We talk to our dogs. Do they understand the words we use?

Scrolling back through my Instagram posts recently, I came across a short video I took last summer. I'm throwing a ball into a lake for my parent's yellow lab, Johnson, to fetch. Johnson is pretty excited about the whole affair – perhaps in part because after the successful retrieval you can hear my dad, sitting on the dock offscreen, praising his effort: "Good boy! *GOOD BOY!!!*"

This is a scene that probably sounds familiar to many dog owners. We talk to our dogs not only to praise them, but to ask them to perform actions, to identify objects, and sometimes to scold them. And for the most part, they seem to possess some level of understanding. Dogs are motivated by praise, and find this type of social reinforcement equally or more rewarding than food. Your dog may be able to react to many commands, and they may know some of their favorite toys by name. If you ask Johnson, 'Where is your ball?" he will search for it without fail. And Johnson's ability to retrieve his favorite toy is nothing in comparison to what has been reported in some other dogs, like a border collie named Rico that knows the names of over 200 items, or a dog named Sofia that can respond to combinations of two words to perform actions paired with specific objects.

But how dogs process human language was still unknown. To find out more, two research groups used a functional magnetic resonance imaging scanner (fMRI) to see which parts of dogs' brains are active when we talk to them. They are looking for evidence that will tell us if dogs understand what words are, what words mean, and whether the areas of their brains that they use to process this information are similar to the areas we use.

The first step toward asking these questions was training the dogs to lie still in the MRI scanner without restraint – something that even people struggle with. If you have ever had an MRI you can see why. The process is loud, claustrophobic, and long – and while the scanner is analyzing the brain even slight movement can ruin the data. The dogs in these studies learn to tolerate all of these challenges one by one, until they are ready for the real thing. Even this first step is a big breakthrough – most MRI studies in animals require that they are sedated or restrained, which adds a level of stress that can make interpreting data from these studies difficult.

A research group based in Budapest used this training technique to do a study where they talked to 13 dogs while they were in the MRI scanner, unrestrained and happy. The Researchers played these dogs a recording of a trainer praising them or saying neutral words, and then repeating each type of word either in a praising tone or a neutral tone. The results – published in *Science* in 2016 – were astounding.

The researchers reported that dogs process words and their tone independently and on different sides, or hemispheres, of the brain. Moreover, they found that emotional cues like tone were processed on the right side of the brain, while words were processed on the left side – just like in humans. Because the left side of the dog's brains responded to praise words even when said in a neutral tone, the researchers concluded that dogs possess some ability to understand the meaning of words. But in order for the dog to find praise rewarding, the word meaning and tone needed to match – only praising words said in a praising tone activated reward areas in the dog's brains.

This was *huge news* in the field of language processing, especially because it was previously thought that only humans showed a left hemisphere bias for speech processing. It was also big news to the world of dog lovers – the ensuing media explosion was full of articles claiming that science has proved that your dog *really understands* what you are saying.

But an erratum published six months after the paper reveals that the researchers mixed up the sides of the brain in their scans. So instead of dogs showing a human-like left hemisphere bias for language processing, they actually show a bias toward processing language on the *opposite* of their brains. Which could actually mean that dogs don't process language like humans do at all.

In fact, a research group in Atlanta that also studies brain activity in dogs posted a manuscript to a preprint server last summer that supports the idea that dogs process language much differently than we do. Their study investigates lexical processing, the ability to tell words from pseudowords, which are arrangements of syllables that resemble words but have no meaning. In humans, activation of speech processing areas is typically higher when hearing a real word than when hearing a pseudoword.

But in dogs, the region of their brains that was active when they heard a word they knew was actually *more active* when they heard a pseudoword. Dogs, then, may then be more biased toward processing novel sounds, and this might explain why our friend Rico the border collie was so good at learning the new object in a group of familiar ones. The original study concluded that it was because he was able to infer the name of the new objects by excluding the familiar objects, a process called fast mapping, but an alternate hypothesis is that he was driven by an inherent preference for novelty.

The researchers also found that the regions of the dog's brains active during the task were more closely associated with actions than typical language processing regions in humans. This means that while dogs do seem to show some level of lexical processing, it is in a way that may be fundamentally different than in humans. Instead of a symbolic representation of a word like we have, dogs may associate words more strongly with actions.

One takeaway from these studies is that we still have a lot to learn about language processing. But one caveat to consider: it can be hard to decipher exactly what fMRI data is telling us. What fMRI actually measures is *blood flow*. When fMRI tells us that blood flow to an area of the brain is increased, we interpret that as an increase in neuronal activation in the region. But it doesn't give us information about the type of neurons that are active, their underlying computational properties, or how they connect to and interact with other brain areas. And while in humans this can be paired with linguistic studies to get a more in-depth picture of how we understand language, it's hard for us to say exactly what (and if) a dog like Johnson imagines when we say the word *ball*.

But importantly, just because dogs may not process the meaning of the words in the same way that we do doesn't mean they don't understand us in some way. One thing that both groups agree on is that dogs find verbal praise rewarding – so go ahead and keep telling them that they are *good dogs*.

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drugs of abuse, can impact that development.

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