

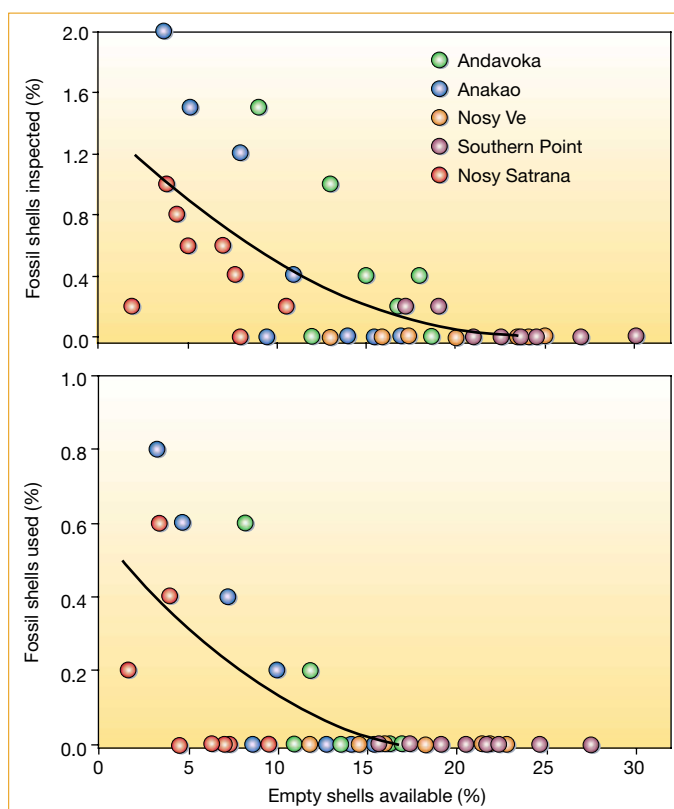
mark also pick them for their anti-desiccation properties<sup>5</sup>. Hermit crabs often suffer from a shortage of shells, however, and so are forced to make do with less suitable shells or even with artificial materials<sup>6</sup>. *Coenobita rugosus* is one species that uses fossil shells as a substitute (Fig. 1) — a much scarcer resource that drops out of limestone rocks as they are eroded.

I found that the number of fossil shells inspected and used by these crabs is proportional to the lack of availability of local shells (referred to as the degree of resource restriction and measured as the proportion of suitable empty shells at three of five sites; Fig. 2). The fossil shells used were from the short-spined, shore-dwelling marine snails *Nassarius*, *Nerita* and *Turbo*. Fossil shells were not used at any locality where suitable empty shells comprised over 13% of all shells; however, when the proportion of these fell below 9%, one or more of 500 crabs examined were found to use fossil shells. One other local hermit-crab species (of seven species investigated), *Calcinus latens*, was seen to use fossil shells (*Nerita*), but only on one occasion. The relationship between the percentage of fossil shells inspected and the restricted availability of non-fossil shells (Fig. 2, top) was similar to that for actual usage of fossil shells and restricted non-fossil-shell availability (Fig. 2, bottom).

Explanations for this behaviour are complex, as the crab is unlikely to appreciate the nature of a shell until it has inspected it. Fossil shells are generally found in close association with the limestone rock of their origin, rather than in locations at which hermit crabs might find many empty shells, such as at the strand line. The relationship between fossil-shell inspection and shell restriction suggests that crabs in shell-restricted areas search for local shells first.

Shelter for hermit crabs could potentially be provided by discarded shells, shells

**Figure 2** Percentage of fossil shells inspected and used by the hermit crab *Coenobita rugosus* as shelter in relation to the availability of empty shells at five different sites in southwestern Madagascar. Each point corresponds to 500 inspections by hermit crabs (top) or to usage by 500 crabs (bottom). Fitted curves are second-order regressions with  $r^2$  values of 0.47 and 0.46, respectively;  $P < 0.01$  (ANOVA) in both cases. Eight counts of 500 gastropod shells were made in each of 5 supralittoral study sites (listed in upper right). Crabs inhabiting fossil shells were identified (as species), as was the fossil (as genus). Percentages of empty mollusc shells, fossil shells and used shells that were mechanically damaged or blocked were all recorded and are not represented in the graphs. Further details are available from the author.



already occupied by another hermit crab or by a living mollusc, and by buried or fossil shells. Of the fossil shells I examined, 93–100% had severe structural hindrances that would block any potential occupant. But the rarity of exploitation by hermit crabs of fossil shells cannot simply be due to the scarcity of usable fossil shells, because otherwise the extent of usage would be three times higher (average frequency of non-fossil shells is 99% of usable shells and average usage is 99.7%; average frequency of fossil shells is 1% of usable shells and average usage is 0.3%). Despite this, fossil shells are probably the third-largest shell supplier of all the potential shell sources as, in common with observations made elsewhere, no shell excavation<sup>6,7</sup> or requisition from living molluscs<sup>3</sup> was seen.

In southwestern Madagascar, as in many parts of the world, particularly East Africa<sup>8</sup>, collecting of shells on the shore is important in artisan fisheries<sup>9</sup>. Living molluscs are generally removed from their shells at the high-tide mark, where piles of shells, which are mostly too large to be of use to hermit crabs, are deposited. However, as shorelines become more intensively exploited, the mean shell size of molluscs collected in this way is getting smaller<sup>8,9</sup>. These piles of discarded shells should therefore eventually help to release hermit crabs from the prevailing shell restriction, and render the use of fossil shells unnecessary.

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## correction

### Early visual experience and face processing

R. Le Grand, C. J. Mondloch, D. Maurer, H. P. Brent *Nature* **410**, 890 (2001)

There is a mistake in Table 1 and its legend, as the result of a coding error. The final two sentences of the legend should read: "For adults, inversion reduced the accuracy of the configural set significantly more than that of the featural set (significant interaction between orientation and stimulus set ( $F_{1,25} = 13.13$ ,  $P < 0.01$ ), followed by analyses of simple effects ( $F_{1,27} = 62.57$ ,  $P < 0.01$ )). Patients were less accurate than controls (matched for age, gender, race and handedness) only for the upright configural set (significant interaction between group, orientation and stimulus set ( $F_{1,26} = 21.92$ ,  $P < 0.01$ ))." Values in the 'featural, upright' column should be 80, 89 and 85 for adults, controls and patients, respectively. This error does not affect our conclusions.



**Figure 1** Houses for hermit crabs: sometimes very old homes are better than newer ones, particularly in situations where non-fossil shells are in short supply.

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## Neuroperception

# Early visual experience and face processing

Adult-like expertise in processing face information takes years to develop<sup>1</sup> and is mediated in part by specialized cortical mechanisms<sup>2</sup> sensitive to the spacing of facial features (configural processing)<sup>3</sup>. Here we show that deprivation of patterned visual input from birth until 2–6 months of age results in permanent deficits in configural face processing. Even after more than nine years' recovery, patients treated for bilateral congenital cataracts were severely impaired at differentiating faces that differed only in the spacing of their features, but were normal in distinguishing those varying only in the shape of individual features. These findings indicate that early visual input is necessary for normal development of the neural architecture that will later specialize for configural processing of faces.

For face recognition, subtle differences in the shape of specific features (featural information) and/or in their spacing (configural information) must be encoded. We created two sets of faces that differentiated configural from featural processing<sup>4</sup> (Fig. 1a, b). We asked 26 normal right-handed adults to view the faces from each set binocularly to decide whether they were the same or different when upright and inverted. Adults were equally accurate in differentiating faces from the two sets in their canonical upright position (Table 1). Inverting the faces decreased adults' accuracy for the configural but not the featural set, consistent with previous findings<sup>4,5</sup>.

We used these stimuli to test face processing in 14 patients (6 male; 13 right-handed; 11 caucasian) born with a dense central cataract in each eye that prevented patterned stimulation from reaching the retina<sup>6</sup>. After removal of the natural lens, an optical correction was fitted to focus visual input (mean duration of deprivation, 118

days from birth; range, 62–187 days); patients had had at least nine years of visual experience after treatment before testing and, when necessary, wore an additional optical correction to focus the eyes at the testing distance.

Compared with age-matched normal subjects, the deprived patients distinguished faces from the featural set normally, but were significantly impaired for the configural set of upright faces (Table 1). Performance was not related to the duration of the deprivation for either set ( $P > 0.10$ ; Fig. 1c). There was no correlation between acuity (range from 20/25 to 20/80 in the better eye; median, 20/40) and patients' accuracy on either set ( $P > 0.10$ ).

Our results indicate that visual experience during the first few months of life is necessary for the normal development of expert face processing. Because normal infants have poor visual acuity<sup>7</sup>, their cortex is exposed only to information of low spatial frequency which, for faces, specifies the global contour and location of features but little of their detail<sup>8</sup>. This early information sets up the neural architecture that will specialize in expert configural processing of faces over the next 10–12 years<sup>9,10</sup>. When visual input is delayed by as little as two months, permanent deficits result.

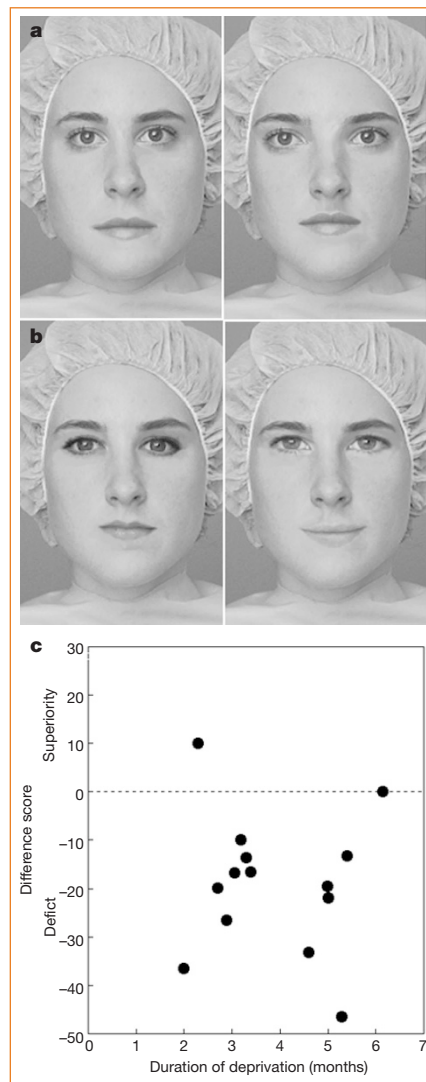
Patients performed normally in a different task requiring the discrimination of geometric patterns based on the location of an internal feature<sup>11</sup>. This suggests that deficits in configural processing may be restricted to the processing of faces, as expected from evidence that normal adults use separate systems for processing face and non-face objects<sup>12,13</sup>.

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**Figure 1** Measurement of configural versus featural processing. Examples of stimuli from **a**, the configural set (created by moving the eyes and mouth), and **b**, the featural set (created by replacing the eyes and mouth). On each trial, one of the five possible faces appeared for 200 ms, and following an interstimulus interval of 300 ms, a second face appeared until the subject used a joystick to signal a 'same' or 'different' judgement. **c**, Patients' performance on the upright configural set plotted as a function of the duration of deprivation from birth. Each circle represents the difference between the accuracy (per cent correct) of one patient and his/her age-matched control.

**Table 1** Detection of facial configural and featural differences

| Group    | N  | Mean age (range) | Configural |          | Featural |          |
|----------|----|------------------|------------|----------|----------|----------|
|          |    |                  | Upright    | Inverted | Upright  | Inverted |
| Adults   | 26 | 19 (18–22)       | 80 (1.9)   | 63 (2.2) | 80 (1.4) | 81 (1.8) |
| Controls | 14 | 14 (9–21)        | 81 (2.7)   | 59 (1.8) | 79 (1.9) | 80 (2.9) |
| Patients | 14 | 14 (9–21)        | 62 (3.2)   | 55 (3.0) | 80 (2.4) | 78 (3.1) |

Mean accuracy (per cent correct) and standard error are shown for detecting configural and featural differences in upright and inverted faces. There were 30 trials for each of the four conditions, which were presented in separate blocks. For adults, inversion decreased accuracy only for the configural set (significant interaction between orientation and stimulus set ( $F_{1,25} = 49.78$ ,  $P < 0.01$ ), followed by analysis of simple effects ( $F_{1,27} = 62.57$ ,  $P < 0.01$ )). Patients were less accurate than controls (matched on age, gender, race and handedness) only for the upright configural set (significant interaction between group, orientation and stimulus set ( $F_{1,26} = 8.99$ ,  $P < 0.01$ ), followed by analysis of simple effects ( $F_{1,26} = 16.26$ ,  $P < 0.01$ )).

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