PERGAMON

Neuropsychologia 41 (2003) 1281–1289

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Rapid publication

# Amygdala damage impairs emotion recognition from scenes only when they contain facial expressions

Ralph Adolphs*, Daniel Tranel

*Department of Neurology, Division of Cognitive Neuroscience, University Hospitals and Clinics, University of Iowa, 200 Hawkins Drive, Iowa City, IA 52242, USA*

Received 22 August 2002; received in revised form 23 January 2003; accepted 6 February 2003

**Abstract**

Bilateral damage to the human amygdala impairs recognition of negatively valenced emotions from facial expressions, but it is unclear if this finding generalizes to richer visual stimuli that contain cues in addition to faces. We investigated this issue in 4 subjects with bilateral amygdala damage, 23 with unilateral amygdala damage, 22 brain-damaged controls and 16 normal individuals. Subjects were shown two blocks of complex social scenes; all stimuli in the two blocks were identical, except that the first block had all facial expressions in the image erased. While control subjects were more accurate in recognizing emotions when facial expressions were present, subjects with bilateral amygdala damage did not show the same benefit for negative emotions, often performing equivalently across the two conditions. Most striking, subjects with bilateral amygdala damage were more accurate in recognizing scenes showing anger with faces erased than with faces present, an effect resulting in part from highly abnormal recognition of certain angry facial expressions. All four subjects with bilateral amygdala damage were impaired in recognizing angry faces shown in isolation, and frequently mistook expressions of anger for smiles, a mistake never made by any control subject. Bilateral amygdala damage thus disproportionately impairs recognition of certain emotions from complex visual stimuli when subjects utilize information from facial expressions.


*Keywords:* Amygdala; Facial expression; Fear; Emotion recognition

## 1. Introduction

Real-life social situations typically provide a rich set of cues that permit viewers to evaluate their emotional significance. The general visual context, the relative locations of people, their body postures, head postures, directions of eye gaze, and facial expressions all provide such cues. This general observation raises two related questions: what is the relative importance of these different cues in recognizing emotions? And are different cues processed by different brain structures? Affirmative answers to both questions are supported in the case of faces: the human face is a particularly salient emotional cue, and there appear to be regions of the brain that are relatively specialized for processing faces. Foremost among these brain regions are sectors of extrastriate visual cortex, notably in the fusiform and superior temporal gyri (Allison, Puce, & McCarthy, 2000; Haxby, Hoffman, & Gobbini, 2000), and the amygdala (Adolphs, 2002). Whereas fusiform and superior temporal cortices may participate primarily in constructing detailed perceptual representations of faces (respectively, of the static, structural configuration, and of the dynamic changes among their features), the amygdala has been shown to be required in order to link the perception of the face to the retrieval of knowledge about its emotional and social meaning (Adolphs, 2002).

Ever since the seminal reports of Brown, Shafer, Kluver and Bucy (Kluver & Bucy, 1939), the primate amygdala has been implicated in the regulation of social and emotional behaviors. Lesions of the amygdala in monkeys impair the animal's ability to evaluate the social and emotional meaning of visual stimuli (Emery et al., 2001; Kling & Brothers, 1992; Meunier, Bachevalier, Murray, Malkova, & Mishikin, 1999; Rosvold, Mirsky, & Pribram, 1954; Weiskrantz, 1956; Zola-Morgan, Squire, Alvarez-Royo, & Clower, 1991). While bilateral lesions of the amygdala in humans appear to have less severe consequences than they do in monkeys, they nonetheless result in alterations in social behavior and social cognition (Adolphs, 1999). Particularly clear is the human amygdala's role in the recognition of social cues from faces, a role that is best understood in regard to the recognition of basic emotions. Both lesion and functional imaging studies have demonstrated, respectively, impaired

* Corresponding author. Tel.: +1-319-353-8610; fax: +1-319-356-4505.
*E-mail address:* ralph-adolphs@uiowa.edu (R. Adolphs).
*URL:* http://www.medicine.uiowa.edu/adolphs.

0028-3932/03/$ – see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0028-3932(03)00064-2

recognition of facial expressions following bilateral amygdala damage, and activation of the amygdala during presentation of emotional facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994; Morris et al., 1996). Notably, these findings are most robust for negatively valenced emotions, in particular fear, anger, and sadness in lesion studies, and fear in functional imaging studies (Adolphs, 1999; Adolphs et al., 1999; Broks et al., 1998; Calder et al., 1996; Schmolck & Squire, 2001; Young, Hellawell, Van de Wal, & Johnson, 1996), although the reasons underlying these differential patterns of dependency on the amygdala are debated (see Adolphs, 2002; Rapcsak et al., 2000). The role of the amygdala in processing information about faces is also borne out by single-unit recordings that have found responses relatively selective to faces in both human (Fried, MacDonald, & Wilson, 1997) and non-human primates (Leonard, Rolls, Wilson, & Baylis, 1985).

Given the amygdala's role in recognizing negative emotions from facial expressions when presented in isolation, we wondered if those findings would generalize also to more complex visual social stimuli. Based on the data reviewed above, we hypothesized that the amygdala would be most important to process emotional information from faces, rather than from other visual cues, and that it would be especially important in processing facial expressions of negatively valenced emotions. We thus predicted that damage to the amygdala would yield impaired recognition of such emotions only when the recognition relied on information about facial expressions, and not when it relied on information other than facial expressions. Furthermore, we expected a significant impairment to result from bilateral amygdala damage, but less impairment to result from unilateral amygdala damage, as would be expected and as consistent with prior studies (Adolphs, Tranel, & Damasio, 2001; Adolphs, Tranel, Damasio, & Damasio, 1995; Anderson, Spencer, Fulbright, & Phelps, 2000).

To obtain a clear contrast, we investigated the recognition of emotions from two classes of stimuli that were otherwise identical: complex social scenes containing faces, and the same complex social scenes with the faces digitally erased. In all cases, scenes contained multiple visual cues, including body posture, hand gestures, interpersonal stances, and general context, in addition to emotional facial expressions. By directly comparing performances to the scenes when they contained facial expressions, versus when the faces had been erased, we were able to assess the extent to which subjects were able accurately to utilize information from the face in recognizing the emotion signaled by the scene.

## 2. Methods

### *2.1. Participants*

We compared performances given by 4 individuals with bilateral amygdala damage with 2 other brain-damaged groups: 23 subjects with unilateral amygdala damage, and 22 brain-damaged controls without amygdala damage. Performances were converted to accuracy scores on the basis of data from a reference group of 16 neurologically normal controls (see below). All brain-damaged participants were recruited from the Division of Cognitive Neuroscience's Patient Registry, and had been extensively characterized both in terms of the location and extent of their lesion (Damasio & Frank, 1992; Frank, Damasio, & Grabowski, 1997), and in terms of their neuropsychological performance across multiple cognitive domains (Tranel, 1996). Demographic and background neuropsychological information is given in Table 1. Normal controls were recruited through advertisement. All subjects had given informed consent to participate in these studies as approved by the Internal Review Board of the University of Iowa, and as consistent with the Declaration of Helsinki.

Table 1
Background neuropsychology and demographics of participants

| | Gender | Age | Education | VIQ | PIQ | Faces |
|---|---|---|---|---|---|---|
| SM | F | 32 | 12 | 86 | 95 | 49 |
| RH | M | 44 | 16 | 110 | 116 | 45 |
| SZ | M | 45 | 16 | 95 | 78 | 43 |
| JM | M | 68 | 12 | 90 | 95 | 41 |
| L | 4F/6M | 37 | 14 | 101 | 108 | 44 |
| R | 5F/8M | 34 | 13 | 94 | 98 | 44 |
| BDC | 12F/20M | 55 | 14 | 95 | 105 | 46 |

SM, RH, SZ and JM: subjects with bilateral amygdala damage; L and R: subjects with left or right unilateral temporal lobectomy; BDC: brain-damaged controls; education: years of education; VIQ and PIQ: verbal and performance IQ from the WAIS-R or WAIS-III; faces: scores from the Benton face matching test (all normal). For L, R and BDC groups, means are shown.

#### *2.1.1. Bilateral amygdala damage*

Three of the subjects had bilateral damage to the amygdala and to surrounding regions of the brain due to encephalitis (SZ, JM and RH); all three were densely amnesic and required continual repetition of the instructions during the task. One of the subjects (SM) had bilateral damage selective to the amygdala and a small portion of anterior entorhinal cortex, and was not amnesic. Background information and face recognition abilities have been previously published on subjects SM, JM and RH (Adolphs, 1999; Adolphs & Tranel, 2000; Adolphs et al., 1994, 1995, 1999; Tranel & Hyman, 1990). Neuroanatomy of all four subjects is shown in axial MR scans in Fig. 1, showing bilateral amygdala damage in all cases.

We were able to obtain replicate data sets on multiple testing sessions with three of the subjects (RH, JM and SZ), each separated by at least 1 month. As all three of these subjects were amnesic, none remembered participating in the task previously, and all showed similar patterns of performances across the multiple sessions. In one session, we