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Impaired Perception of Facial Emotions Following Bilateral Damage to the Anterior Temporal Lobe

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Two patients (E.P. and G.T.) were previously described with damage to amygdala and anterior temporal cortex (S.B. Hamann et al., 1996). Both rated emotions in facial expressions normally (the rating task) when the data analysis followed a method that had revealed an impairment in the well-studied patient S.M. The present study reports findings for a 3rd patient (G.P.) with the rating task and reexamines the data for E.P. and G.T. All 3 patients were also given a labeling task in which they selected, from a list of 6 words, which word they thought best described the emotion expressed by a face. All 3 patients were unmistakably impaired on both tasks. However, the impairment exhibited by these patients is different from S.M.'s impairment. The difference may depend on the etiology (congenital vs. adult-onset lesion) or the site of the damage (relatively selective amygdala damage vs. damage to amygdala as well as anterior temporal cortex).

The amygdala has been implicated in emotion and emotional memory in humans and experimental animals (LeDoux, 1995; LaBar, LeDoux, Spencer, & Phelps, 1995; Morris et al., 1996). A number of recent studies have investigated the role of the human amygdala in the processing of emotions in facial expressions. The first patient described and studied in detail was patient S.M., who has nearly complete bilateral damage to the amygdala due to Urbach–Wiethe disease (Adolphs, Tranel, Damasio, & Damasio, 1994). Using a rating task in which participants rated how intensely faces expressed a particular emotion, Adolphs et al. (1994) found S.M. to be severely impaired at recognizing the emotion of fear (i.e., perceiving the intensity of fear in a fearful face). Also, S.M. did not appreciate the similarity between different expressions of emotion that normal individuals judged to be related. Subsequently, a second patient with amygdala damage was described (D.R.), who was also impaired at perceiving facial expressions of fear and anger (Calder et al., 1996; Young et al., 1995).

Following the initial report of patient S.M., we studied two postencephalitic patients with anterior temporal lobe lesions that included the amygdala (E.P. and G.T.; Hamann et al., 1996), and we used both the rating task and the method for data analysis introduced by Adolphs et al. (1994). Because E.P. and G.T. did not exhibit the deficit described for patient S.M., we suggested that etiology (congenital vs. adult-onset lesions) and/or IQ (borderline normal vs. above average) might determine whether or not a deficit appears following amygdala damage. Subsequently, Calder et al. (1996) and Broks et al. (1998) used a different task in which participants were asked to identify (label) emotional expressions. Their 4 patients with adult-onset temporal lobe lesions due to encephalitis were impaired at labeling emotional expressions of fear.

In view of these newer findings using a labeling task, we assessed the ability to both rate and label emotions in the same group of patients. Specifically, in three experiments, we reexamined patients E.P. and G.T., as well as a 3rd patient, G.P., on both the rating task introduced by Adolphs et al. (1994) and the labeling task used by Calder et al. (1996) and Broks et al. (1998). All 3 patients have large temporal lobe lesions, including complete bilateral damage to the amygdala. Whereas the patients were unimpaired on the rating task when the data were analyzed according to the method followed for patient S.M., the patients were unmistakably impaired when the data were analyzed more fully, and they were also impaired on the labeling task. The findings confirm the importance of the amygdala (and related temporal lobe cortex) for perceiving emotion in faces and identify at least two distinct patterns of impairment (one for S.M. and one for our patients, and perhaps others).

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Experiment 1: Labeling Facial Emotions (Choice of Six)

Method

Patients. We studied 3 male patients with anterior temporal lobe damage due to herpes simplex encephalitis. They averaged 63.3 years of age (range = 54–76 years) and 13.3 years of education. All 3 developed profound amnesia after their illness (E.P. in 1992, at age 70; G.P. in 1987, at age 41; and G.T. in 1990, at age 54), and they sustained large, radiologically confirmed, bilateral lesions of the temporal lobe that include the hippocampal region and the amygdala, as well as the adjacent perirhinal, entorhinal, and parahippocampal cortices.

Variable damage is also present lateral to these structures (Schmolck, Stefanacci, & Squire, in press). E.P.'s damage extends through the anterior 7 cm of the temporal pole bilaterally and is primarily medial temporal but also involves the anterior portion of the fusiform gyrus (Stefanacci, Buffalo, Schmolck, & Squire, 2000). Moreover, the lateral temporal cortex and the insula are reduced in volume bilaterally. G.P.'s damage extends through the anterior 7 cm of the left temporal lobe and the anterior 6 cm of the right temporal lobe. In the anterior 1 cm of the temporal lobe, the damage includes the fusiform gyrus as well as the inferior, medial, and superior temporal gyri. More caudally, the damage is limited to fusiform gyrus and the inferior temporal gyrus. The insular cortex is also damaged bilaterally. G.T. has the most severe damage, which extends laterally to involve most of the temporal lobes. The damage to the inferior, middle, and superior gyri extends caudally from the temporal pole for 4.5 cm on the left and for 2.5 cm on the right. The damage to fusiform gyrus continues caudally from the temporal pole for 6.0 cm on the left and 4.5 cm on the right. Insular cortex is also damaged bilaterally (see Schmolck et al., in press, Figures 1–3).

All 3 patients have severe amnesia (Wechsler Memory Scale—Third Edition [WMS–III; Wechsler, 1997] General Memory Index: E.P., 54; G.P., 57; and G.T., 49), moderately severe anomia (Boston Naming Test [Kaplan, Goodglass, & Weintraub, 1983]: E.P., 42/60; G.P., 40/60; and G.T., 18/60), IQ within the normal range (Wechsler Adult Intelligence Scale—Revised [WAIS–R; Wechsler, 1981] Full IQ: E.P., 101; G.P., 98; and G.T., 92), and working memory within the normal range (WMS–III Working Memory Index: E.P., 99; G.P., 99; and G.T., 108). Visuo–perceptual abilities are also in the normal range (e.g., WAIS–R Block Design, age-adjusted scale scores: E.P., 7; G.P., 9; and G.T., 11; for more complex visuo–perceptual processing, see Buffalo, Reber, & Squire, 1998; Stark & Squire, 2000). All 3 patients are agreeable and cooperative, and there is no sign of depression. Further, the patients' families have not reported any history of socially inappropriate behavior. All 3 patients live at home and are cared for by their spouses and other family members.

Controls. Six healthy controls (5 men and 1 woman) were recruited from volunteers and employees at the San Diego Veterans Affairs Medical Center and the University of California, San Diego, retirement community. They matched the patients with respect to age (M = 67.7 years) and years of education (M = 13.6 years).

Materials and procedure. The task was as described by Broks et al. (1998). Sixty slides were presented (Ekman, 1976) in a pseudorandom order on a Telex Caramate 4490 slide viewer. Each slide showed 1 of 10 male or female models expressing one of six facial emotions (happiness, sadness, surprise, fear, anger, or disgust). Each emotion was presented 10 times (expressed once by each model). Participants saw the faces one at a time and in each case were asked to select from a list of six words (the six descriptors listed above) which one they thought best described the emotion expressed by the model. Six practice trials preceded the presentation of the 60 slides. We also determined beforehand that each patient understood the meaning of the six emotions and was able to provide correct descriptions of situations in which he might expect to experience each emotion. Participants worked at their own pace, ordinarily taking about 5 s to judge each face. The 60-slide set was given once to each control and four times to each patient on different occasions during a period of 2 weeks to 3 months.

Results

Figure 1 shows results for Experiment 1, in which participants saw faces one at a time and selected which of six words (the six possible emotions) best described the facial emotion that was displayed. A repeated measures analysis of variance (ANOVA; Emotion × Group, based on the mean percentage correct score that each participant obtained for each emotion) involving the data for all six emotional expressions revealed an effect of emotion, $F(5, 35) = 7.7$, $p < .001$; a marginal effect of group, $F(1, 7) = 5.2$, $p < .06$ (71% vs. 82% correct); and an interaction of Group × Emotion, $F(5, 35) = 3.3$, $p < .05$. The interaction resulted from the fact that the patients were particularly poor at selecting the correct descriptor for faces expressing sadness and fear (for the patients, 58% and 39% correct, respectively; for the controls, 88% and 73% correct), $ts(7) > 2.8$, $ps < .05$. When anger and disgust were expressed by the models, patients also scored lower than the controls (patients, 61% and 75%; controls, 73% and 80%), but these differences were not significant, $ts(7) < 1.2$, $ps > .10$. Finally, when happiness and surprise were expressed by the models, the patients performed a little better than the controls (patients, 99% and 94%; controls, 97% and 80%), but not significantly so, $ts(7) < 1.1$, $ps > .10$.

The 3 patients tended to perform similarly. However, G.T. appeared intact at labeling sad faces, and only G.P. had difficulty labeling faces that expressed anger or disgust. For each facial emotion, the most common error was the same for both patients and controls. For example, when a sad face was presented (also see Figure 4A, later), the most common error for both patients and controls was to choose *disgust* as the best descriptor for the face (on 22% of the trials for patients and on 10% of the trials for controls). In addition, patients made errors in response to a sad face that the controls did not make (*fear,* 8% vs. 0%; *anger,* 9% vs. 0%). When a fearful face was presented, the most common error was to choose *surprise* as the best descriptor (on 33% of the trials for patients and on 17% of the trials for controls). Patients also chose *anger* and *disgust* in response to a fearful face more often than controls (*anger,* 15% vs. 3% of the trials; *disgust,* 12% vs. 7% of the trials). Finally, for both groups, the most common error in response to the remaining four facial emotions was to select *disgust* (in response to an angry face), *anger* (in response to a disgusted face), *surprise* (in response to a happy face), and *fear* (in response to a surprised face).

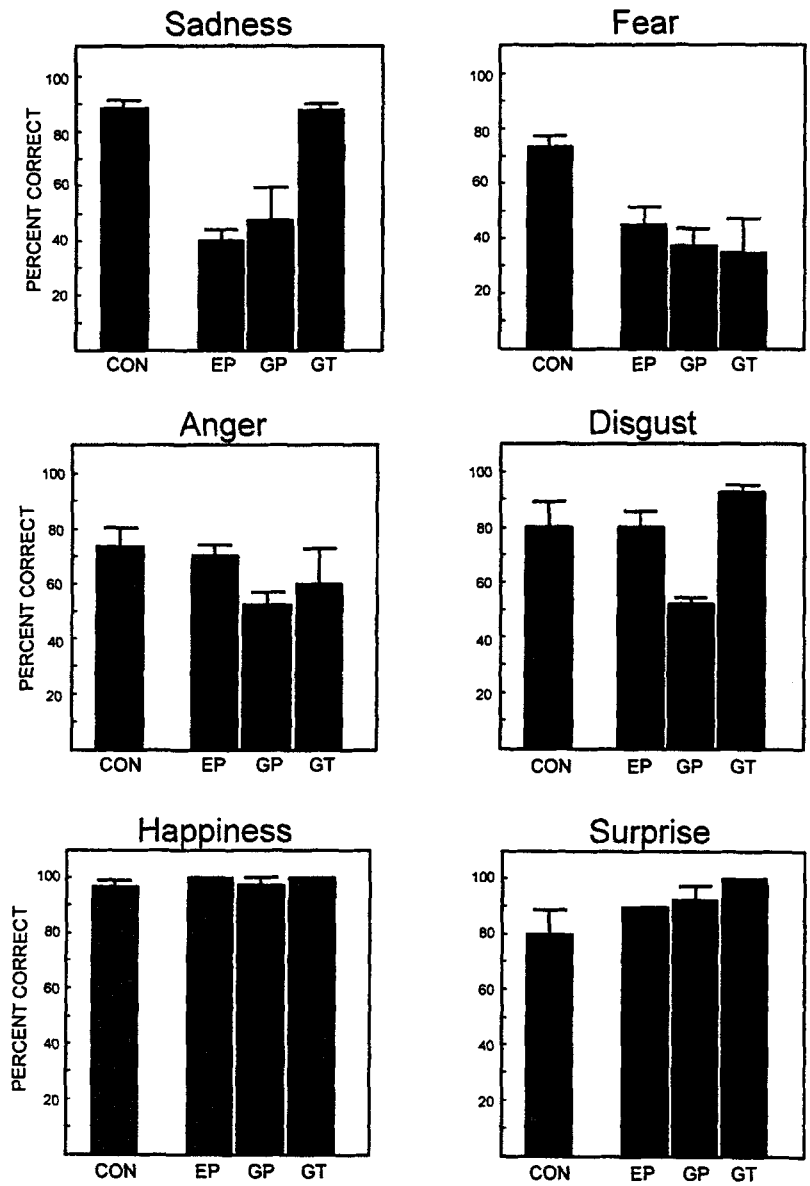

Figure 1. Results for Experiment 1, in which participants saw faces one at a time and selected which of six words (*happiness, sadness, surprise, fear, anger, disgust*) best described the facial emotion displayed. The panels show percentage correct performance for each facial emotion that was displayed. For controls (CON; $n = 6$), the task was given once (10 trials for each facial emotion). For the patients, the task was given four times on different occasions. Vertical lines show standard errors of the mean. EP, GP, and GT = patients E.P., G.P., and G.T.

Experiment 2: Labeling Facial Emotions (Forced-Choice and Yes–No Judgments)

Method

Participants. The same 3 patients and the same 6 controls who took part in Experiment 1 also participated in Experiment 2.

Materials and procedure. The 60 slides used in Experiment 1 were presented in the same order as in Experiment 1. Again, the test was preceded by six practice trials. In the forced-choice task, each slide was accompanied by two words (from the six emotional descriptors), and participants decided which of the two words best described the facial emotion that was displayed. One word was always the appropriate descriptor, and the other word was the incorrect descriptor that had been selected by that participant most frequently (or second-most frequently) in Experiment 1. The 60-slide set was given twice to each control (in one session) and four times to each patient (in two different sessions). The yes–no task was given in the same session as the forced-choice task. The 60-slide set was used again, preceded by six practice trials. Each slide was accompanied by a word (one of the six emotional descriptors), and participants decided (yes–no) whether the word

that was presented best described the facial emotion that was displayed. Half of the slides were accompanied by the correct descriptor, and half were not. The incorrect descriptor for each facial emotion was selected for each participant individually and was the descriptor that had been most often chosen incorrectly for that emotion in Experiment 1. The 60-slide set was given once to each control and twice to each patient on different occasions. For controls, Experiment 2 was carried out an average of 6 weeks (1–9 weeks) after Experiment 1. For the patients, the interval between the last session of Experiment 1 and the first session of Experiment 2 ranged from 3 weeks to 6 months. The second session occurred during the following 2 days.

Results

Forced-choice task. Figure 2A shows performance when participants saw faces one at a time and selected which of two words best described the facial emotion that was displayed. Although the patients performed rather well, they were nevertheless impaired (for patients, 86% correct; for controls, 92%), $t(7) = 2.5, p < .05$. A repeated measures ANOVA (6 Emotions × Group) revealed an effect of emotion, $F(5, 35) = 6.3, p < .01$; an effect of group, $F(1, 7) = 5.8, p < .05$; and a Group × Emotion interaction, $F(5, 35) = 4.6, p < .01$. As in Experiment 1, the patients had particular difficulty when the emotion of sadness or fear was displayed (including G.T., who was not impaired at labeling sadness in Experiment 1; sadness: patients, 77% correct; controls, 99% correct; fear: patients, 72% correct; controls, 88% correct), $ts(7) > 3.1, p < .05$. When the emotion of anger was displayed, the patients scored marginally better than the controls (patients, 92% correct; controls, 83% correct), $t(7) = 2.3, p < .06$. The two groups performed similarly for the other three emotions (patients, 84%–99% correct; controls, 91%–100% correct), $ts(7) < 1.5, p > .10$.

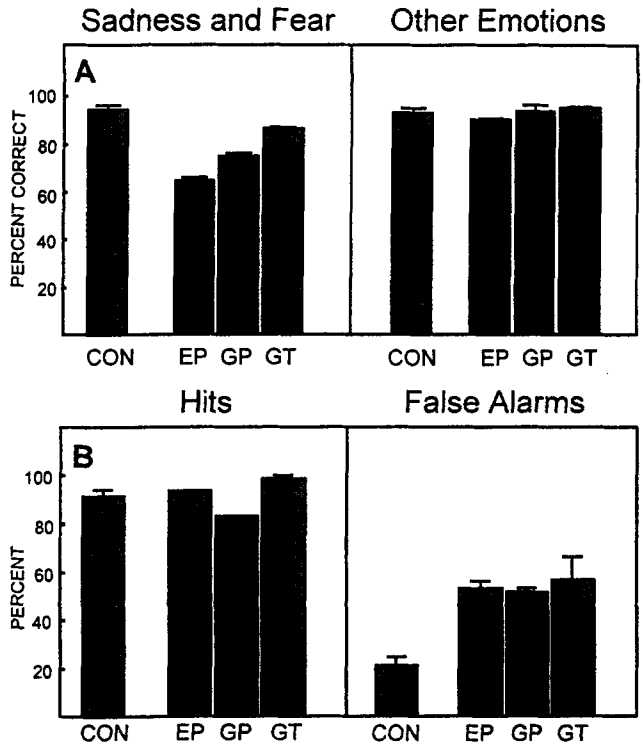

Figure 2. Results for Experiment 2. A: Participants saw faces one at a time and selected which of two words best described the facial emotion that was displayed (forced choice). The task was presented once to the controls (20 trials for each facial emotion) and twice to the patients. B: Participants saw faces one at a time and decided (yes–no) whether the word that was presented (*happiness, sadness,* etc.) best described the facial emotion that was displayed. The left panel shows the percentage of correct "yes" responses (hits: endorsing the presented word when it correctly described the facial emotion that was displayed). The right panel shows the percentage of false alarms (endorsing the presented word when it incorrectly described the facial emotion that was displayed). The task was given once to the controls (10 trials for each facial emotion) and twice to the patients. Vertical lines show standard errors of the mean. CON = controls ($n = 6$); EP, GP, and GT = patients E.P., G.P., and G.T.

Yes–no task. Figure 2B shows performance when participants saw faces one at a time and decided (yes–no) whether the accompanying word appropriately described the emotion that was displayed. Overall, the patients performed more poorly than the controls (for patients, $d' = 1.21$; for controls, $d' = 2.23$), $t(7) = 3.8, p < .01$. Figure 2B (right panel) shows that this difference resulted from the high false-alarm rate of the patients (54% for the patients vs. 21% for the controls), $t(7) = 6.0, p < .001$. Thus, the patients had difficulty rejecting emotional adjectives that did not appropriately describe a facial emotion. The most likely explanation of this impairment is that the patients could not discriminate between facial emotions as well as could controls.

A repeated measures ANOVA based on the d' scores (Emotion × Group) revealed an effect of emotion, $F(5, 35) = 4.2, p < .01$, and group, $F(1, 7) = 14.4, p < .01$, but no Group × Emotion interaction, $F(5, 35) = 1.2, p > .10$. As in the forced-choice task (Experiment 2), all 3 patients had particular difficulty when the emotion of sadness or fear was displayed (sadness, $d' = 1.28$ for patients and 2.92 for controls; fear, $d' = 0.63$ for patients and 2.66 for controls), $ts(7) > 3.6, ps < .01$. When the emotion of happiness was displayed, the patients performed rather well but were nevertheless impaired ($d' = 2.42$ for patients and 3.16 for controls), $t(7) = 2.9, p < .05$. The patients were not significantly different from the controls when the emotions of anger or disgust were displayed ($d' = 0.78$ and 0.70 for the patients; $d' = 1.46$ and 1.56 for the controls) or when surprise was displayed (1.46 for the patients; 1.6 for the controls), all $ts(7) < 1.1, ps > .10$. Overall, the patients performed similarly to each other. However, as in Experiment 1, patient G.P. had particular difficulty labeling faces that displayed the emotion of disgust ($d' = -0.70$), $t(6) = 3.0, p < .05$, for scores for his two sessions compared with the scores of the 6 controls; $t(4) = 4.8, p < .01$, for scores for his two sessions compared with the scores for two sessions of E.P. and G.T.

Experiment 3: Rating Emotional Expressions

Method

Patients. The same 3 patients tested in Experiment 1 also participated in Experiment 3.

Controls. Eight controls (6 men and 2 women, including 4 participants from Experiment 1) were tested in Experiment 3. They averaged 68.5 years of age and 13.3 years of education.

Materials and procedure. The task was identical to the procedure described by Hamann et al. (1996) and Adolphs et al. (1994). The data presented here for patients E.P. and G.T. and 5 of the 8 controls were collected as part of our earlier study (Hamann et al., 1996). A set of 36 slides was presented (Ekman, 1976), each of which showed one of six facial emotions (happiness, sadness, surprise, fear, anger, or disgust) as expressed by six different male and female models. (Three slides of neutral expressions were also presented, and these are not considered further.) Each face on the screen was presented together with an emotional adjective printed in a test booklet (*happy, sad, surprised, afraid, angry,* or *disgusted*) that was either congruent or incongruent with the model's facial expression. In each case, participants rated on a 0–5 scale the intensity with which each face expressed the emotion described by the accompanying adjective. Each face was rated once when it was associated with the congruent emotional adjective and once in association with each of the five incongruent emotional adjectives. The facial emotions and the emotional adjectives in the test booklet were presented in a mixed order.

Results

Participants saw faces one at a time and rated the intensity with which each face expressed the emotion that was described by an accompanying adjective. In earlier reports, Hamann et al. (1996) and Hamann and Adolphs (1999) adopted the scoring procedure described by Adolphs et al. (1994) for patient S.M. and found that (unlike S.M.) patients E.P. and G.T. performed similarly to controls. Performance was measured by correlating the ratings that each participant gave for each face–adjective pair with the ratings given by a control group. Hamann et al. (1996) also reported that the 2 patients and 4 controls gave similar ratings for faces in cases when the accompanying adjective was congruent with the emotion displayed (4.6 vs. 4.3 on a 0–5 rating scale).

A reanalysis of the published data, together with new data for patient G.P. and 3 additional controls, confirmed the results reported previously but also revealed additional findings. Figure 3 shows the mean rating for the trials when the facial emotion was congruent with the accompanying adjective (right two bars) and also for the trials when the facial emotion and the accompanying adjective were incongruent. Overall, the patients rated faces higher than did controls, though the difference between groups reached significance only for incongruent face–adjective pairs: 4.5 versus 4.1 for congruent pairs, $t(8) = 2.1$, $p = .07$; 2.0 versus 1.3 for incongruent pairs, $t(9) = 2.6$, $p < .05$. These differences could have arisen in either of two ways. The patients could have been biased in their use of the rating scale and could have had a pervasive tendency to give high ratings. Alternatively, high ratings could reflect an impaired ability to differentiate among emotional expressions. For example, if the patients could not appreciate the difference between

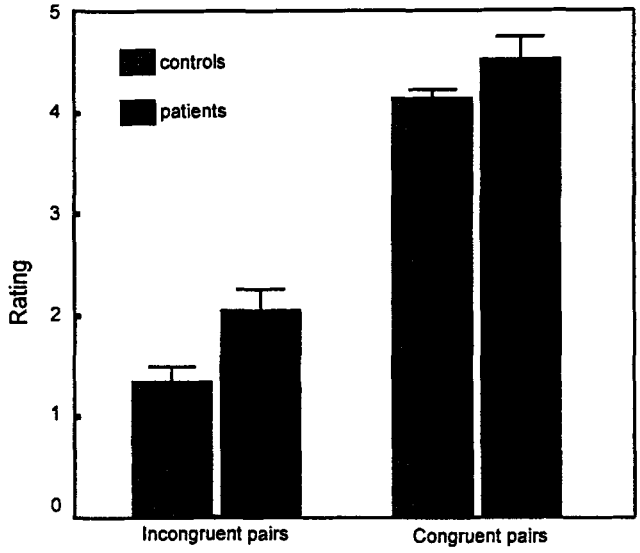

Figure 3. Results for Experiment 3, in which participants saw faces one at a time and rated on a 0–5 scale the intensity with which each face expressed the emotion that was described by an accompanying adjective (*happy, sad, surprised, afraid, angry, disgusted*). The emotional adjective was either incongruent with the facial emotion that was displayed (left two bars) or congruent (right two bars). Both the controls ($n = 8$) and the patients saw 36 faces six times each, so that each face was rated once for each of six emotional adjectives. Vertical lines show standard errors of the mean.

sadness and fear as readily as controls could, then the patients would give abnormally high ratings when judging, for example, the intensity with which a sad face expressed the incongruent emotion of fear and vice versa.

To explore the significance of the high ratings given by the patients, we first conducted a repeated measures ANOVA of Emotion (the facial emotion that was displayed) × Word (the emotional adjective that was rated) × Group, using the ratings given by the participants for each individual face–adjective pair. This analysis revealed an effect of emotion, $F(5, 40) = 25.7$, $p < .001$; word, $F(5, 40) = 18.2$, $p < .001$; and group, $F(1, 8) = 6.1$, $p < .05$, as well as a significant Emotion × Word interaction, $F(25, 200) = 55.5$, $p < .001$, and a significant Emotion × Word × Group interaction, $F(25, 200) = 1.6$, $p < .05$. The effect of group confirms that the patients gave higher ratings overall than the controls, whereas the effects of emotion and word demonstrate that high ratings were not given uniformly for all emotions displayed or for all emotional adjectives rated. The Emotion × Word interaction indicates that some face–adjective pairings received higher ratings than others. Finally, the three-way interaction shows that, when analyzed pair by pair, the patients were more impaired for some face–adjective pairings than others. The individual pairings of faces and adjectives that were given measurably higher ratings by patients than controls ($ps < .10$) were fearful–*sad,* sad–*disgusted,* surprised–*fearful,* disgusted–*angry,* angry–*disgusted,* and angry–*sad.*

To explore further the significance of the high ratings, we compared the ratings that participants made in Experiment 3 to the selections that they made in Experiment 1. Figure 4A shows which emotional adjective was selected by participants in Experiment 1 when a sad face was displayed. Figure 4B shows how participants in Experiment 3 rated sad faces when the sad face was accompanied by each of the five incongruent adjectives. As already noted, the patients gave higher ratings overall to incongruous face–adjective pairs than did the controls (2.4 vs. 1.5), $t(5) = 3.2, p < .05$. A comparison of Figures 4A and 4B shows that errors in Experiment 1 correlated with high ratings in Experiment 3. Specifically, when a sad face was displayed, the correlation between error rate and ratings ranged from .83 to .94 ($ps < .05$) for the 3 patients and from .35 to .7 ($ps > .10$) for the 4 controls who participated in both experiments. Across all six facial emotions, the correlation between errors (Experiment 1) and ratings (Experiment 3) was significant for each patient ($rs > .64$, $ps < .01$) and nearly significant for all 4 controls ($rs = .33$ to $.54$; $ps = .002$ to $.07$).

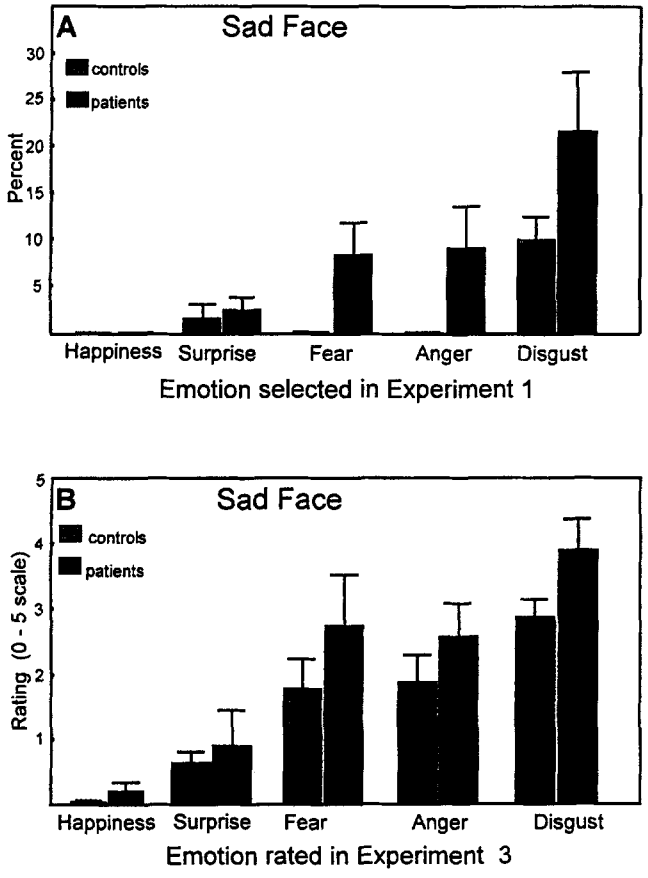

Figure 4. A: Percentage of time that each of the five emotions was erroneously selected as best describing a sad face (from Experiment 1). The controls selected the correct emotion (sad) 88.3% of the time; for the patients, the corresponding score was 58.3%. B: Mean ratings on a 0–5 scale of the intensity with which a sad face expressed each of five other emotions (from Experiment 3). The controls rated the sad face as expressing sadness at an intensity of 4.1; for the patients, the corresponding score was 4.3. Higher ratings (B) were correlated with more errors (A). Data are for those who participated in both Experiments 1 and 3 (controls, $n = 4$; patients, $n = 3$). Vertical lines show standard errors of the mean.

These data show directly that the tendency of the patients to rate incongruous face–adjective pairs higher than did controls was not due simply to a bias in the use of the rating scale. Rather, higher ratings for particular incongruous face–adjective pairs in Experiment 3 predicted that the same adjectives were selected incorrectly when the faces from those pairs were displayed in Experiment 1. Thus, the patients perceived emotional expressions as abnormally similar and therefore made mistakes when attempting to discriminate between them. Note also that this impairment could not have been detected when performance was evaluated (as in Adolphs et al., 1994; Hamann & Adolphs, 1999; Hamann et al., 1996) by simply correlating patient performance with control performance. Specifically, the impairment could not have been detected because the overall pattern of performance was quite similar in both groups, and both groups tended to give high ratings to the same face–adjective pairings.

Discussion

In three experiments, we evaluated the ability of 3 patients with bilateral anterior temporal lobe damage to process facial emotions. In Experiment 1, participants saw faces expressing six different emotions and selected from a list of six words the one they thought best described the emotion that was displayed. In Experiment 2, they also saw faces expressing different emotions, but they selected which of two words best described the emotion that was displayed (forced choice), or they decided whether a single word did or did not best describe the emotion that was displayed (yes–no). In all these tasks, the patients performed more poorly than the controls (as shown in Figures 1 and 2) when the emotions of sadness or fear were displayed.

In Experiment 3, each face was accompanied by an adjective that was either congruent or incongruent with the emotion that was displayed, and participants rated the intensity (0–5) with which each face expressed the emotion described by the adjective. Overall, the patients gave higher ratings than the controls, especially for incongruent face–adjective pairs (as shown in Figure 3). A comparison of the results from Experiments 1 and 3 indicated that this finding did not simply reflect a tendency of the patients to give high ratings. Rather, in Experiment 3 patients gave high ratings to certain incongruent face–adjective pairs (e.g., when a sad face appeared together with the word *disgust*), and in Experiment 1 they were prone to select the same incorrect descriptor for the emotions displayed (i.e., they often selected the word *disgust* as best describing a sad face, as shown in Figure 4). Thus, performance in Experiment 3 (the rating task) was predictive of performance in Experiment 1 (the labeling task). Accordingly, we suggest that the impairment in our patients reflects a difficulty in discriminating

among certain emotions. Specifically, they tended to confuse sadness with disgust and anger, and fear with surprise and anger.

In earlier reports, 2 of our 3 patients (E.P. and G.T.) were described as normal in the rating task of Experiment 3 (Hamann & Adolphs, 1999; Hamann et al., 1996). The data analysis followed the method of Adolphs et al. (1994) and focused on the overall correlation between the face–adjective ratings made by patients and the corresponding ratings made by controls. Patient S.M., who had been studied by Adolphs et al. (1994), was impaired on the rating task when her performance was assessed with this correlational method. For example, patient S.M. gave abnormally low ratings for faces that expressed the emotion fear, and as a result S.M.'s ratings did not correlate well with control ratings. For our patients, the same correlational method did not reveal a deficit. Their ratings were orderly and correlated well with the ratings given by controls. In addition, Hamann and Adolphs pointed out that E.P. and G.T. did not (unlike S.M.) give abnormally low ratings for incongruous face–adjective pairs.

The present findings demonstrate unmistakably that E.P. and G.T., as well as G.P., are impaired at processing facial emotions. However, as described below, their impairment is different from the impairment described for patient S.M. A pattern of impairment apparently similar to the impairment in our patients has been described for patient S.E., who has bilateral amygdala damage caused by herpes encephalitis (as well as damage to the right anterior temporal cortex; Adolphs et al., 1999; Broks et al., 1998; Calder et al., 1996). Like our patients, S.E. was impaired at labeling facial emotions, but he rated congruous face–adjective pairs normally. His ability to rate incongruous face–adjective pairs has not been reported. Three other patients with lesions due to herpes encephalitis have also been assessed with the labeling task and were described as impaired at labeling facial emotions (Broks et al., 1998).

Patient S.M. (Adolphs et al., 1994; Adolphs, Tranel, Damasio, & Damasio, 1995), who has bilateral amygdala lesions due to Urbach–Wiethe disease, exhibits a pattern of impairment that is different from the impairment in our patients. S.M. was described as being insensitive to the emotion of fear in facial expressions, and she assigned low ratings to facial emotions that are typically judged as similar to fear, such as surprise. Overall, she differed from our patients by assigning abnormally low ratings for both incongruous face–adjective pairs and for some congruous face–adjective pairs (our patients gave high ratings; see Figure 3). Thus, S.M. apparently perceived some emotions as less intense than intact individuals did. At the same time, she appeared at most mildly impaired at labeling facial emotions, including faces expressing fear (our patients were markedly impaired; see Figure 1).

Other patients with impaired perception of facial emotion have been described who exhibit some characteristics of our patients, as well as some characteristics of patient S.M. Patients D.R. (Calder et al., 1996; Young et al., 1995) and S.P. (Anderson & Phelps, 2000) have bilateral amygdala lesions due to early-onset epilepsy and subsequent temporal lobe surgery. D.R. was impaired at labeling some negative emotions (like our patients; Calder et al., 1996), and she rated certain congruous face–adjective pairs lower than controls did (like S.M.; Adolphs et al., 1999). Her ability to rate incongruous face–adjective pairs has not been reported. Similarly, patient S.P. (Adolphs, 1999; Anderson & Phelps, 2000) was impaired at labeling emotions (like our patients) and gave abnormally low ratings for some congruous face–adjective pairs (like S.M.), but not for incongruous face–adjective pairs (unlike S.M.). Finally, Anderson, Spencer, Fulbright, and Phelps (2000) described patients with unilateral amygdala damage following right anteromedial temporal lobectomy who, like D.R. and S.P., gave abnormally low ratings to some congruous face–adjective pairs. Moreover, these patients, like patient S.P., assigned high ratings to some incongruous face–adjective pairs.

We considered whether the impairment we observed might reflect a general difficulty in processing faces per se rather than a specific difficulty with facial emotion. All 3 of our patients have damage bilaterally to the fusiform gyrus, an area that in functional imaging studies has been associated with the recognition and identification of faces (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; George et al., 1999; Haxby et al., 1994; Ishai, Ungerleider, Martin, Schouten, & Haxby, 1999). However, the damage in our patients is in each case anterior to the fusiform gyrus "face area" identified in these studies. Moreover, the impairment that we observed occurred for some emotions and not for others and exhibited a distinctly abnormal profile (e.g., sad faces were much easier for controls to label than faces exhibiting disgust or surprise, whereas the patients were impaired at labeling sad faces and were better at labeling both disgusted and surprised faces; see Figure 1). Furthermore, Broks et al. (1998) reported impaired labeling of facial emotions in a group of postencephalitic patients, in the absence of abnormalities on a face matching test. Accordingly, the pattern of impairment observed in our patients is unlikely to be related to a general difficulty with face processing.

Perhaps the most direct evidence that difficulty in face processing itself does not underlie the impairment we observed in our patients comes from a recent study of discrimination ability (Stark & Squire, 2000). A series of seven "oddball" tests were given in which participants were shown six stimuli and asked to decide which of the six did not belong with the others (Buckley, Booth, Rolls, & Gaffan, 1998). One of the tests involved presentations of different orientations of the same male face together with a sixth orientation of a different face. The task was to select the unique face. On all seven tests, E.P., G.P., and G.T. scored 79.6% correct (controls, 80% correct). The patients scored lower on the faces test than the controls (57% vs. 68%), but this difference did not approach significance ($p > .10$). Also, performance on the face discrimination task did not correlate with any measure of performance in Experiments 1–3.

Our patients have bilateral damage to all the structures of the medial temporal lobe, as well as variable damage to more lateral temporal cortex. Damage to inferolateral tem-

poral cortex can impair semantic memory (e.g., Garrard, Perry, & Hodges, 1997; Hodges, Patterson, Oxbury, & Funnell, 1992). One might therefore ask whether the patients had difficulty in appreciating the meaning of the emotional adjectives that were used. This possibility seems unlikely inasmuch as all our patients were able to provide correct descriptions of situations in which they would expect to experience each emotion.

It is nevertheless possible that the impairment seen in our patients reflects not only bilateral damage to the amygdala but also damage to other temporal lobe structures important for appreciating faces and facial emotions. If so, the different patterns of performance observed in patients with different etiologies and lesion types (see below) might be determined by the fact that some patients have relatively circumscribed amygdala damage and other patients have amygdala damage together with damage to anterior temporal cortex.

What might determine the pattern of impairment that we observed? The etiology and/or the age of the patient when the damage occurred may be important factors. Also, temporal lobe damage beyond the amygdala, which is present in the patients described here, must be considered. S.M., whose condition is congenital, and whose lesion is probably more selective than the lesions in other patients who have been studied, appears to exhibit a unique pattern of impairment. Patients S.P. and D.R. (Anderson & Phelps, 2000; Calder et al., 1996; Young et al., 1995), who have early-onset epileptogenic lesions of the amygdala and subsequent temporal lobe surgery, exhibited some deficits like S.M. (low ratings for congruous face–adjective pairs) but unlike S.M. did not give low ratings to incongruous face–adjective pairs. S.P. and D.R. also appeared to have more difficulty labeling negative emotions such as fear than S.M. did. Finally, our patients with adult-onset, postencephalitic lesions (and patient S.E.) were poor at labeling negative emotions and gave abnormally high ratings for incongruous face–adjective pairs. As other patients become available for assessment, it will be important and useful to use common test instruments, so that performance can be rigorously compared on the same tests.

Although there are differences in the performances of patients from different studies, it should be emphasized that all the patients with amygdala damage described to date have exhibited impairments in the processing of one or more negative facial emotions (fear, sadness, anger, and sometimes disgust). This finding is in accord with the general proposal that the amygdala is important for the processing of stimuli signaling fear and threat (Adolphs, 1999; Broks et al., 1998).

In summary, we have described 3 patients with bilateral anterior temporal lobe (including amygdala) damage who were impaired at processing emotion in faces. Two of these patients were described as normal in an earlier report (Hamann et al., 1996) when the data analysis was limited to a procedure developed for patient S.M. (Adolphs et al., 1994). The impairment in our patients appears to reflect difficulty in discriminating negative emotions in faces from related facial emotions (especially surprise and anger in the case of fear, and disgust and anger in the case of sadness). The impairment exhibited by our patients (and other postencephalitic patients) differs from the impairment exhibited by the well-studied patient S.M. and suggests that at least two different factors contribute to the impaired processing of facial emotion. One factor, which was impaired in our patients, involves the ability to discriminate among negative facial emotions as measured by the labeling task and by the tendency to assign high ratings in the rating task when incongruous face–adjective pairs were presented. The other factor, which was impaired in S.M., involves the ability to recognize (or experience the intensity of) negative facial emotions as measured by the tendency to assign low ratings in the rating task. Our findings help to explain differences that have been described on two tasks (labeling facial emotions and rating facial emotions) that have frequently been used to assess emotional perception following anterior temporal lobe damage.

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