The Final Frontier of Honeybee Cognition: Can Bees Learn Art ?

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Introduction

Given the small size of their brain, honeybees have astonishing cognitive capacities, comparable in many respects to vertebrates [1,2]. Much of this is based on their remarkable visual learning and discrimination abilities that extend beyond learning simple colours, shapes or patterns.

Indeed, honeybees can discriminate landscape scenes, types of flowers, and even human faces, suggesting that they have a highly developed capacity for processing complex visual information. Here, we investigated whether this capacity extends to complex images that humans distinguish on the basis or artistic style: Impressionist paintings by Monet and Cubist paintings by Picasso.

Fig. 2 Above: five pairs of Monet and Picasso paintings used for training bees to discriminate between the two painting styles. **Below:** four pairs of Monet and Picasso paintings used to test bees for generalization to novel pairs. All pairs matched for colour and luminance.

Methods

Assay: Using a simple choice assay, we trained free-flying honeybees into a tunnel, at the end of which they encountered photographic prints (7 x 9.5 cm) of a Monet and a Picasso painting **(Fig. 1)**. Underneath the paintings were holes through which the bees could enter into chambers behind the paintings, one of which contained a feeder with sugar.

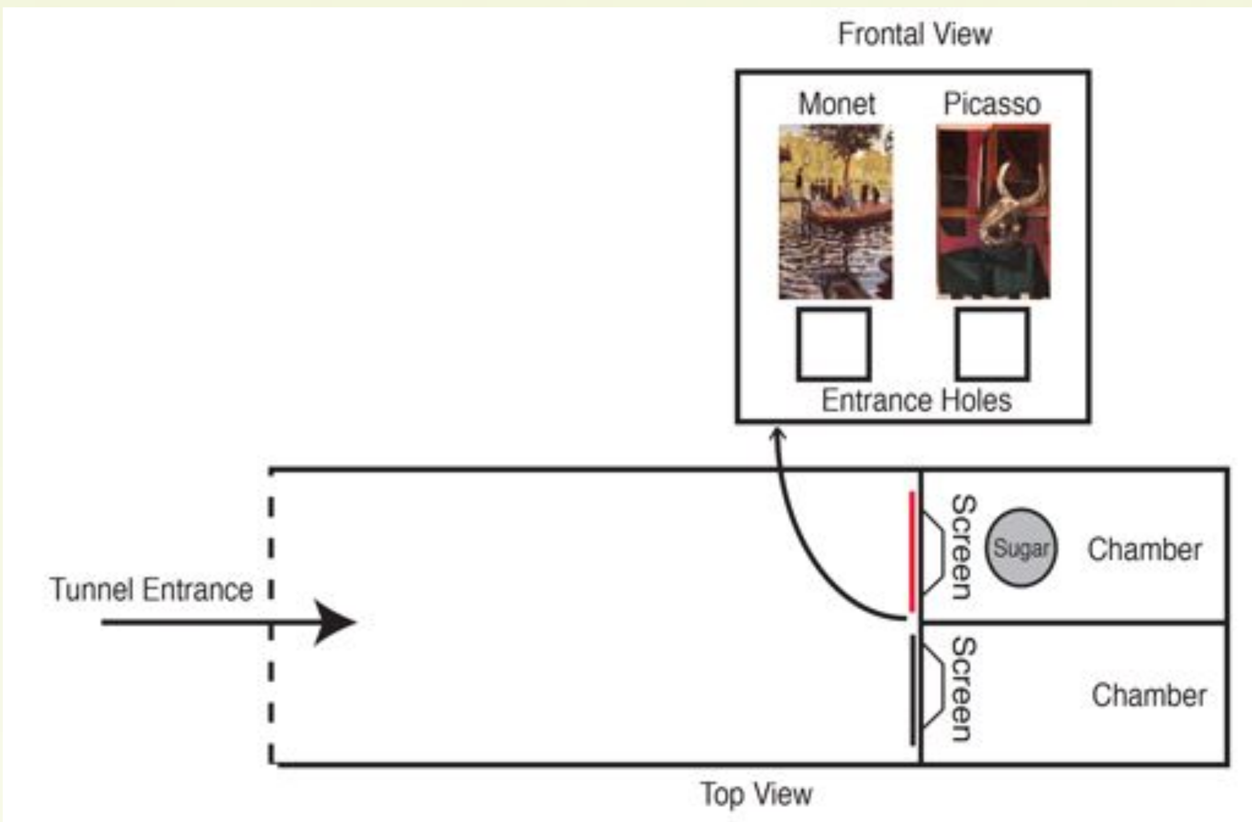

Fig. 1 Set-up of choice assay investigating honeybee discrimination of Monet and Picasso paintings. Bees entered the tunnel one at a time controlled by a mesh at the entrance. The photos of the paintings were fixed 5 cm apart on a vertical wall 100 cm from the entrance. Bees could enter the chambers behind the paintings through small holes underneath the paintings, to retrieve a sugar reward. A paper screen prevented the bees from seeing the sugar feeder in the chamber before making a choice.

Training: For each experiment, two groups of 25 individually marked bees were trained separately to discriminate between pairs of Monet and Picasso paintings. One group was trained to Monet rewarded, the other to Picasso rewarded. Training was conducted in blocks of 20 min with the rewarded image presented on the right and then on the left side for 10 min each. Painting pairs were presented in multiple blocks over several days, with bees first trained to a single painting pair, then to five paintings pairs in a row **(Fig. 2 above)**, and then presented with novel unrewarded paintings **(Fig. 2 below)** interspersed by training blocks with familiar paintings.

Analysis: Only the first choices of each bee with the rewarded image presented on the left and the right side per block were used for analysis. Results for all bees of a group were pooled for a block, and the mean percentage of correct choices for each block (or set of blocks) analyzed using ANOVA and Fisher post-hoc tests.

Results

Honeybees learnt to discriminate between a Monet and Picasso painting **(Fig. 3a)**, and were able to discriminate at least five painting pairs at the same time **(Fig. 3b)**. They easily transferred their discrimination ability to grey scale **(Fig. 3d left)**, demonstrating that colour was not used for discrimination. To some extent, honeybees could generalize knowledge about the visual structure that differentiates Monet from Picasso paintings to new images they had never encountered before **(Fig. 3c)**, in particular when the novel paintings were presented in grey scale **(Fig. 3d right)**. This suggests that honeybees are able to discriminate art by extracting the characteristic visual information inherent in a painting style [3].

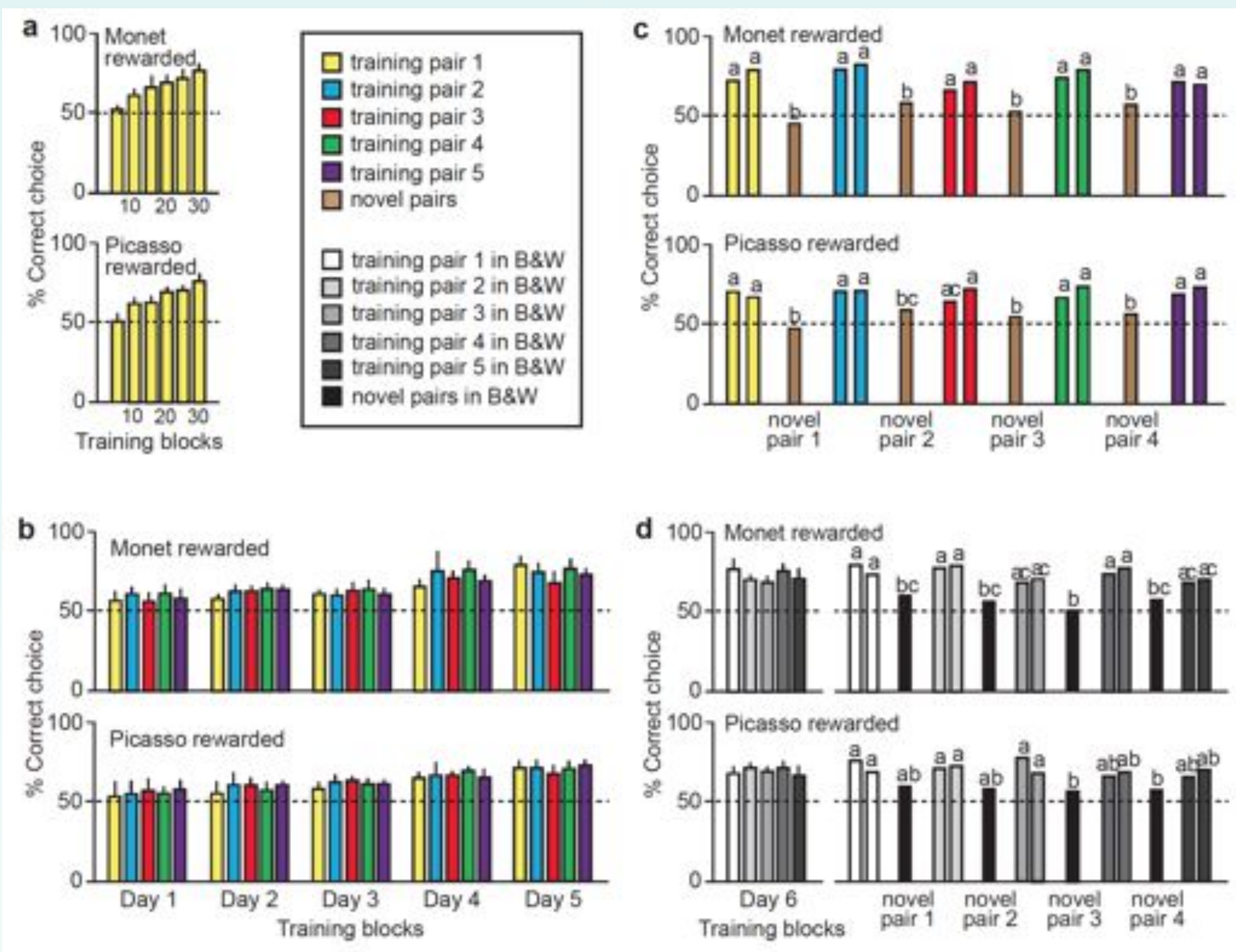

Fig. 3 (a) Percentage of correct first choices for Monet-Picasso pair 1 after training for 30 blocks over 3 days. Each bar represents the mean $\pm$ SD of 5 training blocks. **(b)** Percentage of correct first choices for five Monet-Picasso training pairs. Each bar represents the mean $\pm$ SD of 5 training blocks. **(c)** Percentage of correct first choices for unrewarded novel pairs of Monet-Picasso paintings interspersed by training blocks. Each bar represents one block. **(d) Left:** percentage of correct first choices for the five Monet-Picasso training pairs in greyscale. Each bar rpresents the mean $\pm$ SD of 5 blocks. **Right:** percentage of correct first choices for unrewarded greyscale versions of the novel Monet-Picasso paintings interspersed by training blocks. Each bar represents one block. Different letters above bars in (c) and (d) represent statistically significant difference at $p<0.05$.

Which visual cues do bees use for painting discrimination? Bees do not rely on luminance or colour for discriminating paintings. Neither could they use orientational information potentially contained in shape configurations, lines and edges for discrimination of style: due to the complexity and uniqueness of each painting there was no distinct orientational information inherent in all Picasso paintings compared to all Monet paintings [3]. Similarly, 2-D Fast Fourier transforms (FFT) of the paintings revealed an equivalent distribution of spatial frequency information in the two painting groups **(Fig. 4)**. We propose that **bees use the underlying visual regularities that are consistent across all paintings by the same artist**, which can be revealed by singular value decomposition capturing the most salient structural regularities inherent in a painting style **(Fig. 5)**.

Fig. 4 FFT of Monet and Picasso paintings averaged across all paintings, revealing similar spatial frequency distributions.

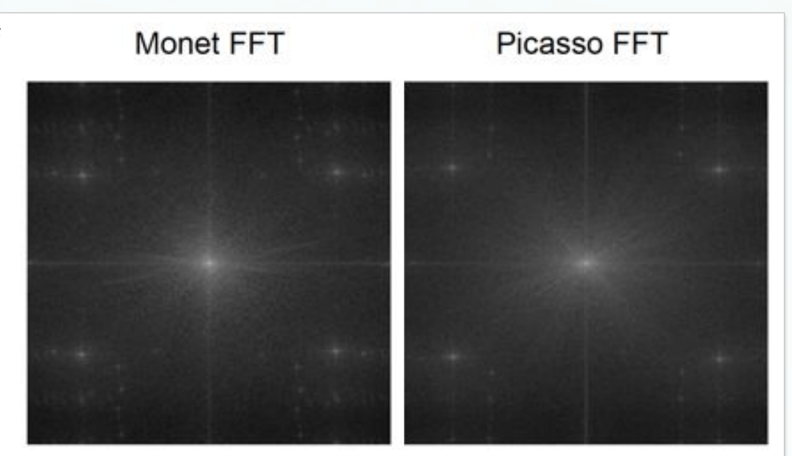

Fig. 5 Pair of Monet and Picasso paintings and reconstructed Monet and Picasso paintings using underlying visual regularities. Dimension reduction and reconstruction was achieved using singular value decomposition (SVD). Reconstructed images reflect the 10 primary dimensions that most strongly differentiate Monet from Picasso across a set of 160 paintings from each artist. Modified from [3].

Conclusions

Our study suggests that honeybees discriminate Monet and Picasso paintings by extracting and learning the characteristic visual information inherent in each painting style.

Our study also suggests that discrimination of artistic styles is not a higher cognitive function unique to humans, but simply due to the capacity of animals to extract and categorize the underlying visual characteristics, such as structural regularities, of complex images.

References

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