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Sequential ordering of morphed faces and facial expressions following temporal lobe damage

Reiko Graham [a], Orrin Devinsky [b], Kevin S. LaBar [a,*]

[a] *Center for Cognitive Neuroscience, Duke University, United States*
[b] *Neurology, Psychiatry, and Neurosurgery, New York University School of Medicine, United States*

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Abstract

A card ordering task was developed to evaluate the role of the temporal lobe in perceiving subtle featural displacements of faces that contribute to judgments of facial expression and identity. Individuals with varying degrees of temporal lobe damage and healthy controls were required to manually sort cards depicting morphs of facial expressions or facial identities so that the cards were sequentially ordered from one morph endpoint to another. Four morph progressions were used—three emotion morphs (neutral-to-anger, neutral-to-fear, and fear-to-anger) and an identity morph. Five exemplars were given per morph type. Debriefing verified that participants were using feature-level cues to sort the cards. A patient with bilateral amygdala damage due to epilepsy did not differ in her sorting abilities from unilateral temporal lobectomy patients or controls. In contrast, a post-encephalitic patient with widespread left temporal lobe damage showed impairments that were most marked on the fear-to-anger and identity sorts. These results show that amygdala-damaged individuals can use information contained in facial expressions to solve tasks that rely on feature-level analysis, which recruits processing in other temporal lobe regions involved in making fine featural distinctions.

Keywords: Amygdala; Emotion; Facial affect; Face morph; Brain lesions

The idea that the amygdala plays a critical role in processing facial expression was advanced by Adolphs, Tranel, Damasio, and Damasio (1994), who described a patient with rare selective bilateral amygdala damage (S.M.) characterized by impairments in rating the intensity of facial expressions, especially the expression of fear. This finding was replicated in other patients with bilateral amygdala damage (e.g. Adolphs et al., 1999; Calder et al., 1996; Young, Aggleton, Hellawell, Johnson, & Broks, 1995; Young, Hellawell, Van De Wal, & Johnson, 1996) and has also been supported by neuroimaging studies showing amygdala activation to fearful faces in healthy adults (e.g. Morris et al., 1998; Whalen et al., 1998, 2001).

The specificity of the amygdala's involvement in processing fearful facial expressions, however, has remained unclear. Studies of individuals with bilateral amygdala damage have provided some inconsistencies, with different patients showing varying degrees of facial emotion decoding abilities (e.g. Adolphs et al., 1999; Adolphs & Tranel, 2004; Calder et al., 1996; Hamann et al., 1996; Hamann & Adolphs, 1999; Sato et al., 2002). Neuroimaging evidence has also provided mixed results regarding amygdalar involvement in processing expressions other than fear (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Blair, Morris, Frith, Perrett, & Dolan, 1999; Kesler-West et al., 2001; LaBar, Crupain, Voyvodic, & McCarthy, 2003; Whalen et al., 2001; Yang et al., 2002). A recent study by Adolphs et al. (2005) may provide an explanation for some of these inconsistencies. Their patient S.M.'s deficits in processing fearful facial expression appears to stem from the fact that she fails to spontaneously attend to the eye region of faces, which is critical for identifying fear. It is possible that the apparent involvement of the amygdala in evaluating certain facial expressions may be due to its involvement in processing information from the eye region of faces. The degree to which this finding holds for other patients may provide one account for inter-individual variability in the patient findings as well as the specificity of the neuroimaging findings to some categories of emotion over others.

* Corresponding author at: Center for Cognitive Neuroscience, Box 90999, LSRC, Duke University, Durham, NC 27708-0999, United States. Tel.: +1 919 668 0664; fax: +1 919 681 0815.
E-mail address: klabar@duke.edu (K.S. LaBar).

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A related explanation for the variability in the patient findings is that amygdala-damaged patients may use slower, compensatory cognitive mechanisms to aid them with expression identification. This idea was supported by Graham, Devinsky, and LaBar (2006), who found that when heuristics use was discouraged by reducing exposure time to morphed facial expressions, deficits in the perception of anger and anger/fear blends, as well as fear, were evident in a patient with bilateral amygdala damage. However, with unlimited exposure durations, performance significantly improved. According to this conception, the amygdala's role in processing facial expression will vary depending on the demands of the task. The use of strategies to ameliorate deficits in facial expression processing has been found in children with autism (Teunisse & de Gelder, 2001), but the possibility that amygdala-damaged individuals could also be using strategies to differing degrees of success has not received much attention. Adolphs et al. (2005) reported that when patient S.M. was instructed to attend to the eye region of faces, her perception of fearful facial expressions appeared normal. This finding suggests that if individuals with bilateral amygdala damage are told what to look for, they can use this information strategically to help them overcome more automatic processing deficits due to amygdala damage.

Amygdala activation in healthy adults is also sensitive to task demands under some circumstances, especially those that relate to intentional (explicit) versus incidental (implicit) aspects of emotion processing (e.g. Critchley et al., 2000; Whalen et al., 1998). For example, Carlsson et al. (2004) demonstrated that masked phobic stimuli elicit left amygdala activation, whereas awareness of phobic stimuli was associated with bilateral amygdala activation and additional activity in a network of cortical brain regions, including the insula, anterior cingulated, and orbitofrontal cortex. Given that the amygdala is more consistently implicated in rapid, covert processing of faces (e.g. Bishop, Duncan, & Lawrence, 2004; Vuilleumier, Armony, Driver, & Dolan, 2003; Williams, Morris, McGlone, Abbott, & Mattingley, 2004), additional task-related factors may influence its involvement on explicit emotion processing tasks. Explicit emotional judgments tend to recruit additional processing in frontotemporal cortical areas compared to non-emotional judgments (e.g. gender or age judgments) using the same facial expressions (Critchley et al., 2000; Gorno-Tempini et al., 2001; Gur et al., 2002). Therefore, task demands could affect the extent to which the amygdala versus cortical regions are preferentially recruited across different studies (see also Hariri, Bookheimer, & Mazziotta, 2000) and could also account for some of the inconsistencies observed in the current literature regarding the amygdala's role in processing facial expression.

One explicit processing strategy that could aid emotion recognition judgments is feature analysis, where decisions regarding facial emotion are based on a deliberate analysis of the perceptual displacement of specific facial features. In particular, expression processing after amygdala damage could be preserved if the task emphasizes strategic, featural processing, and recruits cortical areas that are involved in making fine-grained distinctions between visual stimuli. The amygdala has been linked to the rapid processing of low frequency components of faces and facial expressions through magnocellular channels, whereas ventral and lateral temporal neocortical areas have been linked to processing high frequency components via parvocellular channels (Vuilleumier et al., 2003). This suggests that two routes exist for information regarding facial expressions of emotion: a rapid, implicit, amygdala-mediated pathway and a more voluntary, strategic, cortically-mediated pathway. Therefore, processing the high frequency information necessary to perform fine featural discriminations should not be dependent upon the amygdala, even if emotional faces are used as stimuli. Instead, more lateral and ventral temporal lobe areas may be important, consistent with their role in using featural information to discriminate objects within a category, as previously shown in monkeys (Freedman, Riesenhuber, Poggio, & Miller, 2003).

In the present study, a sequential ordering task was developed using morphed faces to assess the role of the amygdala and other temporal lobe areas in perceiving the featural displacements that accompany changes in facial emotion and identity. This task involves presenting subjects with cards showing facial expression and identity morphs of varying increments, and requires the subject to order the cards in a logical progression from one morph endpoint to another. Because this task provides all the relevant perceptual cues across the morph increments simultaneously, we reasoned that the execution of this task should promote cortically-mediated strategies such as analysis of featural displacements. Accordingly, ventrolateral temporal lobe areas should be involved in performing this task, whereas medial temporal lobe structures, including the amygdala, should not be critical.

The task was administered to three different patient types that varied in their degree of temporal lobe damage—(1) a group of unilateral medial temporal lobectomy patients (TLBs) who underwent excision of the anteromedial temporal lobe for the surgical treatment of retractable epilepsy, (2) patient S.P., a right temporal lobectomy patient who had sustained additional damage circumscribed to her left amygdala (Phelps et al., 1998), and (3) patient C.B., a post-encephalitic patient with more widespread damage to the left temporal lobe. We hypothesized that patient S.P. and the TLB patients would show relatively intact performance on this task. We previously found that patient S.P. is impaired at two-alternative forced choice recognition of the same morphs, especially under time constraints. Therefore, a demonstration of intact performance in the present study would show a dissociation in performance as a function of task demands using identical stimuli. For patient C.B., three outcomes were considered. First, if the right ventrolateral temporal lobe areas implicated in face processing are primarily responsible for performance on this task (e.g. Haxby, Hoffman, & Gobbini, 2000; Kanwisher, McDermott, & Chun, 1997; McCarthy, 2000), then C.B. should perform normally since her right hemisphere is spared. Alternatively, if left temporal lobe areas implicated in the analysis of surface details (Peper & Irle, 1997) and face parts (Rossion et al., 2000) are critical to this task, then C.B. should have problems across all sorts presented. Finally, as a task that emphasizes both faces and feature analytic strategies, which vary in their respective dependence on the two cerebral