Angry and Happy Expressions Affect Forward Gait Initiation Only When Task Relevant

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Whole-body movements represent an ecologically valid model for assessing the effect of emotional stimuli valence on approach/avoidance reactions as they entail a change of the physical distance between such stimuli and the self. However, research in this field has provided inconsistent results as the task relevance of the emotional content of the stimuli was not properly controlled, and very often, it is impossible to dissociate the effect of arousal from that of valence. To overcome these limitations, we studied the effect of facial emotional expressions (anger and happiness) on forward gait initiation using an experimental paradigm that allows us to compare the impact of the stimuli emotional content when they are task relevant and when they are not. We found that angry and happy expressions altered forward gait initiation parameters differently only when relevant for ongoing goals. In particular, both the reaction times and the percentages of omission errors increased when the go signal was an angry face compared to when the go signal was a happy face. These results indicate that forward step movements share the same features as reaching arm movements regarding emotional stimuli, that is, facial emotions do not automatically influence behavioral responses. Instead, their effects depend critically on their conscious appraisal.

Keywords: gait initiation, emotional facial expressions, task relevance, go/no-go task, healthy adults

Making sense of others' emotional states and intentions is pivotal for successful social interactions. This process, called social cognition, enables us to interpret the current social context, shaping our behaviors accordingly. However, although there is no doubt about the link between motor processes and emotions, the exact way they interact is still largely unclear. Current evidence is inconsistent as empirical findings provide contradictory results. A classical theoretical framework used to interpret behavioral reactions to emotional stimuli is the motivational model (Bradley et al., 2001; Lang & Bradley, 2010). According to this model, emotions trigger the activation of two motivational systems, one appetitive and one defensive, evolved to react to salient stimuli to different degrees according to their level of arousal. The appetitive system is activated in contexts that promote survival, that is, by positive stimuli, and the defensive system is activated in contexts involving threat, that is, by negative stimuli. It is usually thought that the activation of the appetitive system facilitates approaching behaviors, whereas the defensive system facilitates avoidance behaviors (Kozlik et al., 2015). However, some authors showed that approach/avoidance responses do not coincide with the stimuli's emotional valence as unpleasant emotions such as anger (Carver & Harmon-Jones, 2009; Wilkowski & Meier, 2010) or fear (Marsh et al., 2005) can promote approach. Crucially, a widely believed assumption is that such behavioral reactions occur automatically, that is, independently from the subject's current goals, as emotional stimuli would be capable of biasing selective attention, prioritizing their processing reflexively (Lang et al., 2000; Vuilleumier, 2005). However, literally taken, this hypothesis is too rigid to accommodate the everyday experience and the empirical evidence that the same emotional stimulus can induce wide ranges of behaviors. By contrast, appraisal theories of emotions (Moors & Fischer, 2019) can better account for the heterogeneous results obtained when studying the relationship between actions and emotions. These theories suggest that valenced stimuli do not automatically trigger approach or avoidance. Instead, they elicit different behaviors according to their relevance in a given context. In other words, goal relevance is the crucial determinant of emotion processing

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(Moors & Fischer, 2019; Scherer & Moors, 2019). Recent research provides strong support for this view. Mirabella (2018), using two versions of a go/no-go task, showed that emotional facial expressions (happy and fearful) affect motor readiness and accuracy of reaching arm movements only when they are task relevant. Such results have been replicated and extended by including angry faces (Mancini et al., 2020). In both studies, when participants had to respond according to the emotional content of the stimuli, threatening expressions elicited an increase in the reaction times (RTs) and the percentage of omission errors (instances in which participants did not move although they had to), compared to happy faces. Differently, when the same images were shown but participants had to move or withhold their movements according to the faces' gender, all differences between happy and threatening faces disappeared. Mancini et al. (2022) showed that inhibitory control, a key executive function (Mirabella, 2014), is also impacted by facial emotions provided that they are task relevant.

Importantly, in all these studies, the effects of emotions were due to valence and not to stimuli arousal. In sum, this evidence suggests that motor control of reaching arm movements is affected by facial emotions only when they carry valuable information for participants' goal accomplishment.

The Impact of Facial Emotions on Whole-Body Movements

One open issue is whether motor control of whole-body movements shares the same features as unilateral reaching arm movements with respect to emotional stimuli. The question is very relevant as such movements represent a more ecologically valid model for assessing the link between valenced stimuli and whole-body movement direction (Koch et al., 2009). In fact, moving the whole body toward or away from an emotional stimulus decreases or increases the physical distance between this stimulus and the self. In the literature, three types of whole-body movement paradigms have been employed: (a) gait initiation (GI), in which the kinematic parameters of a single forward or backward step in response to emotional stimuli are measured (e.g., Bouman et al., 2015; Stins et al., 2011); (b) quiet standing, in which the body sway to the presentation of emotional stimuli is measured (e.g., Roelofs et al., 2010); and (c) locomotion, in which the kinematic parameters of several steps toward emotion-eliciting stimuli are studied (Naugle et al., 2010; Vernazza-Martin et al., 2015). The most common hypothesis is that positive stimuli should activate the appetitive system, increasing approach tendencies, for example, facilitating a forward step, while negative stimuli should trigger the defensive system eliciting avoidance tendencies, for example, facilitating a backward step or freezing behaviors. Often this is referred to as the motivational direction hypothesis (MDH). As described in the following, experimental results are remarkably contrasting. A number of studies showed that the execution of a forward step toward pleasant stimuli is faster than toward unpleasant stimuli (Gélat & Chapus, 2015; Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014). However, Naugle et al. (2011) found that RTs speed up with respect to pleasant stimuli when participants see high-arousing unpleasant, but not low-arousing, pictures for a long time. Stins et al. (2015) showed that this effect was because in Naugle et al. (2011), participants were instructed to step forward at stimulus offset and not at stimulus onset as in most previous works. Moving in response to stimulus disappearance allowed participants to view the pictures for a longer time before initiating the step. This observation drove Bouman et al. (2015) to assess how viewing duration of emotional stimuli affects forward GI. They found that RTs were longer for emotional stimuli than for neutral stimuli for short (100–500 ms) viewing duration, but these differences disappeared when stimuli were observed for a long duration (3,000–4,000 ms). Crucially, however, pleasant and unpleasant pictures never yielded differences in forward GI. Therefore, the authors concluded that their findings could not be explained by the valence but by the higher arousal of emotional than neutral stimuli. According to their interpretation, short picture viewing of high-arousal emotional stimuli captivates participants' attention and increases alertness interfering with forward GI. However, prolonged view diminishes the impact of emotional stimuli, making the forward GI process of high-arousal stimuli comparable to low-arousal (neutral) stimuli. The high arousal level of emotional pictures also caused larger step sizes and smaller anticipatory postural adjustment, regardless of viewing time. These results do not agree with the MDH, which predicts that valence and not arousal should impact approach/avoidance behaviors, that is, pleasant stimuli should affect GI differently than unpleasant stimuli. Nevertheless, scrutinizing the previous literature reveals that in many cases, the arousal instead of, or together with, the valence could drive the behavioral effects on whole-body movements (e.g., Bouman & Stins, 2018; Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014). Other evidence contrasting the MDH comes from studies in which backward steps were requested (Bouman & Stins, 2018; Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014). According to the MDH, unpleasant items should facilitate backward body displacements to allow people to avoid real or potential threats. Nevertheless, no effect of emotional stimuli was found on backward GI parameters (Bouman & Stins, 2018; Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014). Again, the effect is mediated by arousal and not valence. Studies analyzing quiet standing have reported that threatening/unpleasant pictures can induce a temporary reduction in body sway (Azevedo et al., 2005; Roelofs et al., 2010; Stins et al., 2011), indicative of a freezing response. This reaction is compatible with the MDH as freezing restrains movement initiation, allowing a subject to evaluate the potential threat. However, Bouman and Stins (2018) found that the postural sway immediately preceding backward GI was increased by high-arousing pictures, either pleasant or unpleasant, with respect to low-arousing (neutral) pictures. Finally, a few studies showed that locomotion is facilitated when participants walk forward toward pleasant stimuli and disturbed when they walk toward unpleasant stimuli, in line with the MDH (Naugle et al., 2010; Vernazza-Martin et al., 2015).

The overall picture emerging from this research is controversial. The effect of emotional stimuli on whole-body movement direction depends on several factors, for example, images' arousal, the timing of the go instruction (i.e., whether participants have to move at the onset or the offset of the emotional stimuli), and the step direction, and not just on valence. Often it is impossible to dissociate the effect of arousal from that of valence. When considering whole-body backward movements, the effects of emotions seem to vanish. Therefore, it is hard to draw any firm conclusion as to how stimuli valence impacts whole-body movement direction.

One element that has not been thoroughly considered is the goal relevance of emotional stimuli. On the one hand, when participants are instructed to perform just forward (Bouman et al., 2015; Naugle et al., 2011; Stins et al., 2015; Vernazza-Martin et al., 2015) or backward (Bouman & Stins, 2018) whole-body movements, they are forced to move in a given direction and might potentially completely overlook the valence of the images. On the other hand, when participants are requested to perform a backward or a forward movement according to the stimulus valence (Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014), the emotional content is task relevant, but its effect potentially conflates with the need of planning different movements. Interestingly, Stins et al. (2014) showed that if participants are instructed to step forward or backward depending only on the faces' gender and not on their emotional expressions, participants do not show any difference between opposite movement directions. Still, the authors found that when averaging across step directions, participants made slower GI to angry female faces with respect to all other emotional expressions, while there were no differences in terms of RTs of GI between neutral, happy, and angry male faces. Thus, when emotions were task irrelevant, they had a different effect on whole-body movement than when emotions were task relevant (Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014). The main limitations of this study are (a) that it did not adopt a within-sample design to compare the condition in which emotions were task relevant versus when they were not and (b) that the sample was comprised only of women. There are also a few more caveats. First, in most studies (Bouman & Stins, 2018; Bouman et al., 2015; Naugle et al., 2011, 2010; Stins et al., 2015; Vernazza-Martin et al., 2015), images were taken from the International Affective Picture System (IAPS; Lang et al., 2005). In this database, pleasant and unpleasant images have different visual features; for example, the subjects could be humans, animals, or things, and sometimes faces, parts of the body, or objects are in the foreground, while other times they are in the background. Moreover, it has been shown that low-level perceptual features (i.e., spatial frequency profile, or brightness contrast) of selected images can also have different effects on emotional processing and ratings (Lakens et al., 2013; Redies et al., 2020). Given such heterogeneity, it is not that simple to ascribe the effects of emotional stimuli on movements solely to stimuli valence. Second, in all studies, the number of trials performed by each participant was relatively small, that is, less than 70 (Bouman & Stins, 2018; Bouman et al., 2015; Naugle et al., 2011, 2010; Stins et al., 2014, 2011; Vernazza-Martin et al., 2015). As is well known, a low number of trials is a source of increased variability.

To avoid these ambiguities, in the current study, we exploited the experimental paradigm of Mirabella (2018) for studying the effect of valence on forward GI when emotional stimuli are task relevant and when they are not, using a within-subject design, for the first time. Images used in this investigation were facial expressions (happy, angry, and neutral faces). This choice was motivated by two considerations. First, faces are among the most potent tools in nonverbal social communication (Jack & Schyns, 2015). In particular, emotional facial expressions convey salient and specific information to the observer (Blair, 2003). Therefore, facial displays are a category of stimuli particularly prone to studying the effect of emotions. Second, faces allow comparing different emotions expressed by the same actor, minimizing the differences of visual features. Based on our previous results on reaching arm movements (Mancini et al., 2020, 2022; Mirabella, 2018), we predicted that emotional facial expression would affect forward GI only when task relevant.

Method

In this section, we report how we determined our sample size, all data exclusions, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

Participants

We used the software G*Power 3.1 (Faul et al., 2009) to investigate the sample size needed to obtain a power of .80, with a two-factor repeated-measures analysis of variance (ANOVA), and a moderate effect size. The input variables were retrieved from available published data (Mancini et al., 2020; Mirabella, 2018): two-tailed test with α = .05, effect size f = .15–.25, correlations among repeated measures r = .85, and nonsphericity correction ε = .80–1. The output established that a minimum sample of 20 participants was required.

Thus, we enrolled 20 students, 10 men ($M \pm SD$ age: 23.0 $\pm$ 1.0 years) and 10 women (22.2 $\pm$ 1.3 years), from the University of Trieste. Participants were recruited via advertisements hung in university buildings. Recruitment lasted 6 months. Subjects participated voluntarily and did not receive compensation. All participants were Caucasian, were naïve to the purposes of the experiment, had a normal or corrected to normal vision, and did not have a history of neurological or psychiatric disorders, injuries of lower extremities, or other injuries that prevented them from walking or standing. The study was conducted in accordance with the ethical guidelines set forth by the Declaration of Helsinki and had approval from the Ethics Committee of the University of Trieste (82/2018). Informed consent was obtained from all participants.

Stimuli

Photographs of faces were taken from the Pictures of Facial Affect database (Ekman & Friesen, 1976). We used faces of four different persons, two men and two women, each with a neutral, happy, or angry expression, for a total of 12 images. At the end of the experimental session, participants evaluated the level of arousal (8-point Likert scale), valence (15-point Likert scale), and recognizability of each picture. The recognizability of emotions was assessed by asking participants whether they recognized the presence of emotional faces and, if yes, to write the name of the emotional expression. The analyses reported in Table 1 revealed that, as expected, the valence of the three facial expressions differed (anger: M = −2.90, SD = 1.90; neutral: M = −.03, SD = .45; happiness: M = 5.68, SD = 1.46). In addition, the arousal of angry faces (M = 4.11, SD = 1.16) was lower than that of happy faces (M = 5.25, SD = 1.55), and both had different arousal from the neutral expressions (M = 1.06, SD = 1.11). Finally, all participants detected the presence of happy and neutral facial expressions, and

Table 1
Results of the Statistical Analyses on the Arousal and Valence Scores

Variable	Effect	Factors	*df*	Statistics	*p* value
Arousal	Main	Emotion	2, 38	$F = 63.06$	.000
	Post hoc comparison	Happy vs. anger	19	$t = 4.104$	.002
		Happy vs. neutral	19	$t = 8.599$	.000
		Anger vs. neutral	19	$t = 8.411$	.000
Valence	Main	Emotion	2, 38	$F = 152.5$	.000
	Post hoc comparison	Happy vs. anger	19	$t = 12.873$	.000
		Happy vs. neutral	19	$t = 17.054$	.000
		Anger vs. neutral	19	$t = -6.525$	.000

Note. Post hoc tests were adjusted according to Bonferroni.

all but one detected the presence of anger emotional expressions. One participant identified the negative emotional expression as sadness. However, as his behavioral performance was in line with all other participants, his data were included in the analyses.

Apparatus

Participants stood in front of a large projector screen (2 × 2 m) placed at a distance of 2.8 m. The pictures, displayed by a projector, were 0.6 m wide by 0.9 m high, corresponding to ~12° × 18° of visual angle. Movements and positions of the feet were recorded by the eight cameras (acquisition frequency of 120 Hz) of the optoelectronic motion capture system Qualisys OQUS. Spherical reflective markers were placed on the head of the second metatarsal bone and the calcaneus of the left and right feet.

Procedure

Participants were required to step forward as quickly and accurately as possible when the go signal (described in the next paragraph) appeared or stand still when the no-go signal appeared. Each trial began with a fixation cross (500 ms) followed by a blank screen (lasting 300–1,000 ms) and by the presentation of the go or no-go stimulus (1,000 ms; Figure 1). The interstimulus interval lasted 1,000 ms. Acoustic feedback was provided for all correct responses.

In the emotional task (Figure 1A), participants were required to perform a single step forward when an emotional expression was shown (either expressing anger or happiness; go stimulus). Instead, they had to withhold the movement while maintaining the standing position when the face had a neutral expression (no-go stimulus). There were eight pictures (2 genders × 2 persons × 2 emotions) for the go trial condition and four pictures (2 genders × 2 persons × 1 neutral expression) for the no-go trial condition. Each picture was repeated 15 times for a total of 180 trials randomly presented (120 go trials, frequency = 67%; 60 no-go trials, frequency = 33%).

In the gender task (Figure 1B), participants were instructed to take a step forward when a male (or female) face was presented (go stimulus) or inhibit the movement while maintaining the standing position at the presentation of a female (or male) face (no-go stimulus). The gender of participants and that of pictures were balanced. There were six pictures (1 gender × 2 persons × 3 emotions) for the go trial condition and six pictures (1 gender × 2 persons × 3 emotions) for the no-go trial condition. Each picture was repeated 15 times for a total of 180 trials randomly presented (120 go trials, frequency = 67%; 60 no-go trials, frequency = 33%). The presentation order of the two tasks was counterbalanced across participants. In all cases, no instructions were given on step size or speed.

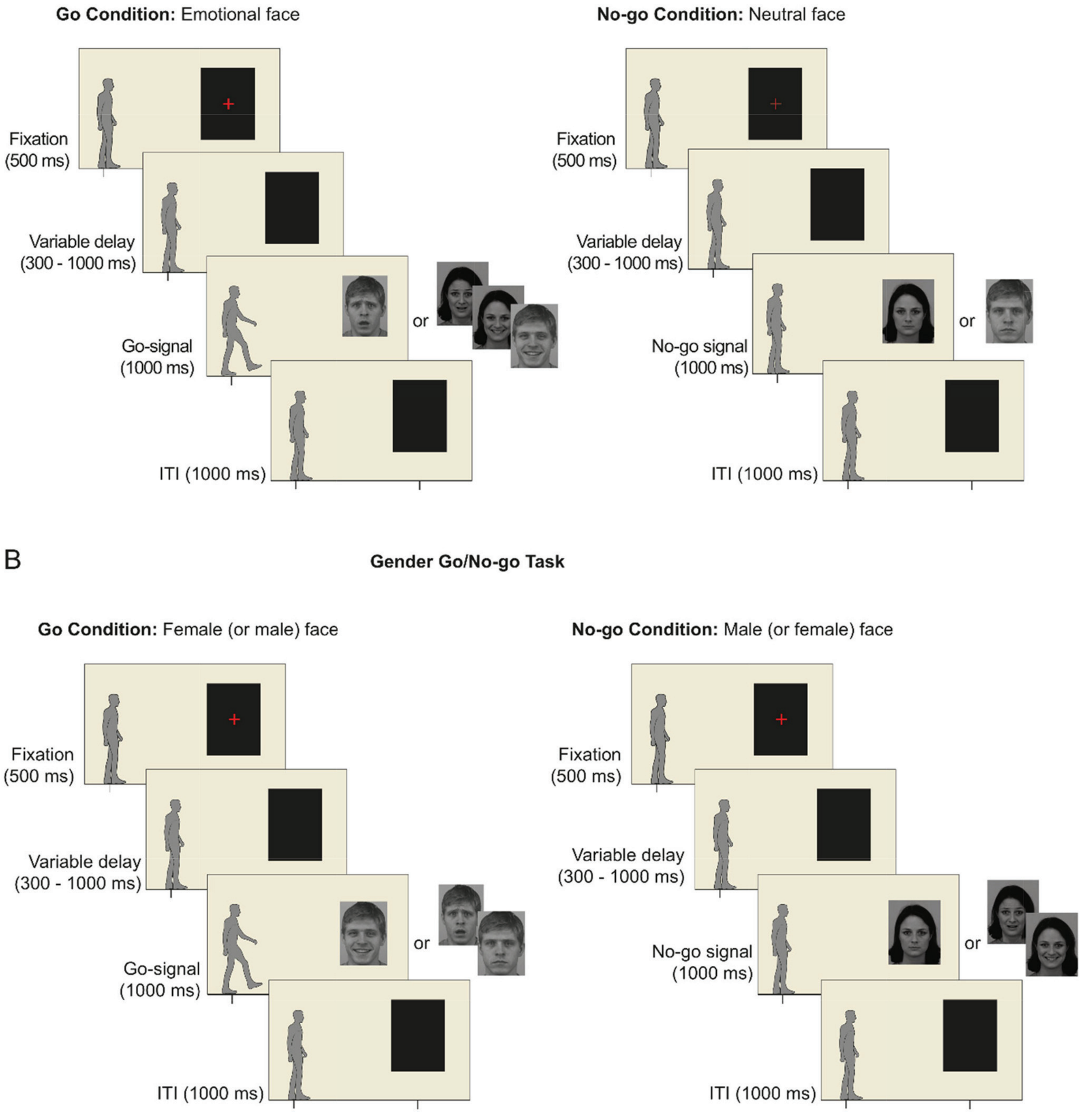
Data Analyses

The data of the left and right heel marker positions were smoothed and differentiated using a LOESS (generalized Savitzky–Golay) filter. Movement start (and stop) was detected on the instantaneous velocity profile, and it was based on the first heel 3D displacement that continuously exceeded (or was lower than) 0.5 mm (this value is based on the instrument error). The anticipatory postural adjustments have not been measured because we could not use a force plate to record kinetic data.

We analyzed kinematic data to calculate (a) the RT (defined as the interval of time between the go stimulus onset and the movement start), (b) the movement time (defined as the interval of time from the beginning to the end of the first step), (c) the step length, (d) the maximum step height, (e) the average velocity, (f) the peak velocity, (g) the time to peak velocity, (h) the average acceleration, (i) the peak acceleration, and (j) the time to peak acceleration. We also analyzed the lifting and displacement components of the step by computing the velocity and acceleration parameters on the vertical and anteroposterior axis, respectively.

The parameters were analyzed with an ANOVA with two within factors, that is, task (emotional, gender) and emotion (angry, happy), and one between factor, that is, the delta arousal (high, low). The inclusion in the analysis of the between factor was necessary because the arousal level of the angry and happy faces was different for each participant. Hence, we used the Revised Standardized Difference Test (RSDT; Crawford & Garthwaite, 2005) to compare arousal ratings for happy and angry faces. The RSDT allows checking whether the standardized difference between individuals' ratings differed significantly from the average difference of the other *n*-1 judgments, considered as a control group. The method generates an index for the rarity of the individual's difference, which is expressed as a proportion of the population with a greater discrepancy. We used this index, named delta arousal and expressed as a percentile, to create two equally sized subgroups. Participants with a standardized difference in arousal ratings below the 25th percentile and above the 75th were included in the "high arousal difference" group, while the others, that is, those with an index between the 25th and 75th percentiles, were included in the "low arousal difference" group. Post hoc comparisons were corrected with the Bonferroni method, and effect size measures were reported as partial eta squared and Cohen's *d*. We also computed the Bayes factor

Figure 1
Experimental Design



Note. Panel A: Emotional task. Each trial started with a fixation cross at the center of the display, which disappeared after 500 ms. The screen remained black for a variable period of 300 to 1,000 ms. Then, a picture of one of six facial expressions appeared. Participants were instructed to step forward when the face expressed an emotion (happiness or anger; go signal) or to remain still when the face displayed a neutral expression (no-go signal). Correct trials were signaled with acoustic feedback. Panel B: Gender task. The sequence of the events was the same as in Panel A. However, in the male version, participants were instructed to step forward only when a male face was shown irrespective of his emotion (go signal) and refrain from moving when a female face was presented (no-go signal), and vice versa in the female version. Correct trials were signaled with acoustic feedback. ITI = intertrial interval. In the figure, we used face stimuli from the Karolinska Directed Emotional Faces database (Goeleven et al., 2008), which can be freely published. See the online article for the color version of this figure.

Table 2
Means and Standard Deviations of Behavioral and Kinematic Parameters

Variable	Emotional task		Gender task		
	Angry	Happy	Angry	Happy	Neutral
Reaction time (ms)	687 ± 57	622 ± 56	628 ± 80	619 ± 75	621 ± 68
Errors (%)	2.15 ± 3.51	.25 ± .61	.34 ± 1.04	.17 ± .75	.25 ± .90
Movement time (ms)	526 ± 67	531 ± 70	530 ± 84	530 ± 80	540 ± 112
Peak velocity (m/s)	2.32 ± .33	2.29 ± .32	2.29 ± .32	2.29 ± .33	2.30 ± .36
Time to peak velocity (ms)	274 ± 32	278 ± 33	278 ± 40	276 ± 44	276 ± 42
Peak velocity anteroposterior (m/s)	2.25 ± .34	2.22 ± .32	2.23 ± .32	2.22 ± .33	2.22 ± .36
Time to peak velocity anteroposterior (ms)	280 ± 33	287 ± 35	283 ± 42	283 ± 45	283 ± 44

Note. Post hoc tests were adjusted according to Bonferroni.

(BF_{10}; Jarosz & Wiley, 2014) using default priors by the R package BayesFactor (Morey & Rouder, 2018). Although the Bayes factor is a continuous statistical index, the strength of the evidence supporting the alternative/null hypothesis can be graded as follows: (a) $BF_{10} > 2$ and $BF_{10} > 10$ constitute substantial and strong support for the alternative hypothesis, respectively; (b) $BF_{10} < .10$ and $BF_{10} < .33$ provide strong and substantial support for the null hypothesis, respectively; and (c) $.33 < BF_{10} < 2$ can be considered as inconsistent for any hypothesis.

To compare the temporal dynamic of the movement elicited by happy or angry facial expressions in emotional and gender tasks, we extracted the mean profiles of the instantaneous velocity, normalizing the execution time for each participant between the starting frame (movement initiation, 0%) and the frame at the heel-off of the leading foot (100%). At each time point (percentile), and for each trial, we computed the instantaneous velocity difference between happy and angry facial stimuli in both tasks. For these differences, we calculated paired-samples *t* statistics, testing for significant differences from zero. Significance thresholds were set at $\alpha = .025$. Finally, we computed the BF_{10}, expressed in terms of logarithms to maintain the same scale as the *t* scores, with values greater than 1.10 and 2.30, respectively, indicating substantial and strong support for the alternative hypothesis and values lower than −1.10 and −2.30, respectively, indicating substantial and strong support for the null hypothesis.

Transparency and Openness

All data, analysis code, and research materials are freely available from the Open Science Framework platform (Mirabella, 2022). This study's design and its analysis were not preregistered.

Results

The mean values and statistics of behavioral and kinematic parameters are summarized in Tables 2, 3 and 4 and will be presented separately in the next paragraph. The parameters of step length, maximum step height, average velocity, peak and time to peak velocity of the vertical component, average acceleration, peak acceleration, and time to peak acceleration did not yield any statistical differences between conditions and therefore will not be discussed further.

Reaction Times

The ANOVA on mean RTs showed a statistically significant main effect of the factors of task and emotion and the interaction between them (see Table 3). The main effect of emotion was because participants reacted more slowly after the presentation of angry than happy faces. The main effect of the task indicated that participants had shorter RTs in the gender than in the emotional task. Their interaction qualifies both main effects. During the emotional task, the RTs to angry faces were longer than to happy faces. By contrast, there was no difference in RTs between the two facial expressions in the gender task (see Figure 2). The Bayesian analyses strongly supported the existence of a significant difference between angry and happy expressions in the emotional task ($BF_{10} > 100$). By contrast, the same analyses yielded inconclusive results in the gender task ($BF_{10} = 1.23$). As in the go trials of the gender task, we presented angry, happy, and neutral facial expressions, and we compared the mean RTs among these conditions via a one-way ANOVA (factors: facial expressions [happy, anger, neutral]). We did not find any significant difference, one-way ANOVA: $F(2, 38) = 1.93$, $\eta_p^2 = .0026$; $p = .158$; $BF_{10} = .53$.

Omission Errors

The ANOVA on the omission errors showed a statistically significant main effect of the factors task and emotion and a significant interaction between them (see Table 3). Emotion's main effect was because participants made a higher rate of omission errors for angry than for happy faces. The task's main effect was due to a higher percentage of omission errors during the emotional than during the gender task. Their interaction qualifies both main effects. During the emotional task, omission errors to angry faces were higher than to happy faces. Even though this difference was not statistically significant ($p = .063$), the Bayesian analysis ($BF_{10} = 2.26$) supported the alternative hypothesis for the existence of a difference between angry and happy expressions. Differently, in the gender task, there was no difference between the two facial expressions (see Figure 2), and the Bayesian analyses strongly supported the absence of differences between emotional facial expressions ($BF_{10} < .33$). The other Bayesian analyses provided moderate support in favor of the alternative hypothesis for the main effects of emotion, task, and their interactions (BF_{10}s ranged from 2.01 to 3.61). We could not perform a one-way ANOVA comparing omission errors for angry, happy, and neutral

Table 3
Results of the Statistical Analyses on Behavioral Parameters

Variable	Effect	Factors	*df*	Statistics	*p* value	ES	BF_{10}
Reaction time	Main	Task	1, 18	*F* = 8.08	**.011**	.31	61.52
	Main	Emotion	1, 18	*F* = 81.82	**.000**	.82	672.44
	Main	Delta arousal	1, 18	*F* = .65	.432	.03	0.68
	Interaction	Task × Emotion	1, 18	*F* = 54.66	**.000**	.75	173.54
	Interaction	Task × Delta Arousal	1, 18	*F* = 3.46	.079	.16	13.07
	Interaction	Emotion × Delta Arousal	1, 18	*F* = .13	.724	.01	1.32
	Interaction	Task × Emotion × Delta Arousal	1, 18	*F* = 2.18	.157	.11	0.10
	Post hoc comparison	Emotional task: anger vs. happy	18	*t* = 9.87	**.000**	2.27	2,824,001
		Gender task: anger vs. happy	18	*t* = 1.96	.132	0.45	1.23
Omission errors	Main	Task	1, 18	*F* = 5.19	**.035**	.22	2.31
	Main	Emotion	1, 18	*F* = 5.02	**.038**	.22	3.61
	Main	Delta arousal	1, 18	*F* = .51	.484	.03	.35
	Interaction	Task × Emotion	1, 18	*F* = 4.55	**.047**	.20	2.01
	Interaction	Task × Delta Arousal	1, 18	*F* = .12	.731	.01	.32
	Interaction	Emotion × Delta Arousal	1, 18	*F* = .02	.882	.00	.32
	Interaction	Task × Emotion × Delta Arousal	1, 18	*F* = .32	.576	.02	.44
	Post hoc comparison	Emotional task: anger vs. happy	18	*t* = 2.33	.063	0.54	2.26
		Gender task: anger vs. happy	18	*t* = .57	1.000	0.13	0.27
Movement time	Main	Task	1, 18	*F* = .03	.876	.00	.23
	Main	Emotion	1, 18	*F* = 3.28	.087	.15	.24
	Main	Delta arousal	1, 18	*F* = .35	.564	0.02	.72
	Interaction	Task × Emotion	1, 18	*F* = 2.89	.106	.14	.32
	Interaction	Task × Delta Arousal	1, 18	*F* = .68	.421	.04	.72
	Interaction	Emotion × Delta Arousal	1, 18	*F* = .77	.39	.04	.30
	Interaction	Task × Emotion × Delta Arousal	1, 18	*F* = .07	.798	.00	.39
	Post hoc comparison	Emotional task: anger vs. happy	18	*t* = −2.52	**.043**	0.58	3.15
		Gender task: anger vs. happy	18	*t* = .32	1.000	0.07	0.24

Note. Delta arousal = index of the arousal difference between angry and happy faces stimuli (see text for more details); ES = effect size, partial eta squared for the ANOVAs and Cohen's *d* for the post hoc tests; BF_{10} = inclusion Bayes factor, computed by means of Bayesian model averaging across matched models satisfying the principle of marginality. *p* values are reported in bold when $< .05$.

faces because participants did not make any errors on neutral expressions (and very few for happy and angry expressions).

Movement Times

The ANOVA on movement times did not show any significant effect. Therefore we will not discuss this behavioral parameter further.

Kinematic Parameters

The ANOVA on the peak velocity showed a significant main effect of the factor emotion and a significant interaction between task and emotion (see Table 4). The main effect of emotion was due to the fact that the peak velocity was higher for angry than for happy faces (see Table 2). The interaction between task and emotion better explained the main effect. The peak velocity for the angry faces was higher than for happy faces in the emotional task, but there was no difference in the gender task. The ANOVA on time to peak velocity showed only an interaction between the factors task and emotion. Such interaction was because the time to peak velocity was shorter for angry faces than for happy faces just in the emotional task but not in the gender task.

The ANOVAs of the velocity parameters on the anteroposterior component (peak and time to peak) provided similar results (see Table 4). We found a main effect of the factor emotion, indicating a higher mean value of the anteroposterior peak velocity for angry than for happy faces. This effect is explained by the significant effect of the interaction between task and emotion, showing that the anteroposterior peak velocity was higher for angry than for happy faces just in the emotional task. The analyses on the time to peak velocity of the anteroposterior component showed only a significant effect of the interaction between task and emotion. This was because the time to peak velocity was shorter for angry than for happy faces in the emotional task. No differences were found in the gender task. It is worthy of underlining that in all instances, Bayesian analyses on kinematics parameters provided inconsistent support in favor of the alternative hypothesis for the interaction Emotion × Task (all BF_{10}s $\leq .40$). Nevertheless, the Bayesian analyses provided substantial or strong support in favor of the alternative hypothesis for the post hoc tests comparing the effect of happy versus angry faces in the emotional task (all BF_{10}s > 6).

Finally, the comparison of the instantaneous velocities (Figure 3) revealed that in the emotional task, the profile was higher for angry than for happy facial stimuli between the 30th and 50th percentiles. In particular, the percent time to peak velocity occurred earlier for angry expressions (angry faces: % peak velocities = 53%, *SE* = 1%; happy faces: % peak velocity = 54%, *SE* = 1%; *t* = −2.67; *df* = 19; *p* = .030). By contrast, the instantaneous velocity profiles for angry and happy faces almost overlapped in the gender task.

Discussion

We assessed the impact of task relevance of angry and happy facial expressions on forward GI for the first time. As we predicted, we found that such emotional faces affected forward step movements only when relevant to participants' goals, that is, when the

Table 4
Results of the Statistical Analyses on Kinematic Parameters

Variable	Effect	Factors	*df*	Statistics	*p* value	ES	BF_{10}
Peak velocity	Main	Task	1, 18	$F = .07$	.789	.00	.25
	Main	Emotion	1, 18	$F = 9.57$	**.006**	.35	.26
	Main	Delta arousal	1, 18	$F = .12$	.737	.01	.71
	Interaction	Task × Emotion	1, 18	$F = 5.45$	**.031**	.23	.36
	Interaction	Task × Delta Arousal	1, 18	$F = .87$	.364	.05	.91
	Interaction	Emotion × Delta Arousal	1, 18	$F = .99$	.334	.05	.30
	Interaction	Task × Emotion × Delta Arousal	1, 18	$F = .54$	.473	.03	.38
	Post hoc comparison	Emotional task: anger vs. happy	18	$t = 3.26$	**.009**	.75	12.96
		Gender task: anger vs. happy	18	$t = -.23$	1.000	.05	.24
Time to peak velocity	Main	Task	1, 18	$F = .02$	.882	.00	.23
	Main	Emotion	1, 18	$F = 1.93$	.181	.10	.24
	Main	Delta arousal	1, 18	$F = .72$	.407	.04	.69
	Interaction	Task × Emotion	1, 18	$F = 5.04$	**.038**	.22	.40
	Interaction	Task × Delta Arousal	1, 18	$F = .01$	.929	.00	.30
	Interaction	Emotion × Delta Arousal	1, 18	$F = 2.56$	.127	.13	.32
	Interaction	Task × Emotion × Delta Arousal	1, 18	$F = .83$	.374	.04	.37
	Post hoc comparison	Emotional task: anger vs. happy	18	$t = -2.94$	**.018**	.67	6.81
		Gender task: anger vs. happy	18	$t = .92$	.736	.21	.35
Peak velocity (anteroposterior)	Main	Task	1, 18	$F = .12$	.730	.01	.27
	Main	Emotion	1, 18	$F = 14.43$	**.001**	.44	.28
	Main	Delta arousal	1, 18	$F = .12$	.738	.01	.68
	Interaction	Task × Emotion	1, 18	$F = 7.90$	**.011**	.31	.38
	Interaction	Task × Delta Arousal	1, 18	$F = .85$	.370	.05	.86
	Interaction	Emotion × Delta Arousal	1, 18	$F = 2.50$	.131	.12	.32
	Interaction	Task × Emotion × Delta Arousal	1, 18	$F = .01$	.934	.00	.44
	Post hoc comparison	Emotional task: anger vs. happy	18	$t = 3.88$	**.002**	.89	45.25
		Gender task: anger vs. happy	18	$t = -.05$	1.000	.01	.23
Time to peak velocity (anteroposterior)	Main	Task	1, 18	$F = .00$	.968	.00	0.23
	Main	Emotion	1, 18	$F = 4.01$	.060	.18	0.31
	Main	Delta arousal	1, 18	$F = .57$	.461	.03	0.66
	Interaction	Task × Emotion	1, 18	$F = 5.31$	**.033**	.23	0.39
	Interaction	Task × Delta Arousal	1, 18	$F = .00$	.979	.00	0.31
	Interaction	Emotion × Delta Arousal	1, 18	$F = .15$	.707	.01	0.30
	Interaction	Task × Emotion × Delta Arousal	1, 18	$F = 2.17$	.158	.11	0.35
	Post hoc comparison	Emotional task: anger vs. happy	18	$t = -3.11$	**.012**	.71	9.47
		Gender task: anger vs. happy	18	$t = -.16$	1.000	.04	.24

Note. Delta arousal = index of the arousal difference between angry and happy faces stimuli (see text for more details); ES = effect size, partial eta squared for the ANOVAs and Cohen's *d* for the post hoc tests; BF_{10} = inclusion Bayes factor, computed by means of Bayesian model averaging across matched models satisfying the principle of marginality. *p* values are reported in bold when $< .05$.

instruction was to move at the presentation of one of the two emotional expressions. In such instances, angry faces increased the RTs and the percentages of omission errors and concurrently increased several velocity parameters with respect to happy faces. By contrast, when the valence of facial expressions was task irrelevant, that is, when the instruction was to move at the presentation of a male/female face, the valence of emotional expressions did not yield any effect. This evidence strongly suggests that whole-body movements share the same processing of facial emotions of reaching arm movements (Mancini et al., 2020, 2022; Mirabella, 2018). In both cases, the context appraisal seems to be the key factor determining whether or not movement will be affected by the emotional content of the stimuli (Moors & Fischer, 2019; Scherer & Moors, 2019).

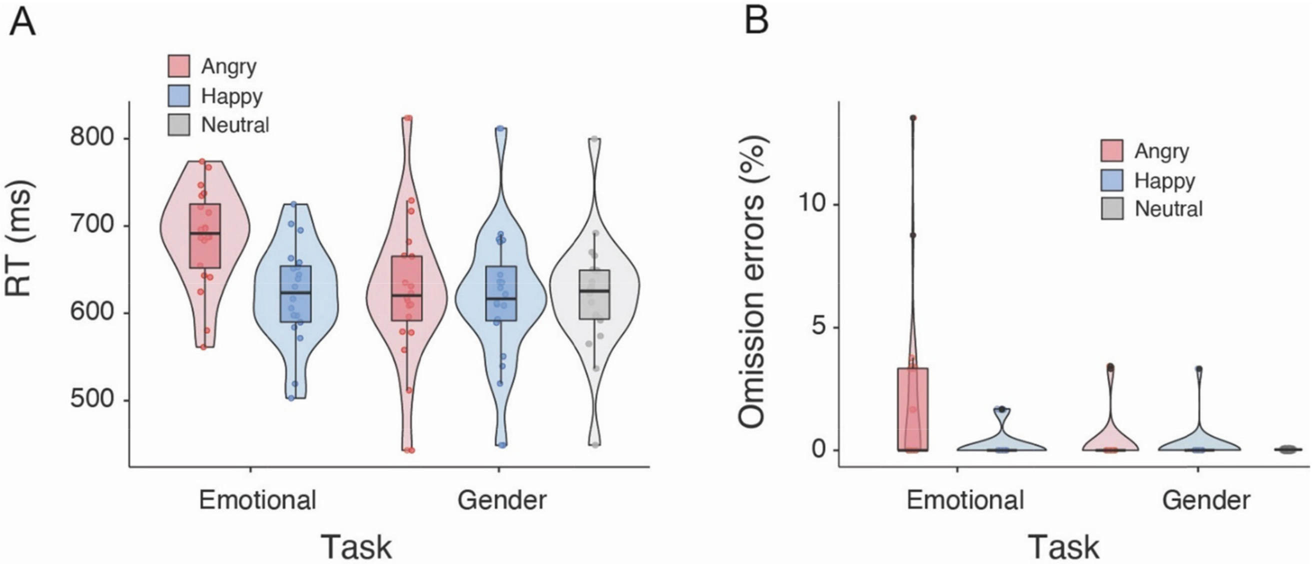
We believe that our results are very robust for several reasons. First, we adopted a within-subject design where all participants performed the two versions of the task. Second, we compared the effect of the same pictures when they were task relevant and task irrelevant on the same movements, that is, forward steps. Third, we included the factor arousal in all our analyses, and we found that differences in this dimension of the emotional stimuli cannot explain the results. Fourth, Bayesian factors provided moderate or substantial support to the existence of (a) a difference between the effect of angry and happy faces on RTs, omission errors, and the above-described velocity parameters in the emotional task and (b) the absence of such differences in the gender task.

The Importance of Conscious Appraisal and Task Relevance in Processing Facial Emotions

Our data do not support the idea that pleasant items automatically promote approaching behaviors while unpleasant items trigger avoidance behaviors (Bradley et al., 2001; Vuilleumier, 2005). Differently, we found that the effect of facial emotions critically depends on the conscious appraisal of the context in which a person is acting. Thus, the presentation of angry faces elicits a freezing-like response by increasing the length of RTs and the rate of omission errors with respect to happy faces only when participants are explicitly instructed to pay attention to emotional facial expressions. These results are in keeping with the idea that emotion processing is a dynamic and multicomponent process in which a crucial component is the conscious stimuli evaluation (Scherer &

Figure 2

Effect of Emotional Facial Expressions on Reaction Times (RTs; Panel A) and the Rate of Omission Errors (Panel B) in the Emotional Task (on the Left) and in the Gender Task (on the Right)



Note. Only in the emotional task, participants were slower and made a higher percentage of omission errors when the go signal was an angry face than when it was a happy face. See the online article for the color version of this figure.

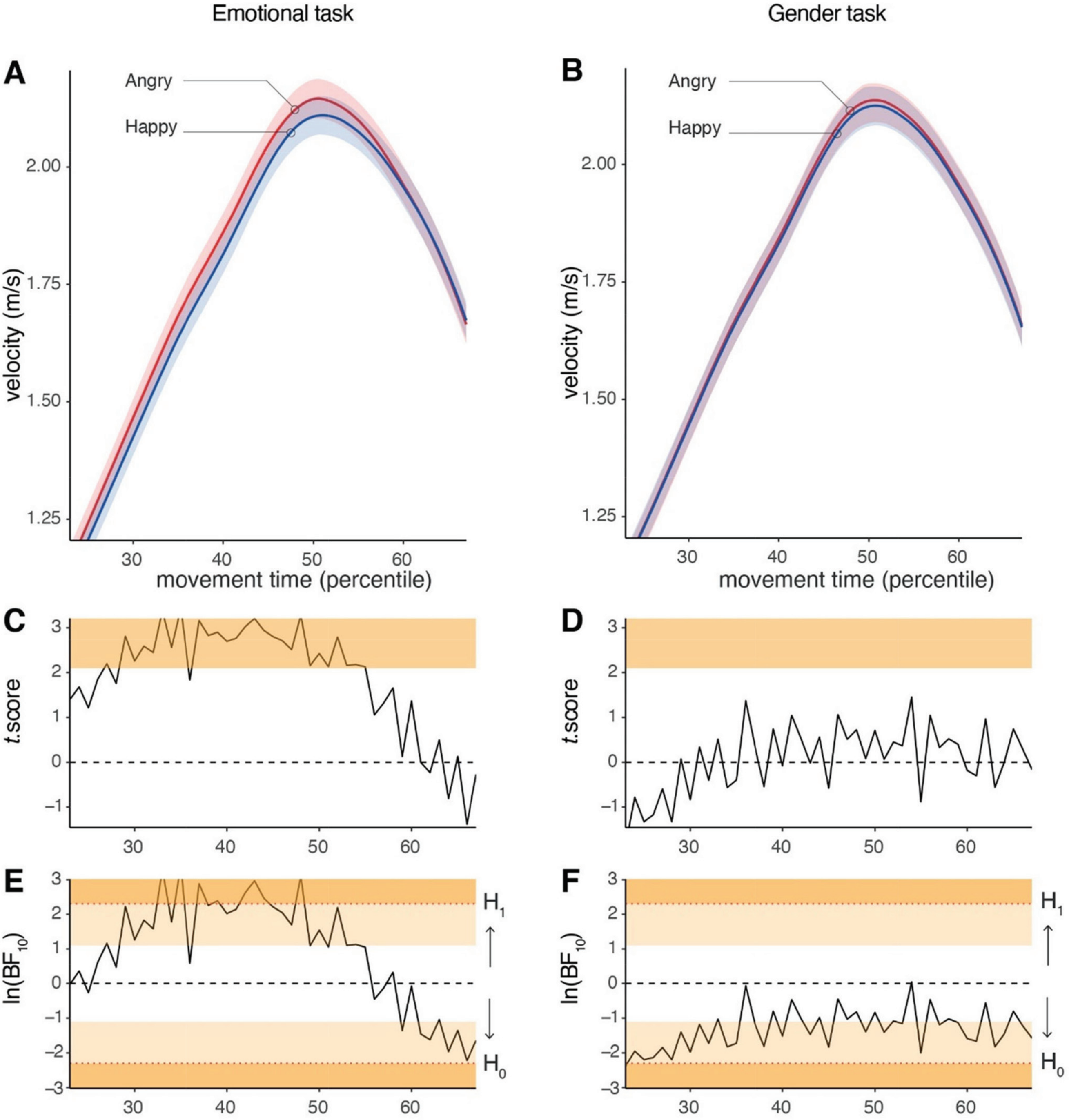
Moors, 2019). According to this view, the valence of a stimulus does not necessarily produce a specific action tendency, that is, approach or avoidance behaviors. Accordingly, Eder and Rothermund (2008) showed that the effect of affective stimuli depends upon the action instructions. This is also what we found, that is, the valence of the stimuli is weighted on the task goals. Therefore, subjects evaluate the valence of the same angry face very differently in the emotional and gender tasks. In fact, in the former task, angry and happy expressions yielded different RTs of forward GI, while in the gender task, the faces' valence did not affect the participants' performance, that is, participants reacted in similar ways to angry, happy, and neutral expressions. Such evidence is in line with that of Mancini et al. (2022), who showed that when stimuli valence was task irrelevant, participants withheld movements with similar degrees of success to neutral, fearful, or happy expressions.

Previous evidence also suggested that task relevance impacts forward GI, but the picture is much less clear-cut. Often emotional pictures are task irrelevant. A design that has been frequently adopted is the one in which participants are instructed to execute a forward (Bouman et al., 2015; Gélat & Chapus, 2015; Naugle et al., 2011; Stins et al., 2015) or a backward (Bouman & Stins, 2018) step at the presentation of IAPS pictures. At least in principle, in all these instances, participants could disregard the emotional content of the images to perform the task because they always have to move when a picture is shown. This is likely why results are very mixed, and several findings seems to contradict the MDH. First, as described in the introduction, the image valence does not affect step parameters when backward steps are required. Second, the effects of emotional pictures on forward GI depend (a) on whether participants have to move at the onset or offset of the images, that is, emotions do not always have the same effect, and (b) on the pictures' arousal. In fact, Bouman et al. (2015) showed that the effect of viewing duration on forward GI is due to the arousal and not to the valence of IAPS pictures. Using a different approach, Stins et al. (2014) found that when participants are requested to step forward or backward according to the faces' gender, disregarding the facial emotions, the RTs of steps were longer for angry than for neutral or happy female faces regardless of movement direction. However, male faces did not affect forward GI. Thus, in this instance, the effect of emotions on forward GI seemed to depend upon the actors' gender. Clearly, this is at odds with the MDH, which, among other things, does not predict different effects of emotions according to such images' features, that is, same valence but different gender. Interestingly, the design of this experiment is similar to that of our gender task. However, as Stins et al. (2014) did not control for the pictures' arousal, and they included only women, it is hard to make a comparison with our results.

When emotional images were task relevant (Stins & Beek, 2011; Stins et al., 2011; Yiou et al., 2014) and participants were requested to step backward or forward according to the stimulus valence, the results were less ambiguous, but such effect potentially conflates with movement planning. A common finding is that forward steps toward unpleasant pictures (Stins et al., 2011; Yiou et al., 2014) or angry faces (Stins & Beek, 2011) had longer RTs than toward pleasant images (Stins et al., 2011; Yiou et al., 2014) or happy faces (Stins & Beek, 2011). By contrast, emotional images never affected backward steps. Crucially in all these experiments, valence and arousal of emotional pictures differed, but arousal was never used as a factor in the analyses. Therefore, it is impossible to disentangle the effect of these two dimensions on GI.

Figure 3

Mean Instantaneous Velocity Profiles for Angry and Happy Faces



Note. Panels A, C, and E refer to the Emotional Task, and panels B, D, and F refer to the Gender Task. Mean instantaneous velocity profiles for angry and happy faces in the emotional task (Panel A) and gender task (Panel B). The movement time has been normalized to 100%. Panels C (for the emotional task) and D (for the gender task) show the *t* score of the comparison between the instantaneous velocity profiles for angry and happy faces computed at each time point. The colored band indicates the significance threshold for $\alpha = .025$. Panels E (for the emotional task) and F (for the gender task) show the values of the Bayes factors (BF_{10}) computed at each time point on a logarithmic scale. Values greater than 1.10 and 2.30, respectively, indicate substantial and strong support for the alternative hypothesis. Values lower than −1.10 and −2.30, respectively, indicate substantial and strong support for the null hypothesis (see text for more details). See the online article for the color version of this figure.

All in all, these data provide weak support, if any, to the MDH. First, the fact that backward GI is unaffected by images' valence (Bouman & Stins, 2018) is at odds with the MDH, which would predict that unpleasant stimuli should facilitate backward whole-body movements to allow the agents to increase the distance from potential threats. Second, the MDH predicts that pleasant stimuli would always promote forward whole-body movements, and the strength of the effect should increase with the stimuli arousal (Bradley et al., 2001). However, both predictions failed to be supported by empirical data as viewing duration and arousal values affect movement directionality (Bouman et al., 2015; Naugle et al., 2011; Stins et al., 2015). So, for instance, at picture onset, facilitation to approach positive items occurs only for low- but not high-arousing pleasant stimuli (Stins et al., 2015). In addition, when participants have to move at pictures' offset, the GI's parameters are influenced by the items' arousal and not by their valence (Bouman et al., 2015). Finally, the results of many studies are questionable as it is impossible to dissociate the effect of arousal from that of valence as images differ for both (Naugle et al., 2010; Stins et al., 2015; Yiou et al., 2014), or the arousal value was not measured (Stins & Beek, 2011; Stins et al., 2014).

Overall, the MDH does not provide a reliable account of either our findings or the mixed results of the literature. Differently, the suggestion that emotional pictures are appraised differently according to their relevance to the subject's goal might provide a better explanation of current evidence. Importantly, the effect of task relevance on the processing of emotional facial expressions we found in this and other studies (Mancini et al., 2020, 2022; Mirabella, 2018) speaks against the automatic processing of facial emotional expressions. Our results suggest that emotions do not influence cognitive processes unless the context requires it. The "dual competition framework" (Pessoa, 2009) suggests a theoretical framework for linking stimuli valence, motivation, cognitive processes, and behavioral responses in the recent past. This hypothesis suggests that emotions and motivation affect both the perceptual competition between stimuli and the competition between executive functions as they share common processing resources. According to Pessoa (2009), the impact of valenced stimuli on behavior would depend on how they affect the functioning of executive functions. This would be determined by two factors: (a) the threat level and (b) the task relevance. When the threat level is low, the automatic attentional bias toward emotional stimuli is moderately enhanced, and the behavioral effect, although weak, enhances target processing. Conversely, when the level of threat is high, then the attentional prioritization is very potent, and thus common processing resources are diverted away from other executive functions that are impaired. As a consequence, emotional items that are high in threat will impair behavioral performance even though their sensory processing is enhanced. Relevant for our findings are the predictions made according to stimuli task relevance. Pessoa (2009) suggested that when emotional stimuli are task relevant, behavioral performance would be improved because additional processing resources will typically be devoted to its processing (relative to neutral). Differently, when task irrelevant, emotional items would impair performance because resources will be taken away from the task at play. The predictions of the dual competition framework do not fit our results as, when task irrelevant, emotional faces do not yield different effects on behavior with respect to neutral stimuli. Furthermore, task-relevant emotional stimuli do not generically improve behavioral performance but have a different effect according to their valence. Finally, differently from what Pessoa (2009) predicted, in low-threat conditions like those occurring in laboratories, the effects of emotional faces are not weak but very consistent. Notably, we do not completely exclude the possibility that emotional items could grab attention automatically. Such an event could occur when the subjects' arousal is very high, for example, when a person is or feels like they are in real danger.

The Effect of Happy and Angry Faces on Forward GI

We found that when task relevant, angry expressions increase the RTs and the rate of omission errors with respect to happy faces. These results indicate that participants tend to delay the approach to unpleasant stimuli and vice versa. Importantly, these effects are due solely to the valence and not to the arousal of the stimuli. Similarly, the effects on kinematic parameters related to peak velocity are due just to the picture valence as the factor of arousal is never significant. The outcomes of these analyses showed that both overall and anteroposterior peak velocities and times to peak velocity were shorter for angry expressions than for happy expressions. Further, the instantaneous velocity profile was higher for angry than happy faces in the emotional task. In other words, when participants have to step forward after the presentation of task-relevant angry faces, they tend to postpone the start of the movement, but as soon as they initiate the step, they move faster than when task-relevant happy faces are shown. The simultaneous slowdown of step initiation and speed up of movement execution can be interpreted as a compensation mechanism aiming to optimize the motor strategy. However, to be effective, the increase of velocity parameters for angry expressions should lead to faster movement times, but this is not the case. Further studies will need to clarify this issue. Importantly, whether the behavioral tendency described above for angry faces is compatible with the MDH is questionable as it is unclear whether anger primes an approach or avoidance behavior (Carver & Harmon-Jones, 2009). On the one hand, Wilkowski and Meier (2010) showed that task-relevant facial anger expressions facilitate approach behaviors, and they explained their results by arguing that when a person's social status or relationships are challenged, the most adaptive response is to face and overcome the threat. On the other hand, Marsh et al. (2005) showed precisely the opposite, that is, task-relevant angry faces elicit avoidance behavior, while fearful faces elicit approach tendencies. According to the authors, the latter result could be explained because fearful faces could elicit caregiving from other conspecifics. In both studies, participants were required to use the upper limb, images' arousal was not assessed, and the sample sizes were relatively large (> 48). Thus, it is not easy to explain these opposite results. To the best of our knowledge, there is just one study in which the effect of anger on forward GI was studied (Fawver et al., 2014). Fawver et al. (2014) found that self-generated emotional states of anger elicit approach responses. In sum, our study is the first one to assess the effect of task-relevant angry expressions on perceivers' forward GI. Further research is needed to assess the effects on forward GI of anger as well as of other facial negative emotions, that is, fear, sadness, and disgust, as each of them conveys different social signals. It would also be of great interest to study the effect of proximity of emotional faces as it has been shown that the distance at which a facial expression is shown affects behavioral reactions (Dureux et al., 2021).

Conclusions

We compared the effect of task relevance of angry and happy facial expressions on forward GI using a within-subjects design and controlling for both the arousal and the valence dimensions of emotional images. Our results indicate that emotional expressions affect gait parameters only when participants are explicitly told to move according to the valence of the picture. Importantly, when facial emotions are task relevant, participants approach pleasant faces more easily than unpleasant faces. By contrast, picture valence does not affect forward GI when facial expressions are irrelevant to the task performance. These results show that the effect of facial emotions on whole-body movements is analogous to the one exerted on reaching arm movements (Mancini et al., 2020, 2022; Mirabella, 2018). Such evidence is not trivial as with the development of bipedal gait, the neural control of upper limbs became independent from that of lower limbs, although arm swing can actively contribute to locomotion (Kaupp et al., 2018). Thus, the influence of facial emotional expressions on movements goes beyond the effectors employed, once again revealing the crucial role of such stimuli in social interactions (Blair, 2003; Jack & Schyns, 2015). As a consequence, it derives that, at least in low-threat conditions, facial emotions do not affect behavioral tendency automatically. Instead, their effects depend critically on their conscious context-related evaluation (Scherer & Moors, 2019). Future studies will be needed to assess whether these findings could be extended to all emotional stimuli. In particular, it would be particularly interesting to check whether task relevance has the same effect on IAPS pictures (Lang et al., 2005), that is, one of the most widely used sets of emotional images. Actually, it has been shown that IAPS pictures have higher arousal than facial expressions (Britton et al., 2006). Thus, in principle, a higher level of arousal might not allow individuals to disregard the emotional content of the picture even when task irrelevant.

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