# REVIEW OF *NEURAL MECHANISMS FOR LEXICAL PROCESSING IN DOGS* BY ANDICS *ET AL.* (2016)

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The publication of the article *Neural mechanisms for lexical processing in dogs* written by a team of Hungarian researchers in the widely read magazine *Science* last August immediately sparked a series of sensationalist headlines, ranging from the tentative *Dogs May Understand Even More Than We Thought* (Scientific American) to the more emphatic *Your Dog Knows Exactly What You're Saying* (National Geographic). While dog owners around the globe let out a sigh of relief when they found out their caring and encouraging words had not fallen on deaf ears after all, most scientists – dogless or otherwise - were more skeptical (*"Lexical Processing" – by Dogs?*, Psychology Today). And rightly so.

Although we could dismiss it as a mere case of marketing strategy, where the title caters to popular human interests (communication between dogs and humans), rather than referring to the actual content of the article, the authors of the article genuinely believe dogs engage in lexical processing. Anna Gábor, the PhD student and first author says in an interview for the American Veterinarian: "It shows that for dogs, a nice praise can very well work as a reward, but it works best if both the words and the intonation are praising. So dogs not only tell apart what we say and how we say it, but they can also combine the two, for a correct interpretation of what those words really meant. Again, this is very similar to what human beings do."

It is exactly regarding these two essential ingredients of speech processing that are *meaning* and *combinatory processing* that reside the primary flaws in the authors' reasoning. Firstly, to say that lexical items are merely associations of arbitrary sound sequences and meaning seems to grossly underplay the complexity of the lexicon for language processing and the type of information (morphological, syntactic) encoded in it. Secondly, the claim that dogs can interpret what 'words really meant' seems to suggest that there is a common ground between conceptual and semantic structure in dogs and human beings, which seems highly unlikely. The authors seem to confuse the activation of symbolized meaning representation with the ability to interpret or understand the vocalizations and intentions of human beings, yielding a specific response in the dog, whether it be excitement or fetching a particular item. Such that their readiness to be tuned into our actions and vocalizations, and their ability to read human social behavior is indeed astounding, but their linguistic ability is less so. In that regard, the author's paper shows that dogs, as do many animals have a knack for processing speech sounds, which indicates that our human skills for acoustic analysis do not stand alone in evolutionary history. This result, in itself, is not without merits, and it fits nicely with the already existing comparative literature.

The problem is that the authors jump to conclusions. Namely, they conclude that dogs distribute processing into different anatomical areas: the left hemisphere for lexical information, the right hemisphere for prosodic information. Now this is a far more serious claim. It stands to reason that humans separate sound and meaning representations because it is the most efficient way to use a finite set of features (such as phonological distinctive features) and recombine them yielding an infinite number of sequences. It is this combinatory feature, potentially yielding ever novel sounds and structures, that gives human language its creative potential, which has not yet been found in any other animal communication system. However, it is not at all evident that animals *need* to separate meaning and sound in order to interpret the vocalizations of their interspecies communication system, given that there is a pretty one-to-one relation between a specific call and the kind of response (flight, excitement, food, etc.) associated to it, mostly unaffected by context.

But let us return to the beginning. However appealing the title, it seems that the main objective of the authors is not to investigate whether dogs understand words; rather, they are interested in the evolution of brain structures that support language processing, and, more specifically, whether the functional distribution of cognitive processes among the left and right hemisphere is unique to humans. Indeed, their main goal is to see whether the left and the right lateralization of lexical and prosodic processing, respectively, can also be found in dogs. Furthermore, the results are interpreted to explain how and why a possible pre-existing left hemisphere bias for meaning processing may have evolved for lexical processing in human language.

The functional distribution of language processing is a hot topic, given that recent studies shifted their focus from anatomic localization to the dynamic nature of language processing. Much evidence has been found on the right lateralization of prosodic processing, and the specialization of the left temporal lobe for phonological processing (SKEIDE & FRIEDERICI, 2016). The authors take for granted that lexical processing is also left lateralized. However, it would be wise to consider the complexity of that claim. The authors define the term lexical item as the "association of arbitrary sound sequences with meaning". That in itself, suggests lexical access involves phonological processing, which is indeed generally considered to be left lateralized (SKEIDE & FRIEDERICI, 2016; POEPPEL & HICKOK, 2007). Unless properly defined, meaning processing is a generic term. Lexical meaning may refer to a broad conceptual meaning, built up from amodal features and conceptual frames distributed over different anatomic areas, where the left temporal lobe may function as a type of central hub (PYLKKÄNEN, 2015; BERWICKE *et al.*, 2013, SOTO, M., 2014). But lexical meaning is also built up of minimal semantic features (such as animacy or concreteness), and morphological and syntactic attributes (such as category and argument structure) (MARSLEN-WILSON, BROWN & TYLER, 1988). Many researchers agree that lexical representation, especially when inserted in morphological or syntactic context, are left lateralized (SKEIDE & FRIEDERICI, 2016; FRIEDERICI, 2011), but others foresee only a weak left hemisphere bias for lexical processing, given that integration of lexical meaning with context and world knowledge is taken to be bilateral (POEPPEL & HICKOK, 2007). Studies on semantic aphasia and amodal semantic processing also point to the left temporal lobe as the main semantic hub (PYLKKÄNEN, 2015).

Not only are the authors invested in seeing a functional distribution of lexical processing in dogs similar to humans - in itself a controversial enough claim -, they also propose that the results indicate why left lateralization for lexical processing in humans has developed. Their first hypothesis is based on a now seminal paper by Poeppel & Hickok (2007) in which they present their dual stream speech processing model. Basically, their model foresees that both left and right hemispheres process speech sounds in parallel, breaking the information up into different levels. Due to the intrinsic computation properties of the right hemisphere, which presents a slower sampling frequency in comparison, the right hemisphere is biased for operating on suprassegmental level (e.g. syllables), whereas the left hemisphere, boasting comparatively faster sampling frequencies, operates on segment level scales (e.g. phonemes). While processing spoken words, both information streams are integrated, mapping onto lexical representations, which, in turn, have a slight left hemisphere bias. In this light, you could say that the left lateralization for lexical processes stems from an anatomically induced processing bias, leading to the specialization of the left temporal lobe for extracting phonological information from acoustic input. Alternatively, the consistent role of the temporal lobe in (amodal) semantic processing could also have led to the specialization of the left temporal lobe for lexical representation. The authors present these competing views as the acoustic (phonological bias) and the functional (semantic bias) hypotheses.

Thus by proving that semantic processing (or lexical processing) is left lateralized in animals, you could show that a left hemisphere bias for semantic processing must have been instrumental for the emergence of left lateralized lexical processing in human language. Nevertheless, to study meaning representation, especially of the symbolic kind, in animals is to say the least, complicated. There are several animals that display rich conceptual complexity in social structures and the ability to grasp abstract concepts. However, it is very common to find that their vocalizations do not match a similar level of complexity (HAUSER *et al*, 2002). Chimpanzees are a good example of this category. Their social behavior is highly complex, and genetically they are very similar to humans; they also show -albeit limited- ability of acquiring human-like symbolic representations, and seem to display a rudimentary form of Theory of Mind. Still, the difficulty in teaching them language-like communication may be, among other things, due to the fact that, despite their intelligence, it is not natural for them to engage in social-communicative behaviors, which is reflected in their relatively poor repertoire of vocalizations (HARE & THOMASELLO, 2005). Furthermore, even those animals that can boast lexical-like elements in their interspecies communication -such as green vervet monkeys that have different warning calls for different kinds of predators- these calls seem to be restricted to functionally important contexts, such as food and dangers. Rather than meaning interpretation, these calls evoke an immediate response, are restricted in number and application, and represent no creativity in order to describe novel situations or experiences.

On the other hand, there is plenty of evidence of left lateralization for sound processing in a series of, much studied, mammals and birds (e.g. gerbils, mice, macaques as well as song bird species (ANDICS, *et al.*, 2016), There also several animals who can not only perform complex acoustic analysis on their own interspecies calls, but can also learn and recognize acoustic properties that relevant to human speech (such as frequency formants and distinctive features, such as voicing). Some of these are Japanese macaques (SOMMERS *et al.*, 1992), chinchillas (KUHL & MILLER, 1975), and various bird species, such as the budgerigars, zebra finches (DOOLING, BEST & BROWN, 1995) and Japanese quails (KLUENDER, DIEHL & KILLEEN, 1987). Why then study dogs?

The vocal interspecies communication system of dogs does not make them an obvious candidate for comparative animal model research. However, the long-standing bond between domesticated dogs and their human owners does. Through this allegiance dogs have learned to be tuned to the human voice and the acoustic properties of human speech. Behaviorally, they respond well to commands voiced by humans and they can discriminate up to 1000 different sound sequences and respond to them in different ways (e.g. retrieve different objects) (ANDICS *et al.,* 2016). Hare and Thomasello (2007) also describe the enhanced social skills of dogs which enable them to read humans' communicative intentions, such that when humans look or point at a hidden object in a row of opaque containers, the dog can interpret the hint helping it to make the right choice. Children can also do this well after 14 months, whereas chimpanzees, for example, are surprisingly bad at this task.

In terms of auditory processing of human speech, the authors cite results from an earlier fMRI study which showed dog brains presented an overlap in activation patterns for processing acoustic cues from human and dog vocalizations in the auditory brain regions (ANDICS *et al*., 2014). Also, not unimportant, there is the fact that dogs are readably trainable to stay motionless during the scanning sessions in the MRI scanner, which is vital to the technical criteria of data collecting, and its subsequent analysis.

Having presented the rationale behind the study, and its potential success and failure, let us now have a look at the experiment itself. In the MRI scanner, specially trained dogs listened to two types of words: (i) 'meaningful' praise words (meaning something like *Good boy!*); (ii) 'neutral' words that were supposedly not known to the dogs (such as *although*). Both types of words were pronounced with praising intonation (high pitch) and with 'neutral' intonation (low pitch), summing a total of 4 conditions, and a total of 24 words. If it is the authors' intention of dissociating lexical and prosodic processing, we quickly find a confound in the 'neutral' word condition. The authors state that the words were chosen because they supposedly do not 'mean' anything to the dog. If the dogs process these sound sequences without attaching any meaning to them, it would suggest these stimuli function as pseudowords, thus, engaging phonological processing. Therefore, we may conclude that rather than hearing praise and 'neutral' words, the dogs hear praise words and pseudowords. Not unsurprisingly, in the analyses presented in the paper, we can see lateralization indices (which are a quantification of how much one hemisphere was more activated than the other), which show some level of left lateralization for all conditions, which may that all types of words have engaged acoustic analysis of human speech sounds. However, the authors choose to focus on the fact that the highest left lateralization indices are for the praise word category (irrespective of pitch). They take this to be a lexical effect. This conclusion hinges on the presupposition that dogs have something that resembles meaning representation, which, as argued before, is quite a bold claim. Another explanation might be that 'meaningful' words may be have been more familiar, not only because of its 'meaning', but also merely based on their phonological form. We might consider, for instance, that function words, such as *although*, which were presented as neutral words, are much attenuated, less salient, when inserted in continuous speech, and thus be phonologically very different, than when pronounced in isolation. Another interesting effect is that the lateralization index for praise words with neutral pitch was significantly higher than that for praise words with high pitch. If lexical processes was really responsible for left lateralization, then we would not expect these two categories to present different result, since lexically both are the supposedly the same. However, if familiarity of form, both phonological and prosodic, plays a role, then we might expect there to be a difference.

Still, in the end, the authors conclude that dogs, similar to human beings, distribute lexical and prosodic processing - without presenting any robust evidence for the generalized right lateralization of prosodic processing. So, as long as there is no proof of specialization for prosody, we cannot infer that lexical or phonology or prosody is processed separately. They also build their conclusion on another analysis, focusing on the primary reward regions (the mesolimbic dopamine system), consisting of the ventral striatum (VS) and dopamine neurons of the ventral tegmental area and substantia nigra (VTA-SN). In literature, these areas have consistently shown to be sensitive to reward signals both in humans as well as in dogs. By zooming in on these areas, the researchers show that there is a response in that area only when there the stimulus contains praise both prosodically and 'lexically'. If I have made my argument clearly, we now start to consider whatever the authors refer to as 'lexical' as (phonologic) word form rather than representing any real lexical content. In that respect, it is interesting to see that the emotional response for praise in dogs is not merely caused by pitch modulation – something which is often suggested in popular science – but also depends on, at the least, some phonological analysis.

The fact that dogs respond emotionally to the specific form of words and not merely to the tone in which words are said is an interesting and surprising finding, breaking with the popular myth that dogs only pay attention to 'how you speak'. Indeed, the paper shows that dogs are both sensitive to prosodic and phonological information. In previous studies dogs have shown to be able to discriminate between an impressive number of words, as well as associate them to different responses or cues in their environment. Whether there is possibly a difference between segment and prosodic level processing is still difficult to tell, as there is no direct evidence to indicate it. In my analysis, the authors did not bring any convincing evidence that would warrant separate processing streams for lexical and prosodic processing; firstly, due to methodological inconsistencies, and, secondly, because there are some conceptual flaws that taint the whole rationale from the get-go. Therefore, the left lateralization found by the team of researchers is likely due to processing of human speech sounds in dogs enabling them to discriminate between acoustic properties relevant for human languages, such as is the case for a number of other mammals and birds. Thus, in terms of our understanding of the evolutionary track of the left lateralization for language, the question remains open to debate. So, no, your dog does not know exactly what you're saying, but make sure you enunciate clearly for his benefit!

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