What can bees *really* tell us about the face processing system in humans?

Cognitive abilities present in humans, such as face processing, are likely to have evolved under various ecological pressures. A comparable and specialized face processing system observed in sheep and non-human primates suggests a possible common origin in evolution (Pascalis et al., 1999; Kendrick et al., 2001; Parr, 2003). However, it is important to determine when this system emerged during evolution if we are to fully understand it. Studies conducted with honeybees (*Apis mellifera*) and wasps (*Polistes fuscatus*) could potentially contribute to our understanding of this ability.

Dyer et al. have demonstrated that bees are able to learn and recognise the picture of a human face when paired with a novel face (Dyer et al., 2005), which is consistent with our existing knowledge of the bees' visual ability. However, we believe that Dyer's extrapolations about how recognition is achieved and whether or not it is facilitated by specialised brain regions are misleading.

Face recognition is carried out by an automated and specific process in humans, which is known as configural processing (perceiving metrical relations between face features). Contrary to Dyer's argument and to earlier research findings (Diamond and Carey, 1977), it is now debatable whether such processing develops late in childhood (Schwarzer et al., 2005). Furthermore, studies that have created 'visual experts' who develop configural processing for non-face objects require many more hours of intensive training than reported by Dyer et al. In their study, there is no clear evidence of configural processing and it is likely that the bees' recognition relied on specific features.

In human adults, functional neuroimaging studies have identified a network of areas within the ventral temporal cortex that are highly responsive to faces (Haxby et al., 2000), with maximum selectivity in the right middle fusiform gyrus: the so-called 'fusiform face area' (FFA) (Kanwisher et al., 1997). A comparable functional specialization supports face processing in the primate brain (Tsao et al., 2006). Critically, however, normal face identification relies on the integrity of this complex network, as prosopagnosic patients with lesions sparing the FFA show impaired use of optimal information for face identification (Caldara et al., 2005; Schiltz et al., 2006).

With data collected from just five bees, it is too speculative to conclude that specialised brain regions are not necessary for face processing in humans. Humans and bees have not shared a common ancestor for roughly 600 million years and have evolved very differently since this separation. We can therefore expect them to process faces differently. Clearly, more studies are required to determine *how* the honeybee succeeds in simple face matching tasks before attempting to establish potential similarities between its visual recognition abilities and those of different species. It is first necessary to establish whether bees are able to recognise or categorise conspecifics in a similar way to the wasp (Tibbetts, 2002; Tibbetts and Dale, 2004). Given that humans appear capable of only processing faces confined to human and non-human primate categories, it would be somewhat paradoxical if the bee demonstrated recognition with human faces but not with conspecifics. Finally, artificial computing systems without a neural substrate also demonstrate an optimal ability to recognize individual faces. Does such evidence question the neural specificity of face processing in humans?

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Response to 'What can bees *really* tell us about the face processing system in humans?'

Whilst humans have a large brain with regional specialization for solving complex tasks (Kandel et al., 2000), in certain cases the miniature brain of invertebrates performs analogous tasks. For example, bees are capable of using top-down visual processing (Zhang and Srinivasan, 1994), can balance conflicting speed accuracy demands in task allocation (Chittka et al., 2003), learn principles of symbolic matching (Giurfa et al., 2001), solve complex maze-type problems and demonstrate context-dependent learning (Zhang and Srinivasan, 2004) and can use a symbolic coding system to communicate with conspecifics (von Frisch, 1967).

Studies of the capabilities of bees question the extent to which large specialized brains are required to solve sophisticated cognitive tasks (Zhang and Srinivasan, 2004). What we can learn from the miniature brain is the extent to which higher functions can be achieved without the complexity (and associated cost) of a large mammalian brain. For bees, it is reasonably straightforward to control the ontogenetic history of individuals, and if the bee's brain can reveal novel solutions for face processing this will potentially lead to algorithms for artificial intelligence.

Our recent study (Dyer et al., 2005) does not exclude the possibility that humans have regional specialization that allows for fast processing of a relatively large number of faces (p. 4713). However, the finding that bees can recognize stimuli representing human faces does question the extent to which regional specialization is actually *necessary* for a brain to perform particular tasks; especially for reasonably straightforward face recognition tasks (although even in humans very few subjects score perfectly on Warrington face tests) (Warrington, 1996). It is clear from our study that some level of face recognition is possible from a miniature brain with absolutely no evolutionary history for this task.

It is unlikely that bees will be able to recognize conspecifics using facial cues, not because of a lack of cognitive ability but because individual bees probably have insufficient facial markings to enable a visual identification. An important factor in the impressive conspecific face recognition capabilities of paper wasps is that different individuals have specific face marks (Tibbetts, 2002), which bees do not have. Even humans are typically poor at recognizing face stimuli when the stimuli class appears too similar; for example, recognizing individuals from a different race category (Valentine and Endo, 1992). Thus, it would not really be surprising if bees cannot recognize conspecifics, even though it is clear that highly trained individual bees are capable of recognizing human faces.

The study by Schwarzer et al. (Schwarzer et al., 2005) does show some evidence that children use configural processing less than adults (p. 352) and so does not fully discount the idea that the visual system develops configural strategies with experience. In agreement with previous work that demonstrates that humans use feature extraction and configural processing for face recognition (Collishaw and Hole, 2000), the study by Schwarzer et al. presents evidence that humans use both feature extraction and/or configural strategies (Schwarzer et al., 2005). The interesting point from recent insect vision studies is that bees also appear to use feature extraction and configural processing depending upon level of experience with stimuli (Giurfa et al., 2003), and thus bees serve as a good model to understand how processes might operate in a miniature brain. As visual strategies used by bees can potentially be wholly transferred to artificial intelligence applications (Srinivasan et al., 1997), this is an exciting model from which we might learn a great deal.

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