COGNITION AND EMOTION, 2014
Vol. 28, No. 2, 325–344, http://dx.doi.org/10.1080/02699931.2013.824871

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# Happiness takes you right: The effect of emotional stimuli on line bisection

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Emotion recognition is mediated by a complex network of cortical and subcortical areas, with the two hemispheres likely being differently involved in processing positive and negative emotions. As results on valence-dependent hemispheric specialisation are quite inconsistent, we carried out three experiments with emotional stimuli with a task being sensitive to measure specific hemispheric processing. Participants were required to bisect visual lines that were delimited by emotional face flankers, or to haptically bisect rods while concurrently listening to emotional vocal expressions. We found that prolonged (but not transient) exposition to concurrent happy stimuli significantly shifted the bisection bias to the right compared to both sad and neutral stimuli, indexing a greater involvement of the left hemisphere in processing of positively connoted stimuli. No differences between sad and neutral stimuli were observed across the experiments. In sum, our data provide consistent evidence in favour of a greater involvement of the left hemisphere in processing positive emotions and suggest that (prolonged) exposure to stimuli expressing happiness significantly affects allocation of (spatial) attentional resources, regardless of the sensory (visual/auditory) modality in which the emotion is perceived and space is explored (visual/haptic).

*Keywords:* Bisection; Emotional valence; Hemispheric asymmetry; Haptics; Cross-modal.

The ability to recognise the emotional state of other individuals is critical for social interactions. Emotions can be inferred by facial expressions or body gestures, by vocal expressions (such as laughing or crying) and the emotional lexicon, but also conveyed by speech intonation, stress and rhythm (i.e., emotional prosody). Perception of emotions is subtended by a complex network of cortical and subcortical regions, including the amygdala–hippocampal region, the anterior cingulate, the basal ganglia, the medial orbitofrontal cortex, the ventromedial and dorsolateral prefrontal

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This work was supported by Vigoni/DAAD grant (years 2012–2013) to CCC and ZC.

We thank Simone Riva and Carlo Toneatto for technical support, Susanna Schiavi and Laura De Vita for helping with data collection.

cortex, the superior temporal cortices, and sensory regions (e.g., Britton et al., 2006; Davidson & Irwin, 1999; Grimm et al., 2006; Heilman, 1997; Peelen, Atkinson, & Vuilleumier, 2010; Said, Haxby, & Todorov, 2011; Tamietto & de Gelder, 2010; Vuilleumier & Pourtois, 2007). Interestingly, neuroimaging findings suggest that specific emotions may be represented supramodally in the brain (i.e., regardless of the emotion being conveyed by facial expressions, gestures, or vocal sounds; Klasen, Kenworthy, Mathiak, Kircher, & Mathiak, 2011; Peelen et al., 2010).

Notwithstanding the massive research carried out on this topic, whether emotions involve the two hemispheres to a different extent is still a highly debated issue (see Demaree, Everhart, Youngstrom, & Harrison, 2005; Killgore & Yurgelun-Todd, 2007; Watling, Workman, & Bourne, 2012, for reviews). On one side, the "right-hemisphere model" posits that emotions are mainly represented in the right hemisphere, regardless of their valence (e.g., Borod, Obler, Albert, & Stiefel, 1983; Gainotti, 2012; Tucker, 1981). On the other side, the "valence model" argues that positive emotions mainly activate the left hemisphere and negative emotions the right hemisphere, a lateralisation that would mainly be evident in anterior brain regions (Davidson, 1992, 2003). It has also been suggested that emotional-valence dependent hemispheric specialisation may be modulated (or mediated) by related factors, such as whether emotion is perceived or actively expressed (e.g., Nicholls, Ellis, Clement, & Yoshino, 2004), or its associated level of arousal (calming vs. arousing) and action tendency (approach vs. withdrawal; cf. Maxwell & Davidson, 2007; see also Todorov, 2008).

Behavioural paradigms assessing laterality—employing, for instance, divided visual field presentation or dichotic listening—and neuroimaging and electrophysiological studies have led to contrasting results regarding hemispheric specialisation in emotional processing (see Demaree et al., 2005; Gadea, Espert, Salvador, & Marti-Bonmati, 2011; Killgore & Yurgelun-Todd, 2007, for reviews). In fact, even highly restricted behavioural paradigms of face perception with two basic emotions, happiness and sadness, yield inconsistent findings. For instance, using divided visual field presentation, Natale, Gur, and Gur (1983) found an overall right hemisphere (RH) advantage in emotional recognition, but also a left hemisphere (LH) bias in judging faces as more positive. Asthana and Mandal (2001) only reported a left visual-field (RH) superiority for sad facial emotions but no hemispheric advantage for happy faces. In classifying the expression (happy or neutral) of unfamiliar faces, a right hemisphere superiority was seen in terms of higher accuracy for left-visual field and bilateral presentation compared to right visual field presentation (Schweinberger, Baird, Bluemler, Kaufmann, & Mohr, 2003). Using a different paradigm, Jansari, Tranel, and Adolphs (2000) reported that healthy individuals were better at discriminating happy from neutral faces when the happy face was located to the viewer's right of the neutral face. Conversely, discrimination of sad from neutral faces was better when the sad face was presented to the left, supporting a role for the LH in processing positive valence and for the RH in processing negative valence (these results were only partially replicated though with brain-damaged patients; see Jansari et al., 2000). Data on hemispheric processing through the auditory modality showed similar inconsistencies (see Gadea et al., 2011, for a review). In an early study (Carmon & Nachshon, 1973), participants were more accurate in identifying stimuli (human laughing, crying, and shrieking) presented to the left ear (RH), regardless of their emotional valence. Accordingly, a consistent left ear/RH advantage for both happy and sad prosody (e.g., Rodway & Schepman, 2007) and vocal emotion (e.g., King & Kimura, 1972) was reported. Nonetheless, Bryden and MacRae (1988) observed an overall RH superiority for all prosodic emotion perception, but larger for sad than for happy stimuli (see also Erhan, Borod, Tenke, & Bruder, 1998). Grimshaw, Seguin, and Godfrey (2009) found that sad emotional prosody resulted into a reduction of the typical right ear advantage in word processing, indexing significant activation of the RH, whereas happy prosody did not.

Recently, Schepman, Rodway, and Geddes (2012) found a right/left ear advantage for happy/sad prosody, respectively, which was though conditioned by a series of factors including sex of participants (see below) and the type of vocal sound (original vs. morphed; Schepman et al., 2012).

Moreover, previous studies suggest that valence-dependent laterality may depend on the gender of the perceiver. For instance, Rodway, Wright, and Hardie (2003) found a valence specific laterality effect in female but not male participants, with females showing higher accuracy in discriminating negative facial emotions when these appeared in the left hemifield, and positive facial emotions more accurately when presented in the right hemifield. However, Schepman et al. (2012) reported a slight right-ear advantage for happy stimuli in male participants, and a left-ear advantage for sad stimuli in females. The gender of the person expressing the perceived emotion also matters: for instance, in a recent fMRI study both men and women showed greater neural responses to laughter in the same gender and crying in the opposite gender (Chun, Park, Park, & Kim, 2012). In a recent quantitative meta-analysis of neuroimaging studies (Stevens & Hamann, 2012), for the first time examining gender differences as a function of positive versus negative emotional valence, a consistent greater left amygdala response to negative emotion for women and greater left amygdala activation for positive emotional stimuli in men was found across several studies (Stevens & Hamann, 2012; see Kret & de Gelder, 2012, for another recent review on this topic). These works suggest the importance of paying attention to the gender variable in emotional studies to clarify inconsistencies likely depending on the specific task, participants' characteristics and material used.

Regardless of these hemispheric specialisation issues, there is general agreement that mechanisms mediating emotion perception and attention in the brain are strongly interconnected: actually, emotional stimuli (especially threatening ones; but see Brosch, Sander, Pourtois, & Scherer, 2008) attract attention more than neutral stimuli, a phenomenon that would be evolutionarily adaptive in facilitating response preparation (e.g., Öhman, Flykt, & Esteves, 2001; Phelps, Ling, & Carrasco, 2006). A standard task employed in clinic and research to assess allocation of spatial resources is the line bisection task, in which individuals are required to estimate the midpoint of a line. When tested with this task, right-hemisphere damaged neglect patients usually show consistent rightward deviations from the true midline (Halligan & Robertson, 1999; Marshall, 1998), whereas healthy individuals typically show a slight but systematic bisection bias to the left, referred to as pseudoneglect (Bowers & Heilman, 1980; see Jewell & McCourt, 2000, for a review), likely reflecting right-hemisphere dominance in spatial attention. Accordingly, fMRI evidence has shown that visual bisection tasks involve superior and inferior parietal lobes bilaterally, but predominantly on the right, beyond other regions such as the prefrontal cortex bilaterally, the anterior cingulate and parts of the cerebellum (Fink, Marshall, Weiss, & Zilles, 2001). Previous studies have demonstrated that bisection biases can be modulated, both in healthy individuals and patients, by the concurrent presentation of flankers conveying (directly or indirectly) directional information, such as arrows, eye gaze, or digits of different magnitude (Bonato, Priftis, Marenzi, & Zorzi, 2008; de Hevia, Girelli, & Vallar, 2006) or by concurrent manipulations affecting hemispheric activation (Nicholls et al., 2012). Brain stimulation findings suggest that the parietal cortex, and in particular the angular gyrus, play a critical role in mediating cueing effects (specifically, numerical cueing effects) on bisection accuracy (e.g., Cattaneo, Silvanto, Pascual-Leone, & Battelli, 2009). Notably, cross-modal effects have also been reported: for instance, listening to numbers of different magnitude has been found to affect tactile bisection in both healthy and neglect patients (Cattaneo, Fantino, Mancini, Mattioli, & Vallar, 2012; Cattaneo, Fantino, Tinti, Silvanto, & Vecchi, 2010). Although representing a quite sensitive tool to measure changes in attentional biases induced by concurrently presented stimuli, line bisection has never been used to directly investigate hemispheric specialisation in emotional processing. In fact, we are aware of only two studies that used (emotional) faces as flankers in a line bisection task at all. In the first one, Tamietto et al. (2005) investigated the effect of a face showing a happy, neutral or angry expression presented as unilateral flanker in affecting visual bisection in a neglect patient and a group of right-brain damaged control patients without neglect. In patients with no neglect, left flankers shifted the bisection bias to the left and right flankers to the right, with no modulation on this pattern exerted by the expressed emotion. Conversely, in the neglect patient, left happy and angry faces were both more (and equally) effective than left neutral faces in reducing the rightward bisection bias (Tamietto et al., 2005). More recently, Claunch et al. (2012) used famous faces as flankers in a visual vertical line bisection task to demonstrate that faces, by increasing ventral stream activation, enhance pre-existing upward attentional bias. In that study, though, the emotional content of faces was neither controlled (the publication's stimulus figure shows two smiling famous faces but whether all faces were smiling is not specified in the manuscript) nor considered at all. Moreover, to the best of our knowledge no studies have ever used a line bisection task during the concurrent presentation of emotional auditory content, such as laughing or crying.

In the present study we carried out three experiments using the visual line bisection task (Experiments 1 and 3) and the tactile line bisection task (Experiment 2) to shed light on the pattern of hemispheric asymmetry for happy and sad emotions. In Experiment 1 a visual line bisection task was used in which emotional faces (neutral, happy, or sad) were employed as concurrent bilateral flankers. If the emotion conveyed by the facial expressions engages the two hemispheres to a different extent, this should result into a significant modulation of the bisection bias. In fact, the more a hemisphere is activated, the more attention is shifted toward the controlateral side of space (see Jewell & McCourt, 2000). Therefore, according to the "valence model" (Davidson, 1992, 2003), happy faces should activate the left hemisphere more, resulting into a rightward shift of the bisection bias, whereas sad faces, by activating the right hemisphere more, should increase pseudoneglect (i.e., the tendency to err leftward). In Experiment 2, a haptic bisection task was administered during the concurrent auditory presentation of human laughing, crying or of a neutral human vocal sound ("mh"). Studies investigating hemispheric specialisation for positive and negative auditorily perceived emotions have led to inconsistent results: again according to the "valence model" (Davidson, 1992, 2003), listening to human crying should shift attention to the left (by activating the right hemisphere more). The opposite pattern should be observed in response to laughing. We chose tactile bisection (rather than visual bisection) because tactile judgements require more time then visual judgements, the former thus being more prone to be influenced by a simultaneous auditory stimulus (see Cattaneo, Fantino, et al., 2012). Finding a similar pattern across the visual bisection–visual emotion (Experiment 1) and the haptic bisection–auditory emotion (Experiment 2) conditions would clarify whether hemispheric specialisation for positive (happy) and negative (sad) emotions subsists regardless the sensory modality in which the emotion is perceived, and whether this affects attentional shifts in the external space regardless of the sensory modality in which space is explored. Finally, Experiment 3 was carried out to investigate whether hemispheric specialisation for positive and negative emotions only emerges in cases of sustained exposure to the same emotional content (see Schepman et al., 2012).

# EXPERIMENT 1

## Method

### *Participants*

Twenty-six students (13 male, $M_{age} = 21.7$ years, $SD = 2.13$), all right handed (Oldfield, 1971), took part in the experiment.

### *Face stimuli*

The face set consisted of four different young Caucasian female faces and four male faces, each of which had a neutral emotional expression, a happy expression, or a sad expression (see Figure 1A for examples). In sum, we generated 12 (female) + 12 (male) = 24 facial stimuli. To reduce facial distinctiveness and make the different faces more average-like, each facial stimulus was obtained by linear morphing of four different original faces using Fantamorph (Abrosoft©).

The faces were rated for affective valence by a group of 40 students (20 male, $M_{age} = 21.1$ years, $SD = 2.26$), all right-handed (Oldfield, 1971),

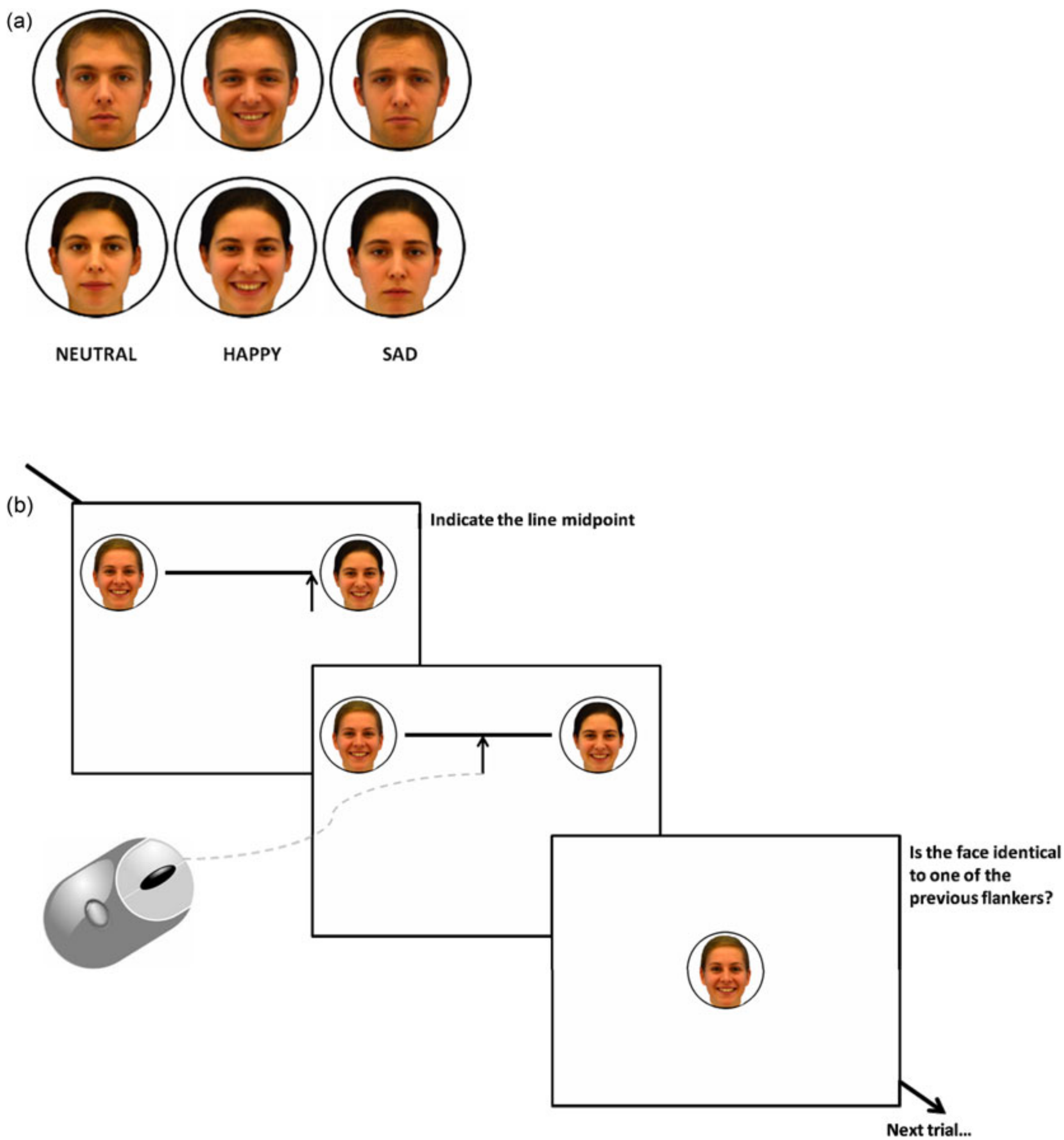


**Figure 1.** *(A) Example of a male (upper panel) and of a female (lower panel) face used in the visual bisection task of Experiment 1. The faces show—from left to right—a neutral, a happy and a sad expression. (B) Example of an experimental trial in the happy faces block. Participants indicated the estimated midpoint of the presented line by using the mouse. In order to make sure that participants paid attention to the face flankers, the bisection task was followed by a second task testing memory for the face flankers.*

none of whom participated in the bisection experiment. Participants were required to indicate on a 7-point scale the emotion expressed by the face (1 = *Very sad*; 7 = *Very happy*). Participants were seated in front of a computer; during the rating test, each face was individually presented in random order at the centre of the screen and remained visible until the participants' response. Before the rating test, all the faces were sequentially presented for two seconds each (ISI = 1 s) in random order for familiarisation purposes. Analyses on the rating scores were performed by grouping together for each emotional state (neutral, happy and sad) the four faces belonging to the same gender. Mean scores for neutral faces were equal to 3.63 ($SD = 0.61$) for female faces and 3.28 ($SD = 0.74$) for male faces. Mean scores for happy faces were equal to 6.28 ($SD = 0.52$) for female faces and 6.18 ($SD = 0.43$) for male faces. Mean scores for sad faces were equal to 1.94 ($SD = 0.54$) for female faces and 1.88 ($SD = 0.55$) for male faces. Pairwise *t*-tests indicated that female sad faces were perceived as significantly sadder than neutral female faces, $t(39) = 17.68$, $p < .001$; and that happy female faces were perceived as significantly happier than neutral female faces, $t(39) = 23.81$, $p < .001$. Similarly, sad male faces were rated as significantly sadder than male neutral faces, $t(39) = 11.70$, $p < .001$, and happy male faces were rated as significantly happier than neutral male faces, $t(39) = 25.78$, $p < .001$. Gender of participants did not affect the emotional valence rating of the face stimuli in any of the considered conditions (female neutral, happy, sad faces; and male neutral, happy, sad faces: all *p*-values > .05). The obtained ratings scores indicate that our face stimuli were successful in eliciting the intended emotion.

### *Procedure*

The task was a computerised cued line bisection task. The stimuli were presented on a portable PC (12.1-inch, 1024 × 768 pixels). Participants were seated in front of the computer and were instructed to maintain a central position about 57 cm distant from the screen. The software, E-prime 2.0 (Psychology Software Tools, Inc., Pittsburgh, PA, USA), was used for stimuli presentation and data recording. Each trial was composed of a black line flanked by two circles (diameter = 2.5 degrees of visual angle). In the "baseline block" the circles were empty; in the "face blocks" the circles contained faces. The circles were presented at a distance of 7 pixels from the end of the line. To increase stimulus variability and to reduce the possibility of assessing the centre of the line by merely inspecting the frame of the screen, several precautions were taken: two different line lengths (8 and 12 degrees of visual angle) were presented that could appear in eight different positions—specifically, lines were always displaced 1 deg of visual angle right or left from the centre and could appear in four different vertical positions (from the centre, displaced 1 or 3 deg of visual angle up or down). In each experimental block (see below), long and short lines appeared an equal number of times in each of the eight possible positions. The changes in line length and line position, however, did not constitute experimental manipulations, and were therefore not analysed.

The experiment consisted of four experimental blocks: baseline, neutral faces, happy faces, and sad faces. Emotions were presented in "block" in line with previous studies finding valence-specific laterality effects only for emotions presented in block (Schepman et al., 2012; see also Bryden & MacRae, 1988; Erhan et al., 1998). In fact, it has been hypothesised that the prolonged exposure to the same emotion better promotes activation of frontal areas more specialised according to valence (Schepman et al., 2012). Also, a blocked design may make participants more aware that the task is emotion-related possibly facilitating identification of the emotion, being this repeated across multiple consecutive trials. All participants started with the baseline block, whereas the order of presentation of the other three blocks was randomised. Each block started with a practice sub-block, consisting of four practice trials. The baseline block consisted of 16 trials, eight for each line length. Each faces block consisted of 32 trials. Figure 1B shows an example of experimental trial in the faces blocks. In each trial of the faces blocks, faces used as flankers were of the same gender (i.e., either both males or both females) and showed the same emotion (either both neutral, happy, or sad). Each face appeared an equal number of times as left flanker and right flanker. Each face was presented in combination with itself (resulting in eight trials in which the two flankers were identical) and twice with all the other three faces of the same gender (and emotion), once as left and once as right flanker. If a pair of faces flanked the short line in one trial, the same two faces (in the reverse left-right position) were used as flankers of the long line in the other trial of the same block, and between the two trials the line position was different. The same face pairs (with a different emotional expression) were associated with the same line length and line position across all the three faces blocks. Before starting the experiment, participants were instructed to indicate the line midpoint by using the mouse. The mouse cursor was a fully vertical arrow that appeared underneath either the left or the right extreme of the line, at a fixed distance of five pixels under the stimulus, and moved only horizontally. The initial position of the mouse cursor and the position of the line on the screen were randomly assigned on each trial. In order to make sure that participants paid attention to the face flankers (see Claunch et al., 2012; see also Lichtenstein-Vidne, Henik, & Safadi, 2012), in the faces blocks, the bisection trial was followed by a memory test: after bisection, the screen was cleared up and a face was presented in the middle of the screen. Participants had to indicate whether the face matched either one of the faces that were used as flankers in the preceding bisection trial, with left/right key press using their left middle and index finger. The face used as target was always of the same gender and always showing the same emotion as the faces used as flankers in the preceding trial. In half of the trials, the face was identical to one of the flankers used in the preceding bisection trial (or to both flankers, when the two flankers were identical). For bisection trials in which the two flankers showed two different faces and the target face was identical to one of them, half of the time the target face was identical to the left flanker, half of the time to the right flanker. Before starting the faces blocks, participants were informed about the memory test and were instructed to pay attention to both faces. Each of the 24 faces was used as target memory face an equal number of times.

Although the instructions emphasised the combination of speed and accuracy, there were no time limits in either the bisection or the memory tasks. The experiment lasted approximately 30 minutes.

## Results and discussion

Accuracy on the memory task was high in all the faces blocks, 89.9% ($SD = 10.4$) for happy faces, 90.6% ($SD = 12.3$) for neutral faces, 89.6% ($SD = 9.1$) for sad faces, and did not differ depending on the emotion ($p = .784$). These data indicated that participants did indeed pay attention to the faces before bisecting the line.

As it has been done in previous studies (e.g., Cattaneo, Fantino, et al., 2012; Cattaneo, Lega, Vecchi, & Vallar, 2012), deviations from the veridical centre were converted to signed percentage scores (positive if bisections were to the right, negative if to the left) by subtracting the true half-length of the line from the measured distance of each setting from the left extremity of the line (this bias was automatically computed by the software in pixels), and then dividing this value by the true half-length and multiplying the quotient by 100.

Participants' biases for each emotional block (neutral, happy, sad) are shown in Figure 2. A first $t$-test was performed to compare the averaged bias scores in the baseline condition (empty circles as flankers) against zero (i.e., the real midpoint value). This analysis indicated that participants tended overall to bisect slightly to the left of the veridical centre, $t(25) = 3.53$, $p = .002$ (mean leftward bias $= -1.34\%$, $SD = 1.94$), showing pseudoneglect. A pairwise $t$-test was used to

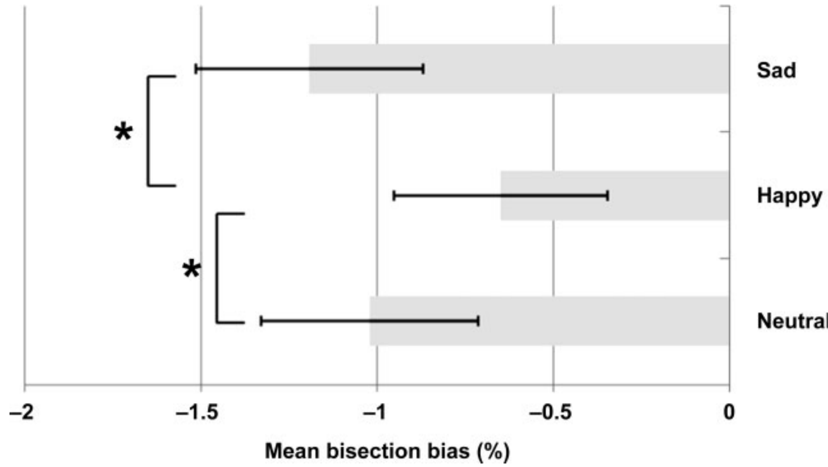


**Figure 2.** *Mean percentage of the visual bisection bias in Experiment 1. Although participants showed a leftward bias in all conditions, the leftward deviation was significantly smaller in the happy faces block compared to both the sad faces block and the neutral faces block. The magnitude of the leftward bias did not significantly differ between the neutral and the sad faces blocks. Error bars represent* ±*1 SEM.*

compare the bias in the baseline condition with the bias in the neutral faces condition: the analysis indicated that the bias in the two conditions did not significantly differ, $t(26) < 1$, $p = .412$, *ns*.

A three-way mixed repeated-measures analysis of variance (ANOVA) was then carried out on the mean percentage bisection bias of the faces blocks only, with Emotion (neutral, happy, sad) and Gender of the Face Flanker as within-subjects factors, and Participants' Gender as between-subjects factor. The main effect of Emotion was significant, $F(2,\ 48) = 3.72$, $p = .031$, $\eta_p^2 = .13$. Neither the main effect of Gender of the Face Flanker ($p = .430$), nor the main effect of Participants' Gender ($p = .371$) were significant. None of the interactions reached significance (all $ps > .05$). Post hoc $t$-tests showed that happy faces shifted the bisection bias significantly to the right compared to both sad faces, $t(25) = 2.53$, $p = .018$, and neutral faces, $t(25) = 2.56$, $p = .017$. No significant difference was observed between sad and neutral faces, $t(25) < 1$, $p = .499$.

Overall, 19 out of 26 participants bisected more rightward with happy faces than with neutral faces, a pattern that significantly differed from what would be expected from binomial distribution ($p = .014$). Similarly, 18 out of 26 participants bisected more rightward with happy faces than with sad faces, again reflecting a response more frequent than the one expected from chances, $p = .037$. Finally, only 14 out of 26 participants bisected more leftward with sad faces than with neutral faces, a distribution that was not significantly different from chance, $p = .422$.

The data from Experiment 1 show that happy faces significantly shifted the bisection bias to the right compared to sad and neutral faces. However, the bisection bias observed when flankers were neutral faces did not significantly differ from the bias reported when sad faces were used as flankers. Hence, our findings only partially support the valence model (Davidson, 1992, 2003). In Experiment 2, we investigated the effect of emotional auditory stimuli (human laughing and crying) on tactile bisection. The results from Experiment 2 will help to clarify whether the emotional content of stimuli differently engages the two hemispheres, thus interfering with normal allocation of spatial attention, regardless of the sensory channel through which emotions are perceived and regardless of the sensory modality in which external space is perceived. Moreover, Experiment 2 will also help to clarify the lack of a modulation of sad faces over the bisection bias reported in the visual modality (Experiment 1).

# EXPERIMENT 2

## Method

### *Participants*

Twenty students (10 male, $M_{age} = 24.5$ years, $SD = 2.76$), all right-handed (Oldfield, 1971), took part in the experiment. None of these participants had taken part in Experiment 1.

### *Emotional vocal sounds*

Audio files were recorded using Audacity audio editing software (http://audacity.sourceforge.net) and consisted of 10-second long continuous laughing, crying, or of a non-verbal vocal sound ("mh"). The sounds were generated by professional actors (one male, one female). The emotional vocal sounds were rated for affective valence by the same group of 40 students that rated emotional valence of the face stimuli in Experiment 1. Participants were required to indicate on a 7-point scale the emotion expressed by the vocal sound (1 = *Very sad*; 7 = *Very happy*). Moreover, they were required to indicate whether the vocal sound was expressed by a male or by a female person. In the rating test, vocal sounds were binaurally presented in random order via headphones: after listening to each sound (10 s duration, as in the bisection experiment), participants first verbally indicated their judgement about the affective valence of the sound and then indicated the gender of the voice. Before the rating test, all the sounds were sequentially presented (ISI = 3 s) in random order for familiarisation purposes. All participants correctly reported the gender of all the vocal sounds (100% accuracy for the neutral, sad and happy conditions). Affective valence scores for neutral vocal sounds were equal to 3.75 ($SD = 0.74$) for the female voice and 3.48 ($SD = 0.55$) for the male voice. Mean scores for happy vocal sounds were 6.40 ($SD = 0.63$) for the female laugh and 5.98 ($SD = 0.89$) for the male laugh. Mean scores for sad vocal sounds were equal to 1.15 ($SD = 0.36$) for the female crying and 1.30 ($SD = 0.85$) for the male crying. Critically, the female crying was rated as significantly sadder than the neutral "mh" female sound, $t(39) = 18.88$, $p < .001$; and the female laugh was rated as significantly happier than the neutral "mh" female sound, $t(39) = 17.67$, $p < .001$. Accordingly, the male crying was judged as significantly sadder than the male neutral "mh", $t(39) = 17.62$, $p < .001$, and the male laughing was rated as significantly happier than neutral male "mh", $t(39) = 15.61$, $p < .001$. Gender of participants did not affect the emotional valence rating of the vocal stimuli (for each auditory stimulus, the male vs. female comparison led to $p$-values $> .05$). The rating scores indicate that the vocal sounds we used were effective in eliciting the intended emotion.

### *Procedure*

We employed a haptic line bisection paradigm (for more detailed procedure about this task, see Cattaneo, Fantino, et al., 2012; Laeng, Buchtel, & Butter, 1996). Stimuli consisted of wooden rods (1.40 cm diameter) of five different lengths (30, 35, 40, 45, and 50 cm). Participants were seated at a table: rods were positioned on the table centrally with respect to the midline of the participants, with the centre of the rod being approximately 40 cm distant from subject's mid-sternum. Participants were blindfolded before the experiment. At the beginning of each trial, the participant's right hand was positioned on the rod by the experimenter, either slightly to the left or right of the rod's midpoint while participants were instructed to explore the length of the rod in their preferred direction (left-to-right or right-to-left) using their right index finger only. On each trial, 10 seconds were given to scan the rod, with no limitations about number of explorations within this time window. At the end of the trial, participants were asked to indicate (with their right index finger) the midpoint of the rod. Figure 3 depicts the experimental setting.

The bisection task consisted of four blocks: a "silent" baseline block, and three auditory blocks: (1) a "laughing" block; (2) a "crying" block; and (3) a "neutral" block. In each auditory block, haptic exploration was accompanied by the concurrent binaural presentation via headphones of the corresponding emotional vocal sound (see above).

On each trial of the auditory blocks, the start and the end of the auditory stimulus corresponded


**Figure 3.** *The experimental setting in the haptic bisection task (Experiment 2). Participants were blindfolded and were required to explore rods of different length using their right index finger. During the 10 seconds given for exploration, participants were binaurally presented with a neutral vocal sound, a laughing sound or a crying sound (spoken by a male and a female adult voice).*

with the start and the end of the haptic exploration period, respectively. Each block consisted of 10 trials, two for each rod's length. Within each auditory block, each rod's length was presented once with the female voice and once with the male voice. The order of presentation of the different lengths and of male and female auditory stimuli was randomised within each auditory block. The silent baseline block was always presented as first block, followed by the other three auditory blocks whose order was balanced across participants. A short practice session (not included in the analyses) preceded the experiment in order to familiarise participants with the task (all the different rods were presented once without concurrent auditory stimulation and no exploration time limit); the three auditory stimuli were also presented once for familiarisation purposes.

## Results and discussion

Performance in the silent baseline block indicated a significant tendency to deviate leftward from the true centre, $t(19) = 3.91$, $p = .001$, with such deviation in the silent condition being comparable to the leftward bias found in the neutral auditory block, $t(19) < 1$, $p = .794$. Mean percentage bisection bias in each auditory block is shown in Figure 4. A three-way mixed repeated-measures ANOVA was performed on the mean percentage bisection bias (computed as in Experiment 1), with Emotional Condition (neutral, crying, laughing) and Gender of the Voice as within-subjects factors, and Participants' Gender as between-subjects factor. The analysis revealed a significant main effect of Emotional Condition, $F(2, 36) = 10.87$, $p < .001$, $\eta_p^2 = .38$. Neither the Gender of the Voice ($p = .071$) nor Participants' Gender ($p = .811$) reached significance. None of the interactions were significant (all $ps > .05$).

Post hoc $t$-tests revealed that the leftward deviation was significantly reduced in the laughing block compared to both the neutral, $t(19) = 3.89$, $p = .001$, and the crying block, $t(19) = 4.67$, $p < .001$. No significant difference was observed between the neutral and the crying block, $t(19) < 1$, $p = .832$.

Overall, 16 out of 20 participants bisected more rightward with happy faces than with neutral faces, a response that was significantly more likely than the one expected from chance, $p = .006$. Similarly, 17 out of 20 participants bisected more rightward with happy faces than with sad faces, a distribution that was significant different from chance, $p = .001$. Finally, ten out of 20 participants bisected more leftward with sad faces than with neutral

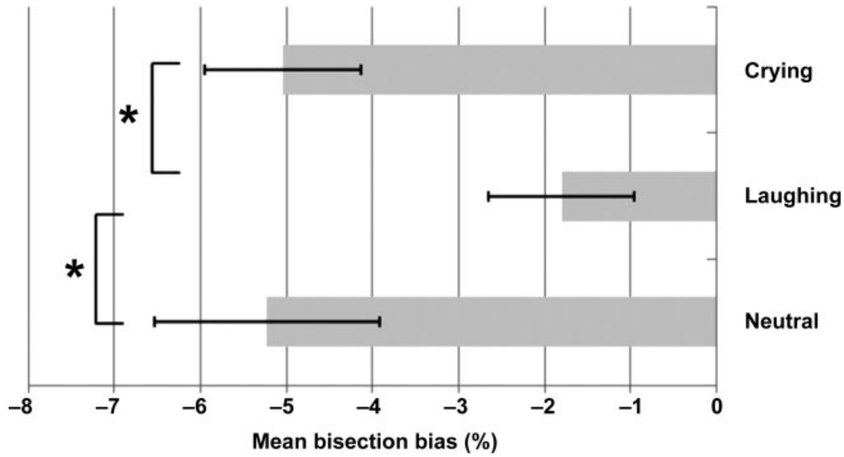


**Figure 4.** *Mean percentage tactile bisection bias in Experiment 2. Overall, in all conditions participants showed a leftward bias. However, this bias was significantly reduced by listening to a laughing voice compared to both listening to a crying voice or to a neutral vocal sound. The leftward bias did not differ between the neutral and the crying condition. Error bars represent* $\pm 1$ *SEM.*

faces, a proportion that is highly expected under chance distribution, $p = .588$.

The results of Experiment 2 mirror those reported in Experiment 1: perceiving happy emotions shifted the bisection bias significantly to the right, by likely activating the left hemisphere more. Conversely (auditorily) perceiving a sad emotion did not significantly increase the pre-existing leftward bias, replicating the lack of a systematic effect of sad faces over the bisection error observed in Experiment 1.

In Experiments 1 and 2 we chose to present emotions in "blocks" according to previous studies reporting valence-specific laterality effects only for prolonged exposure to the same emotion (Schepman et al., 2012; see also Bryden & MacRae, 1988; Erhan et al., 1998). Experiment 3 was carried out to verify whether the effects reported in Experiments 1 and 2—i.e., a rightward shift induced by concurrent processing of stimuli conveying happiness on the bisection bias—would be observed also when positive and negative emotions were intermixed on a trial basis. Moreover, participants in Experiment 3 were also required to rate the intensity of the emotion expressed by the faces and vocal stimuli used in Experiments 1 and 2. In fact, although faces and auditory vocal sounds were unambiguously classified as sad or happy in the first rating study (see above), the intensity of the emotion expressed was not measured. Hence, it might be the case that the lack of hemispheric lateralisation found across the first two experiments for sad stimuli depended on the intensity of sadness conveyed by sad stimuli being lower than the intensity of happiness expressed by the happy stimuli we used.

# EXPERIMENT 3

## Method

### *Participants*

Twenty students (10 male, $M_{age} = 25.0$ years, $SD = 3.24$), all right-handed (Oldfield, 1971), took part in the experiment. None of these participants had taken part in either Experiment 1 or 2.

### *Material and procedure*

Stimuli and procedure were the same as those used in Experiment 1 but trials with faces expressing a neutral, sad or happy emotion were presented in random order within a unique experimental block. The experimental block consisted of 96 trials (32 for each emotional state) and was preceded by six practice trials (two for each emotion). The initial baseline block (empty circles as flankers) was not presented. After completion of the bisection experiment, participants were required to rate on a 7-point scale the level of perceived sadness expressed by each sad face (1 = *Not sad at all*; 7 = *Very sad*) and the intensity of perceived happiness expressed by each happy face (1 = *Not happy at all*; 7 = *Very happy*). In the rating test, each face was individually presented in random order at the centre of the screen and remained visible until participants responded (by pressing the desired key on the computer keyboard). Participants were then required to rate the level of sadness and happiness elicited by the crying and laughing stimuli used in Experiment 2. Vocal sounds were binaurally presented in random order via headphones: after listening to each sound (10 s duration), participants indicated on a 7-point scale by pressing the corresponding key on a computer keyboard the intensity of sadness and happiness associated with the crying and laughing stimuli.

## Results and discussion

### *Bisection task*

Participants' biases for each emotion (neutral, happy, sad) are shown in Figure 5. Participants' mean accuracy on the memory task was 90.7% ($SD = 6.0$) for happy faces, 91.8% ($SD = 6.9$) for neutral faces, and 90.0% ($SD = 7.4$) for sad faces. The emotion expressed by the face did not significantly affect memory ($p = .219$).

A three-way mixed repeated-measures ANOVA was carried out on the mean percentage bisection bias with Emotion (neutral, happy, sad) and Gender of the Face Flanker as within-subjects factors, and Participants' Gender as between-subjects factor. The main effect of Emotion was not significant, $F(2, 36) < 1$, $p = .930$, $\eta_p^2 = .004$, neither was the main effect of Gender of the Face Flankers ($p = .828$). Participants' Gender was not significant ($p = .916$). None of the interactions reached significance (all $ps > .05$).

### *Rating*

*Faces.* Mean intensity scores for sad faces were 3.63 ($SD = 0.61$) for female faces and 3.28 ($SD = 0.74$) for male faces. Mean intensity scores for happy faces were 6.28 ($SD = 0.52$) for female faces and 6.18 ($SD = 0.43$) for male faces. A repeated-measures ANOVA with Emotion (sad vs. happy) and Gender of the Face as within-subjects variables and Participants' Gender as between-subjects variable showed a significant main effect of Emotion, $F(1, 18) = 88.44$, $p < .001$, $\eta_p^2 = .83$, indicating that the intensity of happiness

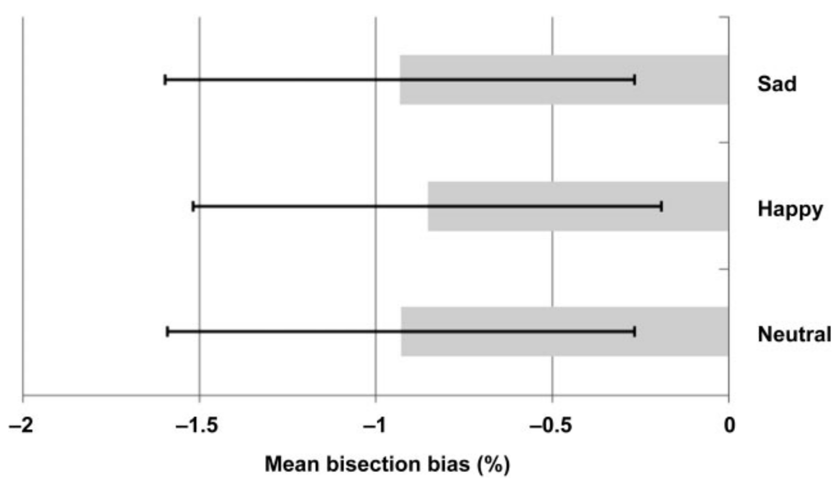


**Figure 5.** *Mean percentage of the visual bisection bias in Experiment 3. Participants showed a leftward bias in all conditions that was not modulated by the emotion expressed by the flanker faces. Error bars represent ±1 SEM.*

($M = 5.86$, $SD = 0.74$) was perceived as greater than the intensity of sadness ($M = 3.61$, $SD = 1.00$). The ANOVA also revealed a significant main effect of Participants' Gender, $F(1, 18) = 4.95$, $p = .039$, $\eta_p^2 = .22$, and a significant interaction of Participants' Gender by Gender of the Face, $F(1, 18) = 9.07$, $p = .007$, $\eta_p^2 = .34$, overall indicating that female participants rated emotions as more intense than male participants but only when judging female faces, $t(18) = 3.16$, $p = .005$ (with male faces, $p = .411$). The main effect of Face Gender was not significant ($p = .244$), nor were any of the other interactions (all $p$s $> .05$).

*Auditory stimuli (laughing and crying).* Female and male crying received an overall intensity evaluation of 6.60 ($SD = 0.50$) and 6.20 ($SD = 0.89$), respectively. For laughing, scores were 6.20 ($SD = 0.52$) for the female voice and 4.70 ($SD = 0.57$) for the male voice. A repeated-measures ANOVA with Emotion (sad vs. happy) and Gender of the Voice as within-subjects variables and Participants' Gender as between-subjects variable showed a significant main effect of Emotion, $F(1, 18) = 37.13$, $p < .001$, $\eta_p^2 = .67$, indicating that the perceived intensity of sadness expressed by the crying ($M = 6.40$, $SD = 0.42$) was higher than the perceived intensity of happiness expressed by the laughing ($M = 5.45$, $SD = 0.46$). The main effect of Voice Gender was also significant, $F(1, 18) = 54.61$, $p < .001$, $\eta_p^2 = .75$, as was the interaction Gender of the Voice by Emotion, $F(1, 18) = 10.73$, $p = .004$, $\eta_p^2 = .37$. Overall, the perceived intensity of the emotion was higher for the female than for the male voice, but this was especially so for happiness ($p < .001$), whereas for sadness the difference between female and male voice did not reach significance ($p = .148$). Participants' Gender was not significant ($p = .423$) nor were any of the other interactions (all $p$s $> .05$).

In sum, rating scores indicated that for face stimuli happiness was perceived as more intense than sadness. However, the opposite pattern was observed for vocal stimuli: in this case, sadness conveyed by the crying was perceived as more intense than the happiness conveyed by the laughing.

## GENERAL DISCUSSION

Directional biases in line bisection are thought to reflect hemispheric imbalance in allocation of spatial attentional resources, and were analysed in the present study to shed light on hemispheric specialisation for processing of happy and sad emotions. Results were entirely consistent across the visual and acoustic modality. In particular, in Experiment 1, happy faces presented as bilateral flankers in a visual line bisection task shifted the bisection bias significantly to the right compared to both sad and neutral face flankers. Accordingly, in the haptic bisection task used in Experiment 2, listening to positive vocal stimuli (i.e., laughing) shifted the bisection bias significantly to the right compared to listening to neutral or negative (i.e., crying) vocal stimuli. Overall, our data point to a preferential activation of the left hemisphere by positive emotions (resulting in an enhanced internal representation of/preferential orienting toward the contralateral right hemifield), thus contrasting with the view of a right-hemisphere overall dominance in processing emotions, regardless of their valence (Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Tucker, 1981).

Our results are compatible with view of the "valence model" postulating that the left hemisphere regulates positive emotions (Davidson, 1992, 2003), but they do not provide full support for this account since no differences between sad and neutral stimuli were observed. In fact, according to the model, the right hemisphere should preferentially regulate negative emotions, and this should be manifested in a bisection task by an increase of the leftward bias caused by sad stimuli compared to neutral stimuli (reflecting enhanced activation of the right-hemisphere by negative emotions). Moreover, our data do not fit with previous reports revealing a higher degree of hemispheric laterality for negative rather than positive emotions (e.g., Adolphs, Damasio, Tranel, & Damasio, 1996). Importantly, the lack of effects of sad cues on the bisection bias did not depend on participants not being able to distinguish sad faces from neutral faces (or crying from the neutral vocal sound): in fact, results of a rating experiment showed that our stimuli were not ambiguous in terms of their emotional valence, with sad faces being rated significantly more sad than neutral faces (a similar pattern was reported for vocal stimuli). Moreover, the lack of effects of sad stimuli did not depend on sad cues being perceived as less "intense" in their emotional content than happy stimuli. In fact, although for face stimuli used in Experiment 1 happiness was perceived as more intense than sadness, the opposite pattern was observed for vocal stimuli: in this case, crying was judged to express sadness more intensively than laughing did for happiness. If the emergence of lateralisation effects on the bisection bias depended on the intensity of the perceived emotion, crying should have been more effective than laughing in engaging the preferred hemisphere in Experiment 2, whereas this was not the case. Additionally, if the effects we reported in the bisection task were related to emotional intensity, the pattern of gender differences observed in the intensity rating scores—with female faces being overall considered as more emotional than male faces by female raters, and female vocalisations (laughing in particular) being overall rated as more emotionally intense than male vocalisations—should have been somehow reflected in the bisection performance, whereas again this was not the case (see below for a discussion on this point).

In previous work (Cattaneo, Lega, et al., 2012) we showed that concurrent binaural presentation of auditory white noise affected individuals' performance in both visual and haptic bisection, reducing their leftward bias. In fact, previous evidence suggested that alerting sounds lower the threshold for activation of both hemispheres by engaging the reticular activating system (see Robertson, Mattingley, Rorden, & Driver, 1998; Van Vleet & Robertson, 2006): this is likely to re-establish a balance of hemispheric activation, counteracting rightward bias in neglect patients (Robertson et al., 1998; Van Vleet & Robertson, 2006) and pseudoneglect in healthy individuals (Cattaneo, Lega, et al., 2012). Emotional stimuli are known to affect alertness/arousal levels (see Adolphs, 2002; Demaree et al., 2005, for reviews): it is hence possible that the stimuli we used induced a rightward shift in the bisection bias as a general effect of increased alertness. In this view, the higher engagement of the left hemisphere in processing positive emotions would have added to the rightward bias induced by alertness *per se* causing the significant rightward shift we observed. In turn, in the case of sad emotions, the alertness-induced rightward shift would have been counteracted by the leftward shift induced by the higher activation of the right hemisphere while processing negative emotions, this resulting in a null detectable shift in spatial attention. In this regard, it is also worth considering that the effect of (directional) cueing has been previously found to be more effective in operating "against" the pre-existing bias than "towards" its direction (e.g., Cattaneo, Fantino, et al., 2012; Tamietto et al., 2005): in fact, when multiple factors simultaneously contribute to a directional shift in bisection, a ceiling or threshold level may be reached at which biases are no further tolerated by the perceptual system, being eventually detected (Laeng et al., 1996). Moreover, happy stimuli are likely to be more alerting than sad stimuli, this possibly potentiating the rightward shift in bisection bias we observed with positive emotions. In fact, happy faces are usually more distinctive from neutral faces than sad faces (smiling causing an expansion of the face), and a perceptual advantage of detecting (and recognising) "happy faces" has been consistently reported (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Becker et al., 2012; see also Hodsoll, Viding, & Lavie, 2011; Kaufmann & Schweinberger, 2004). In terms of acoustic properties our laughing stimuli were also louder and showed more variation in the acoustic spectrum than crying, this likely increasing associated arousal (see Szameitat et al., 2011; see also Chun et al., 2012, supplementary material): in fact, in line with previous studies (e.g., Sander & Scheich, 2001), we preferred not to match crying and laughing for acoustic features in order to preserve their natural character, also in light of data showing that the brain responds differently to genuine emotional sounds than to "synthetic"/ digitally morphed emotional sounds (Rodway & Schepman, 2007; Schepman et al., 2012). It is worth noting here though that crying can also induce high level of arousal as measured by heart rate, blood pressure, or skin conductance (e.g., Boukydis & Burgess, 1982; Zeskind & Collins, 1987) although this is likely to be the case more for infant than adult crying (Parsons, Young, Parsons, Stein, & Kringelbach, 2012).

Critically, our findings also show that the modulation of the bisection bias induced by processing of positive emotions emerges only in case of a sustained exposition to the same emotion. In fact, when happy, sad and neutral stimuli were intermixed within the same block (Experiment 3) the left hemisphere preference for positive stimuli disappeared. Previous evidence suggests that "blocking" trials by emotion type results into enhanced laterality effects (Schepman et al., 2012). In particular, blocking may induce expectation for a specific type of information activating the hemisphere that is most specialised for dealing with that material, thus facilitating processing of stimuli in the contralateral hemifield (Kinsbourne, 1970). Alternatively, blocking may facilitate emotion "contagion", so that due to prolonged exposition participants are more likely to experience the emotion perceived (see Erhan et al., 1998; Schepman et al., 2012, for a discussion). Since the view of the valence model may apply more to specific expressions than the mere perception of any emotions (Demaree et al., 2005) when participants get to experience the emotions they perceive, it is likely that laterality effects become more visible (Schepman et al., 2012).

The extent to which emotional orienting of attention is automatic or requires top-down modulation is a current matter of debate (Lichtenstein-Vidne et al., 2012; Pessoa, 2005; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Shafer et al., 2012; Vuilleumier, 2005). In our study, perceived emotional stimuli modulated allocation of spatial attention without participants paying voluntary attention to their emotional valence, such information being irrelevant for the task at play. Previous studies using faces as flankers in a line bisection task, found that participants tended to ignore the faces if the task did not explicitly require participants to pay attention to them (Claunch et al., 2012; see also Lichtenstein-Vidne et al., 2012). Accordingly, in our visual experiment we introduced a face memory condition in order to make sure that our participants paid attention to the faces before bisecting. However, the emotional expression of the face flankers could not be used as memory cues since the target face always showed the same emotion as the flankers used in the preceding trial: emotional valence of the face was thus irrelevant for both the bisection and the memory tasks. In this regard, our results appear in line with previous studies showing that emotional irrelevant stimuli may affect the task at play, by interfering with allocation of attentional resources (e.g., Hodsoll et al., 2011; Tamietto et al., 2005). Also, attentional effects were entirely driven by the emotional content of the stimuli, but not by the mere presentation of a face or of a vocal stimulus: in fact, the participants' bias was comparable in Experiment 1 for neutral faces and blank circles as flankers, and it was comparable in Experiment 2 for neutral vocal stimuli and the silent condition.

Studies examining gender differences in visual and tactile bisection mainly failed to report significant differences between male and female participants (see Jewell & McCourt, 2000, for a review). Nonetheless, given behavioural and neuroimaging findings pointing to a role of participants' gender in determining the pattern of hemispheric specialisation for positive and negative emotions (see Rodway et al., 2003; Schepman et al., 2012) and fMRI evidence showing a significant interaction between gender of the listener, gender of the actor expressing the emotion, and valence of the emotion (happy vs. sad; see Chun et al., 2012), in our experiments we considered both the gender of participants and the gender of the emotional stimuli as potential relevant factors. Across the three experiments, we did not observe any significant effect on the bisection bias related to participants' gender or to the gender of the emotional stimuli (faces and voices), nor an interaction between these two factors. Hence, our data do not support the existence of significant gender differences in the pattern (or degree) of hemispheric specialisation for happy and sad emotions, nor the existence of an own- versus opposite-gender bias depending on the valence of the perceived emotion. Moreover, discrepancies between behavioural and neuroimaging evidence should be considered with caution, since the relation between differences in brain structure/functions and behavioural differences is far from being linear: systematic behavioural differences between male and female participants may not be reflected at the neurophysiological level and vice versa (cf. De Vries, 2004, for a review).

Finally, our data demonstrate that the effects of emotional valence on allocation of attention affect both the visually and the haptically perceived space, occurring also in a cross-modal vein (auditory–haptic, see our Experiment 2). Previous neuroimaging evidence has shown that specific emotions are represented in the brain at an abstract, modality-independent level (e.g., Klasen et al., 2011; Peelen et al., 2010). In particular, Peelen et al. (2010) reported modality-independent (facial expression, body gestures, voices) but emotion (anger, disgust, fear, happiness, sadness) category-specific activity patterns in medial prefrontal cortex and left superior temporal sulcus, independent of the perceived intensity of the emotions. In a further study, Klasen et al. (2011) pointed to subcortical regions such as the ventral posterior cingulate and the amygdala as the critical loci where emotional information perceived through different sensory channels merges. Our data cannot inform on which areas mediated the effect of emotional cueing over the bisection performance. Neuroimaging evidence (Fink, Marshall, Weiss, & Zilles, 2001) found significant activation in prefrontal (lateral) cortices and cingulate cortices during a bisection task (beyond consistent activation in parietal sites): hence we might speculate that the interaction between emotional cueing and spatial representations occurred at both the subcortical and cortical regions, but future brain imaging or brain stimulation research should more properly address this issue.

In conclusion, our findings critically add to previous related literature by showing consistent effects of both visual and auditory positive emotional stimuli on allocation of spatial attention in the same task (line bisection) performed either visually or haptically. By finding a similar pattern across different sensory modalities our data indicate that the effect exerted by positive stimuli was robust and did not depend on specific features of the stimuli used. Moreover, our data show that lateralisation effects (for positive emotion) emerged even if participants did not pay attention to the emotional content of the stimuli. Nonetheless, a sustained exposition to the same emotion was needed for an effect of emotional stimuli on the bisection bias to consistently emerge. Notably, line bisection has been previously used to assess alteration in the typical pattern of hemispheric asymmetry in different psychiatric disorders—such as severe depression and schizophrenia—in which affective disturbance is a major component. For instance, attenuation of normal pseudoneglect has been reported in schizophrenia (e.g., McCourt, Shpaner, Javitt, & Foxe, 2008; Rao, Arasappa, Reddy, Venkatasubramanian, & Gangadhar, 2010; Ribolsi et al., 2012), and accentuation of normal pseudoneglect has been reported in bipolar affective disorder and in generalised anxiety disorder (He et al., 2010; Rao et al., 2010). In this perspective, testing the effects of different emotional cues on a line bisection task in healthy individuals may help interpreting the abnormal patterns of hemispheric lateralisation observed in many psychiatric populations, especially considering that line bisection is a task routinely used in a clinical context.

Manuscript received 29 October 2012
Revised manuscript received 17 April 2013
Manuscript accepted 10 July 2013
First published online 20 August 2013

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