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Is Happy Facial Expression Identified by the Left or Right Hemisphere?*

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Abstract A critical difference between the right hemisphere hypothesis and valence hypothesis of emotion processing is whether the processing of happy facial expressions is lateralized to the right or left hemisphere. In this study participants from a Chinese sample were asked to classify happy or neutral facial expressions presented either bilaterally in both visual fields or unilaterally in the left visual field (LVF) or right visual field (RVF). They were required to make the speeded responses using either the left or right hand. It was found that for both left and right hand responses, happy (and neutral) expressions presented in the LVF were identified faster than happy (and neutral) expressions presented in the RVF. Bilateral presentation showed no further advantage over LVF presentation. Moreover, left hand responses were generally faster than right hand responses, although this effect was more pronounced for neutral expression. These findings were interpreted as supporting the right hemisphere hypothesis, with happy expression being identified initially by the right hemisphere.
Key words facial expression, positive emotion, happy, hemisphere, divided visual field.

1 Introduction

Correctly identifying other people's facial expressions of emotions is important to human social interaction in all societies. Many studies suggest that the identification of facial expressions in particular and perceptual processing of emotional information is carried out mainly by the right hemisphere of the brain [1~7]. Damage to the right hemisphere generally produces more significant impairment in recognition of all facial expressions of emotion than damage to the left hemisphere [8~10]. However, this right hemisphere hypothesis is challenged by the valence hypothesis which states that processing of positive emotions is lateralized to the left hemisphere whereas processing of negative emotions is lateralized to the right hemisphere [11~20]. Apparently a critical difference between the two hypotheses is whether processing of happy facial expression is lateralized to the left or right hemisphere, although some studies suggested that both hemispheres may be involved in processing positive emotions [10,21,22].

Both the right hemisphere and valence hypotheses are supported by studies using different experimental manipulations and tasks. Evidence concerning affective facial expressions comes mainly from two lines of research [1]. One line used composite (chimeric) faces in which half-faces of different expressions were re-combined and participants were asked to evaluate the emotional intensity of the combined faces [2,5,21,23~25]. This line of research, however, produced contradictory evidence for either the right hemisphere or the valence hypothesis. Another line of research, which is more pertinent to this study, presented full, normal faces

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to the left (LVF) or right visual field (RVF) and asked participants to perform certain tasks that may tap into various levels of emotion processing. If a certain affective expression is preferentially processed by a certain hemisphere, presenting the facial expression in the contralateral visual field should produce more efficient processing than presenting the expression in the ipsilateral visual field. The experimental tasks could require participants to compare or rate facial expressions in brief presentation [19,20,26] or in morphed faces with faint emotion expressions under free-viewing conditions [10,18,27], or to make speeded sample-matching of emotional expressions [4,6,7,28].

Contradictory results regarding the laterality of happy expression, however, were also obtained in this divided visual field paradigm. For example, Reuter-Lorenz and Davidson [19] asked participants to identify which side of a bilaterally presented pair of faces (one neutral and one affective) contained the affective face. Responses to happy faces presented in the RVF were faster than responses to happy faces presented in the LVF. A reversed pattern was observed for sad faces, consistent with the valence hypothesis. Jansari et al [18]. presented participants with a pair of faces from the same man, one with neutral expression and one with subtle emotion expressions gained through morphing the neutral face with a positive or negative expression. Participants' task was to choose the face in the pair that best corresponded to the stated emotion. It was found that the discrimination accuracy was higher when faces with positive expressions were presented on the right-hand side than when they were presented on the left-hand side, even though participants had sufficient time to inspect the faces freely. Conversely, the discrimination accuracy was higher when faces with negative expressions were presented on the left-hand side than when they were presented on the right-hand side. These findings suggest that positive expressions are processed in the left hemisphere while negative expressions are processed in the right hemisphere, and this dissociation can be obtained under free-viewing conditions. Other studies using emotional rating [26], speeded emotion matching[28], or the same design as Jansari et al [17,18]. obtained data that partially support the valence hypothesis, with only women, but not men, showing the predicted laterality effect. Still others obtained contradictory evidence to the valence hypothesis. For example, Strauss and Moscovitch [6] presented briefly a pair of faces to the LVF or RVF and asked participants to decide whether the two faces depicted the same emotion. The authors found a LVF advantage for all emotion in women participants.

A crucial difference between these studies may lie in whether a detailed or subjective evaluation of facial expressions is required by the experimental task [26,27,29,30]. Subjective or prolonged evaluation may be carried out by the left hemisphere since this evaluative process may require rational reasoning, while initial or coarse identification may be carried out by the right hemisphere which is also predominantly responsible for face recognition. The purpose of this study was to provide further evidence, from a Chinese sample, that speeded identification of facial expressions, which presumably taps into the initial stage of processing, is carried out mainly by the right hemisphere.

We continued to employ the divided visual field paradigm in which affective and neutral faces were presented either to the left or right visual field. But rather than requiring participants to match or compare emotions of facial expressions, we asked them simply to make speeded emotion categorization (i.e., whether the expression on the face was happy or neutral) to facial expressions that were presented singularly (i.e., one emotion in one trial). Moreover, we made a number of changes to the typical experimental design. Firstly, we added a condition in which identical faces were presented bilaterally to both visual fields. This condition served as a baseline with which the laterality effect for the left or right visual field could be compared. If happy expression is identified predominantly by one hemisphere, then reaction times (RTs) to faces presented to this hemisphere should be similar to RTs to faces presented to both hemispheres (in bilateral presentation), and both of them should be shorter than RTs to faces presented to the other hemisphere. If, however, both hemispheres are important to the processing of happy expression, then RTs for bilateral presentation should be shorter than RTs for either of the single hemisphere presentation. In contrast to what Schweinberger, Baird, Blümler, Kaufmann, and Mohr [31] claimed, our previous unpublished work showed that there is a bilateral gain in processing both negative and positive facial expressions. RTs in bilateral presentation were shorter than RTs in unilateral LVF or RVF presentation, and the latter did not differ from each other. These findings were taken as evidence for interhemispheric cooperation in processing affective facial expressions. This cooperation, however, could be strategically induced by the requirement of using both hands to respond simultaneously.

Therefore, the second modification in the present study was that two groups of right-handed participants were tested, one group using their left hand and another group using their right hand to make speeded emotion categorization. Because hand responses are controlled by the contralateral motor and supplementary motor cortices and within the same hemisphere there could be direct links between regions responsible for emotion processing and regions responsible for motor movements, the interaction between the visual field of stimulus presentation and hand response could provide important information concerning whether happy expression is identified by the left or right hemisphere. Suppose that happy expression is processed predominantly in the right hemisphere (Figure 1), as assumed by the right hemisphere hypothesis, happy expressions presented in the left visual field will project directly to this hemisphere (A and C) and happy expressions presented in the right visual field will have to be redirected from the left to the right hemisphere before it can be identified (B and D). Then when the left hand is used to make responses (A and B), interhemispheric redirection for the RVF presentation would take time to accomplish, resulting in an RVF disadvantage in RTs; when the right hand is used to make responses (C and D), the left motor cortex has to be linked, possibly through the right motor cortex, to the right hemisphere processing emotion. Compared with LVF presentation, RVF presentation still has a disadvantage because of the interhemispheric redirection. A secondary prediction from the above arguments is that RTs should be generally faster when the left hand, rather than the right hand is to make responses because a right hand response may involve two interhemispheric transmissions, one for facial expression and one for motor control while a left hand response may involve only one transmission for facial expressions. Suppose, however, happy expression is identified predominantly by the left hemisphere, as assumed by the valence hypothesis, a mirror image of Figure 1 would be presented and a RVF advantage would be predicted for identification of happy expression. On the other hand, if both hemispheres are equally responsible for the processing of happy expression, no significant differences would be observed between the LVF and RVF presentation.

The third modification was that, for unilateral presentation, rather than pairing a critical affective face with a neutral face [19], we paired the critical face with a scrambled face and presented them simultaneously, one in the critical visual field and one in the other visual field. The scrambled face, made from the paired face, was unique for each trial. Faces in the LVF may be stronger in attracting attention than faces in the RVF since the right parietal cortex is more involved in spatial attention than the left parietal cortex. This attentional bias may produce LVF advantage unrelated to facial expression identification itself. Having a new scrambled face in the other visual field in each trial could to some extent counteract this attentional bias because new objects may capture attention, making the comparison between RTs to facial expressions in different visual fields more pertinent to emotion processing.

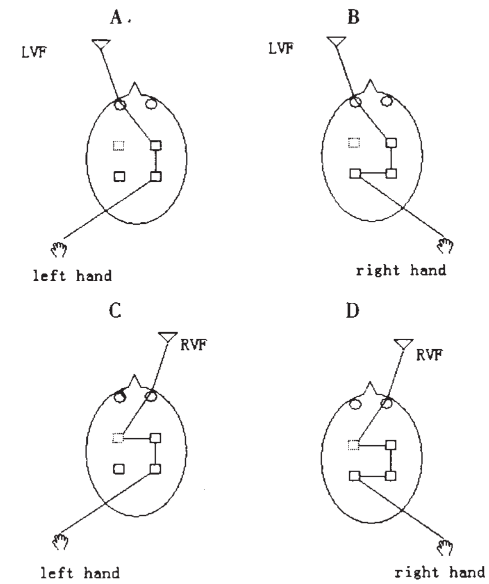

Figure 1 Interaction between stimulus projection and hand response in the brain. Assuming that affective facial expressions are identified by the right hemisphere, A) the left visual field input projects directly to the right hemisphere, where the brain regions connect directly with motor cortexes responsible for the left hand activity; B) the right visual field input projects to the left hemisphere, from whether the information is redirected to the right hemisphere; C) the left side motor cortexes, responsible for the right hand activity, connect across the hemispheres to the brain regions on the right hemisphere either directly or through the motor cortexes on right side; D) in this situation, the processes from stimulus input to hand response are the most complex, with two interhemispheric transmissions of information, one for stimulus input and one for motor control.

2 Method

2.1 Participants

A total of 32 right-handed participants were tested, 16 each for right or left hand responses. In each run, half of the 16 participants were male, half female. They were undergraduate students from Peking University and were paid for their participation. All had normal or corrected-to-normal vision and all gave their informed consent to participate in the study.

2.2 Stimuli

A total of 84 faces were used, 42 with happy expressions and 42 with neutral expressions. Half of the faces in each set were males and half females. All the faces were from different individuals, and they were taken from a standard Chinese facial expression set [32] and from our own unpublished set. To prevent participants from using simple perceptual strategies based on the visibility of teeth when judging facial expressions, care was taken to ensure that happy faces could display either open- or closed-mouth. All faces were edited using Adobe PhotoshopTM, converted to greyscale, and framed within a rectangular of 6.0cm×7.6cm or $3.5^{o}\times4.4^{o}$ in visual angle, with all background removed. Stimulus eccentricity (center to fixation) on the computer screen was 5.0cm, corresponding to a angle of about 2.9^{o}. For unilateral presentations, each face was paired with a unique pattern mask which was created by scrambling randomly the paired face divided into 9×11 pieces. The pattern mask was of the same size as the paired face.

2.3 Procedure

Participants were tested individually in a dimly-lit room and with a viewing distance of 100cm. During each trial, a fixation sign "+" was presented for 1000ms, followed by a pair of identical faces (for bilateral presentation) or a face and a pattern mask (for unilateral presentation) for 150 ms on either side of the fixation, which remained on screen until the end of face presentation. The screen was then blanked for 2000ms, give a total of 3150ms for each trial. Participants were required to classify, by pressing response keys as quickly and as accurately as possible, whether the presented facial expression was happy or neutral. Response keys were on a joystick, two on the left, two on the right, and one above another on either side. Participants were asked to place the index finger of the response hand on the top key and the middle finger on the lower key. The expression-to-key assignment was counter-balanced over participants. Presentation of stimuli and recording of participants' responses were controlled by the software DMDX [33].

Each run had 252 trials, with each of the 84 facial expressions presented three times, once in the BVF condition, once in LVF and once in RVF. These trials were completely randomized for each participant, with two breaks allowed every 84 trials. Before the formal test, a practice block of 24 trials, covering all the relevant conditions, was administered to each participant.

3 Results

Trials with incorrect responses were excluded from analyses. Median RTs and error percentages were then calculated for each participant as a function of experimental conditions. Exactly the same pattern of results were found when mean RTs were used in statistical analyses. Table 1 summarizes the inter-participant means of RTs and error percentages for different types of facial expressions in the three presentation conditions.

Table 1 Mean Reaction Times (ms) and Error Percentages (in parenthesis) to Happy and Neutral Expressions Presented Bilaterally or Unilaterally

	Happy			Neutral		
	BVF	LVF	RVF	BVF	LVF	RVF
Left Hand	623	627	650	843	857	868
	(4.1)	(4.0)	(7.0)	(6.1)	(5.5)	(6.3)
Right Hand	661	665	705	964	967	990
	(3.3)	(4.0)	(5.4)	(8.2)	(8.6)	(9.7)
Average	642	646	677	903	912	929
	(3.7)	(4.0)	(6.2)	(7.1)	(7.0)	(8.0)

For RTs, the main effect of facial expression was highly significant, $F(1,30)=226.42$, $p<0.001$, indicating that responses to happy expressions (655ms) were much faster than responses to neutral expressions (915ms). The main effect of visual field was also significant, $F(2,60)=17.07$, $p<0.001$, and this effect did not interact with response hand, $F(2,60)<1$, nor with facial expression, $F(2,60)<1$, suggesting that for both types of responses and for both happy and neutral expressions, participants' response speed was affected by whether the affective faces were presented at the left, right, or both visual fields. Bonferroni-corrected comparisons showed that responses to bilateral presentation (773ms) were equally fast as responses to LVF presentation (779ms), both of which were faster than responses to RVF presentation (803ms), with $p<0.001$.

The main effect of response hand was marginally significant, $F(1,30)=3.05$, $0.05<p<0.1$, indicating that left hand responses (745ms) were generally faster than right hand responses (825ms). However, this effect interacted with facial expression, $F(1,30)=4.66$, $p<0.05$, indicating that the difference in response speed between response hand was mainly contributed by neutral expressions (left hand, 856ms vs. right hand, 973ms), and only little by happy expressions (633ms vs. 677ms).

Analyses of response error rates found a significant main effect of facial expression, $F(1,30)=5.20$, $p<0.05$, with more errors committed on neutral expressions (7.39%) than on happy expressions (4.62%). The main effect of visual field was marginally significant, $F(2,60)=3.01$, $0.05<p<0.1$, with slightly higher rate in RVF (7.1%) than in BVF (5.4%) and LVF (5.5%). No other effects reached significance.

4 Discussion

For both left and right hand responses, happy (and neutral) expressions presented in the LVF were identified faster than happy expressions presented in the RVF. Bilateral presentation showed no further advantage over LVF presentation. Moreover, left hand responses were generally faster than right hand responses, although this effect was more pronounced for neutral expression. These findings strongly suggest that happy expression is identified predominantly by the right hemisphere, consistent with the right hemisphere hypothesis.

This pattern of effects can be easily understood under the framework depicted in Figure 1. If identification of happy expressions is lateralized to one hemisphere, stimulus input from the ipsilateral visual field would projected to contralateral hemisphere and this input has to be redirected to the "correct" hemisphere before it could be processed. This interhemispheric transmission takes time to accomplish and would result in delayed emotional categorization. This visual field effect is not affected by the hand used to make responses. But hand response does interact with visual field of stimulus presentation in deciding the overall speed of categorization. Although all our participants were right handed, their responses to both neutral and happy expressions were slowed when the right hand, rather than the left hand was used to make categorization. This finding is consistent with the assumption in Figure 1 that when affective emotions are identified by the right hemisphere, using the right hand to response would need additional interhemispheric connections between motor cortex and brain regions responsible for affective processing.

The question is then why the present study obtained evidence supporting the right hemisphere hypothesis while some other studies obtained evidence supporting the valence hypothesis, even though essentially the same visual field paradigm was used. As pointed out by some researchers such as Davidson [29], Ley and Strauss [30], Rodway et al [27]. and van Strien and van Beek [26], a crucial difference between these visual field studies may lie in whether the experimental task requires detailed analyses of an emotion and whether this analyses cause participants to experience the emotion. While perception and identification of happy expression may be in the right hemisphere, experience of this happy emotion conveyed by faces may be in the left hemisphere. Tasks that require rapid, more perceptually based classification of emotions, such as the one used in the present study, may involve little emotion experience while tasks that demand careful evaluation or comparison for affect, such as those used in Reuter-Lorenz and Davidson[19] and Jansari et al. [18], may require participants to experience the subtle emotion convey by the stimulus. Thus, depending on the task demand and the level of processing, identification of positive facial expressions may be lateralized to the left or right hemisphere. But the initial perceptual identification is probably predominantly in the right hemisphere [1].

It follows from the above arguments that processing of facial expressions is divided at least into two stages. In the first stage, features related to human faces and to different emotions are first extracted and categorized by the right hemisphere. Labeling of emotional valence can be provided if it is required by an experimental task because different expressions have different sets of facial codes [34]. In the second stage, emotional values of the corresponding facial expressions, such as whether the smile is sincere or faked, are assessed and possibly experienced by the viewer. Emotional valence, individual and sex differences may arise at this stage. Here the appraisal of happy expression may be lateralized to the left hemisphere.

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