"Birdbrain" you say? Why thank you!

For many years, it was believed that birds – and pigeons in particular – were not capable of any intelligent acts. However, Professor Michael Colombo, from the University of Otago, New Zealand is keen to change these views. It turns out pigeons can learn to count and recognise words just as well as monkeys. Despite not having a cortex – a part of the brain associated with intelligence in primates – birds can learn and master complicated new skills.

When you think about all the intelligent animals in the world, birds are probably not top of the list. These feathery creatures are not known for their intellectual ability and thinking skills. In fact, calling somebody a 'birdbrain' or a 'featherbrain' is seen as an insult. This is the view held not only by the general public but by most scientists as well.

In the 1960s, there were some attempts to go against the grain and show that birds are just as capable as monkeys, but any achievements – no matter how impressive – were simply dismissed as mere party tricks. It was as if birds could only show these behaviours because they were trained to repeat them, whereas, for primates, these behaviours were part of their natural abilities.

In the 1980s and 1990s, this perception started to change slightly. It all started with scrub jays, a colourful and bright member of the corvid family. These small birds can remember past events, including when, where and what happened, can take into account the perspective of others, and have the ability to plan for the future.

After these studies, the idea that all birds are dumb was overturned, and parrots and crows were elevated to 'feathered apes'. The rest of the bird world, however, including the lowly pigeon, continued to be considered brainless and mindless creatures incapable of original thought.

Despite not having a cortex (a part of the brain associated with intelligence in primates) birds can still learn and master skills including counting and reading.

Finally, in the 1990s, it all changed for pigeons. Fascinating experiments showed that researchers had far underestimated their mental abilities. Like the one from Shigeru Watanabe's lab in Keio University in Tokyo, where pigeons were trained as 'art critics' and learnt to distinguish between Picasso's and Monet's paintings.

Keen to understand how the pigeon brain works, Professor Michael Colombo and his team from the University of Otago, New Zealand have been training these birds to overcome some tough and gruelling challenges. The big question is, how will these birds fare in such challenges when compared to monkeys?

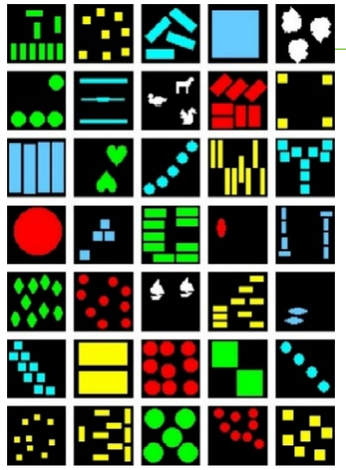
CAN BIRDS LEARN TO COUNT AND READ?

The first challenge was learning to count. Humans are privileged to have advanced numerical abilities, but it's believed these skills are built on an approximate number system which is certainly not exclusive to us.

It should not come as a surprise that monkeys can understand this concept. For example, Elisabeth Brannon and Herb Terrace, from Columbia University, New York, taught their monkeys to order images from one to four items. The monkeys had to first touch the picture with one item, then two items, then three items, and finally, four items. Not only did the monkeys learn to play the game very quickly with up to four items, but they also manage to extrapolate the concept to learn by themselves to count from five to nine.

To test the pigeons' math skills, Professor Colombo and his colleagues trained their birds in a similar manner, with the only difference that pigeons started with quantities one to three and then were later introduced to numbers four to nine. Maybe surprising for some, but pigeons performed just as well as monkeys. "At least with respect to numerical competence, pigeons are on par with primates and are well perched to inform us about the selection pressures and neural structures required for abstract numerical cognition", said the researchers.

Dr Damian Scarf



Type of stimuli used to test the pigeons' numerical abilities.

William van der Vliet

A pigeon playing a numerical game.

The second challenge, reading, was a slightly more complex task. Children learning to read, for example, need to be able to associate a letter with a particular sound, as well as the ability to visually recognise words. Researchers know that associating a letter with a sound is clearly unique to humans, but recent studies suggest that identifying words may just be an extension of the ability to recognise everyday objects. Once again, this skill is not unique to humans.

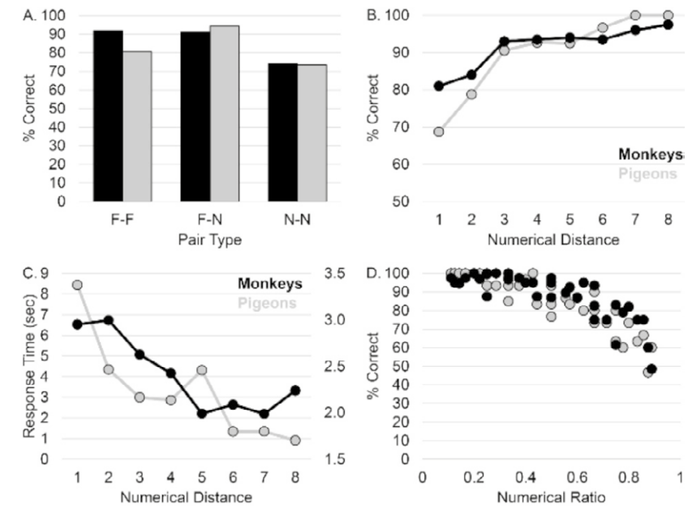
For example, Jonathan Grainger and colleagues, from Aix-Marseille University in France, trained their baboons to recognise that words like TEST are different from nonwords like LTAQ. By adding a new word every time they had learnt the previous, the monkeys' vocabulary slowly increased. Several months later, they had learned over 300 words against a backdrop of 8,000 nonwords. Over time, the monkeys reached a point where they could identify words that they had never seen before, indicating that somehow they could tell the difference between words and nonwords.

The fact that pigeons' performance was indistinguishable from that of the baboons strongly suggests that the ability to process orthographic information is not limited to the primate brain.

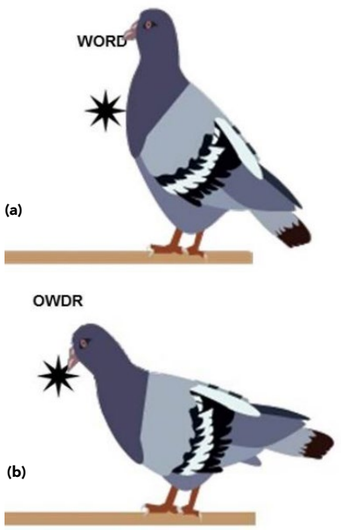
Again, Colombo and his team showed that pigeons could perform just like baboons when it came to recognising words. And just as before, not only had pigeons learnt the difference between words and nonwords, they could also apply that knowledge to words they never saw before. It seemed like they actually developed a sense for what a word should look like.

"The fact that pigeons' performance was indistinguishable from that of the baboons strongly suggests that the ability to process orthographic information is not limited to the primate brain", said Professor Colombo. "Specifically, we demonstrated that pigeons trained to discriminate words from nonwords picked up on the orthographic properties that define words and used this knowledge to identify words they had never seen before".

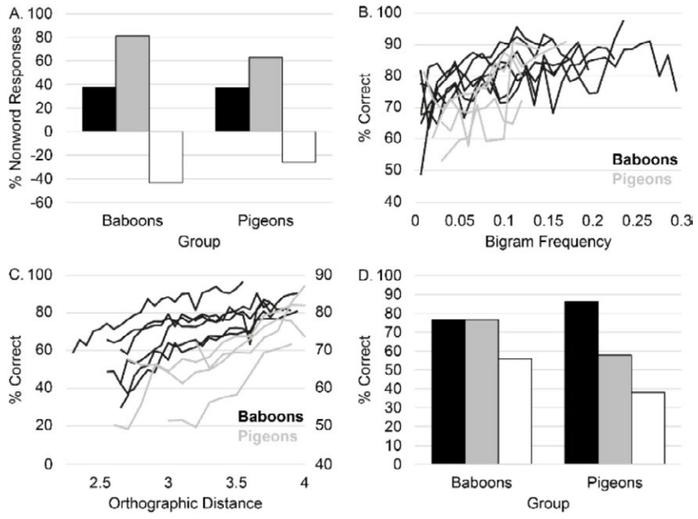
Colombo and his colleagues believe there simply is no cognitive ability that a monkey can display that a pigeon can't also display. Choosing one species as more intelligent than the other is obviously wrong, they say. When factors that may impact the results - like vision for monkeys and olfaction for rats - are properly accounted for, the performance between species becomes indistinguishable.



(A) Performance on the test pairs. (B) Accuracy as a function of distance. (C) Response latency as a function of distance. (D) Accuracy as a function of ratio. From: Scarf, Hayne & Colombo. *Science*, doi: 10.1126/science.1213357



Procedure of the orthographic study. If a bird saw a word it had to peck the word, whereas if it saw a nonword it had to peck the star.



Performance of baboons and pigeons on the orthographic task. (A) Test performance. (B) Performance as a function of bigram frequency. (C) Performance on nonwords as a function of their orthographic distance to words. (D) Performance on the transposed word test. Note in all cases the data for the pigeons mirrors that of the baboons. From: Scarf & Colombo (2020). *Front Psychol*, doi:10.3389/fpsyg.2019.03017

Like psychologist Euan Macphail, from the University of York, UK defended back in the 1980s, Colombo believes that there are no qualitative differences in intelligence between vertebrate species. This idea met with some resistance at first, which is not surprising. We look at monkeys, and we can identify the similarities between us, but it's harder to look at a pigeon – a winged rat for many – and recognise an intelligent and creative animal. Slowly, however, we are starting to see that intelligence comes in all shapes and forms.

THE AMAZING ARCHITECTURE OF THE AVIAN BRAIN

After these challenges, we know that birds are not dumb at all, but it's interesting to go back and understand how that idea started. It turns out that birds lack a part of the brain called cortex, which is often associated with our own remarkable intellectual abilities. In those early experiments, no cortex meant no capacity for higher thinking.

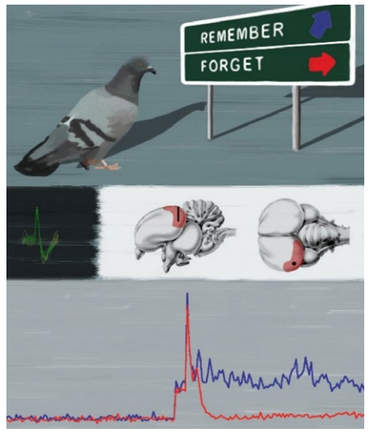
As it happens, birds can achieve all their remarkable abilities even without a cortex. Rather than being arranged in layers like in the mammalian brain, nerve cells in birds are arranged in clusters, also known as nuclei. What is even more interesting is that, due to this nuclear architecture, bird brains can pack more neurons than a primate brain of the same size. Songbirds and parrots, for example, contain twice as many neurons in their brain as the brain of similarly sized primate. "Even the 'birdbrained' pigeon, because of its nuclear architecture, has the same number of neurons as a primate of similar size. It may actually be the case that the avian brain, because of its nuclear architecture, packs more firepower than a primate brain!" said Professor Colombo.

Fascinated by the pigeon brain, the team are now exploring the birds' remarkable nuclear architecture further to understand how it supports such exceptional skills. "Who knows... perhaps modern-day software that is based on the primate layered architecture should instead be based on the avian cluster architecture", concludes Professor Colombo.

It may actually be the case that the avian brain, because of its nuclear architecture, packs more firepower than a primate brain!

Dr Damian Scarf

A pigeon playing the orthographic game.



Dr Jonas Rose

Colombo and colleagues also conduct neural studies on the avian brain. The study depicted on the right showed that, like for monkeys, there are neurons in the pigeon's brain that code for what the animal is remembering: when the bird is told to remember they turn on (blue), and when they are told to forget they turn off (red). From: Rose & Colombo (2005) *PloS Biology*, doi: 10.1371/journal.pbio.0030190

Behind the Research

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Research Objectives

Michael Colombo's main research interests are the neural basis of learning and memory and exploring the cognitive abilities of animals.

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Bio
Professor Colombo received his undergraduate degree in molecular biology and psychology from the University of Colorado, and his PhD from Rutgers University with a research emphasis on comparative animal cognition and neuroscience. Following his PhD, he was awarded an NIH Postdoctoral Fellowship to study the neural mechanisms of visual processing and memory in monkeys at Princeton University. He joined the Department of Psychology at the University of Otago in 1992.

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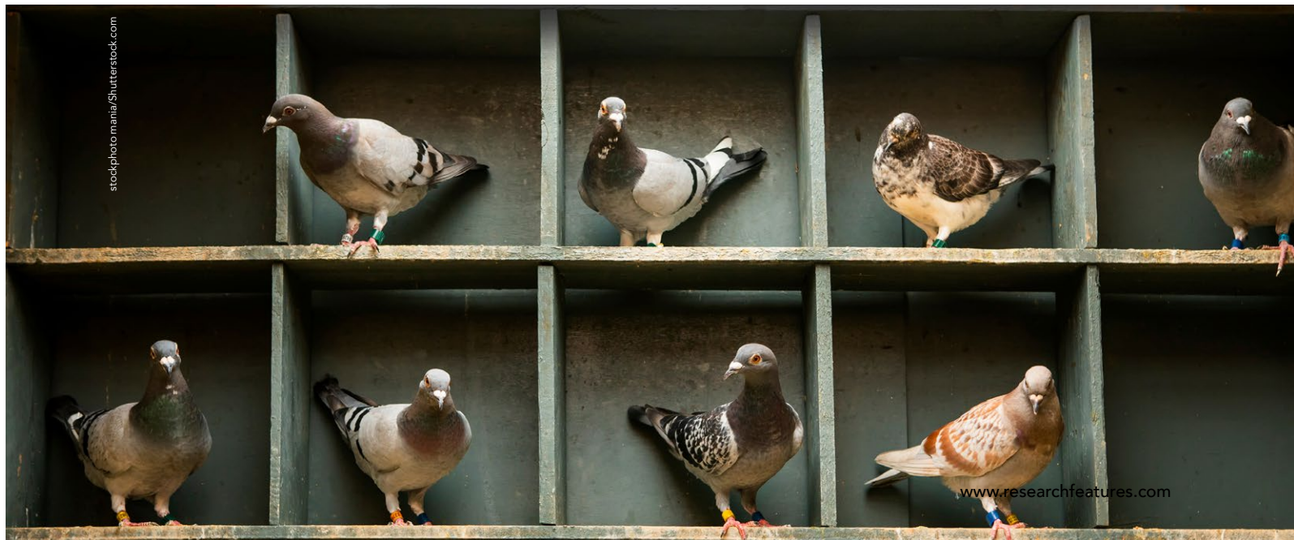
Personal Response

What is the next challenge for the pigeons?

"By understanding how the avian brain can support the remarkable abilities of birds, indeed abilities that are no different than that of nonhuman primates, we can begin to unravel whether there is anything special about the human brain. Along these lines we continue to push the limits of what pigeons can accomplish, and are currently training birds to play the classic 'memory game' in which you try to match two similar cards by turning over two cards at a time. Additionally, we are training pigeons to play tic-tac-toe. Given enough time, I think I could even train a pigeon to solve Rubik's Cube!"



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