

# Perception and Emotion

## How We Recognize Facial Expressions

Ralph Adolphs

*Division of Humanities and Social Sciences and Division of Biology, California Institute of Technology*

---

**ABSTRACT**—*Perception and emotion interact, as is borne out by studies of how people recognize emotion from facial expressions. Psychological and neurological research has elucidated the processes, and the brain structures, that participate in facial emotion recognition. Studies have shown that emotional reactions to viewing faces can be very rapid and that these reactions may, in turn, be used to judge the emotion shown in the face. Recent experiments have argued that people actively explore facial expressions in order to recognize the emotion, a mechanism that emphasizes the instrumental nature of social cognition.*

**KEYWORDS**—*face perception; faces; emotion; amygdala*

---

An influential psychological model of face processing argued that early perception (construction of a geometric representation of the face based on its features) led to subsequently separate processing of the identity of the face and of the emotional expression of the face (Bruce & Young, 1986). That model has received considerable support from neuroscience studies suggesting that the separate processes are based on separable neuroanatomical systems: In neuroimaging studies, different parts of the brain are activated in response to emotional expressions or identity changes; and brain damage can result in impairments in recognizing identity but not in recognizing emotional expressions, or the reverse.

### **SOME PROCESSING IS RAPID AND AUTOMATIC AND CAN OCCUR IN THE ABSENCE OF AWARENESS OF THE STIMULI**

Some responses in the brain to emotional facial expressions are so rapid (less than 100 ms) that they could not plausibly be based on conscious awareness of the stimulus, although the responses, in turn, may contribute to conscious awareness. Evidence comes from studies using event-related potentials, measures of the brain's electrical activity recorded at the scalp (or, much more

rarely, directly from the brain in surgical patients). In those experiments, the responses to many presentations of emotional stimuli are averaged across stimuli, and the changes in electrical potential can be accurately timed in relation to stimulus onset. Evidence has also come from studies in which viewers were shown facial expressions subliminally. Especially salient aspects of faces are most potent in driving nonconscious responses: For instance, subliminal presentation of only the whites of the eyes of fearful faces results in measurable brain activation (Whalen et al., 2004). One specific structure involved in such rapid and automatic neural responses is the amygdala, a structure in the medial temporal lobe that is known to be involved in many aspects of emotion processing.

Findings such as these have been of interest to psychologists, as they provide a potential mechanism consistent with two-factor theories of human behavior. For instance, the theory that affect and cognitive judgment are separate processes, and that affect can precede cognitive judgment, receives some support from the neuroscience findings (Zajonc, 1980). The data also add detail to theories of visual consciousness. In one set of studies, emotional facial expressions were shown to neurological patients who, because of their brain damage, were unable to report seeing the stimuli. An individual with damage to the visual cortex had “blindsight” for emotional faces: He could discriminate the emotion shown in faces by guessing, even though he reported no visual experience of seeing the faces. A neuroimaging experiment in this same individual revealed that the amygdala was activated differentially by different emotional faces, despite the absence of conscious visual experience (Morris, deGelder, Weiskrantz, & Dolan, 2001).

These and other studies have suggested a distinction between subcortical processing of emotional visual stimuli (e.g., involving the amygdala and brainstem nuclei such as the superior colliculus), which may be independent of conscious vision (Johnson, 2005), and cortical processing, which is usually accompanied by conscious experience. It is interesting to note that amphibians and reptiles have only subcortical visual processing, since they lack a neocortex. One broad interpretation of these observations is thus that the subcortical route for processing emotional stimuli is the more ancient one, and that in

---

Address correspondence to Ralph Adolphs, HSS 228-77, Caltech, Pasadena, CA 91125; e-mail: radolphs@hss.caltech.edu.

mammals an additional, cortical route has evolved that probably allows more flexible behaviors based on learning and conscious deliberation.

A final wrinkle has come from psychological studies of the relationship between attention and emotion. It has been known for some time that emotionally salient stimuli can capture attention, an interaction that makes much adaptive sense (Ohman, Flykt, & Esteves, 2001). But more recent studies have also shown the reverse: that volitionally allocating attention to stimuli can influence their emotional evaluation. Inhibiting attention to visual stimuli that are distractors in a search task, for example, results in devaluation of those stimuli when subjects are asked to rate them on affective dimensions (Raymond, Fenske, & Tavassoli, 2003). Emotions thus represent the value of stimuli—what people approach or avoid, cognitively or behaviorally, volitionally or automatically.

### FEAR AND DISGUST MAY BE PROCESSED SPECIALLY

Several studies have found evidence that the amygdala, the subcortical structure discussed earlier, is disproportionately important for processing facial expressions of fear, although by no means exclusively so. The only other emotion for which a similar neuroanatomical specificity has been reported is disgust. A region of the cortex called the insula represents motor and sensory aspects of that emotional response (Calder, Lawrence, & Young, 2001). In lesion studies, damage to the amygdala is shown to result in impairment in the ability to recognize fear from facial expressions. Similarly, damage to the insula can result in impairment in the ability to recognize disgust from facial expressions. However, questions remain regarding exactly which emotion category or dimension is being encoded in these brain regions, since other emotions are often also variably impaired.

Especially informative have been studies in a rare patient, SM, who has total damage to the amygdala on both sides of the brain. The subject can accurately judge age and gender from faces, and she has no difficulty recognizing familiar individuals from their faces. She also has little difficulty recognizing most facial expressions, with the notable exception of fear. When asked to judge the fearfulness of faces, SM is selectively and severely impaired (Adolphs, Tranel, Damasio, & Damasio, 1994). However, other patients with similar damage are impaired on a wider array of emotions; in functional neuroimaging studies, activation of the amygdala is seen in response to several emotions in addition to fear; and even SM's highly specific impairment depends on the questions she is asked. For example, when asked to classify faces into categories of basic emotions, SM is rather selectively impaired on fear; but when asked to rate how arousing the emotion shown in the face is, she is impaired on all emotions of negative valence (Adolphs, Russell, & Tranel, 1999). These data suggest that, while the amygdala is critical for recognizing fear in faces, its role encompasses a broader, more

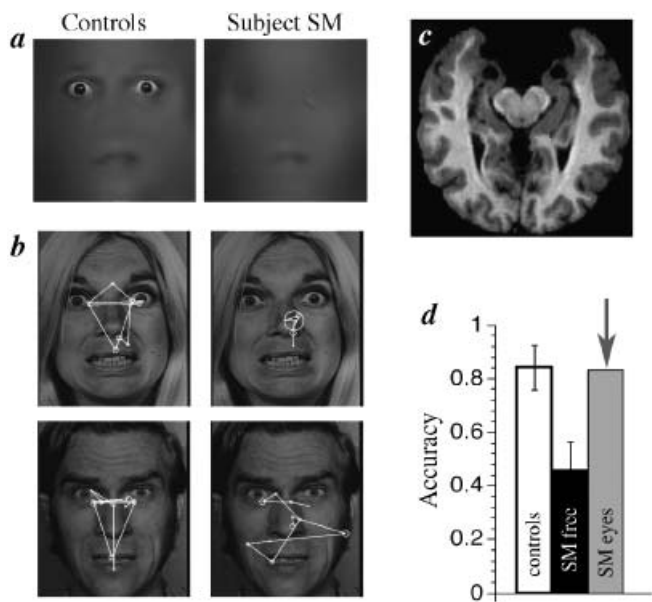
abstract, and perhaps dimensional rather than categorical aspect of emotions, for which fear is but one instance—an issue I take up again below.

### MANY BRAIN STRUCTURES ARE INVOLVED

Just as there is good evidence that the amygdala does more than solely detect fear, there are of course brain structures other than the amygdala that participate in perceiving emotion from faces. Brain-imaging studies, in particular, have found evidence for a large number of other brain structures that may come into play, depending on the emotion shown in the face and on the demands of the experimental task.

One framework that summarizes these data runs as follows. Visual areas in the temporal cortex encode the face's features and bind them into a global perceptual representation of the face. Subcortical visual areas (such as the superior colliculus, prominent in animals such as frogs) carry out coarser but faster processing of the face. Both routes, the cortical and the subcortical, feed visual information about the face into the amygdala. The amygdala then associates the visual representation of the face with an emotional response in the body, as well as with changes in the operation of other brain structures. For instance, it likely triggers autonomic responses (such as skin-conductance response, the sympathetic autonomic response of sweating on the palms of the hands) to the face, and it also modulates visual attention to the face.

Tracing the path from initial perception of the face to recognizing the emotion it expresses is complicated by feedback loops and by multiple pathways that can be engaged. One class of proposals, as influential as they are controversial, argues that the emotional response elicited by the amygdala can in fact be used by the viewer to reconstruct knowledge about the emotion shown in the face. Roughly: if I experience a pang of fear within myself upon seeing a fearful face, I can use the knowledge of my own emotion to infer what the emotional state of the person whose face is shown in the stimulus might be. Broader theories in a similar vein do not restrict themselves to the amygdala or to fear, but more generally propose that we make inferences about other people's emotional states by simulating within ourselves aspects of those states (Goldman & Sripada, 2005). Emotional contagion and imitation may be the earliest aspects of such a mechanism that can already be seen in infants, and empathy and theory of mind may be more complex elaborations that develop later in life. In support of these ideas, a provocative study recently found that constricted pupils make sad facial expressions look more sad, and that this effect is correlated with an empathic pupillary response in the viewer. In other words, looking at a sad face with more constricted pupils causes one's own pupils to constrict, an effect accompanied by activation of brain regions known to be important for emotion and empathy (Harrison, Singer, Rothstein, Dolan, & Critchley, 2006). That finding is in line with prior reports documenting facial reactions when subjects viewed facial



**Fig. 1.** Impaired recognition of fear in facial expressions, resulting from impaired eye gaze onto faces. The figure shows data from a study in subject SM, who has bilateral damage to the amygdala. Panel a shows images depicting the regions in faces that viewers use to discriminate fear. Normal subjects, on the left, make notable use of the eyes, as well as some use of the nose and mouth. By contrast, SM, on the right, fails to make use of the eyes. Panel b shows eye movements (white lines) and locations of fixation (white circles) when participants view facial expressions of fear. Whereas normal subjects explore the faces in a particular pattern, concentrating on the eyes and the mouth (left), SM either does not explore the face at all or does so in a haphazard fashion that fails to make the normal number of fixations onto the eye region. The brain damage in subject SM is shown in panel c: A horizontal magnetic resonance scan through SM's brain shows the front of her brain at the top of the image, and the back of her brain at the bottom of the image. The two symmetrical black circles near the top middle part of the brain image are her lesions of the left and right amygdala. The graph in panel d plots the accuracy in matching expressions of fear with the word "fear," in a task in which 6 different emotions and words were given to subjects. While SM is impaired (black bars) compared to healthy controls (white bars) when viewing the faces without instruction (in which case she does not fixate on the eyes of the faces normally), the explicit instruction to fixate on the eyes brought her performance to normal levels (gray bar, arrow). From "A Mechanism for Impaired Fear Recognition After Amygdala Damage," by R. Adolphs, F. Gosselin, T.W. Buchanan, D. Tranel, P. Schyns, & A.R. Damasio, 2005, *Nature*, 433, pp. 69, 70, 71. Copyright 2005, MacMillan Press. Reproduced with permission.

expressions—even facial expressions shown so briefly that they are only subliminally, not consciously, perceived (Dimberg, Thunberg, & Elmehed, 2000).

### PERCEPTION OF EMOTION IS ACTIVE

The studies discussed above have provided models of how several different brain structures interact, at various points in time and often as a function of context and individual differences, to infer another person's emotional state from observation of their overt behavior. This account emphasizes the constructive role that emotion can play in generating knowledge about the world, and emphasizes the inferential, creative nature of the

processing whereby we go from the appearance of a face to its social meaning. Yet there is one ingredient missing: It is assumed that all the sensory information on the basis of which the subsequent processing is triggered is already given in the stimuli that subjects are shown. The account treats the initial acquisition of sensory information from the stimulus as a passive process. In fact, it is known from both experiment and everyday experience that our perception of the social world is much more instrumental, and involves actively querying other people as we seek out relevant social information in the first place.

A recent study in the subject with total amygdala loss, SM, provided striking evidence for such a mechanism. As noted earlier, SM is impaired in recognizing fear from facial expressions due to her amygdala damage, but it has remained unclear whether this means the amygdala is specialized for fear as such, or whether it means the amygdala is involved in a broader function that happens to be particularly important for fear recognition. To obtain a detailed inventory of how different features within a fearful face are processed, we conducted an experiment in which subjects were shown a large number of faces in which most of the face was occluded and only very small portions of the face were randomly revealed. Viewing these stimuli, called "bubbles," was similar to viewing facial expressions through a piece of cardboard into which random little holes had been poked. Thus, on some trials, viewers might see a part of an ear, or part of the mouth or the eyes. A discrimination task asked subjects to discriminate whether these "bubbles" faces looked happy or fearful. After thousands of trials, we then related the performance accuracy of the subject on a given trial to the regions of the face stimulus that had been revealed on that trial. This method generates a resulting image that shows the strength and reliability of the association between features of the face and discrimination of the emotion. For example, certain parts of the face such as the mouth and eyes would be associated with a better discrimination performance than other parts such as the chin or ears (which do not provide discriminative information for telling emotions apart).

Not surprisingly, we found that the eyes and the mouth of faces are most useful to viewers in discriminating the emotion; that is, they showed high performance accuracy on the emotion-discrimination task when these features were revealed in the face stimuli. Remarkably, subject SM failed to make normal use of the eyes in this task: Unlike healthy individuals, she did not benefit in her recognition of emotion when shown the eye region of facial expressions (Fig. 1a). Importantly, this impairment was present for all emotional expressions, not just fear: It just happens to be the case that the eyes are the feature that most distinguishes fear expressions from those of the other basic emotions. The deficit was even more basic, however. It turned out that SM failed to direct her gaze to the eye region of faces (Fig. 1b). These data suggested that at least part of the reason SM fails to recognize fear is that she fails to make use of the ex-

pression of the eyes in faces; moreover her impaired use of the eye region of faces was associated with her not looking at the eyes in the first place. Apparently, the amygdala is involved not only in the emotional responses to faces, once perceived, but also provides the prerequisite for such perception by guiding gaze and attention to emotionally salient regions of the face at the outset. This account was supported in a further experiment, in which SM was explicitly instructed to look at the eyes in facial expressions; when she did so, she was able to discriminate fear normally (Fig. 1d).

This active aspect of emotion perception, the ability to search for relevant social cues in faces, may also be one of the deficits in people with autism. Many people with autism also do not direct their gaze normally at others, an impairment that may contribute to their impaired social behavior and point to possible strategies for intervention and rehabilitation. Dysfunction in allocating attention to emotionally relevant stimuli is also likely to contribute to other psychiatric disorders, ranging from post-traumatic stress disorder to schizophrenia.

### FUTURE DIRECTIONS

One very intriguing approach for the future would be to combine the “bubbles” technique (cf. Fig. 1a) with other dependent measures. For instance, viewers could be shown randomly sampled parts of faces while neural (e.g., functional magnetic resonance imaging, fMRI) or psychophysiological (e.g., skin-conductance response) measures of emotional response are obtained. Analogous to asking what features in faces drive behavioral-perceptual discrimination of emotions, we could then ask what features drive psychophysiological response, or what features drive regional brain activation. A state-of-the-art experiment that is now in principle possible could begin with the response measured by fMRI within a region such as the amygdala or the insula and use this as the independent variable to see how well it predicts the trial-by-trial features revealed in the randomly sampled face parts (essentially the reverse of a standard neuroimaging analysis, which uses the fMRI response as the dependent variable and the stimuli as the independent variable). Such an experiment would provide a statistical visualization of the parts of the face that are the most effective at driving activation within that brain structure. Studies like these could also provide insights into causal relationships between psychophysiological response, regional brain activation, and overt behavioral performance. Are the features of faces that drive amygdala activation the same as those that drive skin-conductance response? If so, this would support the idea that the amygdala triggers the skin-conductance responses.

A second critical future direction concerns the social communicative role of emotional expressions, an aspect already pointed out by Charles Darwin. To date, the vast bulk of research has focused on the perceptual end. What is needed are studies

that probe the signaling end as well—ideally in naturalistic situations involving face-to-face interactions between people. It is worth stressing that essentially all studies of visual emotion perception have used rather artificial stimuli: static (often black-and-white) photographs of (often posed) facial expressions—or in some cases just drawings of facial expressions. It seems reasonable to suppose that our emotional reactions and eye-gaze responses to photographs of faces would be different than those to real faces, and that context effects and individual differences would offer a rich source of variance to explore with such naturalistic stimuli. Does the ability to produce clear facial expressions of emotion go hand in hand with the ability to recognize such expressions? Do these two abilities develop at the same ages? Are we more accurate at recognizing our own facial expressions than those of others, as some studies suggest (Elfenbein & Ambady, 2003)? The future of research on facial emotion will depend on integrating the powerful tools provided by cognitive neuroscience with ethological approaches to human behavior.

---

### Recommended Reading

- Adolphs, R. (2002). Recognizing emotion from facial expressions: Psychological and neurological mechanisms. *Behavioral and Cognitive Neuroscience Reviews*, *1*, 21–61.
- Adolphs, R., Gosselin, F., Buchanan, T.W., Tranel, D., Schyns, P., & Damasio, A.R. (2005). (See References)
- Gosselin, F., & Schyns, P.G. (2001). Bubbles: A technique to reveal the use of information in recognition tasks. *Vision Research*, *41*, 2261–2271.
- LeDoux, J. (1996). *The emotional brain*. New York: Simon and Schuster.
- 

**Acknowledgments**—Supported by grants from the National Institute of Mental Health, the Cure Autism Now Foundation, and the Autism Speaks Foundation.

### REFERENCES

- Adolphs, R., Gosselin, F., Buchanan, T.W., Tranel, D., Schyns, P., & Damasio, A.R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature*, *433*, 68–72.
- Adolphs, R., Russell, J.A., & Tranel, D. (1999). A role for the human amygdala in recognizing emotional arousal from unpleasant stimuli. *Psychological Science*, *10*, 167–171.
- Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature*, *372*, 669–672.
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*, 305–327.
- Calder, A.J., Lawrence, A.D., & Young, A.W. (2001). Neuropsychology of fear and loathing. *Nature Reviews Neuroscience*, *2*, 352–363.
- Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, *11*, 86–89.

- Elfenbein, H.A., & Ambady, N. (2003). When familiarity breeds accuracy: Cultural exposure and facial emotion recognition. *Journal of Personality and Social Psychology, 85*, 276–290.
- Goldman, A.I., & Sripada, C.S. (2005). Simulationist models of face-based emotion recognition. *Cognition, 94*, 193–213.
- Harrison, N.A., Singer, T., Rothstein, P., Dolan, R.J., & Critchley, H.D. (2006). Pupillary contagion: Central mechanisms engaged in sadness processing. *Social Cognitive and Affective Neuroscience, 1*, 5–17.
- Johnson, M.H. (2005). Subcortical face processing. *Nature Reviews Neuroscience, 6*, 766–774.
- Morris, J.S., deGelder, B., Weiskrantz, L., & Dolan, R.J. (2001). Differential extrageniculostriate and amygdala responses to presentation of emotional faces in a cortically blind field. *Brain, 124*, 1241–1252.
- Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*, 466–478.
- Raymond, J.E., Fenske, M.J., & Tavassoli, N. (2003). Selective attention determines emotional responses to novel visual stimuli. *Psychological Science, 14*, 537–542.
- Whalen, P.J., Kagan, J., Cook, R.G., Davis, F.C., Kim, H., Polis, S., McLaren, D.G., Somerville, L.H., McLean, A.A., Maxwell, J.S., & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science, 306*, 2061.
- Zajonc, R.B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*, 151–175.