carry out the basic logic operations AND, OR and NOT. In principle, this is all that is needed to perform more complex logic operations. However, the efficiency of these logic gates will be significantly reduced when their inputs and outputs are connected to other logic gates in a large digital circuit. In order to avoid this problem, there should be some way of amplifying the gate signals; otherwise, their logic applications will unfortunately be limited. The multiple steps in quantum conductance that the authors observe with increasing voltage are also remarkable, but probably not of sufficiently practical use in view of their limited reproducibility.

Yet the main result is of great beauty and simplicity, and is scalable to nanometre-sized addressable bits. The authors have done well to protect their work with several patent applications. ■

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1. Terabe, K., Hasegawa, T., Nakayama, T. & Aono, M. *Nature* **433,** 47–50 (2005).
2. Terabe, K., Hasegawa, T., Nakayama, T. & Aono, M. *RIKEN Rev.* **37,** 7–8 (2000).
3. Terabe, K., Hasegawa, T., Nakayama, T. & Aono, M. *Appl. Phys. Lett.* **80,** 4009–4011 (2002).
4. Terabe, K., Hasegawa, T., Nakayama, T. & Aono, M. *J. Appl. Phys.* **91,** 10110–10114 (2002).
5. Agraït, N., Levy Yeyati, A. & van Ruitenbeek, J. M. *Phys. Rep.* **377,** 81–279 (2003).

Cognitive science

Staring fear in the face

Patrik Vuilleumier

The unusual case of SM, a person who has a very specific deficit in recognizing fearful expressions on people's faces, is providing intriguing insights into how we perceive emotion.

Charles Darwin thought that the ability of humans to display and perceive emotional states on a face evolved to convey non-verbal signals rapidly[1]. If an individual's expression could communicate a potential threat, for example, his neighbours would be able to respond quickly and direct their attention to the source of the danger. Thus, a common view is that the perception of fear might guide appropriate visuomotor behaviour[2]. In a striking reversal of this perspective, work by Adolphs *et al.* on page 68 of this issue[3] suggests that discerning fear in faces may depend on how one scrutinizes them in the first place.

The authors describe a patient (SM) who has bilateral brain lesions in the amygdala, a region of the medial temporal lobe known to be critical for the perception of fear[4]. SM cannot recognize fear from facial expressions[5], and Adolphs *et al.* show that this is because she fails to look spontaneously towards the eyes on a face. When shown a face displaying an unmistakable expression of terror, she tends to fixate unworriedly on the nose and mouth regions, neglecting to notice the wide, scared eyes. Thus, she erroneously judges that the face has a neutral expression. By contrast, normal people always look immediately at the eye region of a face, and all the more so when the face is fearful[6].

SM avoids the eyes of all faces, no matter what their expression. But, remarkably, only her perception of fear is impaired — she can recognize other emotions. This suggests that visual cues provided by the eyes are particularly critical for the recognition of fear; other facial emotions can presumably be recognized without looking at the eyes (happiness can be inferred from a smile, for example). SM was also tested on a 'bubble' visual task[7], in which she had to discriminate between fearful and happy faces seen through apertures that revealed only small parts of the image. This allowed the investigators to determine which region of the face she used to distinguish the expressions. Again unlike normal individuals, SM failed to use information from the eye area, but she could still take cues from around the mouth.

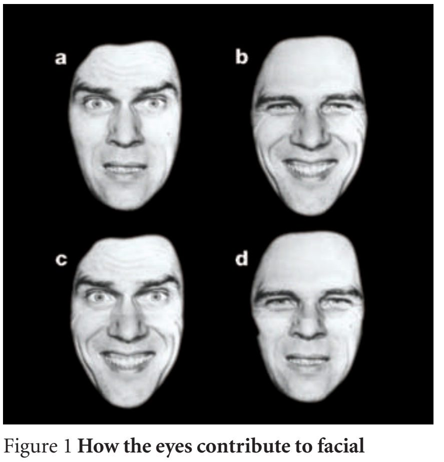

Figure 1 **How the eyes contribute to facial expressions of fear.** a, b, **Examples of fearful** (a) **and happy** (b) **faces from a standard image set[19].** c, d, **Composites using the top and bottom halves from the same faces with fearful eyes but happy mouth** (c) **or happy eyes but fearful mouth** (d)**. As can be seen, the global configuration in composites is affecting the perceived emotion expressed by the face. A study by Adolphs *et al.*[3] sheds new light on how the amygdala in the brain is involved in processing the eyes in such expressions.**

Most surprisingly, simply instructing SM to "look at the eyes" could restore normal recognition of fearful expressions, indicating that she still knows what fear 'looks like' but seems unable to notice scared eyes when she is not prompted to look at them. This 'rescue' was short-lived, however, and SM needed to be reminded continually to look at the eyes. These new results unexpectedly reveal that the damage to the amygdala might impair attention and exploration strategies, rather than causing a perceptual deficit affecting the visual analysis or categorization of specific facial traits.

Much recent research has focused on the role of the human amygdala in fear recognition. Numerous brain-imaging studies confirm that the human amygdala responds more to fearful faces than to faces expressing other emotions, but the exact function of the amygdala during recognition of facial expressions remains a mystery. Initially, the observation that SM's perception of fear is impaired while her recognition of other emotions remains intact[5] was thought to support the idea that different categories of emotion involve distinct neural circuits in the brain[8]. The findings of Adolphs *et al.*[3] now suggest a very different mechanism, perhaps involving a more general role for the amygdala in modulating visual and attentional processing[9]. The amygdala is known to be sensitive to perceived gaze direction, responding most when the eyes in a facial image seem to be looking at the observer[10]. In agreement with Darwin's theory, it makes sense if fear perception is intimately connected with locating the threat that fearful eyes are seeing[11]. The simplicity of such a mechanism might allow for swift responses to danger, even with poor or crude inputs, or during inattention. Indeed, it was recently found that when a normal subject is shown shapes that look like the whites of a pair of eyes, his amygdala responds more to larger shapes (corresponding to wide, fearful eyes) than to small (happy) shapes[12].

However, the amygdala is probably not just an 'eye detector', and perception of fearful expressions is unlikely to rely solely on wide eyes. Previous research[13–15] suggests that processing single 'diagnostic' features in faces is not sufficient to appraise their expression fully, but that more global configural information is important (for example, see the composite faces in Fig. 1). Moreover, the bubble task might induce a bias to use the local details visible through the bubble apertures rather than configural information, which would be more natural[16], particularly in a dichotomous fearful–happy classification task (for instance, SM might simply check for the presence of a smile, and therefore never need to look at the eyes to perform this particular task). The demands of particular tasks also influence whether the subject uses local or global visual features during face processing[17]. Furthermore, brain-imaging data indicate that even though the amygdala might respond to fearful eyes when they are presented alone, it is activated most in response to whole faces[18].

Finally, it remains to be determined whether SM's attention to other facial features is normal (only her response to the eye region was recorded), and to explain why she can still recognize expressions of sadness or anger in which eye information is important (normal subjects find it more difficult to recognize these emotions when the eyes are erased)[3].

The intriguing implications of these new findings need to be explored. What are the neural circuits by which the amygdala might guide eye scan-paths? How does SM judge expressions in composite faces such as those in Figure 1? How does she perform on more implicit tests of fear recognition, or using graded rather than dichotomous measures? Does she orient her eyes normally to emotional visual stimuli other than faces, and to emotional voices? What is the amygdala's normal role in exploring social situations and looking at other people, and are these mechanisms altered in diseases such as phobias or autism that are thought to involve the amygdala? We are just beginning to realize how the brain processes emotionally relevant cues in the environment, and the unusual features of SM will provide much food for future thought. ■

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1. Darwin, C. *The Expression of Emotion in Man and Animals* (Oxford Univ. Press, 1872).
2. Ohman, A. *Psychophysiology* **23,** 123–145 (1986).
3. Adolphs, R. *et al. Nature* **433,** 68–72 (2005).
4. LeDoux, J. E. *Annu. Rev. Neurosci.* **23,** 155–184 (2000).
5. Adolphs, R., Tranel, D., Damasio, H. & Damasio, A. *Nature* **372,** 669–672 (1994).
6. Yarbus, A. L. *Eye Movement and Vision* (Plenum, New York, 1967).
7. Gosselin, F. & Schyns, P. G. *Vision Res.* **41,** 2261–2271 (2001).
8. Calder, A., Lawrence, A. & Young, A. *Nature Rev. Neurosci.* **2,** 352–363 (2001).
9. Vuilleumier, P., Richardson, M., Armony, J., Driver, J. & Dolan, R. J. *Nature Neurosci.* **7,** 1271–1278 (2004).
10. Kawashima, R. *et al. Brain* **122,** 779–783 (1999).
11. Sander, D., Grafman, J. & Zalla, T. *Rev. Neurosci.* **14,** 303–316 (2003).
12. Whalen, P. J. *et al. Science* **306,** 2061 (2004).
13. McKelvie, S. J. *Br. J. Social Psychol.* **34,** 325–334 (1995).
14. Calder, A. J., Young, A. W., Keane, J. & Dean, M. *J. Exp. Psychol. Hum. Percept. Perform.* **26,** 527–551 (2000).
15. Prkachin, G. C. *Br. J. Psychol.* **94,** 45–62 (2003).
16. Murray, R. F. & Gold, J. M. *Vision Res.* **44,** 461–470 (2004).
17. Schyns, P. G. & Oliva, A. *Cognition* **69,** 243–265 (1999).
18. Morris, J. S., deBonis, M. & Dolan, R. J. *Neuroimage* **17,** 214–222 (2002).
19. Ekman, P. & Friesen, W. *Pictures of Facial Affect* (Consulting Psychologists Press, Palo Alto, 1976).

Evolutionary genetics

Differentiation by dispersal

David W. Coltman

Gene flow between populations — caused by migration, for instance — is most often viewed as a homogenizing force in evolution. But two studies of wild birds and non-random dispersal find otherwise.

Whether or not two separate populations of a species become genetically different is thought to depend largely on gene flow. Classical population-genetics theory predicts that populations that frequently exchange individuals through dispersal will remain genetically similar[1]. Disconnected populations, by contrast, have a greater capacity to become distinct through forces such as genetic drift and adaptation to local conditions. In population genetics, dispersal is often viewed as a diffusion-like, random process, and selection and genetic variation are assumed to be locally homogeneous. Populations of organisms with high rates of dispersal — such as songbirds — are therefore expected to be fairly genetically alike at small spatial scales. But two new independent studies of wild great tits, *Parus major*, challenge this assumption: they show that when dispersal is non-random, genetic differentiation can be produced at surprisingly fine spatial scales (see pages 60 and 65 of this issue[2,3]).

Postma and van Noordwijk[3] studied clutch size in great tits (Fig. 1) on the tiny — 4,022-hectare — island of Vlieland in the Netherlands from 1975 to 1995. They first found that birds that bred in the western part of the island laid, on average, 1.15 more eggs than birds from the eastern part. How much of this difference is determined by the environment, and how much is genetically controlled? Fortunately, 10% of the females born on one side of Vlieland disperse to breed on the other, and this allowed genetic and environmental effects to be teased apart. The authors' analysis showed that birds of eastern ancestry produced consistently smaller clutches in either environment — so there is clearly a large genetic component to the difference in clutch size between the regions. In fact, genetic effects accounted for about 40% of this difference. But, given that the western and eastern regions are separated by only a few kilometres, and they exchange migrants and receive immigrants from outside Vlieland, why does this genetic difference persist?

NATURE

100 YEARS AGO

Writing on the subject of "Greek at Oxford," a correspondent of the *Times* again expressed the common belief that "Darwin regretted not having learnt Greek." A letter from Mr. Francis Darwin in the *Times* of December 29, 1904, shows that the statement is altogether opposed to Darwin's views. Darwin says of his education at Shrewsbury School:— "Nothing could have been worse for the development of my mind than Dr. Butler's school, as it was strictly classical, nothing else being taught, except a little ancient geography and history" ("Life and Letters," i., 31). He was, in fact, a victim of that "premature specialisation" which is generally referred to in a somewhat one-sided spirit, and from which the public schoolboy is not yet freed. Mr. Darwin adds:— "If the name of Charles Darwin is to be brought into this controversy it must not be used for compulsory Greek, but against it. In 1867 he wrote to Farrar, 'I am one of the root and branch men, and would leave classics to be learnt by those alone who have sufficient zeal and the high taste requisite for their appreciation' ('More Letters of Charles Darwin,' ii., 441)."

From *Nature* 5 January 1905.

50 YEARS AGO

The expedition organized jointly by the Zoological Society of London and the British Broadcasting Corporation returned to Britain just before Christmas from ten weeks field-work in Sierra Leone, bringing a large collection of animals and a considerable quantity of cinematograph films and sound recordings… One of the main objects of the expedition was to find the nesting habitat of *Picathartes gymnocephala*, a rare passerine bird the systematic position of which is obscure; this bird has seldom been seen alive by Europeans. The habitat was found in difficult hilly bush country, and in spite of the dense shade cast by the forest successful films were made of the birds on and near the nests, of the eggs and of the parents feeding the young by regurgitation. Sound records were also obtained of the voices of the birds in their natural surroundings, and a living specimen was captured and brought to London. Another species never before exhibited in captivity that was successfully sought and found is the brilliantly iridescent emerald starling *Coccycolius iris*.

From *Nature* 8 January 1955.