Bees Never Forget a Face

Honeybees can be trained to recognise stimuli representing human faces. Adrian Dyer explains this seemingly difficult visual task and its implications.

Who was that? The ability to distinguish our friends, family and colleagues from total strangers is important for both social and security reasons. But how does a visual system and brain manage to perform this task, and how might it be possible to generate new computer algorithms to reliably recognise faces in situations such as airport security checks?

What might be the minimum processing requirements of a brain to solve such a task? Is recognising human faces a special ability of humans, or might other animals also be able to complete this visual task?

The human brain is very large (containing about 10^{11} neurons), and interpreting how information is processed in such a system can be difficult. For example, functional magnetic resonance imaging can reveal increased blood flow in the different regions of the brain when a subject looks at visual stimuli. This technique has revealed that a particular region of the brain, the fusiform face area (FFA), is active when normal subjects view faces but not when control images such as houses or animals are viewed.

Together with evidence that humans show a disproportionate impairment in recognising faces when rotated by 180°, the data from the FFA imaging studies indicate that we have specialised mechanisms within the brain to facilitate facial recognition.

However, other experiments show that the FFA may be a region of the brain dedicated to expertise in pattern matching: experts (e.g. those trained in bird or car identification) also show increased activity in the FFA when viewing stimuli from their particular class of expertise. So perhaps we are all experts at facial recognition because we happen to see faces every day, and this is why the FFA shows increased activity when normal subjects view faces.

One way to understand the importance of species-specific facial processing is to present faces to other animals to see if they can perform the task. A team of researchers in Cambridge, UK, found that sheep were very good at recognising both sheep and human faces. In addition, paper wasps (*Polistes fuscatus*) can recognise specific facial markings on other wasps within a hive.

Bees have relatively small brains (less than one million neurons), but are able to perform some cognitive tasks that might be considered to be the domain of much larger brains, and can use their

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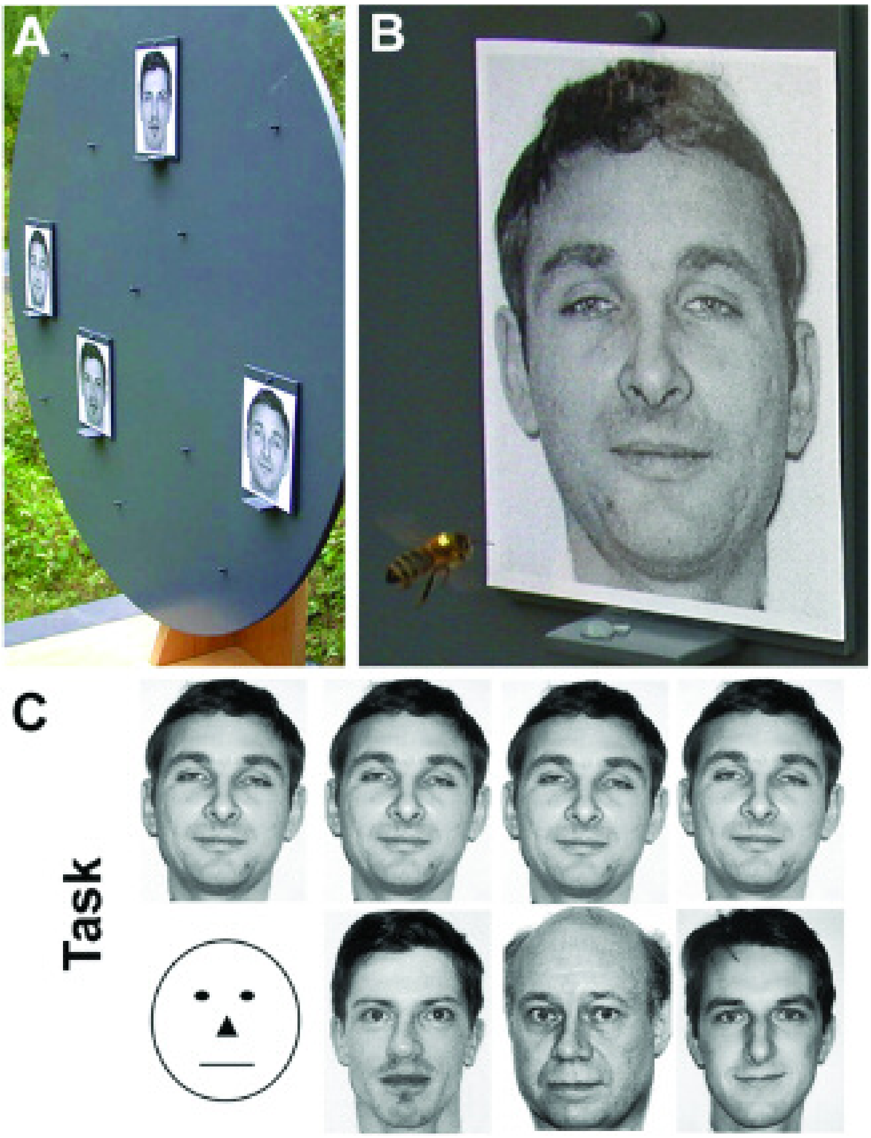

Figure 1. (a) The flight arena used to test the ability of bees to recognise human faces. The large screen could be rotated to change the positions of photos so that bees could not learn to visit the correct stimuli via positional cues alone. (b) A honeybee looking at a target face during learning. (c) The range of faces with which bees were first trained and then tested. The top row shows the target face and the bottom row the distractor faces with which the bees were tested. In the initial training, bees learnt a simple task of discriminating a face from a cartoon (first column). Bees then slowly learnt to discriminate the target face from a very similar distractor face (second column). Finally, bees successfully recognised the already learnt target face from previously unseen distractor faces (columns 3 and 4).

skills to find highly patterned flowers. Therefore, it was important to know whether bees might also be able to learn how to recognise human faces in order to determine the minimum cognitive processing required for this task.

Teaching a bee how to solve such a task is a bit like trying to show a friend how to solve a problem without talking or making hand gestures: it requires time and patience. First, the bee was taught to visit a specially constructed test arena (Fig. 1a) and to land on a small platform in return for sucrose solution. Attached to each platform was a vertically mounted black and white picture of a face (Fig. 1b), which the bee needed to recognise. Another platform also contained a small, clear droplet of solution of quinine, which is bitter and distasteful to a bee. The bee must learn to avoid the stimulus presented on this platform.

At first the task was made very simple: discriminate the human face from a simple cartoon face (Fig. 1c). The bee quickly mastered this task and was ready to start leaning how to discriminate between stimuli representing human faces.

This is not such an easy task, so the bee must learn to fly in front of each face and look carefully at the different features (Fig. 1b). This learning is termed "differential conditioning": the bee learns a target stimulus in relation to its differences to a similar distractor stimulus. The learning is not straightforward, and the task takes more than 50 landings, including many drinks of the distasteful quinine, for the bee to learn reliably.

The stimuli was continually moved to new positions so that the bees didn't simply learn which position was the correct one to fly to.

Once a bee had learned to recognise the target face with greater than 80% accuracy, it was tested with all rewards removed to exclude any possible influence from olfactory (smell) or positional cues.

When this procedure was repeated for a number of bees, a highly significant preference was found for platforms associated with the target face. This is facial discrimination: bees could tell the difference between the learnt faces.

However, true recognition is an even tougher task. To test if bees could now recognise the learnt face from previously unseen faces, each bee was then given a non-rewarded test with the original target face and some new distractor faces. All the stimuli were from a standard neuroscience test for human facial recognition (Fig. 1c) and represented a reasonable degree of difficulty, even for human subjects. Again, bees showed a strong preference for landing on the platforms associated with the target stimuli, showing that bees can both discriminate between and recognise the different human faces.

The fact that bees have less than one million neurons but are able to learn a seemingly difficult visual task of recognising faces may be important for our understanding of the brain function necessary to recognise a face. For example, children who have abnormal brain circuitry and later develop autism often have deficits in recognising faces, and the FFA is not active when these subjects look at faces.

However, recent work suggests that if children who are detected with early signs of autism are given extensive training for faces, then there is an increased rate of the children having a normal category of behaviour by school age. In some cases, face recognition in subjects with autism can be reliably facilitated by regions of the brain other than the FFA.

The evidence from bees that a brain with absolutely no innate interest in faces can learn to do the task is highly suggestive that:

- regions of the brain in humans other than the FFA should be able to do the task; and
- other animals with brains larger than bees might also be able to reliably discriminate between and recognise human faces.

The fact that a miniature brain can solve this type of task has raised the prospect of modelling how a biological system can solve it and the possibility of clues for developing new algorithms for computers to recognise faces. For example, modelling of a bee's use of optic flow (the movement of images on a bee's retina) to gauge distance and flight velocity as it flies has contributed to the development of self-autonomous model aircraft at The Australian National University. In 2001, Prof Mandyam Srinivasan, Dr Shaowu Zhang and Dr Javaan Chahl of the Australian National University were awarded the *Australasian Science* Prize for extending knowledge of the behaviour and intelligence of bees to artificial intelligence.

Two ways in which faces might be recognised by biological systems are by a configural (holistic) recognition strategy or a piecemeal (feature extraction) visual strategy. In a configural strategy, all components are processed as a whole; piecemeal recognition is facilitated by the use of particular salient features.

Understanding which of the strategies bees use when first learning and consequently recognising faces may provide clues to how relatively simple and reliable algorithms for computer recognition might be found, because the bees are able to achieve this impressive task without the benefit of the large mammalian brain.

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