

UNIVERSIDADE DO ALGARVE

***THE INFLUENCE OF HANDEDNESS ON ASSYMETRIES IN
EXPRESSION OF BASIC EMOTIONS***

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***INFLUÊNCIA DA LATERALIDADE MOTORA NAS
ASSIMETRIAS EXPRESSIVAS DE EMOÇÕES BÁSICAS***

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Dissertação para obtenção do Grau de Mestre
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Professor Doutor Luís Miguel Madeira Faísca

2015

***The Influence of Handedness on Assymetries in Expression of
Basic Emotions***

Author's Declaration

I declare that this thesis is my own work, which is original and inovative. All authors and literature consulted are accordingly cited in this thesis and present in the references.

Angelica Muresan

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***Influência da Lateralidade Motora nas Assimetrias Expressivas
de Emoções Básicas***

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ABSTRACT

A large amount of research has been dedicated to hemispheric asymmetries in facial emotion processing, reporting consistently right-hemisphere dominance either for recognizing emotions as for the emotional facial expression. This hemispheric domination explains why emotions are more expressive and intense in the left side of the face (left emotional facedness). However, in spite of considerable evidence supporting left facial asymmetries for emotion expression, most studies based their findings on right-handed normal individuals. Data from the few investigations specifically conducted with left-handed subjects is scarce and somewhat controversial, so the main purpose of the present study was to investigate the possible interaction between poser's handedness and his/her emotional facedness. Twenty-four judges (12 females) performed two tasks where they had to identify and evaluate the intensity of emotions conveyed by symmetric chimeric faces (left-left composite and right-right composite faces). Stimuli were generated from pictures taken to naïve female actors (20 right-handed and 20 left-handed) posing expressions of happiness, fear, anger and sadness. Our results seem compatible with the hypothesis that emotional expressions are more intense in left-hemifaces for both left-handers and right-handers. However, the accurate recognition of emotions expressed by right-handed actors did not reveal the expected supremacy of the left hemiface; on contrary, as predicted, left-handed actors show a small advantage of left hemiface for emotion recognition accuracy. The apparent dissociation between intensity and accuracy measures of facial emotion expressiveness and its consequence for the question of the interaction between poser's handedness and emotional facedness are discussed.

Keywords: emotion, chimeric faces, facial asymmetries, handedness

RESUMO

A dominância do hemisfério cerebral direito na expressão de emoções faciais encontra-se amplamente documentada na literatura uma vez que as assimetrias faciais são mais intensas e evidentes na hemiface esquerda. A maior parte dos estudos que se debruçam sobre a questão do processamento emocional e, em particular, a produção de expressão através da face, foi realizada em população destra. De facto, os estudos que contemplam nas suas amostras indivíduos esquerdinos são mais reduzidos assim como, por vezes, reportam a resultados controversos no que respeita à lateralização hemisférica desta população na expressão de emoções faciais. Por este motivo, consideramos pertinente para o presente trabalho a investigação de possíveis interações entre a lateralidade manual do ator (isto é, a pessoa que expressa a emoção) e as assimetrias faciais durante a produção da emoção. As faces quiméricas representam um dos paradigmas mais implementados no estudo das assimetrias expressivas de emoções. Em particular, as faces compósitas simétricas permitem avaliar independentemente a expressão emocional veiculada por cada hemiface controlando a interferência de assimetrias perceptivas que advêm do enviesamento para o hemicampo visual esquerdo uma vez que o mesmo estímulo é apresentado nos dois hemicampos visuais em simultâneo. Participaram no estudo vinte e quatro juízes (12 mulheres e 12 homens) que realizaram julgamentos de quatro emoções básicas (alegria, medo, raiva e tristeza) através de uma tarefa de acuidade e eficácia na identificação de emoções e uma tarefa de julgamentos sobre a intensidade da expressão veiculada pela face. Os estímulos quiméricos foram construídos a partir de fotografias de quarenta atores naïve do sexo feminino (20 canhotos e 20 destros), que expressaram as quatro emoções básicas. Os principais resultados obtidos são compatíveis com a hipótese de que a hemiface esquerda é mais intensa na expressão das emoções, independentemente da lateralidade manual do ator. Contudo, no que respeita à eficácia do reconhecimento da emoção expressa, não foram observadas assimetrias faciais significativamente à esquerda nos atores destros. Contrariamente, os atores esquerdinos revelaram uma ligeira vantagem da hemiface esquerda na medida de acuidade e eficácia da expressão emocional. Esta dissociação entre a lateralização da intensidade da expressão e da eficácia da expressão é discutida à luz do seu impacto na interação entre a lateralidade manual do ator e as assimetrias expressivas de emoções.

Palavras-chave: emoção, faces quiméricas, assimetrias faciais, lateralidade manual

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1. INTRODUCTION

Facial emotional expressions are a crucial component of human emotional and social behavior as they serve as visual communicatory signals that rapidly convey mood and valence information to conspecifics. A large amount of research has been produced over the neural and neuropsychological mechanisms that supports this type of communication, approaching issues related to the production of the emotional expressions and those involved in the interpretation of the emotional expressions in others (for a review, see Blair, 2003). A wide range of methodologies has been used in this respect, but traditionally researching facial emotions usually employs photographs of the whole face, hemifaces and composite faces as well as dynamic and static videotapes of emotional expressions.

A much debated topic in the literature on emotion processing is the hemispheric lateralization for the recognition and expression of facial emotions. The concept of hemispheric lateralization refers to differentiated functional organization of the left and right cerebral hemispheres for cognitive and motor function. Literature provides us several data from behavioral and functional studies as well as clinical reports suggesting different information processing systems for the two hemispheres. Accordingly, each cerebral hemisphere is responsible for motor control of the opposite part of the body; furthermore, each hemisphere is also dominant for specific cognitive functions. Based on this, a consensual assumption is that the left hemisphere is dominant for linguistic information processing whereas the right hemisphere is dominant form visual-spatial and configural information processing, inclining facial emotion processing.

Specifically concerning the question of the hemispheric lateralization for emotion recognition (thus focusing on the perceiver's perspective), the literature has consistently revealed right hemisphere advantage for processing this kind of information (Adolphs, Damasio, Tranel, & Damasio, 1996; Ashwin, Wheelwright, & Baron-Cohen, 2005; Bourne, 2005; Bourne, 2010; Coolican, Eskes, McMullen, & Lecky, 2008; Megreya, & Havard, 2011; Rahman, Wilson, & Abrahams, 2004). On the other hand, evidence from studies approaching the mechanisms underlying hemispheric asymmetries for the production of facial emotional expressions (focusing on the poser's perspective) also points to overall right hemisphere dominance (Borod, & Caron, 1980; Borod, Caron, & Koff, 1981; Borod, Koff, & White, 1983; Borod, Koff, Lorch,

Nicholas, & Welkowitz, 1988; Borod, & Koff, 1990; Borod *et al.*, 1998; Indersmitten, & Gur, 2003; Sackeim, & Gur, 1978).

Understanding lateralization of facial expression is relevant for both the production and perception of emotion as, in a face to face situation, the poser's left side of the face falls into the perceiver's right visual field, which projects to the perceiver's left hemisphere. This creates a situation in which the side of the poser's face that expresses greater emotional intensity (left hemiface) is projected to the perceiver's hemisphere believed to be less competent in facial recognition and processing of emotional information (left hemisphere). This situation may be viewed either as an advantage or disadvantage, depending upon the desirability of effective communication of emotional intensity. With this line of reasoning, the greater emotional intensity of the left hemiface might be considered a byproduct of contralateral projections within the visual system, which is regarded, from an evolutionary point of view, as an adaptive mechanism that compensates for a perceiver's bias by communicating greater intensity to the hemisphere less used to process this kind of information and which could easily miss subtler signals (Sackeim, Gur, & Saucy, 1978).

As mentioned above, most studies on facial expression have found facial asymmetries to be more pronounced in the left hemiface. A number of researchers demonstrate asymmetries between the two hemifaces for both expression intensity and extent of movement of the facial musculature when the expression is displayed. Thus, left hemiface superiority can be related to facial asymmetry or facedness (Borod, & Caron, 1980). For non-emotional unilateral facial movement (*i.e.*, when the expression does not convey emotional information), facedness refers to greater muscular control on one side of the face relative to the other. For emotional expression, facedness refers to the relative intensity of expression and the extent of movement on the left and right hemifaces. When emotion is displayed, the left side of the face is judged as more intense and moves more extensively than the right side (Borod, & Caron, 1980; Borod, Caron, & Koff, 1981; Borod, Koff, & White, 1983; Moreno, Borod, Welkowitz, & Alpert, 1990; Nicholls, Ellis, Clement, & Yoshino, 2004; Sackeim, & Gur, 1980). This finding highlights right hemisphere dominance for both emotion expression and movement of facial musculature during expression. Since these studies involve in general deliberate movement of facial musculature, which is considered to be controlled by cortical or pyramidal systems (*i.e.*, central mechanisms), facedness of emotion can be approached from a neuroanatomical perspective as each side of the face, particularly in

the lower region, receives predominant muscular innervations from the contralateral hemisphere.

However, facial movement extent and expression intensity should be regarded as two different measures of emotion expressiveness that taken together report information on facedness for emotion. Evidence for this consideration comes from Borod and Koff (1990) who conducted a review of several studies on the mechanisms underlying hemispheric specialization for facial behavior in normal and brain damaged subjects. In this review, the authors argue that central mechanisms might not fully explain the left-sided facial asymmetry during emotional expression generally found in normal subjects. These authors also contemplate that non-emotional peripheral factors (such as muscular activity and hemiface size) and morphological characteristics present in the resting face might affect judgment of facial emotion. They further reason that if the two hemifaces were to differ in degree of muscular activity, the hemiface with the greater mobility might be perceived as more emotionally expressive and if the hemifaces differed in size, the expression mapped on the smaller side could be perceived as more extensive while the expression on the larger side could appear diluted and perceived as less extensive. For normal subjects, these authors report that while hemiface mobility was left-sided, neutral expressions were left-sided and hemiface size was larger on the right hemiface, these peripheral factors were not related to the direction of facial asymmetries during emotional expressions. For brain damaged subjects, they report lack of significant relationships between measures of emotional facial expression and measures of facial paralysis, muscular mobility and bucco-facial apraxia. Taken together, the findings underscore dissociation between systems controlling facial emotional expression and those controlling non-emotional facial movement.

In addition, the findings for facial asymmetry for emotion expression in normal individuals have been overall corroborated by studies of brain damaged patients as evidence also reveal greater right hemisphere control over the left hemiface for emotional expression (Borod, Koff, Lorch, & Nicholas, 1985; Borod, Koff, Lorch, Nicholas, & Welkowitz, 1988; Borod et al., 1998). In this line of investigation, when approaching facial emotion expression in brain damaged patients from the poser's perspective, Borod and colleagues (1988) call attention to three important measures of expression such as responsivity, appropriateness or accuracy and intensity as clinical findings consistently report that right hemisphere pathology is frequently associated with low levels of arousal, inappropriate and flattened affect display. Considering these

dimensions, right brain damaged patients are more impaired in the production of facial emotional expressions when compared to left brain damaged patients and normal controls, thus rendering support for right hemisphere dominance.

Other issues of hemispheric dominance over emotional expression may also be related to elicitation condition, namely spontaneous or posed emotional expressions and to the type of emotion expressed (*i.e.*, affective valence). When reporting to elicitation condition, a few considerations should be taken into account. Posed expressions are deliberate or volitional movements which are clearly intended by the individual and can be produced on request by others; spontaneous expressions are unintended reactions to emotional stimuli. Evidence from clinical neurological literature (see, for a review, Rinn, 1984) suggests that posed and spontaneous expressions of emotion may be mediated by different and possibly independent neuroanatomical pathways as cortical regions are more implicated in volitional facial movement and sub-cortical regions are more involved in spontaneous reactions.

Emotional expression can be thought of as distributed along a posed and spontaneous continuum and it is not clear whether findings for posed facial expressions of emotion, which comprise the larger amount of data in the literature, can be generalized to spontaneous facial expression. Most studies of posed expression report overall left-sided asymmetries for both positive and negative emotions in right-handed normal individuals (Borod, & Caron, 1980; Campbell, 1978; Sackeim, & Gur, 1978); however, there is a tendency for less consistent facial asymmetry when expressions are positive.

In studies of spontaneous facial expression, random lateralization as well as left-sided asymmetry has been reported; for spontaneous positive expressions, mostly used for this eliciting condition, it has been claimed in general that expressions are not noticeably asymmetrical (Ekman, Friesen, & Ellsworth, 1972); however, there is also some contradictory data from Moscovitch and Olds (1982) who found left-sided asymmetry for smile; moreover, Wylie and Goodale (1988) reported that the left-side of the mouth moved more than the right side during spontaneous but not posed smiles; findings for negative emotions are more difficult to interpret because of small sample sizes and number of expressions in study (Cacioppo, & Petty, 1981). When comparing both conditions, it has been claimed that spontaneous expressions are less lateralized than posed ones, but comparisons have been based mainly on data for positive expressions, which are also less lateralized under posed condition.

On the other hand, Borod, Koff and White (1983) failed to find differences in facial asymmetry as a function of eliciting condition as overall expressions were significantly left-sided, regardless whether were spontaneous or posed; this was true even when they analyzed each facial expression separately in order to rule out the possibility that one particular type of expression (*e.g.*, happiness) might influence these results. Taken these together, differences in methodology may account for some of the disparity in the literature (see, for example, Ross, & Pulusu, 2013).

Another important issue of hemispheric dominance over emotional expression is the type of emotion and its affective valence. Cross-cultural data indicates that at least six distinct emotions can be reliably recognized in the human face, namely happiness, surprise, fear, anger, sadness and disgust. Recognition of these emotions appear to be universal and independent of cultural or sociological background (Ekman, Friesen, & Ellsworth, 1972). A set of photographs of posed facial expressions as well as photographs of faces expressing emotional neutrality collected by these authors have been shown to produce reliable and accurate judgments of emotional expressions in large samples of subjects.

Regardless of strong evidence in the literature suggesting a dominant role for the right hemisphere on emotion information processing, debate on the exact involvement of each cerebral hemisphere remains an issue of actuality. The assumption of right hemispheric lateralization might attain more complex considerations as there is also evidence suggesting left hemisphere involvement to some extent.

Two different hypotheses on the processing of emotions and facial expressions have received considerable attention over the decades, namely the right hemisphere hypothesis and the valence-specific hypothesis. The first hypothesis views the right hemisphere as dominant for emotion processing and thus specialized for all types of emotions regardless of their affective valence (see, for example, Adolphs, Damasio, Tranel, &, 1996; Borod *et al.*, 1998). On the other hand, the valence-specific hypothesis posits that the right hemisphere is dominant for processing negative affective information and the left hemisphere is dominant for processing positive affective information. Accordingly, some studies have shown that negative emotions were more readily recognized in the left side of the poser's face while positive emotions were more readily recognized in the right side of the poser's face (Adolphs, Jansari, & Tranel, 2001; Nicholls, Ellis, Clement, & Yoshino, 2004; Reuter-Lorentz, & Davidson, 1981; Richardson, Bowers, Bauer, Heilman, & Leonard, 2000). However, Nicholls and

colleagues (2004) recommend prudence when referring this valence effect as it appears to be sensible to the orientation of the face when emotional information is produced. More specifically, they suggest that valence effect tends to decrease if faces are mirror-reversed and that even small rotations of the head can significantly influence the expression of positive and negative emotions and, thus, how emotionality is perceived. More recent findings from electrophysiological measures also supports the valence-specific hypothesis for emotional facial expression (Balconi, & Mazza, 2010).

Sackeim and Gur (1978) also found some indirect evidence suggesting that the direction of hemispheric control over emotional expression may be related to affective valence of the emotion expressed; that is, although in general their results indicated higher intensity ratings for left hemifaces than right hemifaces for all emotions except happiness, they also found that the frequency of left hemifaces being judged as more emotionally intense than the right hemifaces was higher for negative emotions as compared to positive ones. Furthermore, evidence for valence-specific involvement also comes from studies with brain damaged patients (see, for example, Borod *et al.*, 1988).

Findings from functional neuroimaging on neural mechanisms of emotion processing during emotional tasks (see, for example, Killgore, & Yurgelun-Todd, 2007) suggest an integrative approach according to which both hypotheses are regarded as different facets of a complex distributed emotion processing system. These authors found that the right hemisphere was more extensively activated than the left hemisphere regardless of emotion valence or visual field of input, which implies that information is transferred to the right hemisphere for processing; a tendency for greater right cerebral activation for negative facial cues was also present. Furthermore, there appears to be a non-dominant posterior left hemisphere system, less capable to process on its own facial emotional information, which recruits bilateral and anterior cortical and subcortical brain regions for emotions processing. New perspectives for the study of brain asymmetry for emotion processing propose a more cooperative approach rather than the view of the two hemispheres in terms of absolute dominance and also that the investigation should be focused on small regions of the brain rather than on whole hemispheres (for a review, see Alves, Fukusima, Aznar-Casanova, 2008).

Differences between left and right-handed individuals in terms of hemispheric lateralization are well documented in the literature (for a review, see Willems, Van der Haegen, Fisher, & Francks, 2014). While motor cortex is perhaps the part of the brain where effects of handedness are most apparent, some amount of work has also

concentrated on the study of relationships between handedness and hemispheric lateralization for particular cognitive functions. One example of this is language. Regardless methodological differences, in general left hemisphere dominance is acknowledged in around 96% of right-handed individuals and around 73% of left-handed individuals. Accordingly, patterns of language lateralization are more consistently defined in right-handers than left-handers (Bryden, Brown, Roy, & Rohr, 2006a).

The relationship between handedness and hemispheric lateralization for processes related to the right hemisphere has also been investigated. In general, right-handed individuals reveal more strongly lateralized than left-handed individuals for visual-spatial tasks (Floël, Buyx, Breitenstein, Lohmann, & Knecht, 2005; Luh, 1995) and for facial emotion perception (Bourne, 2008a; Bourne, 2008b; Levy, Heller, Banich, & Burton, 1983; Luh, Redl, & Levy, 1994). Moreover, both right and left-handers show left visual field bias in tasks of this nature, although the bias is significantly reduced in left-handers, thus suggesting more attenuated hemispheric lateralization for facial processing. Considering this, Butler and colleagues (2005) report that some left-handers can present perceptual asymmetries comparable to right-handers while others show atypical performance either by exhibiting converse perceptual asymmetries or by lacking significant perceptual bias altogether and, thus, reflecting perhaps greater cooperation between the two cerebral hemispheres. Aside from handedness, there is also evidence on sex differences in cognition showing that women and men outperform each other on specific tasks. In general, consistent findings report higher performance for men on tasks related to spatial abilities whereas women outperform men on tasks requiring verbal-linguistic processing. Women also reveal better performance than men on face recognition tasks (Bourne, & Maxwell, 2010; Lewin, & Herlitz, 2002; Mcbain, Norton, & Chen, 2009; Rehnman, & Herlitz, 2007), and this advantage seems to include the processing of facial emotional information (for a review, see Brewster, Mullin, Dobrin, & Steeves, 2011).

When it comes to emotion expression, left-facedness (*i.e.*, greater expression intensity and more extensive facial movement on the left hemiface) has been consistently demonstrated in right-handed individuals when posing emotional expressions (Campbell, 1979; Heller, & Levy, 1981; Sackeim, & Gur, 1978), imagining emotional situations (Borod, & Caron, 1980) and relating emotional experiences (Moscovitch, & Olds, 1982). Moreover, Borod and Caron (1980) found that right-

handed individuals are significantly left-faced and that left-handed individuals tend to be also left-faced for emotion expression as left-facedness was found for 77% of their right-handed subjects and for 65% of their left-handed subjects. Moscovitch and Olds (1982) found that spontaneous smiles occur more on the left side of the face in right-handed individuals and that left-handed also tend to be left-faced though not significantly; they found this bias in a larger proportion of females than males. Campbell (1979) conducted an investigation with left-handers subjects and found that posed smile was also more left-faced than right-faced, consistent with their previous finding for right-handed individuals.

Furthermore, when poser's gender is considered, Campbell (1978) found left-facedness for males and females during both positive and negative emotional expressions. Borod, Koff and White (1983) report that negative emotions were left-sided for all subjects, while positive expressions were significantly left-sided for males only. This is contrasting with previous data suggesting that females are more lateralized than males for emotional processing and are also more expressive in and to emotional situations. Wylie and Goodale (1988) also found different patterns of asymmetries for male and female and in left and right-handers. Specifically, they report greater left-facedness for spontaneous smiles in left-handed women and right-handed males; right-handed females showed very little asymmetry in their spontaneous smiles. This stands in opposite direction to the claim by Ekman and colleagues (1981) that posed facial expressions are left-faced while spontaneous facial expressions are more symmetrical. Wylie and Goodale (1988) explain this considering that the previous study tested only right-handed individuals. Furthermore, they argue that male right-handers showing larger left-sided asymmetries than right-handed females is consistent with previous findings from Borod, Koff, and White (1983) described above. Borod and Caron (1980) found a sex difference in facedness with females being more left-faced for emotionally pleasant and communicative expressions while male, controversially, were more left-faced for negative and reactive emotions. They authors explain their findings from a social perspective rather than neuroanatomical as they suggest that females probably receive more reinforcement for the display positive affect and that they may be also more practiced than males in the communication of emotions. Further, Borod and colleagues (2004) support this explanation in a later study. However, data relating to sex and handedness differences is rather controversial as other authors failed to find significant facial asymmetries (Sackeim, & Gur, 1978). One main assumption that can

be drawn is that, similar to performance on perceptual asymmetries, left-handed individuals reveal a more attenuated hemispheric lateralization for emotion expression. Disparity of data would also suggest that although neuroanatomically the face area is adjacent to the arm area in the motor cortex of each cerebral hemisphere, facedness for emotion is not simply a motoric function in spite of recruiting movement of facial musculature. Also, methodological considerations are required as handedness assessment measures varied widely across these studies when considering dimensions of preference and motor performance.

2. OBJECTIVES AND HYPOTHESES OF THE PRESENT STUDY

The literature review on the studies approaching the mechanisms underlying hemispheric lateralization for the production on facial emotional expressions reports that facial asymmetries are more pronounced in the left hemiface. However, most findings have demonstrated this in right-handed individuals. Furthermore, data from the few studies conducted with left-handed subjects is somewhat controversial as either lack of facial asymmetries is reported or left-handed individuals tend to be also left-faced for emotion expression though to a lesser extent than right-handed individuals. Given these scarce findings from the literature on the performance of left-handers on tasks of this nature, our goal was to investigate if the left hemiface advantage for emotion expression depends or not on poser's handedness. To this end, we will develop a emotion evaluation task using chimeric faces constructed from only left- or right-side composites.

Considering the evidence available in the literature, our working hypotheses will state that the left-hemiface superiority for emotional expressiveness will be independent on poser's handedness.

Thus, our first hypothesis predicts that emotions expressed by LL-composite faces will be rated as more intense than RR-composite faces, both for right-handed and left-handed actors.

The second hypothesis predicts that emotions expressed by LL-composite faces will be more accurately recognized than RR-composite faces, both for right-handed and left-handed actors.

The third hypothesis predicts that emotions expressed by LL-composite faces will be recognized faster than emotions expressed by RR-composite faces, and that this advantage does not depend on actor handedness.

Finally, a fourth hypothesis predicts that LL-composite will be more expressive (i.e., more intense as well as more accurately and efficiently recognizable) than the RR-composite for the different emotions, regardless of their affective valence, and that this effect will not depend on actor handedness.

3. MATERIALS AND METHODS

Participants

Participants in this study were selected in two phases. In the first phase, we recruited from the community female individuals whom were to pose as naïve actors for emotional facial expressions from where the stimuli were later constructed. For convenient distinction, these participants will be further referred to as actors. All actors were naïve to the specific aims of the study. Both verbal and written informed consent was obtained prior to participation.

All actors were native Portuguese speakers and completed a basic self-report demographic questionnaire providing information about age, education level and current occupation. The actors also completed a 15-items handedness questionnaire adapted from the Edinburg Handedness Inventory (Oldfield, 1971). In this questionnaire, participants were instructed to rate hand preference for daily living activities described in each item according to a 7-point Likert scale ranged from -3 (always using left hand) to +3 (always using right hand), with total handedness scores ranging from -45 points (strongly left-handed) to +45 points (strongly right-handed) and indicating the degree and consistency of hand preference for each actor. Actors scoring between -15 points and +15 points were excluded from the study, as their total handedness score reveal weakly lateralization. The recruitment proceeded until a final sample of forty strongly lateralized female actors was obtained (20 left-handed and 20 right-handed participants). Left-handed participants had a mean handedness score of -42.85 points ($SD = 2.01$) and right-handed participants had a mean handedness score of +44.30 points ($SD = 1.26$).

All actors reported negative on cognitive impairment, history of alcohol or other substance abuse in the last six months, history of neurological or psychiatric disorder, acquired head trauma or current psychotropic drug treatment or other health treatment for anxiety, clinical depression or any other psychiatric, neurological and medical condition that could potentially affect cognitive functioning and emotional facial expression. They also reported negative on motor or sensorial impairment that could potentially affect facial expression. Measures of depression were also administered (BDI-II – Beck Depression Inventory-II), with all individual scores indicating absence of clinical depression.

The right-handed group was composed of twenty females (two of which African-European) with age ranged from 21 to 38 years, education level between 12 and 17 years, with 68% of the subjects being university graduates and 32% undergraduates. The left-handed group was also comprised of twenty females (three of which African-European) with age ranged from 20 to 40 years, education level between 12 and 15 years, with 52% of the subjects being university graduates and 48% undergraduates. Table 3.1 characterizes both handedness groups.

Table 3.1. Characterization of right- and left-handed actors

	<i>Total Actors</i> (N = 40)	<i>Right-handed Actors</i> (N = 20)	<i>Left-handed Actors</i> (N = 20)	<i>Cohen's d</i>	<i>Mann-Whitney test</i>
	M(SD)	M(SD)	M(SD)		
<i>Age (years)</i>	28.45 ± 4.89	29.50 ± 4.59	27.40 ± 5.07	0.43	.108
<i>Education (years)</i>	15.85 ± 0.86	16.20 ± 1.01	15.50 ± 0.51	0.87	.030*
<i>BDI II scores</i>	3.05 ± 2.44	3.40 ± 2.70	2.64 ± 2.23	0.29	.445
<i>Handedness scores</i>	N.A.	(+)44.30 ± 1.26	(-)42.85 ± 2.01	51.6	.000**

*p ≤ .05 **p ≤ .01 Notes: BDI-II – Beck Depression Inventory-II (0-10: normal; 11-16: dysphoria; 17-20: minimal to mild depression 21-30: moderate depression; 31-40: severe depression; > 40: major depression).

In the second phase, we recruited from the community twenty-four individuals (12 male, 12 female) who will assess the stimuli on two tasks. For convenient distinction, these individuals will be further referred to as judges. All judges were naïve to the specific aims of the study. Both verbal and written informed consent was obtained prior to participation.

All judges were native Portuguese speakers and completed a basic self-report demographic questionnaire providing information about gender, age, education level and current occupation. In this group, ages ranged from 22 to 37 years (mean age = 30.62 years, *SD* = 4.70) and education level ranged from 14 to 16 years (mean education = 16.00, *SD* = 0.66), with 88% of the individuals being university graduates and 12% undergraduates. All judges self-reported right-handed on daily living activities and for writing; these individuals were not submitted to handedness questionnaire as

self-reported information was considered sufficient for the purposes of the study. Measures of depression were also administered (BDI-II – Beck Depression Inventory-II); individual scores ranged from 0 points to 14 points (mean score = 2.38, $SD = 3.32$) and overall scores indicated absence of clinical depression. Note that one male individual rated 14 points on BDI-II, which corresponds to dysphoria and not clinical depression; therefore, he was not excluded from the study. Moreover, all judges reported negative on cognitive impairment, history of alcohol or other substance abuse in the last six months, history of neurological or psychiatric disorder, acquired head trauma or current psychotropic drug treatment or other health treatment for anxiety, clinical depression or any other psychiatric, neurological and medical condition that could potentially affect cognitive functioning and emotional facial expression. They also reported normal or corrected-to-normal vision.

Stimuli

The forty naïve actors were photographed while posing expressions of four basic emotions (happiness, anger, fear, sadness). They were instructed to show the most intense expression except for happiness, in order to avoid ceiling effects. All actors posed for all targeted expressions and three photos of each expression were taken per participant. The order for the emotional expressions varied among actors according to their preference and readiness to simulate. Actors were instructed before session to remove piercings and make-up. On the set they were given access to a mirror and time to practice their expression. Also, examples of facial expressions for each emotion were available from *The Karolinska Directed Emotional Faces* (Lundqvist, Flykt, & Öhman, 1998).

The cue to actually pose the expression was “Ready, go”. Encouragement to maximize or intensify expression was given when necessary. Sessions were conducted individually, with actors seated at 2 m from the camera and instructed to look straight forward and move as less as possible. Illumination conditions, distance and camera resolution were controlled for all participants. Facial expressions were captured by using a digital Canon 450D Camera. A total of 40 actors \times 4 emotions \times 3 photos = 480 high resolution colored photographs with 4272 x 2848 pixels was obtained.

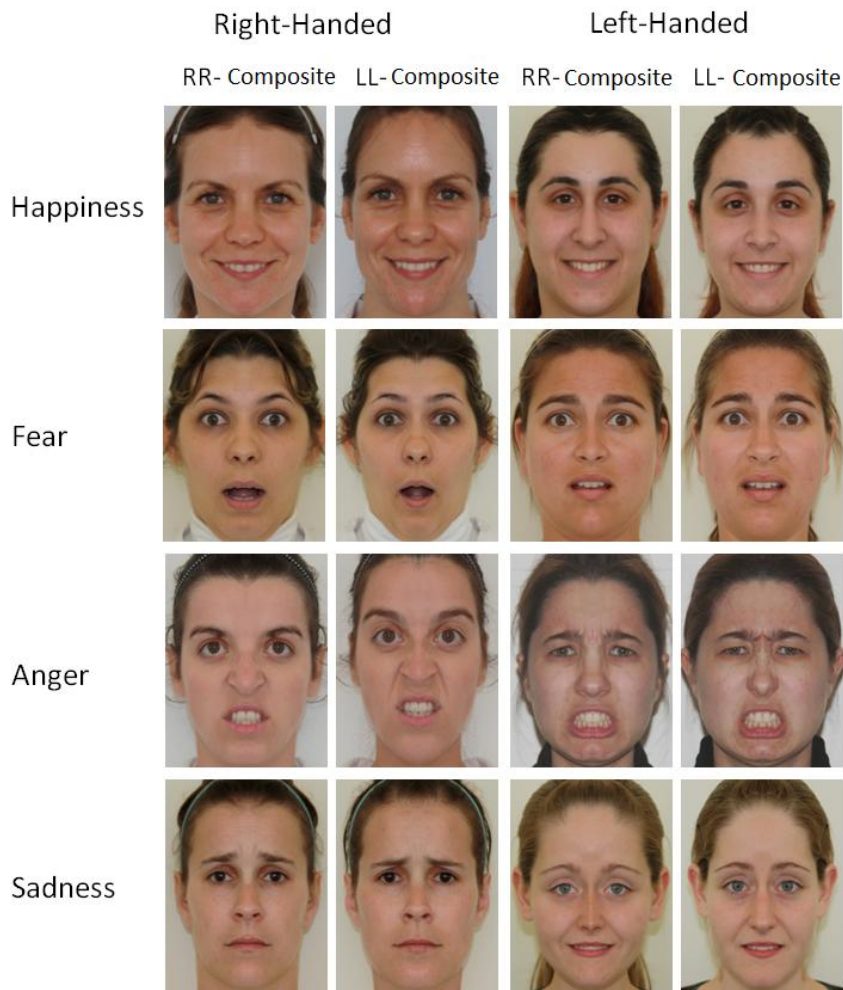
All original photographs were submitted to the scrutiny of thirteen preliminary judges instructed to evaluate each expression based on accuracy and intensity and to select one photograph out of three which best represents each expression posed by each actor. For each actor, photographs were displayed always in the same sequence: happiness, fear, anger and sadness. Labels with targeted emotion were provided before each trial of photographs to inform the judges which emotion they were to assess. Judges were instructed to make a decision and register their selection on a checklist before they moved to the next trial of photographs expressing a different emotion. Agreement between judges was high for most trials (mean percentage of agreement = 69.4%, standard-deviation = 16.6%; range = 38.5% - 100%), except for the occurrence of ties in 15% of the situations. Based on the decisions of these preliminary judges, the final set of 160 original photographs was selected.

To create chimeric faces, duplicates of the photographs with the mirror-reversed orientation were generated using Adobe Photoshop Version 12® (Adobe Systems, San Jose, CA). For each face the position of the head was corrected laterally, vertically and medially by rotation until the face looked exactly toward the viewer in the precise head-on position. The original and reversed versions were divided vertically through midline and the two left-left and two right-right hemifaces were combined to make merged faces with only left-left and right-right hemifaces. This procedure ensured that the composites were exactly symmetrical and that perception biases, often described in the literature, were eliminated for the purposes of this study since judges will be presented the same stimulus in both visual hemifields and observation differences will be discussed as related to asymmetrical expression rather than asymmetrical perception. A total of 320 chimeric faces were obtained.

All photos, including the 160 originals, were cropped above the forehead, below the chin and near the ears and resized for 1300 x 1600 pixels. Brightness and sharpness corrections and removal of nonfacial features (i.e., birthmarks or other) that could tip the judges for facial manipulation were conducted. Figure 3.1 shows examples of the stimuli.

We also created a set of 24 training stimuli from pictures of female models posing for happiness, anger, fear and sadness selected from *The Karolinska Directed Emotional Faces* (Lundqvist, Flukt, & Öhman, 1998). These faces were submitted to the same image quality enhancement and resizing as the target stimuli.

Figure 3.1. Examples of chimeric faces that are composed of only LL-composites or RR-composites of actors showing happiness, fear, anger and sadness expressions



Experimental Design and Procedure

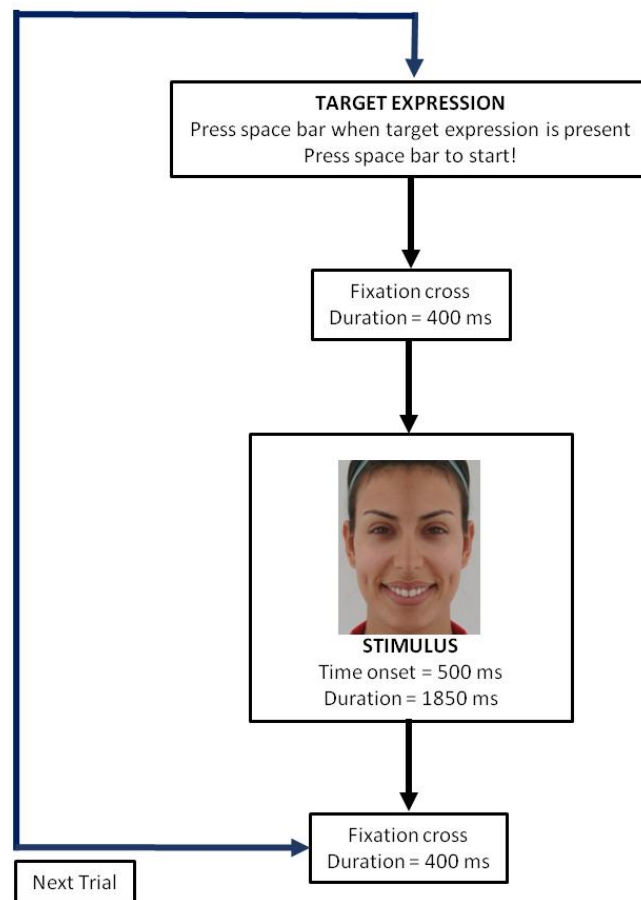
The study aimed to evaluate if the handedness of the actor affects differently the hemiface dominance for emotional expression. To this end, two tasks were implemented: a *Go-No-Go Task* and an *Evaluation Task*.

For the *Go-No-Go Task* we used only chimeric faces and the purpose was to observe if responses to LL-Composites and RR-Composites varied in accuracy and reaction times. Stimuli were organized in homogeneous blocks where the participants were required to detect a specific emotion (target). Each block comprised of 20 faces for the target expression (a go-response was required) and 12 faces representing the other three expressions (distractors, requiring a no-go response), defining a 5:3 ratio for

targets and distractors. In this way, a total of 16 blocks (four blocks for each emotion, happiness, fear, anger and sadness) was obtained; stimuli distribution was counterbalanced and randomized across the blocks and each actor appeared only once per block. Visual labels were displayed before each block initiated in order to inform the judges which emotional expression they were to target. The sequence of presentation for the 16 blocks was counterbalanced. An additional block for training was constructed using the 24 stimuli previously selected from *The Karolinska Directed Emotional Faces*. The software *Presentation*® Version 17.2 (Neurobehavioral Systems, Inc.) was used to deliver the stimuli and to record response accuracy and reaction time.

All twenty-four judges performed the *Go-No-Go Task*. They were seated in front of a laptop computer with a 15.6-inch screen. The display height was adjusted for each judge so that the center of the display was in front of the participant at eye level. The room lighting directly over the participant was dimmed to reduce glare. Stimuli were displayed on computer at a viewing distance of 60 cm. At that viewing distance the stimuli subtended an average visual angle of 10°05' vertically and 8°06' horizontally, corresponding to an image size of 10.5 x 8.5 cm, similar to the size of a real face viewed from 100 cm away, reflecting a natural distance during human interaction (Hsiao, & Liu, 2012). All judges initiated with the training scenario in order to familiarize themselves with the nature of the task. They were instructed to look at the pictures that will be presented in each block and to press space bar on the keyboard as quickly as possible each time the targeted expression appears. Each trial started with a centrally located fixation cross displayed for 400 ms after which the stimulus was presented (time onset at 500 ms); the stimulus was available for observation for 1350 ms and judges were allowed a maximum window of 1850 ms to make a decision. After a decision was made (i.e., by pressing the space bar on the keyboard) or trial timed out at 1850 ms, whichever came first, another trial initiated automatically. The maximum duration of the task was about 40 minutes. Participants were allowed short breaks between blocks as many times they felt necessary. Figure 3.2 shows an example of trial presentation.

Figure 3.2. Go-No-Go task: Scheme for stimuli presentation

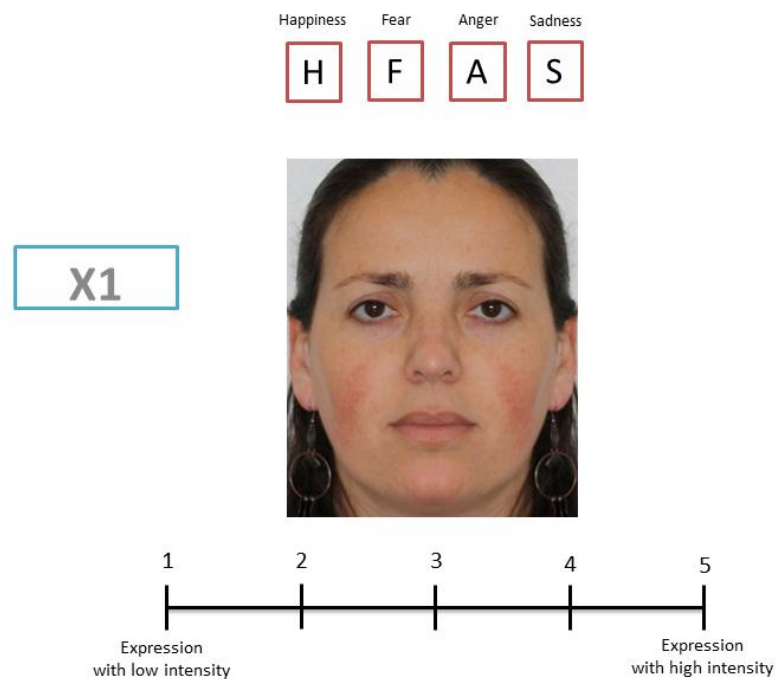


The purpose for the *Evaluation Task* was to collect information on both accuracy and intensity of the facial expressions, using a forced-choice answering format. For this task we used a total of 480 mixed stimuli consisting of both 320 chimeric faces and the 160 originals from where composites were produced. To avoid order effects, stimuli were organized in 12 blocks, each block composed of 40 faces, so that each actor appeared only once per block; both chimeric and originals pictures were randomized and counterbalanced within blocks and three sequences of blocks were considered. This task was carried out on computer software PowerPoint® (Microsoft Office 2013™). Each slide presented one picture in the center and two labels. One label, located above the stimulus, prompting accuracy response by reminding the judges which expressions they should choose from. Labels followed always the same order (happiness, fear, anger and sadness; in Portuguese, it corresponds to alphabetic order); also, boxes with initial

letter for each expression were highlighted to facilitate registration. A second label, located below the stimulus, consisted of a 5-point Likert scale measuring expression intensity ranged from 1 point (low intensity) to 5 points (high intensity). No time limit was set for this task. A checklist was provided and judges were instructed to register both accuracy and intensity responses for each expression.

All twenty-four judges performed the *Evaluation Task*. A latin square design was used to counterbalance the three sequence of presentation for the blocks across judges. According to their preference, judges were allowed to complete this task at a different time than *Go-No-Go Task* since it did not require special participant or setting preparation and also in order to avoid fatigue interference since the task required at least another 40 minutes. Figure 3.3 shows an example of slide presentation.

Figure 3.3. Evaluation task: Example of slide for stimuli presentation



Statistical Analysis

A general linear model with repeated measures was used to analyze the effects of actor handedness (right-handed versus left-handed), composite faces (RR- versus LL-composite faces) and emotion (happiness, fear, anger and sadness) on the different measures of emotional expressiveness (dependent variables: emotional intensity, recognition accuracy and correct recognition reaction time). Separate analyses were conducted for the three dependent variables. Post-hoc comparisons of means followed the Bonferroni correction procedures. The alpha level for rejecting the null hypothesis was set at $p \leq 0.05$. Statistics were generated on computer software SPSS Version 22.0 (Statistical Package for Social Sciences).

4. RESULTS

Intensity

Our goal was to investigate if the left-hemiface advantage for emotion expression depends or not on actor's handedness. The first hypothesis predicted that emotions expressed by LL-composite faces will be rated as more intense than RR-composite faces, both for right-handed and left-handed actors. This hypothesis can be accessed through the results obtained in the Evaluation task. Emotion intensity judgments were submitted to a repeated measures ANOVA with three within-subjects factors (emotion expression, actor handedness and composite face); see results on Table 4.1.

Table 4.1. – Effects of Emotion, Composite face and Actor handedness on the intensity of the emotional expressions (Evaluation task) – repeated measures ANOVA results

Effects	Intensity judgments	Pairwise comparisons
Emotion (E)	$F(3, 69) = 112.9, p \leq .001, \eta_p^2 = .83$	Sadness < (Fear = Anger) < Happiness
Composite face (F)	$F(1, 23) = 1.4, p = .257, \eta_p^2 = .06$	--
Actor handedness (H)	$F(1, 23) = 1.8, p = .193, \eta_p^2 = .07$	--
$E \times F$	$F(3, 69) = 0.6, p = .599, \eta_p^2 = .03$	--
$E \times H$	$F(3, 69) = 4.1, p = .010, \eta_p^2 = .15$	See text
$F \times H$	$F(1, 23) = 0.1, p = .804, \eta_p^2 = .00$	--
$E \times F \times H$	$F(3, 69) = 1.9, p = .147, \eta_p^2 = .07$	--

The effect of emotion on the intensity judgments is the only significant main effect (partial- $\eta^2 = .83, p \leq .001$), with happiness being evaluated as more intense than the other emotions ($M \pm SEM = 4.33 \pm .103$, in a 5-point scale). There was no difference in intensity between expressions of fear and anger (respectively, $3.44 \pm .130$ and 3.49 ± 3.49), while sadness was judged as the less intense expression ($3.14 \pm .124$).

Although the results indicate that the LL-composite expressions tend to be in general more intense than the RR-composite expressions, this effect is small and non-significant (partial- $\eta^2 = .06, p = .257$).

The interaction between Emotion and Face is very small and non-significant ($\text{partial-}\eta^2 = .03, p = .599$), indicating that the intensity judgments for the different emotions were similar when expressed either by LL-composites or by RR-composites. However, the emotion effect seems to depend on actor handedness (interaction Emotion \times Handedness: $\text{partial-}\eta^2 = .15, p = .010$): left-handed actors seem to be more intense than right-handed actors in the expression of Anger (right-handed actors: $3.42 \pm .128$ versus left-handed actors: $3.56 \pm .145; p = .029$), while right-handed actors seem to be more intense than left-handed actors in the expression of Sadness (right-handed actors: $3.18 \pm .135$ versus left-handed actors: $3.10 \pm .117; p = .095$); handedness exerts no significant effect on the intensity of the expression of Fear and Happiness.

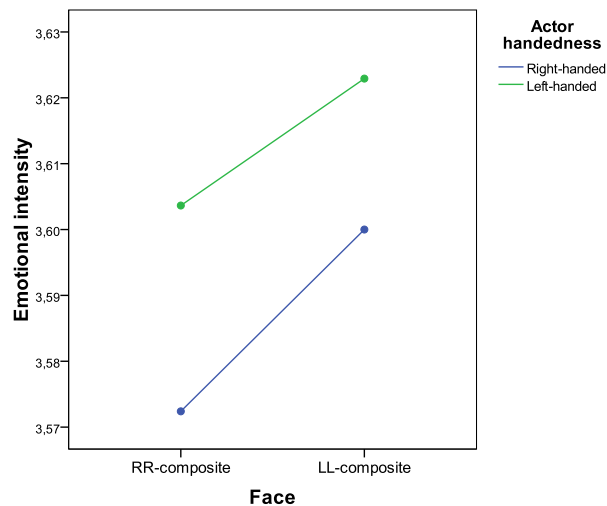


Figure 4.1. – The effect of Composite face and Actor handedness on the intensity of emotional expression

The interaction between Composite Face and Actor handedness is the principal effect for this study. This interaction is clearly negligible ($\text{partial-}\eta^2 = .00, p = .804$; see Figure 4.1), suggesting that the left-hemiface advantage is independent on actor's manual laterality. The analysis of the individual main effects indicates that the expressions of left-handed actors are considered more intense than the expressions of right-handed actors; however, this difference is small and not significant (right-handed actors: $3.59 \pm .114$ versus left-handed actors: $3.61 \pm .118; \text{partial-}\eta^2 = .07, p = .193$). Similarly, despite LL-composites were generally evaluated as more intense than RR-

composites, the difference is not significant (RR-composites: $3.59 \pm .115$ versus LL-composites: $3.61 \pm .117$; $\text{partial-}\eta^2 = .06$, $p = .257$).

The absence of a significant third-order interaction ($\text{partial-}\eta^2 = .07$, $p = .147$) suggests that the pattern of results concerning the effects of Composite face and Handedness will be similar for the different emotions (see Figure 4.2).

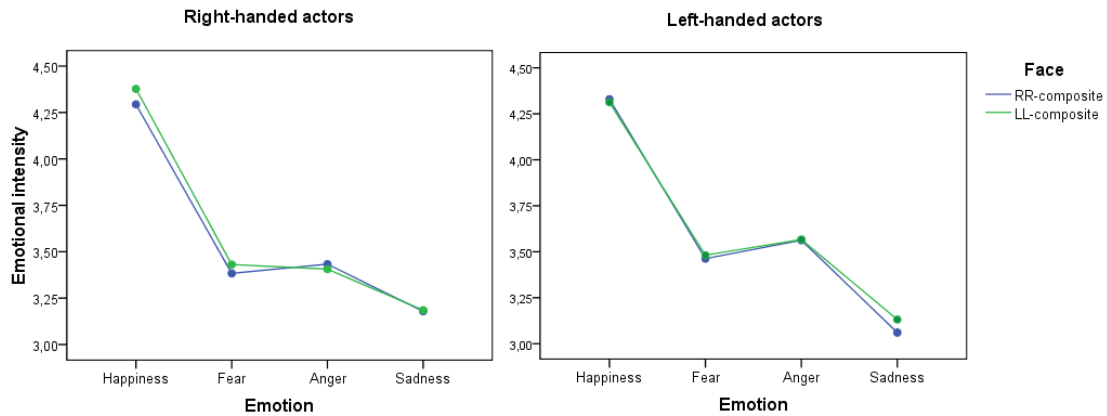


Figure 4.2. – The effect of Composite face and Actor handedness on the intensity of four emotions

Accuracy

The second hypothesis predicted that emotions expressed by LL-composite faces will be more accurately recognized than RR-composite faces, both for right-handed and left-handed actors. This hypothesis can be evaluated through the results obtained in both tasks (the Go no-Go task and the Evaluation task). So, a repeated measures ANOVA model was used to analyze the effects of the within-subjects factors (task, emotion, actor handedness and composite face) on recognition accuracy of emotional expressions (see results on Table 4.2).

Table 4.2. – Effects of Task, Emotion, Composite face and Actor handedness on the accuracy of emotion recognition

Effects	Evaluation task	Pairwise comparisons
Task (T)	$F(1, 23) = 0.0, p = .858, \eta_p^2 = .00$	--
Emotion (E)	$F(3, 69) = 63.2, p \leq .001, \eta_p^2 = .73$	Sadness < Anger < Fear < Happiness
Composite face (F)	$F(1, 23) = 4.6, p = .042, \eta_p^2 = .17$	LL < RR
Actor handedness (H)	$F(1, 23) = 188.9, p \leq .001, \eta_p^2 = .89$	Left-handed < Right-handed
T × E	$F(3, 69) = 0.7, p = .579, \eta_p^2 = .03$	--
T × F	$F(1, 23) = 3.3, p = .082, \eta_p^2 = .13$	Evaluation task: LL < RR Go no-Go task: LL ≈ RR
T × H	$F(1, 23) = 0.1, p = .758, \eta_p^2 = .01$	--
E × F	$F(3, 69) = 3.7, p = .003, \eta_p^2 = .18$	
E × H	$F(3, 69) = 90.2, p \leq .001, \eta_p^2 = .80$	See text
F × H	$F(1, 23) = 12.9, p = .002, \eta_p^2 = .36$	Right-handed: LL < RR Left-handed: RR < LL
T × E × F	$F(3, 69) = 0.7, p = .547, \eta_p^2 = .03$	--
T × E × H	$F(3, 69) = 4.5, p = .006, \eta_p^2 = .17$	
T × F × H	$F(1, 23) = 8.7, p = .007, \eta_p^2 = .28$	See text
E × F × H	$F(3, 69) = 14.3, p \leq .001, \eta_p^2 = .38$	See text
T × E × F × H	$F(3, 69) = 1.0, p = .421, \eta_p^2 = .04$	--

When factors were considered individually, the strongest main effect was found for actor handedness (partial- $\eta^2 = .89, p \leq .001$), with emotions expressed by right-handed actors being more accurately recognizable than emotions expressed by left-handed actors. This main effect is independent of the task (second-order interaction Task × Handedness non-significant).

A strong main effect of emotion was also evident for both tasks (main effect: partial- $\eta^2 = .73, p \leq .001$). This effect is related with higher accuracy levels for happy faces ($M \pm SEM = .99 \pm .003$) and lower accuracy levels for sad faces ($M \pm SEM = .72 \pm .028$); Fear and Anger take intermediate positions ($.89 \pm .025$ and $.84 \pm .025$, respectively). Again, this main effect does not depend on the task (second-order interaction Task × Handedness non-significant).

The main effect of Composite Face is also significant but weaker (partial- $\eta^2 = .17$, $p = .042$) and it depends marginally on task (second-order interaction Task \times Face: partial- $\eta^2 = .13$, $p = .082$): the emotions expressed by RR-composite faces tend to be evaluated slightly more accurately than the emotions expressed by LL-composite faces in the Evaluation task (RR-composites = $.864 \pm .020$ versus LL-composites = $.852 \pm .021$), while this advantage disappears in the Go no-Go task (RR-composites = $.863 \pm .024$ versus LL-composites = $.862 \pm .023$).

Finally, the main effect of the Task is clearly negligible (partial- $\eta^2 = .00$, $p = .858$), indicating that judges reached an equivalent level emotion recognition in both tasks.

However, these effects interacted with each other, producing significant second- and third-order interaction effects. The joint effects of Face composite and Actor handedness are of central importance for this study.

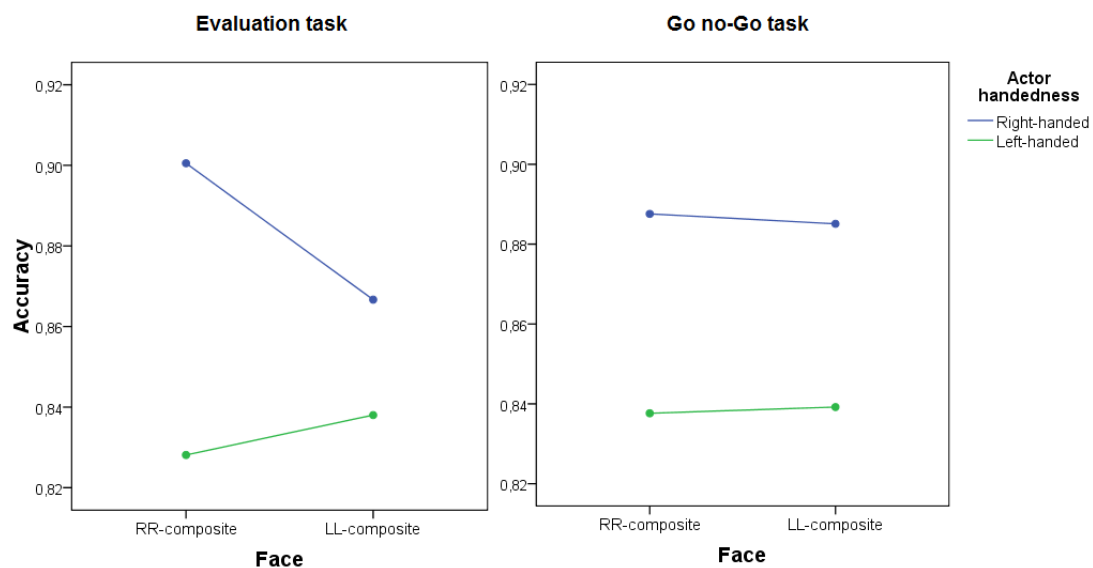


Figure 4.3. – The effect of Composite face and Actor handedness on the accuracy of the emotion recognition in the Evaluation and Go no-Go tasks

The second-order interaction between Face and Handedness has a large and significant effect (partial- $\eta^2 = .18$, $p = .003$) which results from a RR-composite advantage for emotions expressed by right-handed actors (RR-composite = $.894 \pm .019$ versus LL-composites = $.876 \pm .019$), while the left-handed actors showed a small LL-composite advantage (RR faces = $.833 \pm .019$; LL faces = $.839 \pm .019$). However, this

interaction effect seems to depend on the task (third-order interaction Task \times Face composite \times Handedness: partial- $\eta^2 = .28$, $p = .007$; see Figure 4.3). In the Evaluation task, the emotions expressed by right-handed actors are more recognizable when conveyed by RR-composite faces ($.901 \pm .018$) than when conveyed by LL-composite faces ($.867 \pm .020$); on the contrary, for the left-handed actors there is a small advantage of the LL-composite (RR-composite: $.828 \pm .023$; LL-composite: $.838 \pm .022$). In the Go no-Go task, this interaction effect although similar is clearly negligible (right-handed actors: RR-composite: $.888 \pm .025$ versus LL-composite: $.885 \pm .024$; left-handed actors: RR-composite: $.838 \pm .023$ versus LL-composite: $.839 \pm .023$).

The joint effect of Face composite and Actor handedness on accuracy seems to depend on the emotion expressed, resulting in a large significant three-order interaction (partial- $\eta^2 \approx .38$, $p \leq .001$; see Figure 4.4). This third-order interaction does not depend on task (fourth-order interaction non-significant).



Figure 4.4. – Effects of Composite face, Actor handedness and Emotion on accuracy of the emotion recognition

For the left-handed actors, all the emotions seem to be equally well expressed both by RR- and by LL-composite faces with the exception of a small but significant advantage for the LL-composite expression of Anger (RR-composite: $.803 \pm .025$ versus LL-composite: $.831 \pm .027$; $p = .025$); on the contrary, for right-handed actors, the RR-composite expressions of Anger (RR-composite: $.883 \pm .026$ versus LL-composite: $.833 \pm .026$; $p \leq .001$) and Sadness (RR-composite: $.830 \pm .026$ versus LL-composite: $.790 \pm .028$; $p \leq .001$) are significantly more recognizable when compared to

their relative LL-composite expressions; there is also a LL-composite advantage when Fear is expressed by the right-handed actors (RR-composite: $.869 \pm .028$ versus LL-composite: $.890 \pm .025$; $p = .024$), but this seem to occur only on Go no-Go task (results not presented).

Although not directly related to the hypotheses of the present study, the large and significant second-order interaction between Emotion and Actor handedness should be noted (partial- $\eta^2 = .80$, $p \leq .001$). This interaction results from the advantage of right-handed actors not being always equal for the different emotional expression. Thus, while right- and left-handed actors do not differ in the expression of happiness, the expressions of Anger (Right-handed actors: $.858 \pm .025$ versus Left-handed actors: $.817 \pm .026$; $p \leq .001$) and Sadness (Right-handed actors: $.810 \pm .027$ versus Left-handed actors: $.629 \pm .031$; $p \leq .001$) are more recognizable when expressed by right-handed actors; on the contrary, the expression of Fear has an advantage in left-handed actors (Right-handed actors: $.879 \pm .026$ versus Left-handed actors: $.901 \pm .024$; $p = .008$). The interaction between Emotion and Handedness depends on the task (interaction Task \times Emotion \times Handedness: partial- $\eta^2 = .17$, $p = .006$), but this third-order effect seems to result from the left-handed actor advantage in fear expressions appeared only in the Go no-Go task.

The interaction between Emotion and Composite face is also significant (partial- $\eta^2 = .18$, $p = .003$) and does not depend on the task (interaction Task \times Emotion \times Face non-significant). It results from the specific advantage of RR-composite faces for the expression of Sadness (RR-composite: $.730 \pm .028$ versus LL-composite: $.709 \pm .028$; $p = .002$); the differences in accuracy between face composites for the other three emotions are no significant ($p > .150$).

Reaction times

The hypothesis related to the efficiency during the recognition of emotional expressions can be accessed through the results obtained exclusively in the Go-no-Go task. A simple measure of the reaction time for correct responses (hits) was analyzed using a repeated measures ANOVA model with three within-subjects factors (emotion, actor handedness and composite face). This third hypothesis predicts that emotions expressed by LL-composite faces will be recognized faster than emotions expressed by RR-composite faces, and that this advantage does not depend on actor handedness. The ANOVA results are presented on Table 4.3.

Table 4.3. – Effects of Task, Emotion, Composite face and Actor handedness on the hit reaction time (Go no-Go task)

Effects	Hit reaction times	Pairwise comparisons
Emotion (E)	$F(3, 69) = 104.6, p \leq .001, \eta_p^2 = .82$	Happiness < (Fear=Anger) < Sadness
Composite face (F)	$F(1, 23) = 5.1, p = .034, \eta_p^2 = .18$	RR < LL
Actor handedness (H)	$F(1, 23) = 18.8, p \leq .001, \eta_p^2 = .45$	Right-handed < Left-handed
E × F	$F(3, 69) = 1.8, p = .159, \eta_p^2 = .07$	--
E × H	$F(3, 69) = 5.8, p \leq .001, \eta_p^2 = .20$	See text
F × H	$F(1, 23) = 10.6, p = .003, \eta_p^2 = .32$	Right-handed: RR < LL Left-handed: LL ≈ RR
E × F × H	$F(3, 69) = 3.5, p = .020, \eta_p^2 = .13$	See text

With the exception of the second-order interaction Emotion × Composite face, all the remaining effects are significant. The main effect of emotion is strong and parallel to the emotion effect described for accuracy (partial- $\eta^2 = .82, p \leq .001$): recognizing happiness expressions seems to involve shorter reaction times ($M \pm SEM = 463.2 \pm 21.7$ ms), thus being recognized faster than the other emotions, followed by fear (659.7 ± 35.0 ms) and anger (675.0 ± 26.0 ms) and finally sadness (734.1 ± 15.4 ms), that required the longest time for a correct identification. This pattern of results, however, seems to be affected by actors' handedness (Emotion × Handedness interaction: partial- $\eta^2 = .20, p \leq .001$). Specifically, fear and sadness expressions are recognized faster when posed by right-handed actors (for fear, right-handed actors: 641.8 ± 34.5 versus left-handed actors: 677.6 ± 36.3 ; $p = .004$; for sadness, right-handed

actors: 711.6 ± 19.4 versus left-handed actors: 756.5 ± 13.7 ; $p = .003$). Handedness seems not affect reactions happiness or anger expressions ($p > .35$).

Actor handedness exerts a main strong effect on reaction times (partial- $\eta^2 = .45$, $p \leq .001$): emotions expressed by right-handed actors are recognized faster than emotions expressed by left-handed actors (right-handed: 623.8 ± 23.9 versus left-handed: 642.1 ± 23.3). The Composite face effect is also significant but weaker (partial- $\eta^2 = .18$, $p = .034$), resulting from an overall tendency for RR-composites presenting shorter reaction times than the LL-composites (RR-composite: 629.0 ± 23.0 versus LL-composite: 637.0 ± 24.2).

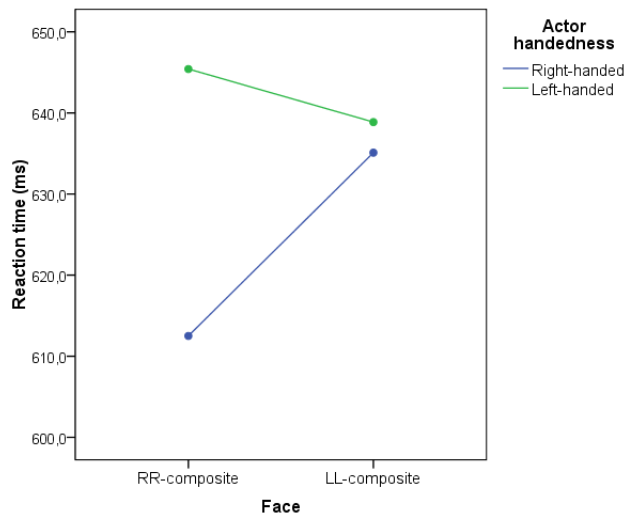


Figure 4.5. – Effect of Composite face and Actor handedness on hit reaction time (milliseconds)

Again, the joint effect of Composite Face and Actor Handedness is central for the present study. This effect was strong and significant (partial- $\eta^2 = .32$, $p = .003$; see Figure 4.5) and results from a clear advantage of the RR-composite for emotions posed by right-handed actors (RR-composite: 612.5 ± 22.6 versus LL-composite: 635.1 ± 25.4 ; $p \leq .001$) whereas a smaller non-significant advantage of the LL-composite emerged for the emotions posed by left-handed actors (RR-composite: 645.4 ± 23.6 versus LL-composite: 638.9 ± 23.3 ; $p = .255$). This pattern of results is affected by emotions (third-order interaction: partial- $\eta^2 = .13$, $p = .020$; see Figure 4.6).



Figure 4.6. – Effect of Composite face, Actor handedness and Emotion on hit reaction time (milliseconds)

The third-order interaction stems mainly from longer reaction times required to recognize Fear expression in LL-composite faces when compared to the same expression in RR-composite faces of right-handed actors (RR-composite: 608.0 ± 30.9 versus LL-composite: 675.6 ± 40.5 ; $p = .003$); for the other emotions, the RR-composite advantage does not reach statistical significance ($p > .3$). For the left-handed actors, the advantage of the LL-composite is smaller (never reaches statistical significance, $p > .15$) and is reversed for Anger.

5. DISCUSSION

The main purpose of this study was to investigate the possible interaction between poser (actor)'s handedness and emotional facedness (*i.e.*, the relative intensity of expression and the extent of movement on the left and right sides of the face). There is considerable evidence in the literature that emotions are more expressive in the left hemiface, implicating greater right hemisphere involvement (Borod, & Koff, 1990; Sackeim, Gur, & Saucy, 1978). The main reason to carry out the present investigation lies in the fact that, in spite of a considerable amount of literature on facial asymmetries of emotion expression, most studies demonstrating left-facedness for emotion based their findings on right-handed individuals whereas left-handed individuals were less taken into account (Borod, & Caron, 1980; Campbell, 1979; Moscovitch, & Olds, 1982). Although data from the few studies conducted with left-handed subjects is scarce and somewhat controversial, we hypothesized that handedness does not influence the tendency for left-facedness observed in right-handers. So, we predicted that the left-left facial emotional composites (LL-composite) will be judged as more emotionally expressive than the right-right facial emotional composites (RR-composite), independent of poser's handedness.

The intensity of emotional expression (intensity measure)

In consistence with the literature, when the emotional intensity of the expression is considered, we expected that both right and left-handed actors would be similar at revealing greater intensity when the emotions are expressed in the left hemiface (LL-composite). Thus, our first main hypothesis predicts that emotions expressed by LL-composite faces will be rated as more intense than RR-composite faces, both for right-handed and left handed actors. Our results indicated that the LL-composite expressions tend to be more intense than the RR-composite expressions, although the advantage of the left hemiface is small (partial- $\eta^2 = .06$) and statistically unreliable ($p \approx .25$). This small advantage of LL-composite was not moderated by actor handedness (the interaction between handedness and composite face was clearly non-significant). These results seem compatible with our hypothesis that emotional expressions are more intense in left-hemifaces for both left-handers and right-handers. Despite being a small effect, the left-hemiface advantage is consistent with the research previously reviewed.

We further anticipated that the tendency for left-facedness would be similar between the right and left-handers across the different emotional expressions considered in this study. Accordingly, a secondary hypothesis predicts that LL-composite will be more expressive (i.e., more intense as well as more accurately and efficiently recognizable) than the RR-composite for the different emotions, regardless of their affective valence, and that this effect will not depend on actor handedness. The absence of a reliable third-order interaction ($p \approx .15$) supports our hypothesis that the left-hemiface advantage is similar for the different emotions. Overall, the results suggest that the tendency for the left hemiface to express emotions more intensely than the right one is not a function of the posers' right or left handedness, thus, confirming our secondary hypothesis.

Not directly related to our hypothesis, we found some results suggesting that left-handed actors seem to be more intense than right-handed actors in the expression of Anger, while right-handed actors seem to be more intense than left-handed actors in the expression of Sadness. These effects of handedness on the intensity of some of the emotional expressions considered in the study are interesting but unexpected; the empirical evidence and theoretical proposals available in the literature (such as the valence-specific hypothesis, Nicholls, Ellis, Clement, & Yoshino, 2004) do not allow us to interpret such differences and this topic should be further investigated in future studies.

The recognition of emotional expression (accuracy and reaction time measures)

Recognition accuracy of emotional expressions was yet another measure employed to test if actors differed or not on emotion expression as a function of their handedness. Our second main hypothesis predicts that emotions expressed by LL-composite faces will be more accurately recognized than RR-composite faces, both for right-handed and left-handed actors. However, contrarily to our results on emotion intensity, present findings do not support the hypothesis; thus the main hypothesis is rejected. In this respect, we found a significant interaction between composite face and handedness (partial- $\eta^2 = .36$) revealing a converse pattern in the efficiency of emotion expression for the two groups of actors.

Specifically, there was a large RR-composite advantage for emotions expressed by right-handed actors, thus highlighting expression efficiency in the right hemiface, which in turn, involved the left hemisphere. On the other hand, left-handed actors presented a small advantage for the left hemiface.

The third main hypothesis predicts that emotions expressed by LL-composite faces will be recognized faster than emotions expressed by RR-composite faces, and that this advantage does not depend on actor handedness. To test this, the accuracy results are reinforced by the analysis of hit reaction times: emotional expressions conveyed by RR-composite faces of right-handers are recognized significantly faster than emotional expressions conveyed by LL-composite faces; on the contrary, LL-composite faces of left-handers seem to be slightly more efficient conveying emotional expressions. Furthermore, overall results for measures of accuracy partially confirm our secondary hypothesis which predicts that LL-composite will be more expressive (i.e., more intense as well as more accurately and efficiently recognizable) than the RR-composite for the different emotions, regardless of their affective valence, and that this effect will not depend on actor handedness.

The superiority of the right hemiface, in general and in right-handers in particular, is unexpected because this finding contradicts the results observed for intensity (where there was a tendency for the emotion to be left-faced). This dissociation appears to be somewhat counterintuitive as one might believe that if a hemiface expresses the emotion more intensely it also would be more accurately or efficiently recognized by the viewer. Moreover, the fact that this apparent dissociation is reported specifically in right-handed actors is also intriguing, as literature has consistently ascertained a pattern of significant left-facedness for typical individuals. Still, the convergence of the intensity and accuracy measures in the same laterality direction for the left-handed actors is consistent with general report in the literature when considering the general tendency for left-facedness (Campbell, 1979; Borod, & Caron, 1980; Heller, & Levy, 1981). Taken together, the opposite effect of the two hemifaces observed in the tasks and the differences found as a function of handedness are difficult to explain as we did not find solid support in the literature. The only authors that we are aware of to report so far a similar dissociation on accuracy and intensity aspects related to emotion expression are Indersmitten and Gur (2003). Even if direct comparisons between our results are not possible since both studies differ methodologically on task construction and data analysis, their findings also report a clear dissociation in the same

main directions as ours. The authors present a few generalist explanations that might worth to be taken into consideration.

First, they raise the possibility that the left hemiface expresses emotions more intensely but also less specifically by mixing in other emotions, thus bringing to the forefront issues of functional hemispheric organization. They encounter support for this speculation in the model developed by Semmes (1968; cit. in Indersmitten, & Gur, 2003) which proposes that focal representation in the elementary functions in the left hemisphere favors integration of similar units and consequently specialization for behaviors which demand fine sensorimotor control as skills and speech. On the contrary, diffuse representations of elementary functions in the right hemisphere may lead to integration of dissimilar units and specialization of multimodal coordination such as spatial abilities. Following this line of reasoning, perhaps actors are indeed mixing in more emotions than expected in both or only one hemiface (apparently the left one) when specific emotional expression is triggered on cue, making the right-hemiface expressions more susceptible to an accurate recognition.

Nonetheless, it is also possible that the observed advantage of the right-hemiface is related to the fact that this side of the face is mostly controlled by the left hemisphere which in turn is more efficient to display specific information in the face on cue because it is more analytic and recruits other high-cognitive functions such as language which provides a verbal label that prompts expression in a faster and more efficient manner. In addition, the nature of the task used by Indersmitten and Gur (2003) as well as ours to assess emotional expression accuracy might facilitate satisfactorily the detection of these differences between the two hemifaces; thus, although these differences might have been there all along, maybe they simply have been ignored as the large bulk of the research has focused on measures of intensity and facial musculature movement alone. It would be interesting to further test accuracy measures in both posed and spontaneous eliciting conditions in order to provide future discussions on this matter.

However interesting these possible explanations may be, the findings could not be fully entrusted to them. Considering this, other aspects should be approached. One might relate to the nature of the tasks we used to test for intensity and accuracy measures. Namely, our results show that the advantage for the right hemiface in right-handed actors for the accuracy measure was observed only for data from the Evaluation task but we did not find any intrinsic reason for this; the fact that accuracy measures are less frequently described in the literature for tasks of this nature makes it even more

difficult to explain. However, if there was a methodological consideration, it would be expected that data for left-handed actors would be also influenced. Therefore, we await for further studies to bring more consideration on similar effects.

Finally, aspects related to non-emotional peripheral factors such as muscular activity and hemiface size as well as singular morphological characteristics for each face (Borod, & Koff, 1990) could provide sufficient distinctions between the faces among our sample in order influence the results. However this is also less likely as the same stimuli were used for both tasks.

Limitations

Although this research was planned following the methodological lines of the published studies on the topic, some weaknesses may have limited the strength of our conclusions. First of all, the stimulus set should be larger: more actors will allow a better stimulus quality (the preliminary selection could be more restrictive) and a larger final stimulus set will ensure more statistical power to detect subtle differences between conditions. However, difficulties in recruiting left-handers and the excessive time required for preparing the chimeric stimulus precluded the increase of the actors' sample. A more complete characterization of actor's laterality (handedness, footedness, as well as genetic factors such as familial handedness or writing posture), not exclusively based on self-reported measures, could result in better defined handedness groups (more homogeneous and more clearly distinct). Other intensity measures besides subjective ratings (for instance, objective measures of the intensity of the expressive movements of the face) could result on stronger differences between hemifaces.

Conclusion

Our results seem compatible with the hypothesis that emotional expressions are more intense in left hemifaces for both left-handers and right-handers. However, the apparent dissociation between intensity and accuracy measures of facial emotion expressiveness challenges current conceptualizations of an overall right hemispheric dominance for emotion expression as it suggests the operation of a more complex system for emotion processing. It would be interesting to further test accuracy measures in both posed and spontaneous eliciting conditions in order to provide a better understanding of neural mechanisms for facial emotion.

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