*. Half of the participants received the congruent instruction, and the other half received the incongruent instruction. In the actual instruction, the words congruent and incongruent were not used. Instead, participants were simply told which step (i.e., forward or backward) had to be performed in response to each of the faces. The instruction was displayed on the monitor on each consecutive trial prior to the stimulus events.

Participants had to stand still prior to presentation of the image (and thus also during presentation of the tone), with the arms relaxed alongside the body, and to initiate a step forward or backward as soon as the facial stimulus appeared on screen. No instructions on step length and speed were given. All steps had to be initiated with the right leg, immediately followed by the left leg, and participants then had to stand still in the new (more anterior or posterior) position. After completing the step, participants had to wait for a message to appear on screen, instructing them to resume their original position and await a new trial.

Prior to each facial stimulus, the auditory stimulus was presented randomly to the left or right ear. The timing of stimulus events was as follows: Each trial started with a fixation cross in the middle of the screen, with a random duration of 2–4 s. This was then followed by the auditory stimulus for a duration of 500 ms. After a further 100 ms interval, the imperative stimulus (the face) was shown for a fixed duration of 6 s. Stimulus presentation was controlled via Psychtoolbox for Matlab.

The experiment consisted of 80 trials in total, which were divided into four blocks of 20 trials (facial stimuli randomized), with a short break in between each block. The experiment was preceded by four practice trials that were not analyzed. Each block was stored as a separate text file, which was later imported in Matlab.

Data Analysis

Using Psychtoolbox, we had programmed brief light pulses coinciding with the main stimulus events, namely onset of the fixation cross, onset of the sound, and onset of the visual stimulus. These light pulses allowed us to mark these events in the force plate data so that reaction times (i.e., time difference between the visual stimulus and movement onset) could be calculated. The data from the light pulses were stored as a separate data channel, and they have a clear square wave shape, signifying the onset and offset of each light pulse.

We used a custom-made program to read in the data, do the preprocessing, and extract relevant variables. Using the light pulses, we isolated each stepping trial in the continuous data signal, allowing us to calculate performance measures of interest.

We calculated reaction time[1] using a method involving the identification of the change from quiet standing (i.e., awaiting the stimulus) to movement onset. Gait initiation is always preceded by a coordinated pattern of weight shifts (called the APA phase) that serves to destabilize the upright body and program the step in a particular direction. We adopted a method based on crossing a force threshold in the anterior–posterior direction. Reaction time was defined as the time interval between stimulus onset and the moment at which the force exceeded 10 N. Prior to this analysis, we applied a 20-point moving average filter to the force trace.

The reaction time values thus identified were then put into separate bins corresponding to the facial emotion and the ear stimulated, and then averaged for statistical analysis. We performed a mixed-factor analysis of variance with the following factors: group (congruent vs. incongruent instruction; between factor), emotion (happy vs. angry faces, within factor), and ear stimulated (left vs.

[1] In principle, the full COP trajectory (see an example in Figure 1) allows us to identify a host of other variables that characterize the organization of the step, such as peak velocity, step duration, postural immobility, APA shape, and so forth, but we decided to refrain from including these other variables to our analysis plan so as to facilitate comparison with comparable studies that employed only reaction time with manual responses.

right, within factor). The statistical analyses were done in jamovi (Version 2.2.5). We adopted a significance level of $\alpha = .05$. Effect sizes are reported as partial η squared (η_p^2). Note that we did not enter step direction (forward/backward) as factor because it is fully determined by the combination of instruction and emotion.

We also performed an exploratory analysis, taking into account putative effects of the gender of the stimulus face, as this has been shown to interact with emotion. We consider this an exploratory analysis since it was not part of our main research question, but it could shed some further light on how stepping movements are coupled to affective social stimuli.

As for effects of ear stimulated on static posture, we tested whether the sound would induce a small but noticeable deflection of the COP in the left/right direction, thus along the mediolateral axis. We determined the mediolateral position of the COP at two discrete instances: the onset of the sound and the onset of the face. We subtracted these values, such that positive values signify a rightward displacement of the COP and negative values a leftward displacement. It is important to emphasize that during this interval, subjects were instructed to stand still (after all, the imperative stimulus is not shown yet), but unintentional postural adjustments may still be visible in the COP profile. The values thus obtained were entered into a paired *t* test.

Results

Our initial screening of the data revealed that the data of six participants (three congruent; three incongruent) could not be used due to a large number of incorrect steps, highly atypical COP traces (perhaps suggestive of submovements and hesitation), or overall very slow movement onset. We decided to exclude these data from further analyses.

Of the remaining 3,680 (46 × 80) steps, a further 146 (4%) had to be discarded from the analysis for the following reasons: 44 steps were too fast (<200 ms; most often caused by failing to stand still prior to the stimulus); 16 steps were too slow (>1,200 ms); 17 steps were made in the wrong direction; 41 steps had a highly atypical profile (e.g., submovements; not coming to a halt after the step; loss of balance); on four trials, no step was executed; 12 steps were performed with the left leg instead of the right leg; and a final 12 steps were not recorded due to software issues. An example COP trace of one forward step is shown in Figure 1.

Main Analysis

None of the effects (main or interaction) were significant. Mean reaction time (RT) across all conditions was 502 ms. Boxplots of the RT values are shown in Figure 2. Even though RTs were faster for the congruent group than the incongruent group (473 vs. 503 ms, respectively), this difference was not significant, $F(1, 44) = 2.54$, $p = .12$, $\eta_p^2 = .055$.

Effect of Ear Stimulated

The mean mediolateral displacement when the left ear was stimulated was 2.4 mm and 5.6 mm when the right ear was stimulated. In other words, there was an overall rightward postural displacement when the right ear was stimulated. This difference was significant, $t(45) = 2.78$, $p < .001$, Cohen's $d = .41$.

Exploratory Analysis: Gender of the Face

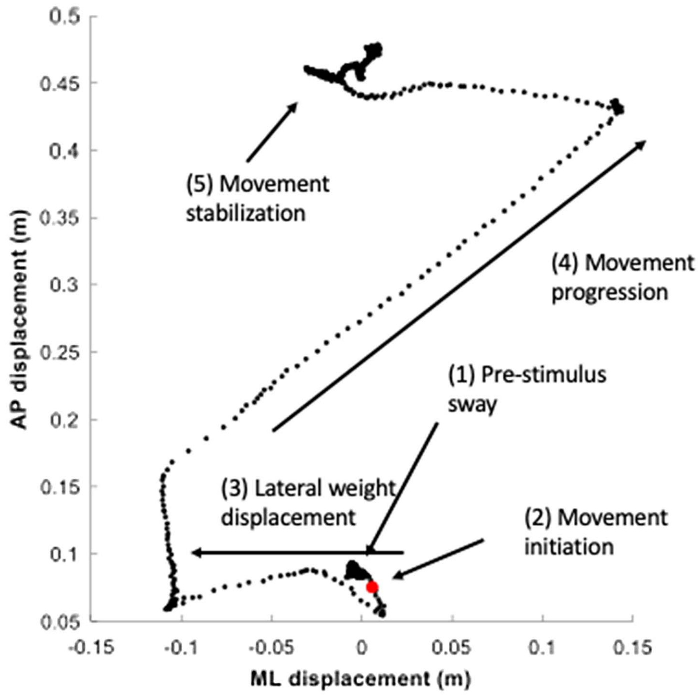
This analysis was the same as before, but now gender of the visual stimulus was added as an extra within-subject factor. The only significant effect was the gender-by-emotion interaction, $F(1, 44) = 10.78$, $p = .002$, $\eta_p^2 = .002$. This was a crossing interaction, such that, when presented with male faces, responding was faster for angry compared to happy expressions (494 vs. 503 ms, respectively), whereas for female faces, responding was faster for happy compared to angry expressions (496 vs. 513 ms, respectively). A post hoc test (*t* test) revealed that the interaction was driven by faster RTs for angry male faces compared to angry female faces, $t(45) = 3.39$, $p = .001$.

Discussion

Our main research question was whether presenting a lateralized tone could be used to prime the left or right hemisphere, so that assumed cortical asymmetries in emotion processing would become evident in an approach–avoidance task. Our task involved producing a single step in the forward or backward direction, thereby

Figure 1

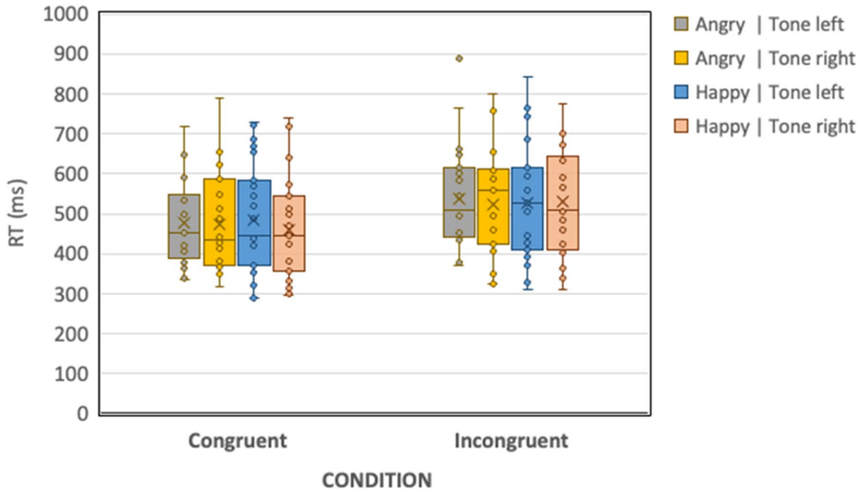
Example Center-of-Pressure Trace, Showing the Profile of a Forward Step of About 40 cm in Amplitude



Note. In this example, a happy face was displayed, and the tone was presented to the left ear. From the figure, various phases can be clearly discerned: (1) Prior to the stimulus, the participant is standing still with some minimal postural sway. When the face is shown, the forward step has to be programmed and executed. The first weight shift represents the change from quiet standing to movement initiation; the red dot (2) corresponds to the reaction time as defined in the text. Following this, the right leg is lifted, resulting in a large leftward shift of the center of pressure (3) and push-off with the left foot in the forward direction. This results in the center-of-pressure (and hence the whole body) making a large forward displacement (4). Finally, the actor has to decelerate and regain postural stability in the new anterior position (5). Each dot represents one sample, that is, 10 ms. AP = anteroposterior; ML = mediolateral.

automatically increasing or decreasing the distance to the valenced stimulus (a facial expression). Analysis of the reaction times revealed that ear stimulated had no differential effect on the time to respond to a happy or angry face, nor on the time to initiate a step in the forward ("approach") or backward ("avoidance") direction. This is in contrast to the finding as reported by Fetterman et al. (2013) using our task version. We reasoned that our task would have the advantage that it (a) did not rely on processing verbal material and (b) involves a more "pure" measure of approach–avoidance behaviors (cf. Koch et al., 2009). At the same time, we took great care to use the same procedure as Fetterman et al. (2013) with regards to the auditory priming component of the task (timing and intensity of the prime). These divergent findings could reside in substantial task differences. Fetterman et al.'s (2013) study was a pure cognitive task involving reading action verbs and classifying them according to some rule. It could be that the auditory prime only affected the temporal lobe, which not only contains the primary and secondary auditory areas but also Wernicke's area, which is involved in language comprehension and is arguably involved in the verb classification task.

Figure 2
Boxplots of RTs, Separate for the Congruent (Left) and Incongruent (Right) Conditions, Showing the Individual Values



Note. The horizontal line in each box is the median; the × is the mean. RT = reaction time.

If this hemispheric activation does not "spread out" to adjacent areas involved in emotion recognition and adaptive behavioral responses, then this could explain why we failed to find a priming effect.

A future experiment could try to prime the emotion centers in the respective hemispheres by presenting emotional sounds as opposed to a neutral tone. As a case in point, Chen and Qu (2017) found that affective auditory stimuli (presented bilaterally) had marked effects on the control of quiet static stance. It could be that such stimuli are better suited to induce a particular motivational state, coupled with the postural control system.

Second, we failed to observe an affective compatibility effect. Even though RTs were overall faster for the congruent group than the incongruent group, this difference was not significant. Many approach–avoidance studies report faster approach responses to pleasant items and faster avoidance responses to unpleasant items, but there are exceptions. For example, whole-body tasks typically observe an affective compatibility effect with forward stepping only and not backward stepping (e.g., Bouman & Stins, 2018; Yiou et al., 2014), whereas this behavioral asymmetry is typically absent (or not reported) in manual versions of the approach–avoidance task. We do not know why the affective compatibility effect did not show up in our results, but it could be due to the fact that the participants received either congruent or incongruent instructions, whereas it is more common to adopt a complete within-subjects design so that all participants receive the same instructions. Rotteveel et al. (2015) also failed to observe the effect in their replication study. Participants either received a congruent or incongruent instruction involving pushing or pulling a lever in response to the valance of "good" or "bad" words, but neither stimulus–response assignment yielded an RT advantage. We initially reasoned that a within-subjects design involving switching of instructions midway the experiment could be a source of confusion for the participants, but this design choice might also have obscured the affective compatibility effect. As regards the study of motivational tendencies and their neural underpinnings, it is unknown whether directional movements such as stepping toward or away from something are associated with lateralized brain activity. A handful of studies have directly compared electroencephalography during forward and backward stepping. For example, Berchicci et al. (2020) found that backward stepping required greater cognitive control as compared to forward stepping, arguably due to the novelty of the motor task. The authors found that these motor activities were characterized by enhanced prefrontal activity. However, no hemispheric differences were reported. But since in this task the direction of the step was not coupled to an emotional stimulus, it is unclear whether the same results would be found in a paradigm similar to ours.

Third, in response to the onset of the auditory cue, we found a fast and unintentional postural reaction that was specific to the ear stimulated. Even though stimulation of both the left and right ear resulted in a rightward displacement, probably related to the initial preparation of the right step, this displacement was larger when the right ear was stimulated than the left ear. Studies by Hiraoka et al. (2015) and Russolo (2002) observed automatic postural reflexes in response to an auditory cue, which seems to mimic the effects of galvanic stimulation.

Finally, we found an interaction between gender and emotion, such that there was a processing advantage for angry male faces and happy female faces compared to the alternate combinations. A comparable finding was reported by Stins et al. (2014), who argued that this could reflect a Stroop-like phenomenon where certain facial features (in this case, gender and expression) are easier to detect than others. This is thus a potential source of variation that should be taken into account by future studies involving these types of stimuli in an approach–avoidance task setting.

In sum, we failed to find an effect of lateralized auditory priming on approach–avoidance-related behaviors. As argued, this could be due to the fact that in Fetterman et al.'s (2013) study, only auditory brain regions receive stimulation and not brain areas that are involved in emotion-guided responses. Future studies using lateralized visual primes such as Alves et al. (2009) and/or direct activation of left/right frontal areas using transcranial magnetic stimulation could be used to test whether the affective compatibility effect can be modulated using lateralized stimuli. If so, this could shed further light on the nature of hemispheric differences in emotion processing.

To conclude, we did not find evidence to support or disconfirm the notion that selective hemispheric activation modulates the coupling between emotional processing and approach–avoidance-motivated stepping. It could be that hemispheric differences are real and present, but this was not observed at the behavioral level in our paradigm.

References

Adolph, D., von Glischinski, M., Wannemüller, A., & Margraf, J. (2017). The influence of frontal alpha-asymmetry on the processing of approach- and withdrawal-related stimuli—A multichannel psychophysiology study. *Psychophysiology*, *54*(9), 1295–1310. https://doi.org/10.1111/psyp.12878

Alves, N. T., Aznar-Casanova, J. A., & Fukusima, S. S. (2009). Patterns of brain asymmetry in the perception of positive and negative facial expressions. *Laterality*, *14*(3), 256–272. https://doi.org/10.1080/13576500802362927

Berchicci, M., Russo, Y., Bianco, V., Quinzi, F., Rum, L., Macaluso, A., Committeri, G., Vannozzi, G., & Di Russo, F. (2020). Stepping forward, stepping backward: A movement-related cortical potential study unveils distinctive brain activities. *Behavioural Brain Research*, *388*, Article 112663. https://doi.org/10.1016/j.bbr.2020.112663

Blom, S. S. A. H., Aarts, H., & Semin, G. R. (2020). Lateralization of facial emotion processing and facial mimicry. *Laterality*, *25*(3), 259–274. https://doi.org/10.1080/1357650X.2019.1657127

Borod, J. C., Cicero, B. A., Obler, L. K., Welkowitz, J., Erhan, H. M., Santschi, C., Grunwald, I. S., Agosti, R. M., & Whalen, J. R. (1998). Right hemisphere emotional perception: Evidence across multiple channels. *Neuropsychology*, *12*(3), 446–458. https://doi.org/10.1037/0894-4105.12.3.446

Bouman, D., & Stins, J. F. (2018). Back off! The effect of emotion on backward step initiation. *Human Movement Science*, *57*, 280–290. https://doi.org/10.1016/j.humov.2017.09.006

Chen, X., & Qu, X. (2017). Influence of affective auditory stimuli on balance control during static stance. *Ergonomics*, *60*(3), 404–409. https://doi.org/10.1080/00140139.2016.1182649

Coudrat, L., Gélat, T., & Le Pellec Muller, A. (2017). Interaction between emotion and postural control associated with forward or backward step initiation. *Movement & Sport Sciences—Science & Motricité*, *98*, 31–38. https://doi.org/10.1051/sm/2017012

Ellmers, T. J., Maslivec, A., & Young, W. R. (2020). Fear of falling alters anticipatory postural control during cued gait initiation. *Neuroscience*, *438*, 41–49. https://doi.org/10.1016/j.neuroscience.2020.04.050

Fetterman, A. K., Ode, S., & Robinson, M. D. (2013). For which side the bell tolls: The laterality of approach–avoidance associative networks. *Motivation and Emotion*, *37*(1), 33–38. https://doi.org/10.1007/s11031-012-9306-5

Gainotti, G. (2023). Some historical notes orienting towards brain mechanisms that could underlie hemispheric asymmetries. *Cortex*, *163*, 26–41. https://doi.org/10.1016/j.cortex.2023.03.001

Gélat, T., Coudrat, L., & Le Pellec, A. (2011). Gait initiation is affected during emotional conflict. *Neuroscience Letters*, *497*(1), 64–67. https://doi.org/10.1016/j.neulet.2011.04.030

Harmon-Jones, E. (2004). On the relationship of anterior brain activity and anger: Examining the role of attitude toward anger. *Cognition and Emotion*, *18*(3), 337–361. https://doi.org/10.1080/02699930341000059

Harmon-Jones, E. (2006). Unilateral right-hand contractions cause contralateral alpha power suppression and approach motivational affective experience. *Psychophysiology*, *43*(6), 598–603. https://doi.org/10.1111/j.1469-8986.2006.00465.x

Harmon-Jones, E., & Gable, P. A. (2018). On the role of asymmetric frontal cortical activity in approach and withdrawal motivation: An updated review of the evidence. *Psychophysiology*, *55*(1), Article e12879. https://doi.org/10.1111/psyp.12879

Hiraoka, K., Ae, M., Ogura, N., Sano, C., Shiomi, K., Morita, Y., Yokoyama, H., Iwata, Y., Jono, Y., Nomura, Y., Tani, K., & Chujo, Y. (2015). Monaural auditory cue affects the process of choosing the initial swing leg in gait initiation. *Journal of Motor Behavior*, *47*(6), 522–526. https://doi.org/10.1080/00222895.2015.1020356

Jansari, A., Tranel, D., & Adolphs, R. (2000). A valence-specific lateral bias for discriminating emotional facial expressions in free field. *Cognition and Emotion*, *14*(3), 341–353. https://doi.org/10.1080/026999300378860

Koch, S., Holland, R. W., Hengstler, M., & van Knippenberg, A. (2009). Body locomotion as regulatory process: Stepping backward enhances cognitive control. *Psychological Science*, *20*(5), 549–550. https://doi.org/10.1111/j.1467-9280.2009.02342.x

Komeilipoor, N., Pizzolato, F., Daffertshofer, A., & Cesari, P. (2013). Excitability of motor cortices as a function of emotional sounds. *PLOS ONE*, *8*(5), Article e63060. https://doi.org/10.1371/journal.pone.0063060

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & Van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition and Emotion*, *24*(8), 1377–1388. https://doi.org/10.1080/02699930903485076

LeDoux, J. E., & Brown, R. (2017). A higher-order theory of emotional consciousness. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(10), E2016–E2025. https://doi.org/10.1073/pnas.1619316114

Meyer, T., Quaedflieg, C. W. E. M., Giesbrecht, T., Meijer, E. H., Abiad, S., & Smeets, T. (2014). Frontal EEG asymmetry as predictor of physiological responses to aversive memories. *Psychophysiology*, *51*(9), 853–865. https://doi.org/10.1111/psyp.12230

Naugle, K. M., Hass, C. J., Joyner, J., Coombes, S. A., & Janelle, C. M. (2011). Emotional state affects the initiation of forward gait. *Emotion*, *11*(2), 267–277. https://doi.org/10.1037/a0022577

Palomero-Gallagher, N., & Amunts, K. (2022). A short review on emotion processing: A lateralized network of neuronal networks. *Brain Structure & Function*, *227*(2), 673–684. https://doi.org/10.1007/s00429-021-02331-7

Price, T. F., & Harmon-Jones, E. (2011). Approach motivational body postures lean toward left frontal brain activity. *Psychophysiology*, *48*(5), 718–722. https://doi.org/10.1111/j.1469-8986.2010.01127.x

Robinson, R. G., & Price, T. R. (1982). Post-stroke depressive disorders: A follow-up study of 103 patients. *Stroke*, *13*(5), 635–641. https://doi.org/10.1161/01.STR.13.5.635

Rotteveel, M., Gierholz, A., Koch, G., van Aalst, C., Pinto, Y., Matzke, D., Steingroever, H., Verhagen, J., Beek, T. F., Selker, R., Sasiadek, A., & Wagenmakers, E. J. (2015). On the automatic link between affect and tendencies to approach and avoid: Chen and Bargh (1999) revisited. *Frontiers in Psychology*, *6*, Article 335. https://doi.org/10.3389/fpsyg.2015.00335

Russolo, M. (2002). Sound-evoked postural responses in normal subjects. *Acta Oto-Laryngologica*, *122*(1), 21–27. https://doi.org/10.1080/00016480252775689

Stins, J. F., Lobel, A., Roelofs, K., & Beek, P. J. (2014). Social embodiment in directional stepping behavior. *Cognitive Processing*, *15*(3), 245–252. https://doi.org/10.1007/s10339-013-0593-x

Stins, J. F., Roelofs, K., Villan, J., Kooijman, K., Hagenaars, M. A., & Beek, P. J. (2011). Walk to me when I smile, step back when I'm angry: Emotional faces modulate whole-body approach–avoidance behaviors. *Experimental Brain Research*, *212*(4), 603–611. https://doi.org/10.1007/s00221-011-2767-z

Yiou, E., Gendre, M., Deroche, T., & Le Bozec, S. (2014). Influence of emotion on the biomechanical organization of backward and forward step initiation. *Motor Control*, *18*(4), 368–382. https://doi.org/10.1123/mc.2013-0015

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