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dominantly 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 In contrast to what Schweinberger, Baird, Blümler, Kaufmann, and Mohr [31] claimed, our previous unpublished work showed that there is a bilateral gain in processing both negative and positive facial expressions.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 secondar bias because new objects may capture attention, making the comparison between RTs to facial expressions in different visual fields more pertinent to emotion processing.

A B

C D

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 6.0cmriaB0.3TD (×)Tj 0.1

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

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 e[illegible] wi g

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