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Quantifying deficits in the perception of fear and anger in morphed facial expressions after bilateral amygdala damage

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Abstract

Amygdala damage has been associated with impairments in perceiving facial expressions of fear. However, deficits in perceiving other emotions, such as anger, and deficits in perceiving emotion blends have not been definitively established. One possibility is that methods used to index expression perception are susceptible to heuristic use, which may obscure impairments. To examine this, we adapted a task used to examine categorical perception of morphed facial expressions [Etcoff, N. L., & Magee, J. J. (1992). Categorical perception of facial expressions. *Cognition*, *44*(3), 227–240]. In one version of the task, expressions were categorized with unlimited time constraints. In the other, expressions were presented with limited exposure durations to tap more automatic aspects of processing. Three morph progressions were employed: neutral to anger, neutral to fear, and fear to anger. Both tasks were administered to a participant with bilateral amygdala damage (S.P.), age- and education-matched controls, and young controls. The second task was also administered to unilateral temporal lobectomy patients. In the first version, S.P. showed impairments relative to normal controls on the neutral-to-anger and fear-to-anger morphs, but not on the neutral-to-fear morph. However, reaction times suggested that speed-accuracy tradeoffs could account for results. In the second version, S.P. showed impairments on all morph types relative to all other subject groups. A third experiment showed that this deficit did not extend to the perception of morphed identities. These results imply that when heuristics use is discouraged on tasks utilizing subtle emotion transitions, deficits in the perception of anger and anger/fear blends, as well as fear, are evident with bilateral amygdala damage.

Keywords: Face perception; Facial affect; Face morph; Valence; Neuropsychology

Neurological studies implicate the amygdala in processing facial expressions of emotion. Initial studies of a patient with bilateral amygdala damage found impaired perception of specific facial expressions of emotion, namely fear, while other aspects of face processing were intact (Adolphs, Tranel, Damasio, & Damasio, 1994, 1995). Subsequent studies have confirmed deficits in processing the facial expression of fear (e.g. Adolphs, Tranel et al., 1999; Anderson, Spencer, Fulbright, & Phelps, 2000; Calder et al., 1996; Young, Aggleton, Hellawell, Johnson, & Broks, 1995; Young, Hellawell, Van de Wal, & Johnson, 1996). These results converge with fMRI studies of healthy participants, which implicate the amygdala in the perception of fear (e.g. Morris et al., 1998; Whalen et al., 1998, 2001; reviewed in Vuilleumier & Pourtois, in press). Together, these findings support the critical role of the amygdala in perceiving fearful facial expressions.

Despite these findings, several issues regarding the role of the amygdala in the perception of facial expressions remain unresolved. First, perceptual processing of fearful expressions is intact in some patients with bilateral amygdala damage (e.g. Adolphs, Tranel et al., 1999; Hamann & Adolphs, 1999; Hamann et al., 1996). Second, patients with bilateral amygdala lesions can show impairments in the perception of other emotional expressions. However, these are not consistent across patients (e.g., Adolphs, Tranel et al., 1999; Calder et al., 1996). Third, deficits in the perception of emotional expressions can vary across testing sessions within a given patient. For example, patient S.P., who has bilateral amygdala damage due to epilepsy (Phelps et al., 1998), completed similar facial expression rating tasks on two occasions, where the only difference between the two tasks was the number of stimulus repetitions (Adolphs, Tranel et al., 1999; Anderson & Phelps, 2000). On the first occasion, S.P.'s ratings were impaired for fear, disgust, sadness and

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anger (Adolphs, Tranel et al., 1999). On the second occasion, S.P. showed impairments in rating fear, disgust, sadness, and happiness (Anderson & Phelps, 2000).

In a prototypical face rating study, subjects rate the intensity of individual basic emotions in faces posing various facial expressions. One criticism of these and other studies of amygdala-damaged patients is that the rating tasks used to assess facial expression processing may be insensitive to subtle deficits (see Calder et al., 1996; Sato et al., 2002). Instead, other measures of expression perception were proposed, such as a two-alternative forced choice task (2-AFC) used in the study of categorical perception (e.g. Etcoff & Magee, 1992). In a typical categorical perception experiment, the stimuli consist of morphed facial expressions that are generated by blending pictures of the same model posing different facial expressions in equal increments. Normal participants perceive these continua as falling into different emotion regions with a sharp boundary between them. In other words, the faces at the extreme ends of a continuum are consistently identified as the predominant emotion in the morph. However, at some point, usually in the middle of a morph continuum, there is an abrupt category shift where responding changes sharply from endorsing the emotion on one end of the continuum to the emotion on the other end of the continuum. This shift occurs across the categorical boundary. The morph level representing the boundary is known as the *point of subjective equality* (PSE), which is the level where subjects are most likely to be guessing. This task is thought to be more sensitive because morphed facial expressions create subtle differences in facial expression, and the response shifts across the categorical boundary can be analyzed.

Calder et al. (1996) adapted this 2-AFC task to examine the perception of facial expression in two patients with bilateral amygdala damage. Compared to control subjects who tended to identify morphed expressions categorically, these patients did not show distinct categorical perception (i.e., the category shift where responding shifted from endorsing one emotion to the other was not as abrupt as controls). This was most apparent in the identification of fear but did extend to other negative emotions, although these deficits were not consistent between the two subjects. A similar design was also used to study another patient with amygdala damage, H.Y. (Sato et al., 2002). Relative to controls, H.Y. had a positive bias in judging the facial expressions of anger and fear that were morphed with happiness. In other words, H.Y. needed more anger and fear in a face in order to categorize it as angry or fearful. In addition, H.Y.'s response curves did not show abrupt category shifts for the anger and fear morphs. These findings suggest that amygdala damage impairs the perception of prototypical expressions of fear and that this impairment could extend to other negative, highly arousing emotions.

One limitation of existing 2-AFC experiments is that results have been described qualitatively; the response curves generated by participants have not been subjected to quantitative analysis. The data from two-alternative forced choice experiments are well-suited to quantitative analysis via signal detection theory. Importantly, signal detection methods can be used to determine whether the abruptness of the shift at the categorical boundary is different for amygdala-damaged patients relative to controls. Analysis of the slope of the response curve around the response shift or categorical boundary allows one to determine whether the perception of facial expression is compromised following bilateral amygdala damage (Teunisse & de Gelder, 2001).

Another limitation of existing 2-AFC studies is that they did not examine sensitivity to differences in emotional intensity (i.e., emotional expressions morphed with neutral ones). Therefore, it is not known whether amygdala damage impairs the detection of subtle changes in the intensity of an emotional expression. Unlike the stimuli used in a typical ratings task, which depict prototypical emotions at maximum intensity, the stimuli created by morphing neutral and emotional faces have subtle gradations of facial emotion expression. Hence, 2-AFC tasks using morphed faces may be more sensitive than ratings tasks using prototypical expressions at detecting deficits in emotion processing.

Another question that remains is whether individuals with amygdala damage show impairments in perceiving blends of facial expression. Adolphs et al. (1994) originally suggested this idea based on their observation that relative to controls, patient S.M. did not rate facial expression categories as similar to one another. Multi-dimensional scaling of her emotion ratings revealed a clustering of facial expressions whereas the ratings of controls were more continuous. However, this observation was not consistent across testing sessions (Adolphs et al., 1994) and was not replicated in two additional patients (Hamann & Adolphs, 1999).

Using the 2-AFC task, the perception of emotion blends was directly examined. Calder et al. (1996) ran a subset of emotion morphs consisting of those emotions that are commonly confused with one another, and Sato et al. (2002) examined morphs between oppositely valenced expressions. Both provide some evidence of impairments in judging emotion blends, although the data were not subjected to quantitative analyses. An unresolved issue is whether amygdala-lesioned patients would be impaired on fear-to-anger morphs. Calder et al. (1996) examined the morphing of fearful to angry expressions, and found that one patient consistently identified faces as fearful regardless of the amount of facial anger, while the other patient's response curve was similar to that of controls but was more variable. If amygdala damage impairs identifying of fear and anger, then performance on fear/anger emotion blends should be particularly difficult.

A critical feature of neurologic studies examining facial affect perception is that faces are presented until a response is made, allowing subjects an abundant amount of time to examine facial features. Amygdala-damaged patients may use compensatory cognitive mechanisms to aid them with facial expression identification. One candidate could be feature analysis, where decisions regarding facial expression are based on the displacement of facial features. For example, decisions regarding the facial expression of fear could be based on the detection of features that are prototypical of this emotion such as widened eyes, eyebrows that are drawn inward and upward, and open mouths with the lips pulled back to expose the teeth. The variable use of compensatory strategies or heuristics could give rise to the inconsistencies in behavioral measures of facial expression pro-