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Left Hemisphere Specialization for Response to Positive Emotional Expressions: A Divided Output Methodology

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An extensive literature credits the right hemisphere with dominance for processing emotion. Conflicting literature finds left hemisphere dominance for positive emotions. This conflict may be resolved by attending to processing stage. A divided output (bimanual) reaction time paradigm in which response hand was varied for emotion (angry; happy) in Experiments 1 and 2 and for gender (male; female) in Experiment 3 focused on response to emotion rather than perception. In Experiments 1 and 2, reaction time was shorter when right-hand responses indicated a happy face and left-hand responses an angry face, as compared to reversed assignment. This dissociation did not obtain with incidental emotion (Experiment 3). Results support the view that response preparation to positive emotional stimuli is left lateralized.

Keywords: dominance, cerebral, emotion, facial expression, laterality, neuropsychology.

Emotions are primarily represented in the limbic system. However, the cerebrum participates in discriminating and responding to displays that differ in emotional valence (Tucker, Derryberry, & Luu, 2000). The right cerebral hemisphere has been widely implicated in the processing of both visual and auditory stimuli that convey emotions with negative valence (e.g., anger, fear, disgust, sadness). With respect to positive valence (e.g., happiness), the literature is divided. Competing models assume that the right hemisphere is specialized for processing not only negative emotions but emotions of every kind, or that the right hemisphere is specialized for negative emotions and the left hemisphere is specialized for positive emotions. These conflicting models rely on extensive literature.

Many studies find processing of all types of emotional expressions to be right lateralized (Borod et al., 1998; Campbell, 1978; Hirschman & Safer, 1982; Hugdahl, Iversen, & Johnsen, 1993; Ladavas, Umilta, & Ricci-Bitti, 1980; Ley & Bryden, 1979; McLaren & Bryson, 1987; Safer, 1981; Saxby & Bryden, 1985; Strauss & Moscovitch, 1981), but the laterality effects may be less marked when the expression is of positive valence (Bryden & MacRae, 1989; Dimond, Farrington, & Johnson, 1976; Ehrlichman & Halpern, 1988; Ley & Bryden, 1979; Sackeim & Gur, 1978, 1980). Some studies find no laterality effect for positive stimuli (Best, Womer, & Queen, 1994; Mandal et al., 1999). Bryden and MacRae (1989) concluded, “the right hemisphere is involved in all emotion, but more strongly with negative material” (p. 171). On the other hand, many studies find a double dissociation with negatively valenced emotions attributable to right hemisphere processing, but positively valenced emotions referable to the left hemisphere (Ahern & Schwartz, 1979; Davidson & Fox, 1982; Natale, Gur, & Gur, 1983; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis, & Moscovitch, 1983; Van Strien & Van Beek, 2000).

The conflicting laterality outcomes for positive emotions may be reconciled if each hemisphere’s contribution depends on the stage of processing that is involved. Facial expression is a much-studied case in point; some studies find no lateral predominance for processing expressions with positive valence, some indicate a preferential role for the left hemisphere. At a minimum, identifying emotional expressions involves perceptual identification and response preparation (Requin, Riehle, & Seal, 1993).

Kinsbourne and Bemporad (1984) and Davidson (1984) suggested that the hemispheres diverge in their emotional specializations at the stage of response preparation. While the right hemisphere is indeed dominant for the perceptual identification of facial expressions, the left hemisphere is dominant for positive expressions at the stage of response preparation. This dissociation would be expected if the left hemisphere is specialized for programming approach and the right for programming withdrawal (Kinsbourne, 1978a). Stimuli with positive valence, such as faces with happy expressions, would be expected to elicit approach tendencies, and these would be subserved by the left hemisphere (Kinsbourne, 1978a; Kinsbourne & Bemporad, 1984) and specifically by left dorsolateral prefrontal cortex (Davidson, 1992). Applying Schneirla’s (1959) basic distinction between approach and withdrawal, Kinsbourne (1978a) suggested that approach and withdrawal, at

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various levels from concrete (orientation followed by locomotion toward or away from the stimulus) to more abstract (e.g., continuing ongoing behavior or interrupting ongoing behavior), are fundamental to human behavior, and that these dimensions map on to the expression of human emotions. Subjects would tend to approach faces that have happy expressions, whereas they would recoil and withdraw from angry, threatening faces. Kinsbourne hypothesized that the left hemisphere was specialized for approach and the right for withdrawal, and applied this dichotomy to positive (left hemisphere) versus negative (right hemisphere) emotions (Bryden, 1982; Davidson, 1984).

An extensive research program led by Davidson (1992) has accumulated support for the mapping of approach/withdrawal to the left and right hemispheres in studies in which differential hemisphere activation was present (Bennett, Davidson, & Saron, 1981; Davidson, Ekman, Saron, Senulis, & Friesen, 1990) even in infants (Davidson & Fox, 1982, 1989), as well as in studies of depression and affective style (Davidson, Chapman, & Chapman, 1987; Henriques & Davidson, 1990, 1991; Schaffer, Davidson, & Saron, 1983; Tomarken, Davidson, & Henriques, 1990). The frequently reported activation of basal ganglia in response to happy faces (Phan, Wager, Taylor, & Liberzon, 2002) is consistent with the view that they elicit approach tendencies.

Conventional laterality designs conflate the two stages of processing, arriving at a combined laterality measure of the two successive processing stages. So considered, the specialization of the right hemisphere for decoding emotional facial expression would be additive with its specialization for withdrawal if the expression is negative (fearful, angry, disgusted, sad) and, therefore, yields a robust left visual field/right hemisphere advantage. However, positive expressions (happy, joyful, enthusiastic) should yield a lesser degree of overall right hemisphere laterality or even a left hemisphere advantage. If the left hemisphere is recruited at the stage of response preparation and action, then left hemisphere dominance would be more likely. This would be particularly the case if the subject were actively responding under time pressure, rather than merely passively viewing the displays and responding at leisure, if responding at all. For positive stimuli that elicit approach, the left hemisphere bias for response would counteract the right hemisphere bias for recognition in determining the overall asymmetry, leading to an attenuated right hemisphere effect or even a reverse bias in favor of the left hemisphere.

In order to study hemisphere specialization for response preparation, we utilized a novel experimental design that dispensed with the usual lateral (half-field) presentation of stimuli. The advantage that the right hemisphere has in early rapid processing should be minimized by presenting the face stimuli centrally and one at a time, thus distributing the information to both hemispheres on all trials. Further, to minimize the advantage conferred on the right hemisphere by its specialization for the identification of briefly exposed stimuli, the stimulus remained in view until the subject has responded. We inferred hemispheric specialization from the relative latency of right and left hand response in choice reaction time.

Manual reaction time studies in conventional laterality experiments use lateral exposures and measure the rate of processing by field of entry. Typically, hand of response is held constant or is counterbalanced without further analysis. However, a theoretical basis exists for making hand of response the independent variable of interest. The responding hand may either be controlled by the dominant hemisphere (congruent condition) or by the subdominant hemisphere (incongruent condition). The dominant hemisphere is inferred to be contralateral to the hand that responds with the shortest latency. The responding hands can be assigned such that the right hand responds for positive valence and the left for negative, or the reverse pairing may be used. The Functional Cerebral Distance model postulates that when two processes are performed in close temporal contiguity, then if they are congruent, they are most efficiently performed by the same hemisphere (Kinsbourne and Hicks, 1978b). The reverse would be the case if the two processes are incongruent. Applied to the present design, this model predicts that if the two pairings of hemisphere and responding hand elicit different levels of performance, then the more efficient pairing will reveal the lateralizations under investigation. We therefore predicted that pairing the right hand with the putatively left hemispheric response to positive stimuli and pairing the left hand with the negative stimuli would be the superior combination. There is a precedent for such reasoning. In a dual task design (Wickens, Mountford, & Schreiner, 1981), the authors simultaneously imposed tasks that were known to rely on processes in opposite hemispheres. Performance was superior when response for the right hemisphere task was by the left hand, and response for the left hemisphere task was allocated to the right hand; that is, when for each task, the processing hemisphere was also the responding hemisphere.

We presented Ekman and Friesen (1978) faces as stimuli and compared the latency of manual responses to happy expressions (apt to attract the viewer and elicit approach) with the latency of manual responses to angry expressions (apt to repel the viewer and elicit withdrawal) in a choice reaction time design that probed response-hemisphere congruence. Right and left index finger key press was counterbalanced across stimulus type.

Experiment 1

Faces with angry or happy expressions were stimuli in a within subjects design. There were two types of key assignment: (a) response-hemisphere congruent–identifications of positive stimuli were indicated by button press with the right hand (left hemisphere), while identifications of negative stimuli were indicated by button press of the left hand (right hemisphere), and (b) response-hemisphere incongruent–positive stimuli were indicated by button press with the left hand (right hemisphere), negative stimuli by button press of the right hand (left hemisphere). Key assignment was reversed from block 1 to block 2.

We predicted that response hand and stimulus emotion would interact significantly, such that right-handed responses would be faster for happy identifications and left-handed responses would be faster for angry responses.

Method

Overview

In each of 240 experimental trials, a centrally presented fixation point was followed by a central target stimulus. Participants were asked to identify the emotion portrayed on the target face, either happy or angry.

Participants

Twenty-six undergraduate and graduate students (16 women, 10 men) were recruited and given course credit or $5. Mean age of participants was 31.4 years (range between 19–60). All subjects were determined to be right-handed on the Bryden Handedness Questionnaire (Bryden, 1977).

Design

A 2 (response hand: left hand, right hand) × 2 (stimulus emotion: happy, angry) within subject design was utilized. Key assignment was counterbalanced between blocks of trials; in the first block, half of the subjects indicated a happy identification with the left hand and an angry identification with the right hand, and in the second block, a happy identification with the right hand and an angry identification with the left hand: for the other half of subjects, the key assignment was reversed.

Stimuli

The face stimuli were drawn from the Ekman Face Battery (Ekman & Friesen, 1978). Face stimuli that were most reliably identified as angry or happy during the original standardization of the Ekman Face Battery were selected. Two poses (angry, happy) of ten distinct identities were selected for a total of 20 faces. All face stimuli were 5.64 cm in width and 8.47 cm in height. They were 8 bit resolution images.

Procedure

Each subject signed a consent form and completed the Bryden Handedness Questionnaire (Bryden, 1977). Subjects were seated in front of a computer monitor and seat height and chin rest were adjusted individually. Following on-screen instructions and two practice trials, the experimental trials were presented. A fixation point was exposed for 1000 ms and immediately followed by a centrally displayed angry or happy face that remained on the screen until the expression was correctly or incorrectly identified. Subjects were not provided feedback for correct or incorrect identifications. Following the key press, the next trial was presented.

The happy and the angry identification key (‘d,’ ‘k’) were covered with blank squares. A sign posted below the monitor indicated key assignments. Subjects were instructed to place the index finger of each hand on the assigned key. They were run individually on a Macintosh Quadra 630 with a color monitor set to 256 grays. They viewed an Apple Color Plus 14″ Display from a distance of 40 cm. Monitor distance and head position were held constant with a chin rest. The room was illuminated by one 40-watt bulb with an in-line potentiometer. Stimuli were presented through the Superlab 1.68 experiment generating software package.

Participants were instructed to identify the emotion portrayed on each face as quickly and accurately as possible by pressing one of two keys. Assignment of the keys to response to happy and angry faces was counterbalanced between subjects for the first block. There were two blocks of 120 trials each, totaling 240 trials. In each block, each of ten face-identities was presented 12 times (6 happy portrayals, 6 angry portrayals) in random order. At the end of the first block, participants took a one-minute break during which they were told that the key placement would be reversed from that in the first block. Following the break and after two practice trials, the experimental trials resumed.

Results

Data from one subject was excluded due to an excessive error rate that was an outlier (10%). Twenty-five subjects, 10 men and 15 women, remained. Their mean age was 31.4 years (range between 19–60).

Reaction times of incorrect responses were excluded from analysis; individual subjects’ errors ranged from 0 to 15 (mean error rate = 3%). To correct for non-normal distribution of reaction times, all subjects’ reaction times were reciprocally transformed (i.e., reaction times were divided into 100). An outlier analysis was conducted on each individual subject’s transformed reaction time data, and latencies that were three standard deviations above or below the mean were excluded from analysis; individual outlier responses ranged from 0 to 5 outlier values (mean 4%). Combining error-associated reaction times and outlier reaction times, individual subjects’ excluded data ranged from 0 to 15 responses (mean 3%).

A preliminary analysis did not reveal any significant differences between key-assignment, block order, or subject gender. Consequently, data from these groups were analyzed together.

A 2 × 2 repeated measure ANOVA, consisting of response hand (left hand, right hand) and stimulus emotion (happy face pose, angry face pose) as factors, revealed the expected interaction of response hand and stimulus emotion, $F(1, 24) = 5.20, p = .03$ (see Figure 1) and a significant main effect of emotion, $F(1, 24) = 12.24$, $p = .002$. There was no main effect of response hand, $F(1, 24) = .615$, $p = .440$.

When subjects were required to identify happy faces with their right hand and angry faces with their left hand, their reaction times were on average 32 ms faster than when the key assignments were reversed. Analyzing individual emotion contrasts, the predicted effect of response-hemisphere congruence was significant in identifications of happy expressions; while angry faces were identified 27 ms faster on average when subjects were required to make an angry identification with their left hand, this magnitude of difference exhibited only trend significance, $t(24) = -1.7$, $p = .103$. In contrast, laterality of identification of happy expressions exhibited

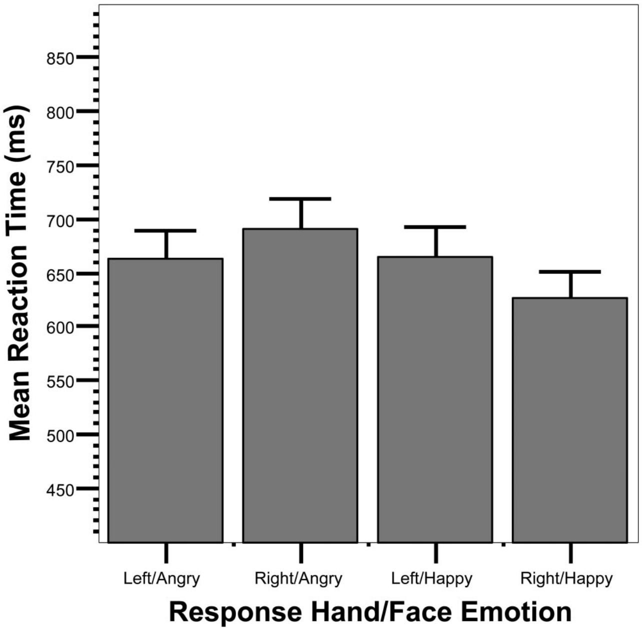

Figure 1. Reaction times for angry and happy emotion identifications by side of response (Experiment 1). Bars represent 1 standard error.

a significant effect, with happy expressions being identified 37 ms faster on average when subjects were required to make a happy identification with their right hand ($t(24) = -2.54$, $p = .018$).

The main effect of stimulus emotion indicates that the emotion portrayed by the stimulus faces significantly affects reaction time. Happy expressions were identified on average 31 ms faster than angry expressions, $t(24) = 3.50$, $p = .002$. This effect was independent of key assignment. It was perhaps due to a withdrawal trend when viewing angry faces that caused a minute but measurable hesitation in key pressing, a putative approach action. We return to this issue in the General Discussion.

Significantly, we did not find an equal and opposite effect for laterality of angry expression identification. From the perspective of lateralized specialization in approach and withdrawal, the right hemisphere should preferentially process angry expressions. The left hand should therefore react more quickly to angry faces than happy faces. However, given the overall processing advantage of happy faces found in previous studies (Ekman & Friesen, 1978; Winston, Vuilleumier, & Dolan, 2003) as well as in the current study, reaction times to happy and angry faces must be interpreted as being mediated both by the hypothesized laterality effect, i.e., the effect of response-hemisphere congruence, and by the overall processing advantage of happy faces, i.e., the main effect of emotion. As such, the greatest difference in latency between angry and happy face identifications is found in the left hemisphere, where response-hemisphere congruence and emotion advantage for happy identifications are additive. In contrast, little or no difference is found between angry and happy face identifications with left hand responding, where response-hemisphere congruence for angry faces in the right hemisphere is offset by the emotion processing advantage for happy faces of the left hemisphere. This additive quality of response-hemisphere congruence and emotion processing advantage for happy faces requires that the effect of interest be analyzed from the perspective of emotion, rather than of hemisphere. Taking into account slower reaction times for angry identifications overall, an equal but opposite pattern of lateralized advantage is evident in the right hemisphere for angry faces and in the left hemisphere for happy faces: angry identifications are faster with the left hand and happy identifications are faster with the right hand. The double dissociation between angry and happy faces in the right and left hemispheres respectively supports the differential role of the hemispheres in emotional processing.

We next sought to determine whether it is necessary to respond to the emotional stimulus in order to elicit this double dissociation. In Experiment 2, we adopted the design of Experiment 1, but added preceding primes (angry, happy, or neutral faces) to which no response was required. If the mere exposure of the primes did not differentially engage the hemispheres, this would suggest that the double dissociation found in Experiment 1 was related to the need for response preparation.

Experiment 2

This experiment tested the prediction that presenting faces for incidental viewing without the requirement to respond differently to the emotion they express has no effect on laterality. It also served as an attempt to confirm the findings of Experiment 1. It was run on the same lines as the first experiment, but in a between-subject design, which obviates the need to switch key assignments between blocks. Would presenting a prime in the form of a happy face amplify the effect of a happy face as target stimulus and would preceding the target with an angry face counteract that effect? Similarly, would an angry face or a happy face presented as a prime affect the laterality outcome in opposite ways when an angry expression was the target?

The priming manipulation was controlled by the use of a neutral face as a prime. Thus the prime-target pairs varied in emotional congruency across three levels: (a) prime-target same, (b) prime-target different, and (c) neutral prime–emotional target.

Method

Overview

Subjects were given 240 experimental trials. On each trial, a centrally presented fixation point was followed by a prime and then a target stimulus. The task was to identify the emotion portrayed on the target stimulus as quickly and accurately as possible. Prime faces portrayed neutral, angry, or happy expressions and target-faces portrayed either happy or angry expressions.

Participants

Twenty-four undergraduate and graduate students (15 women, 9 men) were given course credit or were paid $5 for their participation. Their mean age was 27 years (range between 18–69). All subjects were right handed on the Bryden Handedness Questionnaire (Bryden, 1977).

Design

A 3 (prime emotion: happy, neutral, angry) × 2 (target emotion: happy, angry) × 2 (key assignment) design was used. Subjects either made happy identifications with the right hand and angry identifications with the left hand, or they made happy identifications with the left hand and angry identifications with the right hand. The key assignment varied as a between-subjects factor.

Stimuli

The face stimuli were again drawn from the Ekman Face Battery (Ekman & Friesen, 1978). Three expressions (angry, happy, neutral) posed by ten distinct identities, were selected, for a total of 30 faces.

Procedure

The procedure was as in the first experiment, except that, after the fixation point, a neutral, angry, or happy face was presented for 200 ms, followed immediately by the target face, which remained on the screen until the subject responded, as before.

Trials were organized in two blocks of 120 trials each, totaling 240 trials. In each block, congruent prime-stimulus pairs, incongruent prime-stimulus pairs, and neutral prime-stimulus pairs were presented 40 times each for a total of 120 trials. Following two practice trials, the first block was presented. At the end of the first block, participants took a one-minute break. Following the break, the experimental trials resumed. Key placement was randomly assigned and counterbalanced between subjects.

Results

One subject's data was excluded due to an excessive outlier error rate (26%). The error pattern suggests that this excluded subject reversed the button presses for a substantial segment of the experiment. Twenty-three subjects, 8 men and 15 women, remained. Mean age of participants was 27 years (range between 18–69 years).

Latencies of incorrect responses were excluded from analysis; between subjects, individual errors ranged from 0 to 33 errors (mean error rate = 4%). Normalization and outlier analysis were the same as in Experiment 1. The number of outliers ranged from 0 to 3. Combining error-associated reaction times and outlier reaction times, individual excluded data ranged from 0 to 33 (M = 4%). No participant had a sum of combined error and reaction time values in the outlier range.

Preliminary analysis found no significant effects of subject gender, and therefore data from these groups are analyzed together. A preplanned t-test compared mean latency of right and of left hand response. Overall, left-hand reaction times did not differ significantly from right-handed reaction times, $t(22) = .91$, $p = .37$.

In analyzing experimental effects, a 3 × 2 × 2 repeated measure ANOVA, consisting of prime emotion (happy, neutral, angry), target emotion (angry, happy), and the between subjects factor of key assignment as factors revealed the main effect of key assignment, $F(1, 21) = 11.24$, $p = .003$ (see Figure 2), a main effect of prime emotion, $F(2, 20) = 5.34$, $p = .014$, and a main effect of target emotion, $F(1, 21) = 11.96$, $p = .002$. The interaction of prime emotion x target emotion was not significant, $F(2, 20) = 1.93$, $p = .172$.

As in Experiment 1, response-hemisphere congruence was a significant factor in latency of emotion identification; subjects in the response-hemisphere congruent condition identified face emotion 126 ms faster on average than subjects in the response-hemisphere incongruent condition. The response-hemisphere congruence effect was similar in both angry and happy identifications, with angry faces identified faster when subjects made an angry identification with their left hand, $t(21) = -2.86$, $p = .009$, and happy faces identified faster when subjects made a happy identification with their right hand, $t(21) = -3.77$, $p = .001$, indicating a double dissociation between hand of response and emotional valence.

As in the finding of a significant effect for target emotion in Experiment 1, the main effects of prime emotion and target emotion in Experiment 2 indicated that the emotion portrayed by prime and target faces significantly influenced reaction time latencies. Angry and happy target faces preceded by a happy prime face were identified 12 ms faster than angry and happy targets preceded by an angry prime face, $t(22) = 2.75$, $p = .012$. No significant difference was found for the neutral versus angry prime contrast, $t(22) = .93$, $p = .361$, while a significant difference was found for the neutral versus happy prime contrast, $t(22) = 2.05$, $p = .052$. Similar to Experiment 1, targets portraying happy expressions were identified 36 ms faster than targets portraying angry faces, $t(22) = 3.50$, $p = .002$.

The nature of the prime had no discernible differential effect on the reaction time latencies in regard to response-hemisphere congruence. Response hemisphere congruence was applicable only to faces that were actively responded to, i.e., the target faces, and not to the passively viewed primes. This suggests that preparation for motor response is critical for the response-hemisphere effect. In Experiment 3, we further explored this possibility.

Experiment 3

In Experiment 2 the incidental exposure of a face prime had no lateralized effect on the subject's responding. Would the differen-

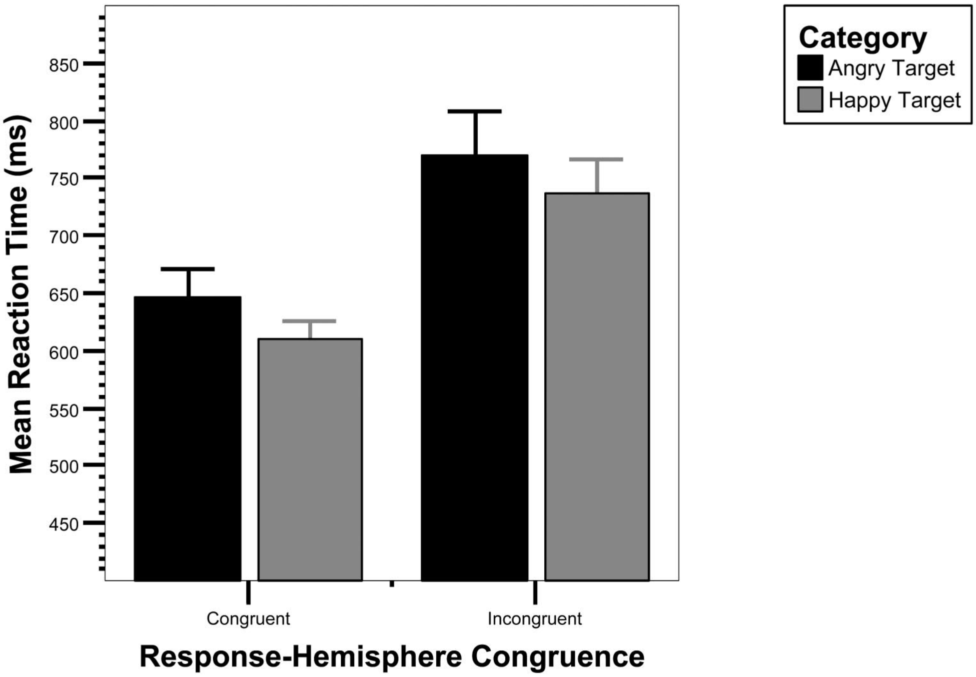

Figure 2. Reaction times for angry and happy emotion identifications by side of response (Experiment 2). Bars represent 1 standard error.

tial laterality effects that were uncovered in the first two experiments survive if the same face stimuli were presented, but attention for action was directed at another salient facial attribute that also subdivides the set? An alternative target attribute was available in the stimulus set in the form of gender, since we were using equal numbers of male and female faces. We did not expect that male and female faces would elicit either approach or withdrawal. However, even unattended facial expressions and facial expressions presented outside awareness have differential effects on brain states (Murphy, Monahan, & Zajonc, 1995; Murphy & Zajonc, 1993; Wong & Root, 2003). If the hemispheric double dissociation between the identification of happy and angry faces stems from differential lateralization at the stage of response preparation, then it might be necessary not only for the relevant displays to be exposed, but for the response to be targeted at the task-relevant stimulus attribute, the expression portrayed by the face. If so, then if facial expressions are kept incidental and the faces' gender rather than expression is the target for discrimination, then the laterality outcomes found in the first two experiments should not occur.

Using the same emotional stimuli as in Experiments 1 and 2, the experimental task in Experiment 3 was changed to gender identification. By requiring subjects to identify the gender of the target faces, the focus of attention was displaced from the affective quality of the stimuli. As a result, any effect of the affective dimension of target stimuli that is mediated by response-hemisphere congruence would be due to incidental, rather than explicit, affective evaluation.

In one condition, subjects indicated male gender by a left finger press and female by a right press. The reverse assignments were made in the other condition. Would an interaction between stimulus emotion and response hand still be observed? Would the gender identification male and female faces with happy expression would be faster with the right hand and vice versa?

Method

Overview

Participants responded to 240 experimental trials. In each, a centrally presented fixation point was followed by a target stimulus. The task was to identify the gender of the target face as quickly and accurately as possible. Male and female faces, each with a happy or an angry expression, were presented.

Participants

Fifty-seven undergraduate and graduate students (29 women, 28 men) were recruited and were paid $5 for their participation. Their mean age was 30 years (range 19–58). Participants were classified as right-handed as determined by the Bryden Handeness Questionnaire (Bryden, 1977).

Design

A 2 (stimulus emotion: happy, angry) × 2 (stimulus gender: male, female) × 2 (response hand: left hand, right hand) within subject design was utilized. Key placement was counterbalanced. Half the subjects pressed the identification key on the right to indicate female in the first block and the key on the left to indicate female in the second block, while for the other half of the subjects the key placement was reversed.

Stimuli

The stimuli used in Experiment 3 were the same as those used in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, except that subjects were instructed to identify the gender of each face as quickly and accurately as possible by pressing one of two keys. Response keys were counterbalanced between blocks and between subjects such that half of subjects used the right-hand key for female identifications in the first block and the left-hand key for female identifications in the second block.

Results

Data from one subject was excluded due to an error rate that was an outlier (6.25%). Fifty-one subjects, 24 men and 27 women, remained. Mean age was 30 years (range between 19–51 years).

Latencies of incorrect responses were excluded from analysis; errors of individual subjects ranged between 0 and 12. Normalization and outlier analysis were the same as in Experiments 1 and 2. Outliers of individual subjects ranged between 0 and 5. Combining error-associated reaction times and outlier reaction times, which were both omitted from analysis, individual excluded values ranged between 0 and 13.

Preliminary analysis found no significant difference between the counterbalancing of key-placement block order or of subject gender. Therefore, data from these groups are analyzed together.

A 2 × 2 × 2 within subjects repeated measure ANOVA was conducted, consisting of stimulus emotion (happy, angry), stimulus gender (male stimulus face, female stimulus face), and response hand (left hand, right hand). The previously discovered interaction of response hand and stimulus emotion was not observed ($F(1, 49) = 1.97$, $p = .166$ (see Figure 3). Analysis revealed a main effect of emotion, $F(1, 49) = 11.41$, $p = .001$, and a main effect of response hand, $F(1, 49) = 9.04$, $p = .004$. Right-handed responses were significantly faster than left-handed responses.

The laterality of categorization of faces by gender has been investigated by (Jones, 1980; Sergent, 1982; Sergent & Corballis, 1989). The findings depend on viewing conditions, but, for judgments of facial gender by manual reaction time made with relatively prolonged exposures (of the order of 200 ms), a right field/left hemisphere advantage was found. Correspondingly, we found a significant right hand advantage, although unlike previous studies, our laterality paradigm minimized any lateralized effect of perceptual discrimination.

The results indicate that response-hemisphere congruity for valence of emotions does not influence reaction time when the emotionality of the stimulus is incidental to the main task of gender identification. In contrast to Experiments 1 and 2, the benefit from response-hemisphere congruence in Experiment 3 was an insignificant 2 ms. The need for a response targeted on emotion to obtain the double dissociation is consistent with the hypothesis that relates the dissociation to response factors. These presumably are differential approach and withdrawal tendencies of the left and right hemisphere.

Despite the absence of a response-hemisphere congruence effect, the effect of stimulus emotion is again observed in Experi-

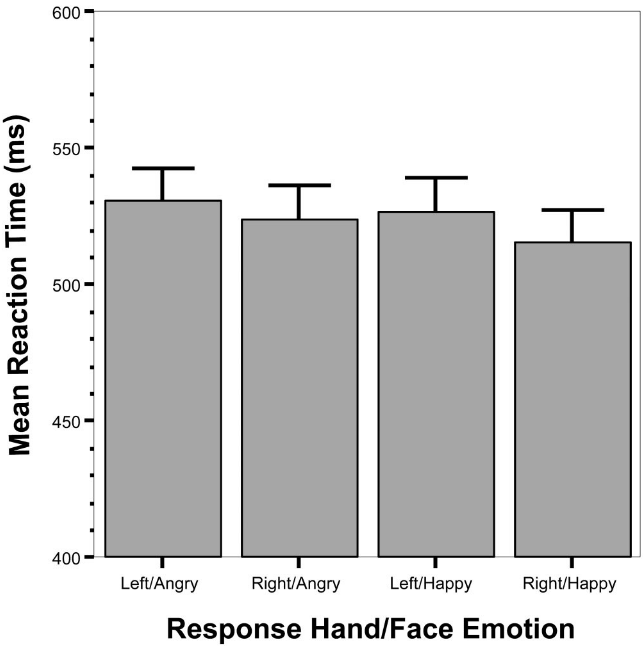

Figure 3. Reaction times for angry and happy gender identifications by side of response (Experiment 3). Bars represent 1 standard error.

ment 3; the gender of faces with happy expressions was identified significantly faster than the gender of faces with angry expressions. Even when the emotionality of stimulus faces is incidental to the main task, emotion expression continues to influence reaction time. Although significant, the magnitude of difference between reaction times to happy faces and angry faces in Experiment 3, (6 ms), $t(50) = 3.24$, $p = .002$, was much decreased from those observed in Experiments 1 and 2 (31 ms and 36 ms respectively) and even from the main effect of the primes in Experiment 2 (13 ms). That gender identification was faster for happy faces may suggest either that angry faces interrupts processing of target gender or that happy faces facilitate it.

General Discussion

The Experiments

We applied the little used method of lateralized response latency to the study of hemispheric contributions to the processing of emotion. We found greater left hemisphere involvement in the identification of happy faces and greater right hemisphere involvement in the identification of angry faces. In a within-subjects design in Experiment 1, we found that the valence of emotional processing and the side of motor response significantly interact; when stimuli with positive valence are identified, the left hemisphere is activated, leading to faster responses on the right. Experiment 2 confirms the basic results of Experiment 1 in a between-subject design and extends the effect of response-hemisphere congruence to identifications of angry expressions. Again, response-hemisphere congruence proves to be a determinant of speed of response; positive stimuli were identified faster with the right hand and negative stimuli were identified faster with the left hand. The results of Experiment 1 and 2 are consistent in indicating independent but complementary contributions of the cerebral hemispheres to emotional processing. In contrast, in Experiment 3, when subjects identified the gender rather than the expression on the same set of faces, the marked response-hemisphere congruence effects that were found in Experiments 1 and 2 were not in evidence. Cell means and standard deviations for all Experiments are presented in Table 1.

The findings of Experiments 1 and 2 are consistent with existing evidence for left hemisphere specialization for positive stimuli and right hemisphere superiority for negative stimuli. More generally, they are consistent with studies that find a relation between rightward direction of attention and positive affect (Beaumont, 1985; Dimond, Farrington, & Johnson, 1976; Drake, 1987; Levick et al., 1993; Nisbett & Wilson, 1977). The results are also consistent with electrophysiological evidence that the left and right hemispheres become differentially activated in the presence of positive and negative emotion respectively (Bennett, Davidson, & Saron, 1981; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson & Fox, 1982, 1989; Davidson, Schwartz, Saron, Bennett, & Goleman, 1979; Schaffer, Davidson, & Saron, 1983; Tucker, Stenslie, Roth, & Shearer, 1981), and with a subset of relevant neuroimag-

Table 1
Cell Means and Standard Deviations for Experiments 1, 2, and 3

Experiment			Congruent target RT (*SD*)		Incongruent target RT (*SD*)		Overall Target RT (*SD*)	
			Angry	Happy	Angry	Happy	Angry	Happy
1			664 (126)	627 (116)	691 (136)	664 (139)	678 (125)	646 (123)
2	Prime emotion	All	646 (85)	609 (59)	771 (122)	737 (100)	706 (120)	670 (102)
		Angry	648 (84)	618 (64)	770 (120)	751 (108)	706 (118)	682 (109)
		Neutral	643 (86)	605 (58)	787 (133)	736 (107)	712 (131)	667 (107)
		Happy	648 (90)	605 (59)	757 (119)	725 (92)	701 (116)	662 (96)
3	Target gender	All	531 (86)	515 (85)	524 (89)	527 (88)	528 (86)	522 (86)
		Female	533 (94)	514 (81)	522 (89)	529 (100)	527 (87)	521 (87)
		Male	530 (85)	520 (100)	529 (102)	527 (82)	530 (90)	523 (87)

Note. RT = reaction times.

ing studies, which find differential lateralized contributions in the processing of emotion categories (Wager, Phan, Liberzon, & Taylor, 2003). Finally, though less consistently (Borod, Bloom, Brickman, Nakhutina, & Curko, 2002), studies of individuals with neurological compromise and of individuals undergoing unilateral hemispheric suppression find complementary contributions of the left and right hemispheres to emotional processing (Gainotti, 1959, 1989; Lee, Loring, Meader, & Brooks, 1990; Sackeim et al., 1982; Terzian & Cecotto, 1959). Davidson (1992) suggested that it is not the mere perception of a positively valences stimulus, but the subjective experience of a positive emotion that implicates the left hemisphere. Much literature is in accord with this formulation. However, our experiment was not designed to implicate subjects' emotions to any greater degree than might have occurred in any of the many other laterality experiments that resulted in right hemisphere superiority for happy faces. The study by Reuter-Lorenz and Davidson (1981) also yielded a left hemisphere effect for positive expressions without seemingly involving any appreciable depth of emotional experience.

As indicated in the Introduction, contrary results are also reported in the literature, and many studies report right hemisphere superiority not only for negative but also for positive stimuli. The literature on hemispheric specialization in emotion is therefore quite mixed. Our effort toward clarifying these contradictions departs from previous behavioral studies of hemispheric emotional asymmetry in several key aspects. The experimental design provides central presentation of a prolonged stimulus, rather than the usual brief stimulus presented in a half-field. It also requires a speeded, lateralized motor response. Central presentation, as opposed to divided visual field presentation, and prolonged exposure, as opposed to brief or masked exposure, are expected to tend to reduce the right hemisphere's advantage in perceptual identification. In previous studies, lengthening the stimulus exposure to no more than 200 ms was sufficient to convert the side of advantage to the left hemisphere, both for letters (Rizzolatti & Buchtel, 1977) and for faces (Glass, Bradshaw, Day, & Umilta, 1985). Further, when side of fastest motor response is used as an index of which hemisphere is primarily involved, response preparation becomes available for study. Manual reaction time is not the usual dependent variable in visual laterality experiments. However, among the few reports of a double dissociation between the recognition of positive and negative face stimuli are three laterality studies that also used manual response latency (Burton & Levy, 1989; Jansari, Tranel, & Adolphs, 2000; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis, & Moscovitch, 1983). Thus, in utilizing central presentation, prolonged exposure, and divided response output rather than brief divided perceptual input, the present study avoids the confounding of functional hemispheric asymmetries for the perception of faces and facial expressions with asymmetries in response preparation. Independent contributions of the two hemispheres emerged.

Response-Hemisphere Congruence

The results of Experiments 1 and 2 do not support any particular response mechanism, but together with the results of Experiment 3 they do highlight direct response to the emotion, rather than a priming or incidental exposure effect. The dimension along which the hemispheres are differentiated and differentially activated in emotional processing has been alternately described as valence (positive/negative) and, here, as prepotent behavioral response (approach/withdrawal). A corresponding interpretation of the present findings would be that when attention for action is focused on the stimulus faces, response to the exposure of a happy face by the left hemisphere is subtly expedited by an approach reaction, but would have conflicted with a withdrawal tendency that is inherent in the right hemisphere; whereas an angry, threatening face would elicit the exact opposite reactions. Therefore, using the right hand to indicate positive stimuli and the left to indicate negative stimuli is the more efficient response assignment.

Incidental Viewing of Emotional Expression

The absence of emotional laterality findings in the third experiment establishes a boundary condition; neither the left hemisphere advantage for identifying happy faces, nor the right hemisphere advantage for angry faces obtained when the emotion was incidental to the task. Emotional information that is not the target of behavioral response would not trigger the lateralized approach and withdrawal tendencies. There is ample evidence that incidentally and even subliminally presented emotional stimuli do affect behavior in clear-cut ways. Affective evaluation has been reported in the absence of awareness of emotional primes (McGinnies, 1949; Murphy, Monahan, & Zajonc, 1995; Murphy & Zajonc, 1993; Wong & Root, 2003) as well as absent the explicit instruction to attend to the emotional dimension of stimuli (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). Such effects have been demonstrated in several other studies utilizing a wide range of stimulus materials and experimental tasks (Klauer, 1998). But neither unconscious emotion perception (Stambrook & Martin, 1983), nor studies of brain metabolism as influenced by unseen emotional stimuli (Vuilleumier et al., 2002) indicate changes that differentially involve one hemisphere. This may be because incidentally or subliminally exposed emotional stimuli are mainly processed subcortically (Adolphs, 2002), while the role of both cerebral hemispheres in emotional processing is concentrated on emotional information that is clearly within the focus of attention and thus a candidate for eliciting action.

Main Effect of Emotion

The main effect of emotion, found in each of the three experiments under review, was a robust finding in Experiments 1, 2, and 3 and consisted of faster reaction times to happy faces in Experiment 1, to prime and target faces in Experiment 2, and to happy male and female face identifications in Experiment 3. One explanation of these findings would be that the graphic and structural characteristics of happy expressions are simply easier identified, thus leading to a faster identification of happy expressions. That happy expressions were responded to faster both when they were the target of identification (Experiments 1 and 2) and when they were incidental to the main experimental task (Experiments 2 and 3), however, underscores the role of affective meaning rather than lower level structural characteristics, in determining reaction time, as there was no requirement to identify either prime emotion in Experiment 2 or target emotion in Experiment 3.

Left Hemisphere and Approach

Our data does not directly demonstrate a left hemisphere approach tendency. Gur, Skolnick, & Gur, (1994) found regional blood flow increase in the left frontal area when subjects viewed faces with happy expressions. This is consistent with a response preparation account of the left hemisphere advantage for positive expressions. Reviewing extensive literature, Davidson (1993) concluded that it is "remarkably consistent—in showing left-sided anterior activation during certain positive emotional states and traits and right-sided interim activation (or left-sided hypoactivation) during certain negative emotional states and traits" (p. 134). By implication, our study found the same even for single trials that conveyed happiness or anger. It has been previously reported that happy faces are identified faster than angry faces (Ekman, Friesen, & Ellsworth, 1982; Feyereisen, Malet, & Martin, 1986; Kirita & Endo, 1995; Kirouac & Dore, 1983; Ladavas, Umilta, & Ricci-Bitti, 1980). Is the overall shorter latency of key press to happy faces due to the approach implicit in the key press? Burton and Levy (1989) required key release rather than key press in response to emotional target stimuli and reported that response latency was shorter to negative than positive stimuli. In contrast, our subjects, who pressed a key to respond, responded with shorter latencies to positive stimuli. However, both outcomes are consistent with the attribution of withdrawal to the right hemisphere. Sobotka, Davidson, & Senulis, (1992) and Schiff and Bassell (1991) equated key press with approach and key release with withdrawal. Wentura, Ruthermund, & Bak, (2000) found faster button press for positive stimuli and faster button release for negative stimuli. Markman and Brendl (2005) review additional studies with similar outcome, but using different response modes, notably pulling a lever closer or pushing it away. The previous studies that reported approach/withdrawal effects on reaction time did not establish their hemispheric laterality. Our study was not definitive in this regard either, since we only used button press, not release. An investigation that counterbalances hand and response mode (press and release) should determine whether these two response modes that appear to correspond to approach and withdrawal do indeed reflect the influence of the left and right hemisphere respectively.

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