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ORIGINAL PAPER

Language preference in the domestic dog (*Canis familiaris*)

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Abstract

Studies have shown that both cotton-top tamarins as well as rats can discriminate between two languages based on rhythmic cues. This is similar to the capabilities of young infants, who also rely on rhythmic cues to differentiate between languages. However, the animals in these studies did not have long-term language exposure, so these studies did not specifically assess the role of language experience. In this study, we used companion dogs, who have prolonged exposure to human language in their home environment. These dogs came from homes where either English or Spanish was primarily spoken. The dogs were then presented with speech in English and in Spanish in a Headturn Preference Procedure paradigm to examine their language discrimination abilities as well as their language preferences. Dogs successfully discriminated between the two languages. In addition, dogs showed a novelty effect with their language preference such that Spanish-hearing dogs listened longer to English, and English-hearing dogs listened longer to Spanish. It is unclear what particular cue dogs are utilizing to discriminate between the two languages; future studies should explore dogs' utilization of phonological and rhythmic cues for language discrimination.

Keywords Language discrimination · Language preference · Canine

Introduction

Infants' early exposure to their native language alters their listening preferences for the language around them. For example, infants generally prefer to listen to utterances with native-language prosody rather than foreign-language prosody (Jusczyk et al. 1993; Mehler et al. 1988). They also listen longer to both their own mother's speech than that of other women (DeCasper and Fifer 1980), and to particular stories they have previously heard (DeCasper and Spence 1986). In addition, infants can differentiate between different languages, listening longer to their native language than even prosodically similar languages by 5 months (Nazzi et al. 2000).

The development of listening preferences is important in that these preferences both reflect and reinforce infants' learning about language. Consider the case of listening to passages in their native language and an unfamiliar language, when both are spoken by an unfamiliar speaker. For infants to demonstrate a preference for their native language, they must draw on their prior experiences and learning of their native language, generalize across extraneous dimensions (the unfamiliar voice and perhaps unfamiliar words or phrases), and recognize aspects of these novel stimuli that are familiar. The ability to show a preference thus demonstrates that infants have acquired knowledge of aspects of their native language, such as its characteristic rhythm or sounds; in this way, infants' listening preferences are an important way to study what they know about their language. But infants' attentional preferences are also important socially, and could help scaffold their learning. Researchers have theorized that familiarity preferences, such as young infants' preference to look at familiar faces (Walton et al. 1992) or listen to familiar voices (Moon et al. 1993) could drive children to attend to their caregivers more, and that in and of itself could provide more learning opportunities (Werker and McLeod 1989). Similarly, in a multilingual community, a preference for the home/native language could encourage listening to (and thus learning from) just that language most relevant for the child.

Prior studies have explored whether infants' ability to learn and recognize aspects of their native language are unique to humans, or whether non-human animals can also

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learn to recognize the sound and rhythm patterns that define the language in their environment (Kluender et al. 2006). Non-human animals can differentiate between languages using prosodic cues (Ramus et al. 2000; Toro et al. 2005); however, the animals in these studies did not have long-term language exposure, so these studies did not specifically assess the role of language experience. Rather, the studies focused on the ability to pick up on differences in acoustic patterns after intense short-term exposure to a specific language. It is unclear whether longer term language experience in a non-human animal would also affect language perception and preference. The domestic dog is an ideal model to address the effect of language experience on language discrimination and preference, as companion dogs have natural, long-term exposure to language in their owner's household; people often include their dog in conversations and more generally have conversations in the presence of their dog (Tannen 2010). This study examines the role of language experience in language discrimination and language preference in the domestic dog.

Language discrimination

Distinguishing between languages can occur either based on familiarity with the specific properties of a given language, or on the basis of clear acoustic differences between languages (even when both are novel). For example, human newborns will distinguish between languages that rely on different rhythmic patterns (French, a syllable-timed language in which both stressed and unstressed syllables are of similar duration, vs. English, a stress-timed language in which unstressed syllables are substantially shortened; Nazzi et al. 1998); but even 5-month-olds cannot distinguish between languages that rely on the same general rhythmic pattern (e.g., French vs. Spanish) unless one of the languages is personally familiar to them (Nazzi et al. 2000).

Most of the research looking at language discrimination in non-human animals has explored discrimination based on clear acoustic differences. For example, Ramus et al. (2000) explored whether cotton-top tamarins performed similarly to human infants in a novel language discrimination task. Both the tamarins and infants could distinguish between Dutch and Japanese, two languages that differ in rhythmic pattern, when the languages were played forwards but not when played backwards (which obscures the rhythmic cues). This demonstrates that language discrimination based on clear acoustic differences is not unique to humans. Rats have also been shown to discriminate between languages from different rhythmic patterns (Toro et al. 2003); however, the rat model requires reinforcement training, limiting direct comparison to the habituation and listening preference methods used with infants. Nonetheless, these studies demonstrate that both newborn infants and non-human animals can discriminate between a habituated or trained language and a second unfamiliar language that differs in rhythmic class. These studies used languages unfamiliar to the subjects, and therefore, cannot address the potential role of language experience in language discrimination.

The role of experience

Unlike tamarins and rats, infants have regular, prolonged exposure to language and utilize their knowledge of the patterns of their native language to tell languages apart. Infants' experience with their native language begins prior to birth, in the third trimester in utero, and shapes their preferences for specific voices, languages, and types of speech. For example, Moon et al. (1993) found that newborn infants already show a preference for their native language over another unfamiliar language, and DeCasper and Spence (1986) demonstrated that newborns listened longer to stories their mothers had read aloud in their third trimester of pregnancy. Thus, even newborn infants are likely to be influenced by prior exposure to their native language, and this experiential-based knowledge only grows over time. Given the extent of infants' language exposure, a better non-human animal model to explore language preference and discrimination would likewise have more regular, long-term language exposure.

Companion dogs have consistent, regular exposure to human language. Moreover, they have been shown to have the ability to learn spoken word forms and later recognize them, implying some ability to store information from the auditory speech signal. As such, dogs' responses to familiar and unfamiliar languages could shed light on the role of language experience in language preference and discrimination. Work with several different individual dogs has suggested that some dogs may acquire vocabularies that are similar in size to those of young children (Griebel and Oller 2012; Kaminski et al. 2004; Pilley and Reid 2011); however, even dogs without special linguistic training have been shown to learn several different words. Companion dogs can recognize several commands, even at a young age (Kutsumi et al. 2012). In addition, companion dogs can distinguish between previously learned words, such as their name, and unfamiliar words, even if they are said in the same intonation pattern (Mallikarjun et al. 2019). Much of this learning occurs even in the absence of explicit training; many dog owners report needing to avoid certain words (such as "walk" or "treat") if they do not want to generate undue excitement in their dogs. This suggests that language exposure, even without training, is sufficient for dogs to learn some aspects of the speech around them.

What is less clear is *how* dogs learn. In particular, is learning the result of speech directed to the dog, the result of speech overheard in their environment, or both? Several studies have suggested that speech directed to dogs differs from that directed towards adults in a number of ways. Dog-directed speech is higher pitched and more variable in pitch than adult-directed speech (Ben-Aderet et al. 2017). As a result of these changes, dogs attend significantly more to dog-directed speech than adult-directed speech (Benjamin and Slocombe 2018); this would suggest instead that dogs would learn best from speech directed to them, rather than adult-directed overheard speech. Yet if dogs can learn from ambient speech in their environment, including speech that is not dog-directed, this would presumably provide them with more opportunities to learn.

The aim of the current study is to determine how language experience in a non-human species affects language preference and discrimination. To explore this question, domestic dogs were presented with stories spoken in either a language they had regularly heard in their environment or a less-familiar language. We focus on two groups of dogs: those who have primarily heard English throughout their life, and those who have primarily heard Spanish throughout their life. Both groups of dogs were presented with fairy tales in both Spanish and English using the Headturn Preference Paradigm, a common method used for testing infants' language discrimination and preference (Kemler Nelson et al. 1995). If experience with language shapes language preference, we would expect that dogs may show similar preferences to infants, in which they listen longer to their most-often-heard language as compared to the unfamiliar language.

We examine these preferences both for speech produced in a dog-directed manner, and for speech directed towards adults (which is more akin to the kind of speech dogs are likely to overhear in their environment). If dogs learn the patterns of their native language primarily from speech directed towards them, we might expect that they would show a greater language preference in dog-directed (rather than adult human-directed) speech. In contrast, if dogs learn patterns from all of the speech in their environment, they might be more likely to show a generalized preference for language that occurs regardless of speaking style.

One very recent paper explored dogs' differentiation of familiar and unfamiliar languages using functional Magnetic Resonance Imaging (Cuaya et al. 2022). Researchers performed fMRI scans on 18 dogs while they listened to Hungarian and Spanish stimuli. Sixteen of these dogs heard Hungarian spoken in the home, and two heard Spanish at home. Multivariate pattern analysis (MVPA) was used on the dogs' neural scans to determine if certain areas showed differential activity based on the language of the speech stimuli. They found that dogs showed differential activation in the ventral auditory cortex based on whether the familiar or unfamiliar language was played. This suggests that, at a neural level, dogs can differentiate between Hungarian and Spanish based on some underlying structural or linguistic features.

It is important to note that different neural responses do not always imply different behavioral responses, which the authors acknowledge. Both dogs and humans show neurological changes to differences that do not elicit behavioral differences. For example, one human study examined Mandarin Chinese linguistic processing in children adopted from China who had no continued input of Mandarin after adoption (Pierce et al. 2014). These adoptees had neural representations of Mandarin that matched patterns seen in native Mandarin speakers, even though they had had no Mandarin input for an average of 12 years and had no conscious recollection of the language. In dogs, one study showed that measurement of event-related potentials (ERPs) showed similar responses for familiar words and perceptually similar nonwords that differed only in the vowel of the initial syllable (e.g., familiar word *marad* and similar nonword *merad*) (Magyari et al. 2020). However, a behavioral study examining the same phenomenon found that dogs do differentiate between a familiar word and a vowel-changed version (Mallikarjun et al. 2020). As such, in both humans and dogs, neural representations and pattern can differ from observed and reported behavior. Thus, while we know that some portions of dogs' brains track acoustic differences between stimuli from familiar vs. unfamiliar languages, this may not be an indication of a behavioral ability to recognize a familiar language and respond differently to it.

Testing Spanish–English language differentiation in dogs

This study examines dogs' looking behavior to English and Spanish speech as a function of their prior exposure to these languages. English differs from Spanish in multiple ways (Prieto et al. 2012). For example, while English has a wide variety of syllable types, Spanish primarily contains consonant–vowel syllables (Delattre and Olsen 1969). In addition, English has vowel reduction in unstressed syllables and final lengthening of vowels (Wightman et al. 1998), while Spanish has no vowel reduction and much less vowel lengthening at syllable-final positions (Hutchinson, 1973; Ortega-Llebaria and Prieto 2007). These traits have traditionally classified English as a typical "stress-timed" language, while Spanish is a typical "syllable-timed" language (Abercrombie 1967). The difference in the amount of "time" the languages give to different syllables is readily perceptible by non-human primates (Ramus et al. 2000; Tincoff et al. 2005), as well as by infants, who discriminate between languages from different rhythmic classes at birth (Nazzi et al. 1998). Thus, we might expect that dogs, too, would be able to perceive these acoustic differences.

However, discriminating between languages is different than developing a listening preference; while a preference for one language over another necessitates being able to discriminate them, discrimination alone does not imply a preference for one language over another. Infants prefer to listen to speech from their native language in comparison to an unfamiliar language, indicating that they not only discriminate between the languages, but also have learned that one type of speech better matches the sounds normally heard in their environment. To test for an effect of language familiarity, it is critical to compare groups of listeners that have different sets of experiences; thus, newborn infants being raised by English-speaking mothers will listen longer to English passages than to Spanish passages, but infants raised by Spanish-speaking mothers show the opposite pattern (Moon et al. 1993). This difference across groups of listeners implies that infant language preference is not driven solely by some acoustic property (e.g., one language sounding more pleasant than another), but is instead tied to the infants' particular experiences with language.

Here, we tested dogs' preferences for Spanish versus English. We expected that dogs could discriminate between these two languages, given that several other non-human animals, like rats and cotton-top tamarins, can discriminate between languages from different rhythmic classes. Importantly, given dogs' language experience and attunement to human speech, we might expect that dogs, like infants, would also show a preference for their familiar language over an unfamiliar one.

Methods

Participants

Fifty-three adult dogs (31 M) participated in this study. Dogs were excluded if they were taking psychiatric medication, or if owners noticed any sign of hearing loss. On average, participating dogs were 4.99 years of age (SD = 3.09).

The Spanish/English language pair was chosen for this study due to the ease of finding local participants in the Washington, D.C. metropolitan area who spoke Spanish to their dogs. Dog owners were asked two demographic questions prior to their dogs' participation in the study. To assess the dogs' current language exposure, we asked for a percentage estimate of the amount of time their dog heard Spanish and the amount of time their dog heard English in any given week. To address potential past language exposure, we asked whether their dog was adopted from an area with mostly Spanish speakers, such as Puerto Rico. Dogs who heard any languages other than Spanish and English were excluded from this study.

Twenty-one dogs who participated in the study heard only English. Of the remaining 32 dogs that heard some Spanish, 11 regularly heard more English than Spanish and 13 regularly heard more Spanish than English. The remaining 8 dogs were adoptees from Spanish-speaking countries into American homes; early on, these dogs heard primarily Spanish, but they then moved to the United States and were adopted by English-only families. We only accepted adoptees that had been adopted within 2 years from their test date and had spent at least as much or more time in their country of origin as they had spent in America.

We then combined the dogs into two groups. One group ($n = 32$) consisted of those dogs who either only heard English, or who were in bilingual homes but heard more English than Spanish; we refer to this group as the "More English" group. Those dogs ($n = 21$) who were in homes where Spanish was spoken more often than English, and those who were recently adopted from Spanish-speaking countries made up the "More Spanish" group.

Test materials

Stimuli for the study were produced by a female bilingual speaker of Spanish and English. The speaker was unfamiliar to the dogs; this should not pose any difficulty, as dogs can readily recognize speech when produced by a novel voice (Griebel and Oller 2012; Mallikarjun et al. 2019, 2020). The speaker learned Spanish and English from birth, and spoke both languages without a noticeable non-native accent. The speaker's English was from the mid-Atlantic United States, and the speaker's Spanish had a Costa Rican accent. The speaker was asked to read passages in adult-directed and dog-directed speech. For the adult-directed passages, the speaker was told to read the passages as though they were speaking to another adult. For the dog-directed speech passages, the speaker was shown a photo of an adult dog and told to record the passages as though they were excitedly reading them to the dog. While the speech would have been more naturalistic if the speaker had been speaking to an actual dog, we needed to ensure a lack of extraneous background noise in the stimuli.

Twenty-two-second audio recordings of fairy tales were recorded by the speaker using a Shure SM51 microphone in a sound-attenuated room. To mitigate the possibility that dogs would become bored or disinterested too quickly with repetitions of the same stimuli, two distinct fairy tales were recorded for both English and Spanish. One was recorded in a dog-directed speech (DDS) style and the other in an adult-directed speech (ADS) style (we use the term "adult-directed" because it is a common term used in the literature; however, we note that "adult" here refers specifically to adult humans, and thus "human-directed" might be more appropriate.). Thus, the speaker produced a total of four

Table 1 Language stimuli

Story	Language	Speech type	Mean F0	SD F0	Min F0	Max F0	Range F0	# of words
Three little pigs	English	Dog-directed	341.9	103.3	160.4	739.5	579.1	61
Three little pigs	Spanish	Dog-directed	344	114.4	151.1	846.5	695.4	57
Jack and the beanstalk	English	Adult-directed	155.3	29.1	50.7	218.4	167.7	79
Jack and the beanstalk	Spanish	Adult-directed	153.6	42.1	44.8	242.6	197.8	70

This table shows the stimuli, language, speech type, and an acoustic analysis of the stimuli. The F0 measurements are in Hz

passages: Spanish DDS, Spanish ADS, English DDS, and English ADS. The story produced in DDS (both in English and Spanish) was the Three Little Pigs, and the story produced in ADS (both in English and Spanish) was Jack and the Beanstalk (see Table 1). English stories did not contain English words/phrases identified as items that 90% or more of dogs know (Reeve and Jacques 2022). While there is no Spanish inventory available, it is likely that a similar set of words would be used for Spanish-hearing dogs, and the translations of the English words are not present in the Spanish stories. The English word *no* does appear in the Spanish story to indicate negation of a verb.

The 22-s clips were then adjusted/normalized to have the same RMS amplitude (in dB relative to computer maximums). Since the four stories contained pauses and silences between words and the amount of silence was not identical between stories, the silence was edited out of each story before adjusting the RMS amplitudes. This ensured that the speech within each passage would be the same intensity.

Apparatus

The study occurred in a three-sided 4’ by 6’ test booth made from pegboard. In the front of the booth, a hole was cut out, and a GoPro camera was placed in the hole to record the studies. Curtains hung from the ceiling to the top of the booth on each side so the dog could not see over the booth (see Fig. 1).

On the front wall and side walls of the booth, lights were mounted. Directly behind the lights on the side walls were speakers to play stimuli for the dogs. The light on the front wall turned on prior to the start of a trial.

A Windows computer was used behind the front wall of the booth for running the study and coding dogs’ looking behavior. The experimenter used BITTSy software to run the study (Newman et al. 2019), indicating on a keyboard when to start trials and where the dog was attending (see “Procedure”).

Procedure

The dog and his or her guardian were brought into the booth by an experimenter and the guardian signed consent forms. In the testing booth, the dog sat either on the owners’ lap or directly in front of them, depending on the dog and owner’s preferences. The dog’s guardian was provided with headphones and masking music to prevent him or her from biasing the dog’s responses. The dog sat either facing the front of the booth or facing the back of the booth, towards their owner, to start. In either case, the dog’s attention was maintained as much as possible at a point equidistant from the two sides of the booth (where the loudspeakers were located). As a result, the dog’s natural inclination upon

Fig. 1 A photo of the testing booth, from Newman et al. (Newman et al. 2021). The booth appears curved due to the wide-angle camera lens, but it is a square three-sided booth with an open back. The front panels are closed over the television during HPP studies such as the one here. The camera in the front allows experimenters to monitor dog’s behavior during the study

hearing a sound through a loudspeaker was to turn their head or body 90 degrees to face the source of sound.

There were two practice trials of classical music to familiarize the dog with the procedure. The dogs' listening time was judged by the amount of time they spent looking at the sound source (the wall behind which the speaker was mounted).

Two experimenters ran the test phase portion of the study: one to code the dog's looks (the coder), and the other to produce auditory attention getters. At the start of the test trials, the light on the front of the booth turned on, and one experimenter made a sound to attract the dog's attention towards the front of the booth. Once the dog attended to the front, a light on either the left or right side of the booth turned on. The experimenter then made a sound on that side. Once the dog attended to that side, a trial began, and one of the four stories (adult-directed English, dog-directed English, adult-directed Spanish, or dog-directed Spanish) played from the speaker on that side; the light provided a visual indication of the "source" of the sound (Kemler Nelson et al. 1995). The coder used a keyboard to code the dog's looks towards and away from that side. A dog was considered to be looking towards a particular side of the booth if their head turned at least 45 degrees from the center position towards the appropriate side of the booth. The stimulus played for a full twenty-two seconds or until the dog looked away for two consecutive seconds, whichever occurred first. A dog was considered to be looking away from the stimulus if they turned at least 45 degrees away from the sound source. Any time the dog spent looking away was subtracted from the dog's overall looking time. The coder wore Peltor aviation headphones playing masking music so she would not be able to hear the trials and have that influence her coding.

The test phase consisted of 16 trials, divided into 4 blocks. Blocks consisted of one trial for each of the four stories, with the presentation order of the stories randomized within each block.

Coding and reliability

HPP is set up such that the trials begin and end based on looking behavior. This means that the study must be coded in real time. Coders are first trained to live-code infant HPP studies, where the original coding standard is that coders press a button when the participant looks at least 30 degrees towards the stimulus location, which is marked by a flashing light (Kemler Nelson et al. 1995).

The dog coding process comes with some different challenges than infant coding, but with practice, coders can easily determine when a dog is paying attention and looking at the proper location, and when the dog becomes bored and turns away. Unlike infants, dogs do not always like to look directly at the light on the side wall and tend instead to train their gaze anywhere on the wall where the speaker is located. As a result, they often will not turn 60–90 degrees to face the side wall speaker, but instead will turn their heads to the front or back corners of the booth. This means that the coder needs to stay attentive and carefully watch the dog's eyes and head to see if he or she is maintaining interest in the stimuli, or if he or she stopped paying attention. Fortunately, dogs often show additional behavioral signs of interest in addition to looking towards the interesting sound source: their ears prick up, their tails wag and they tilt their heads from side to side. While dog attention is a judgment call on the part of the coder, it tends to be fairly consistent across individuals; results in our lab from Mallikarjun et al. (2019) showed that inter-rater reliability is quite high, with a Pearson's correlation analysis showing a correlation coefficient of 0.934 between the first coder and second coder over 10 dogs.

For this study, a second coder re-coded the looking time to speech stimuli in each trial for three randomly selected participants. A single-rating ($k = 2$), consistency, two-way random-effects model was made using the IRR library in R. The estimated consistency was 0.88, CI = [0.79, 0.93], which is considered to be good reliability (see Byers-Heinlein et al. 2021, for more information about HPP and infant testing reliability).

Results

Results for the overall data and individual groups are as follows.

Overall results

Mean listening times across the four blocks of the study were calculated for each trial type (ADS Spanish, DDS Spanish, ADS English, and DDS English).

A linear mixed-effects model of Looking Time was created using the lme() function in R. Fixed effects included Speech Type (DDS versus ADS), Language (English speech versus Spanish speech) and Background (More English or More Spanish), and all interactions (see Supplementary Table 1 for full results). Dog was included as a random intercept.

There were no significant main effects, suggesting that the different stimuli in general were roughly similar in terms of dog listening times (e.g., one type of stimuli was not listened to longer by a significant portion of the dogs). While some studies have found that dogs prefer to listen to dog-directed speech over adult-directed speech (Benjamin and Slocombe 2018), other studies have found that adult dogs fail to show

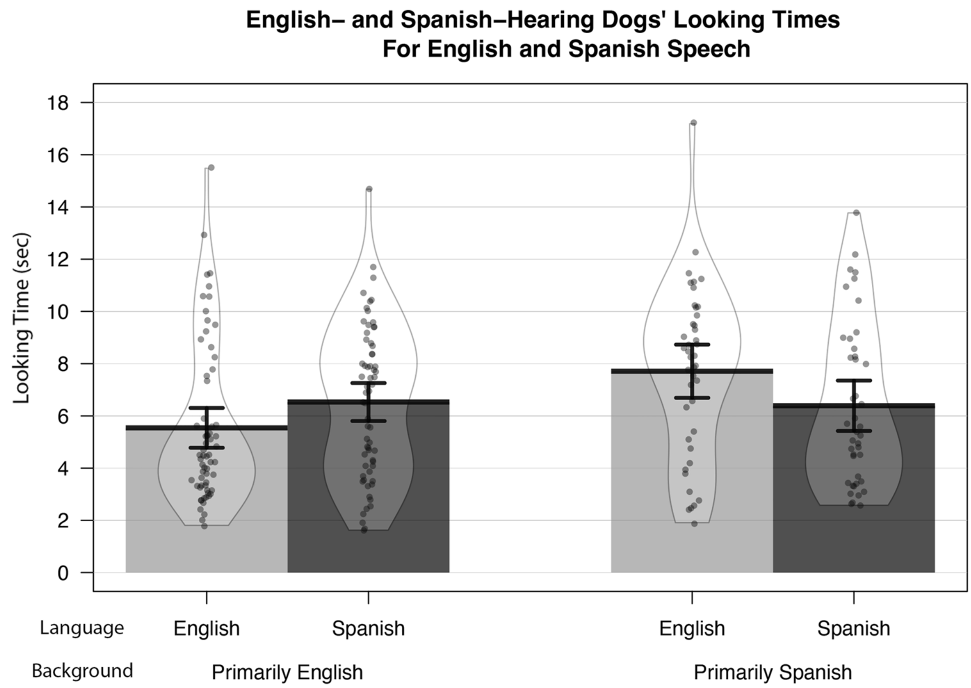

Fig. 2 A graph of primarily Spanish- and English-hearing dogs' average looking times to Spanish and English stories (graph package: Kampstra, 2008). There is an interaction in which primarily Spanish-hearing dogs listen longer to English stories, and primarily English-hearing dogs listen longer to Spanish stories

this preference (Ben-Aderet et al. 2017)) This study, too, failed to show a preference for DDS over ADS in adult dogs.

There was no significant three-way interaction between Speech Type, Language, and Background. The interaction between Speech Type and Background as well as the interaction between Speech Type and Language were not significant (see Supplementary Table 1). Critically, there *was* a significant interaction between Language and Background, $\beta_1 = -1.95$, $t(153) = -2.17$, $p = 0.03$. This means that dogs' looking times to English or Spanish speech was mediated by their language background (see Fig. 2). The direction of this effect is explored further as follows.

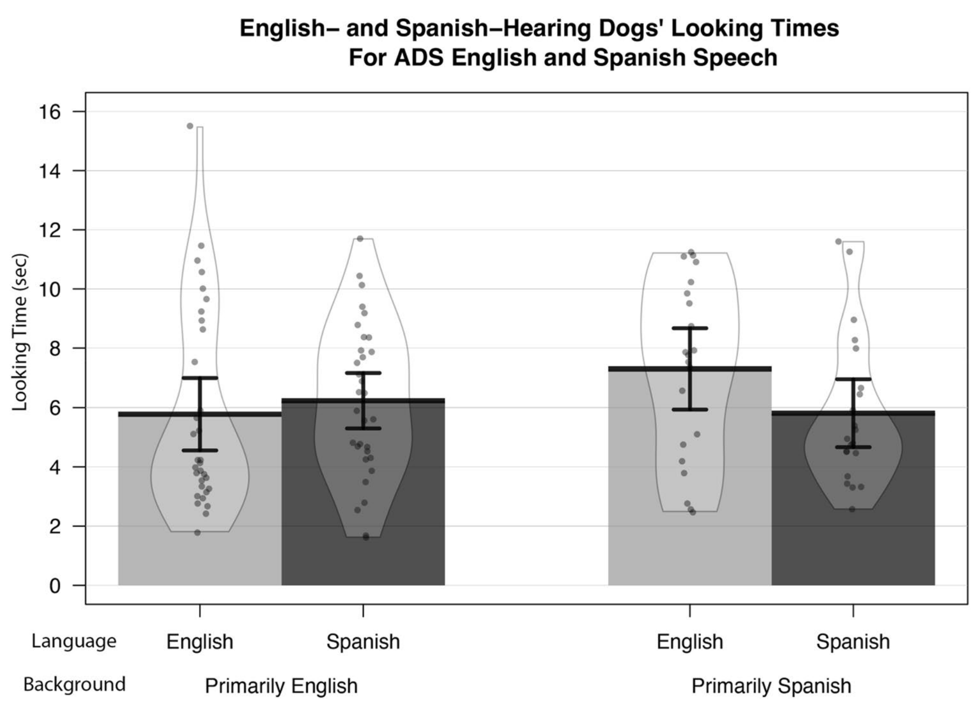

Fig. 3 A graph of primarily English- and Spanish-hearing dogs' average looking times to stories in adult-directed speech (graph package: Kampstra, 2008). There is an interaction between the language of the story and the dogs' language background

DDS and ADS analyses

Individual linear mixed-effects models examined the effect of Language and Background on Looking Time in the two speaking styles (DDS and ADS) separately.

In the ADS speaking style, there is no significant effect of Background, $\beta_1 = 1.52$, $t(51) = 1.86$, $p = 0.07$. There is a significant interaction between Language and Background, $\beta_1 = -1.95$, $t(153) = -2.03$, $p = 0.048$, as seen above in the full analysis (see Fig. 3).

In the DDS speaking style, there is a significant effect of Background, $\beta_1 = 2.81$, $t(51) = 3.12$, $p = 0.003$, such that dogs that hear more Spanish listen significantly longer to DDS speech (mean: 7.55 s) than dogs that hear more English (mean: 6.06 s). Since some of these dogs were adoptees from other countries, they may have spent significant time outside a home setting in which DDS would be used. Beyond that, however, there may be cultural differences in how speakers vary their speech for dogs, like cross-cultural variation in IDS for infants (Farran et al. 2016; Ferguson 1964; Pegg et al. 1992).

There is a significant interaction between Language and Background, $\beta_1 = -2.68$, $t(51) = -3.48$, $p = 0.001$, as seen in the full analysis (see Fig. 4).

To explore the interaction between Language and Background, we used the conducted two linear mixed-effects models with Language as a fixed variable and Dog as a random intercept in dogs who heard more English and dogs who heard more Spanish.

Results for dogs who heard more English

For the dogs who heard more English in their lifetimes, there was a main effect of Language, $\beta_1 = 0.99$, $t(95) = 2.54$, $p = 0.01$. Dogs listened longer to the Spanish stimuli (mean = 6.53 s) than the English stimuli (mean = 5.54 s). Interestingly, these primarily English-hearing dogs listened longer to the language unfamiliar to them (Spanish) than to their familiar language (English).

Results for dogs who heard more Spanish

For dogs who heard more Spanish in their lifetimes, there is likewise a main effect of Language, $\beta_1 = -1.32$, $t(61) = -2.62$, $p = 0.01$. Dogs listened longer to the English stimuli (mean = 7.71 s) than the Spanish stimuli (mean = 6.39 s). Like the English-hearing dogs, the Spanish-hearing dogs listened longer to the language that was *less* familiar to them. In summary, both groups of dogs showed longer listening to the stimuli in the language they heard less often.

Matched subgroup analysis

One concern regards the fact that these two groups are unbalanced; not only are there more participants in the "More English" group than the "More Spanish" group, but the inclusion criteria differ, in that we do not have any dogs who have not had any English exposure. This difference is

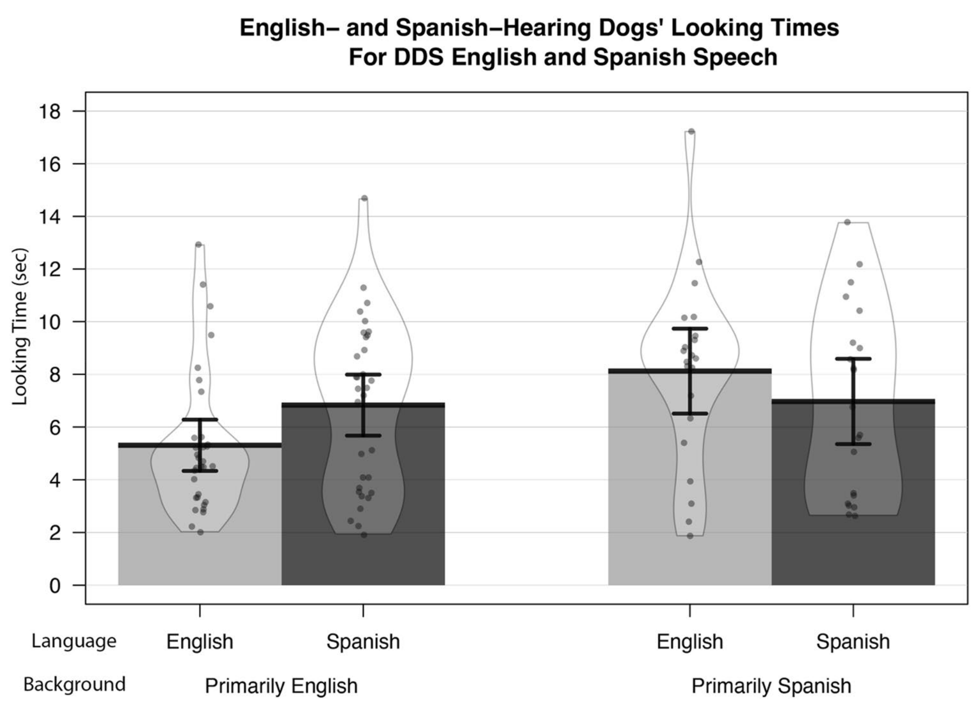

Fig. 4 A graph of primarily English- and Spanish-hearing dogs' average looking times to stories in dog-directed speech (graph package: Kampstra 2008). There is an interaction between the language of the story and the dogs' language background

an unavoidable consequence of testing in the United States, but it could have affected our results in unpredictable ways.

To try and assess this issue, we compared our two most matched subgroups. The first group consists of 13 dogs who hear both English and Spanish, but more than 50% of the speech they hear is in Spanish, in comparison to English (More Spanish group). The other group consists of 11 dogs who hear both English and Spanish, but 50% or less of the speech they hear is in Spanish, in comparison to English (More English group). A linear mixed-effects model of Looking Time with Language and Background as fixed effects and Dog as a random intercept was used. There is a significant effect of Background such that the mostly Spanish group generally listens longer to stimuli than the mostly English group, $\beta_1 = 2.32$, $t(22) = 2.25$, $p = 0.04$. Since the groups consist of two different sets of dogs and dogs' individual baseline looking time for human speech can be different, this is not a surprising result. While the interaction between Language and Background does not reach significance, $\beta_1 = -1.58$, $t(61) = -1.74$, $p = 0.09$, the directionality of the interaction is the same as that found in the overall dataset (see Fig. 5).

Discussion

The aim of this study was to explore the effect of language experience on dogs' language discrimination and language preference. Both primarily English-hearing and Spanish-hearing dogs successfully discriminated between the English and Spanish stimuli (as shown by their consistent preference for one type of stimulus over the other), which is in line with prior non-human animal studies. Most interestingly, dogs' language background affected their language preference; Spanish-hearing dogs listened longer to English than Spanish stimuli, and English-hearing dogs listened longer to Spanish than English stimuli. Finally, this preference appears to be independent of the type of speech (dog-directed vs. adult (human)-directed). We discuss each of these points in turn.

Dogs listened significantly longer to one language than another language in the study, demonstrating their ability to distinguish between languages. This is an expected result given that cotton-top tamarins (Ramus et al. 2000) and rats (Toro et al. 2003) are also able to differentiate between a familiarized language and a second novel language. Moreover, a very recent study found that dogs show different neural patterns for different languages, suggesting that neutrally the languages are differentiable. This study confirms the ability of language differentiation in dogs and further demonstrates a difference in behavior when dogs encounter different languages (Cuaya et al. 2022). This ability provides further evidence for the idea that language discrimination may rely on general perceptual abilities not specific to humans.

The pattern of dogs' language listening in the study was based on their prior language experience; we found that Spanish-hearing dogs listened longer to English stimuli, and vice versa. This demonstrates that dogs are attending to language in their environment and learning information about the underlying structure and patterns of that language.

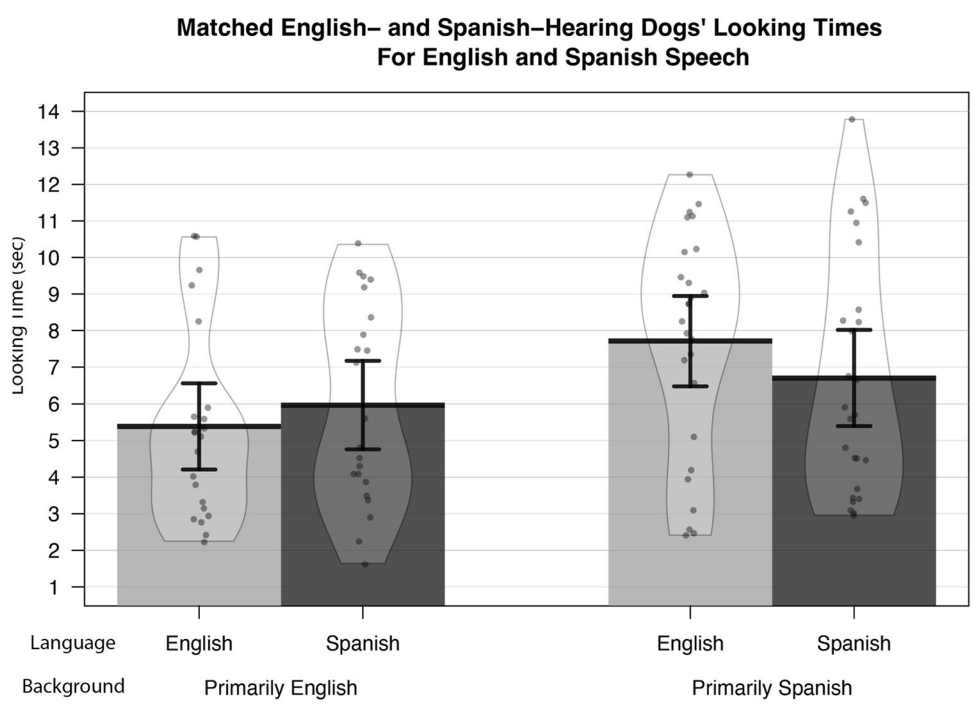

Fig. 5 A graph of the mostly English- and mostly Spanish-hearing dogs' average looking times to stories in dog-directed speech (graph package: Kampstra 2008). There is an interaction between the language of the story and the dogs' language background

Prior research has shown that dogs can learn and later recognize individual words and phrases (Andics et al. 2016; Pilley 2013; Pilley and Reid 2011; Reeve and Jacques 2019). Dogs can also distinguish between recently learned familiar words and unfamiliar pseudowords, which suggests that dogs possess novelty detection (also seen in this study between the familiar and unfamiliar language) as well as some basic auditory representations for the recently taught items (Prichard et al. 2018). Dogs also show neural evidence of underlying pattern recognition within a language (Cuaya et al. 2022). This study further demonstrates that behaviorally, dogs act on the information they learned about the underlying patterns within a language.

While it is possible that, rather than recognizing underlying patterns in the speech, dogs were able to recognize specific words in the short stories read to them, we specifically picked stories that did not contain words likely to be familiar to dogs (e.g., *treat*, *food*, *walk,* or *ball*). While dogs have been shown to identify familiar words, studies generally present these words in an isolated context and not within a sentence (e.g., Prichard et al. 2018). In order to maintain natural speech prosody, function words, which dogs would hear in everyday life, were unavoidable in the stories. However, prior research has shown that dogs find neutral function words less salient than familiar, meaningful words; praise words lead to more activation in dog reward-oriented neural areas than function words (Andics et al. 2016). As such, it seems unlikely that dogs are solely utilizing function words in the stories to differentiate the languages, although this might be a question for future research.

Since Spanish-hearing dogs preferred English speech and English-hearing dogs preferred Spanish speech, the dogs overall demonstrated a novelty preference rather than a familiarity preference, listening longer to the unfamiliar language than their familiar language. This is in contrast with prior results from infants, who show a familiarity preference, listening longer to their native language (Moon et al. 1993). However, for non-linguistic stimuli, infants tend to shift from a familiarity to a novelty bias as they age; it is possible that dogs are following this pattern, such that older dogs show a novelty bias, but puppies or younger dogs may show a pattern more like that of young infants. A study in which dogs of different age groups are tested on their language preference could address this question.

Another potential reason for the difference in infant and dog preference is that there may be a specific predisposition for infants to attend to their native language that dogs do not have. As infants listen to native speech, they are learning information about the statistical regularities of their language. Infants harness the information they learn about the rhythm and acoustics of their language to learn even more information about the structure of their language (Thiessen and Saffran 2007). As such, attending to the native language is part of a long-term language-learning strategy that is adaptive for human infants, but may provide less benefit to dogs. In addition, dogs in general tend to show a novelty preference for a wide range of sensory stimuli; researchers have suggested that dogs may be predisposed towards novelty, as it might have been evolutionarily adaptive (Kaulfuß and Mills 2008). Together, dogs' general predisposition towards novelty and infants' predisposition to listen to their native language may have led to the different pattern seen across these two groups.

These results also have methodological implications for future dog studies. It is useful in many study paradigms to have an idea of the directionality of the preference for study design and future statistical tests. For example, studies of speech perception and language processing in infants often rely on a known preference (say, longer listening to one's name than another infants' name) to examine whether the preference persists under a particular manipulation (e.g., can infants still recognize names in the presence of noise). Using an expected baseline preference eliminates the need for a training or habituation phase, allowing participants to complete the study in fewer trials or fewer sessions, which is an important practical concern for participants with shorter attention spans. Similarly, the finding that dogs' regular language exposure leads to a language preference could make it more practical to test questions of speech perception in a domestic dog model, particularly as it allows for more direct adaptation of methods from prior infant research.

In this study, the dogs are demonstrating a novelty preference, in which they listen longer to the unfamiliar stimulus rather than the familiar stimulus. A novelty preference has been found in dogs for an object selection task (Kaulfuß and Mills 2008) as well as a visual preference task with human faces (Racca et al. 2010). This might suggest that we should expect dogs to generally show a novelty preference in other future studies. However, in Mallikarjun et al. (2019) and (2020), dogs prefer to listen to their own name—a familiar item—rather than another dog's name or a mispronounced version of their name, respectively. In addition, one visual preference task has shown that dogs prefer to look at familiar dog faces rather than novel dog faces (Racca et al. 2010). As such, it is not altogether clear when dogs might be expected to show a familiarity versus novelty effect.

In the infant literature, it is also often unclear whether infants will demonstrate a familiarity preference or a novelty preference. Some studies have shown preferences in the auditory and visual modality for familiar stimuli; for example, infants look longer at their mother's face than a stranger's face, listen longer to their own name than another infant's name, and listen longer to their familiar language than an unfamiliar language. However, other studies have found novelty preferences: for example, after habituation to a stream of artificial words, infants will listen longer to part-words (pieces of other words put together) than full words from the stream (Saffran et al. 1996). Even though they have heard these part-words less often in the habituation phase, they listen to them for a longer period of time during test. Researchers have suggested more generally that infants are likely to show novelty preferences for simpler stimuli or overlearned stimuli, and to show familiarity preferences for items that they are still learning or which are personally important (Houston-Price and Nakai 2004; Wetherford and Cohen 1973).

Further studies could examine what factors predict a familiarity or novelty bias in dogs and how the dogs' results compare to similar studies in the infant literature. This could allow for better design of dog and infant studies and allow for a better understanding of when familiarity and novelty biases occur.

To demonstrate a preference for one language over another, dogs must utilize linguistic cues, like the phonology or prosody of a language, to differentiate them. While dogs successfully discriminated between English and Spanish, it is unclear what cues the dogs are using to tell the two languages apart. Spanish and English are languages that differ in both prosodic rhythm as well as phonology. Infants can distinguish between languages that differ in rhythm from birth, but not languages from within the same rhythmic class; for example, they can distinguish between English and Japanese, but not English and Dutch (Nazzi et al. 1998). It is important to note that these studies with infants, as well as the prior study with dogs, have focused on ADS. At approximately 4 months, infants utilize phonological cues to distinguish between languages in the same rhythmic class (Bosch and Sebastián-Gallés 1997). This difference in age suggests that human infants find prosodic cues more salient than phonological cues. Cotton top tamarins can only discriminate between languages in different rhythmic classes, but not the same rhythm class, which is the same pattern as that seen in younger infants (Tincoff et al. 2005). This supports the notion that prosodic cues may be particularly salient acoustically; if so, we might expect that these cues are also being used by dogs in the current study. However, the tamarins did not have natural, prolonged exposure to a language; they were instead tested with a habituation–dishabituation paradigm. It is unknown whether increased language exposure could alter the cues that animals use to discriminate between languages. This could be tested in the future by examining whether dogs would likewise show a listening preference when the familiar and unfamiliar language differed in phonological properties but not rhythmic ones. For example, German and English are in the same stress-timed rhythmic class, but there are many sounds in German and English that are unique to one of the languages, like the German /ü/ or the English /əʊ/. It is possible that dogs learning one of these two languages could use the difference between sounds to differentiate between the languages and show a novelty preference.

Finally, we did not see any difference between DDS and ADS—neither in terms of an overall preference, nor in terms of an interaction with language. This is in line with some prior studies demonstrating that adult dogs do not show a preference for DDS, while puppies do (Ben-Aderet et al. 2017). Looking at the language preference in the two types of speech separately, we found that the preference for the novel language was present in both DDS and ADS speech. This suggests that the cues that dogs are using to differentiate the speech are present in both DDS and ADS, or that this preference is not driven solely by speech directed to the dogs directly.

In sum, we found that dogs can discriminate between Spanish and English, and that their language preference depends on their language experience. However, Spanish and English differ in both phonology and rhythm, so it is unclear what cue dogs could be using to tell the languages apart. Future studies can further explore the types of cues that dogs can use to differentiate between languages, and how their language experience affects their cue usage. This study is a first step towards understanding the role of language experience in language discrimination in a non-human species.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10071-022-01683-9.

Declarations

Conflict of interest Amritha Mallikarjun, Emily Shroads, and Rochelle S. Newman all declare that they have no conflict of interest.

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