

Discriminating emotional faces without primary visual cortices involves the right amygdala

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Destruction of the brain's primary visual areas leads to blindness of cortical origin. Here we report on a subject who, after bilateral destruction of his visual cortices and ensuing cortical blindness, could nevertheless correctly guess the type of emotional facial expression being displayed, but could not guess other types of emotional or non-emotional stimuli. Functional magnetic resonance imaging showed activation of the right amygdala during the unconscious processing of emotionally expressive faces.

When the brain's primary visual areas are destroyed, cortical blindness normally ensues¹. Although persons suffering from cortical blindness are unaware of the presence of any visual stimuli, some patients have reportedly been able to 'guess' certain visual characteristics of the stimuli with a reliability exceeding chance level, giving rise to the term "blindsight" to describe this phenomenon².

Blindsight has been described for diverse visual features such as spatial location, object orientation and movement³. More recently, it has been suggested that emotional faces may also give rise to this phenomenon⁴. However, this assertion relies on patients with a loss limited to part of the visual field and in whom an indirect role of the intact visual field cannot be excluded⁵. Until now, the only suggestion of affective blindsight with total blindness has been based on a study of visual fear conditioning⁶.

We investigated blindsight for emotional stimuli in a 52-year-old right-handed physician who became cortically blind following two consecutive strokes at a 36-d interval, which destroyed both his right and left visual cortices (see **Supplementary Methods** online). The patient was alert and showed no cognitive impairment except for slight word-finding difficulties. He was aware and understandably worried about his visual impairment. Clinically, he could not detect movement or colors, or even the presence of a strong light source. He was unable to identify any geometric shapes or objects—large or small—in the visual modality alone, and had to rely on hearing and touch in his everyday activities.

A series of behavioral procedures was carried out after the patient had given his informed written consent. In each procedure, 200 stimuli were presented randomly on a computer screen (see **Supplementary Methods** online). The stimuli fell into one of two categories, and the patient was instructed to guess the category for each item. Responses were recorded

by an examiner who sat behind the computer screen and could not see the stimuli. Statistical validity of the patient's performance was established by computing the two-tailed probability value of the number of correct answers on a binomial distribution with a probability threshold at 0.05.

We first carried out an initial baseline test by presenting black squares and circles on the white background of a computer screen and asking the patient to guess the shape. The patient's performance (45% correct answers) was not statistically different from chance level ($P = 0.203$) in this procedure. We next presented a randomized series of pictures depicting angry and happy faces⁷, and asked the subject to guess which of these two emotions was expressed. Here the patient answered correctly at a level that was significantly higher than chance ($P = 0.011$), with 59% correct responses. His responses were also nonrandom when he was guessing whether facial expressions were sad versus happy (61.5%, $P = 0.001$) or fearful versus happy (58%, $P = 0.024$).

To assess whether the patient's performance was due to the actual emotional expressions portrayed by the faces, or to broader, non-emotional facial characteristics, we presented the patient with two tasks. First, he was shown emotionally neutral male and female faces and asked to guess the gender on each photograph. Second, he was shown either normal faces or jumbled faces and was asked whether they represented authentic faces. In contrast to the results of the emotional task, his performance in both these procedures was at chance level (44.5%, $P = 0.12$ and 47%, $P = 0.396$, respectively). We next tested whether the patient responded to emotional faces in particular or to emotions more generally. He was shown photographs of animals in threatening versus non-threatening stances and asked to guess whether the animals were "happy" (nonthreatening) or "angry" (threatening). Here, he obtained 54.5% correct responses, a result that did not exceed chance ($P = 0.203$). Finally, we exposed the patient to pictures showing pleasant or unpleasant scenes (for example, sports or sex, or violence or mutilation)⁸, asking him again to guess whether they were positive or negative. Once more, his score (55% correct responses) was attributable to chance ($P = 0.157$).

To determine the cerebral structures involved in the patient's discriminative abilities, we conducted an experiment using functional magnetic resonance imaging (fMRI). In our activation task, we showed the patient angry, happy, neutral and fearful faces in four consecutive blocks (see **Fig. 1** legend and **Supplementary Methods** online). A response to all emotional faces (anger, happiness and fear compared to neutral) was found in the right amygdala alone ($P = 0.00001$ corrected, $t = 6.47$; **Fig. 1a,b**). Significant activation within the right amygdala was also observed when considering each emotional expression separately, with the strongest effect for fear (fear, $t = 8.86$; happiness, $t = 5.14$; and anger, $t = 4.77$; **Fig. 1c**).

Our findings demonstrate that, despite bilateral destruction of the visual cortex and the consequent lack of conscious visual experience, detection of emotionally expressive faces can nonetheless occur through

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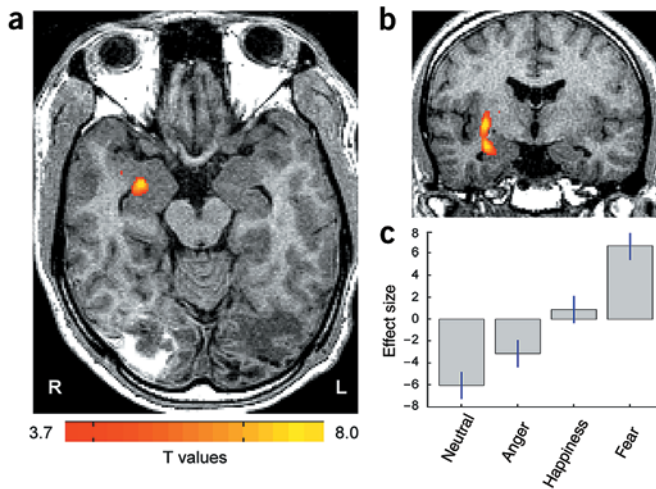


Figure 1 Amygdala response to emotional faces (fear, anger and happiness) compared to neutral faces. (a,b) Highly significant voxels ($P < 0.0001$, uncorrected), principally located in the lateral part of the right amygdala and extending dorsally to the putamen, are shown on horizontal (a) and coronal (b) views of the patient's brain. The axial slice (a) best illustrates the bilateral lesion of the occipital cortex. (c) Parameter estimates (mean \pm s.e.m.) show that all conditions differed significantly from neutral faces, with the highest effect for fear. Error bars, s.e.m. The fMRI procedure was performed on a 1.5 T scanner with an echo-planar-imaging sequence (repetition time = 2 s, echo time = 40 ms, 25 contiguous axial slices, voxel size = $1.95 \times 1.95 \times 3$ mm), using a block protocol. Activation conditions consisted of blocks of angry, happy, neutral and fearful faces presented during 40 s, followed by 20-s rest conditions (black screen). Data analysis was carried out with SPM99 (Wellcome Department of Imaging Neuroscience, University College London).

activation of the right amygdala. This effect was observed despite the fact that the subject's brain damage was recent and that there therefore had been little time for functional reorganization of the cortical networks.

The lateralization of activation corroborates recent imaging studies in non-brain damaged subjects showing that unconscious perception of emotional faces also gives rise to a right amygdala activation^{9,10}. A direct subcortical route via the superior colliculus and pulvinar has been put forward as a possible pathway mediating emotional information^{9,11}. These results further substantiate the view that the amygdala has a role in processing the emotional relevance of faces and that this

is not restricted to the processing of fear alone^{12–14}, even though fear is more efficient as a triggering stimulus.

These findings, in association with the absence of an effect for other emotional stimuli in the behavioral tasks, provide strong evidence that the hypothesized colliculo-pulvinar route possesses sufficient resolution to convey information about facial expressions but not other, less habitual emotional stimuli. By contrast, emotional scenes of a more complex nature appear to necessitate initial processing by cortical visual areas before an amygdala response can be made, a view previously suggested for the processing of emotional faces¹⁵.

Note: Supplementary information is available on the Nature Neuroscience web site.

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COMPETING INTEREST STATEMENT

The authors declare that they have no competing financial interest.

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