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Title:

Animacy perception in dogs (*Canis Familiaris*) and humans (*Homo Sapiens*): comparison may be perturbed by inherent differences in looking patterns

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Abstract

Perceptual animacy is the tendency for observers to represent inanimate objects as animate, based on simple motion cues. Several features of the chasing pattern can elicit animacy perception and, similarly to adult humans, dogs perceive dots showing this pattern as animate. Here, we used moving objects with a heading alignment (isosceles triangles) to investigate whether human and dog behavior continues to show similarities following such slight, but important change in the pattern. We hypothesized that a heading alignment would facilitate animacy perception in both species in a similar manner. We displayed chasing and non-chasing (independent) motions side-by-side on a screen, in two subsequent trials (Trial 1 and 2). Looking duration at each pattern as well as frequency of gaze shifting between the patterns was measured. Humans looked at the independent motion for longer already during Trial 1; however, dogs looked at this pattern longer only during Trial 2, whereas during Trial 1, their looking time increased towards the chasing pattern. Gaze shifting was observed in humans more often in both trials than in dogs. Although ultimate preference for the independent motion suggests rapid perception of the chasing pattern directing gaze in both species toward the "unrecognized" pattern, there was an initial inter-species difference. We suggest that different behavior across humans and dogs could be explained by ecological differences, although the role of differences in visual strategies, irrespective of perception of *animacy,* cannot be excluded.

Keywords: animacy perception; social perception; chasing; comparative perception; vision.

Animacy perception is conceptualized as the tendency for observers to perceive inanimate objects as animate, based on simple motion cues, such as changing speed and direction (e.g. Gao et al., 2009; Scholl & Tremoulet, 2000; Tremoulet & Feldman, 2000). This phenomenon has mainly been investigated in humans, but newly-hatched chicks (*Gallus gallus*) and dogs (*Canis familiaris*) are also sensitive to such cues (e.g. Abdai et al., 2017; Mascalzoni et al., 2010; Rosa-Salva et al., 2016). Prior findings further indicate that pigeons (*Columba livia*) discriminate between displays of apparent motion exhibited by dots, relying on assessment of relative motion of objects (coherent vs incoherent) (e.g. Jitsumori et al., 2013).

In a previous study, we presented dogs and adult humans with simultaneous displays of chasing and independent motion exhibited by two dots (Abdai et al., 2017). We hypothesized that if the motion was perceived as a chasing interaction (dependent motion), subjects would shift their gaze more frequently toward the independent pattern, either due to habituation to the familiar chasing motion or to greater interest in the independent, "unrecognized" pattern (see also Rochat et al., 1997). Dogs divided their looking time between chasing-like and independent motion patterns similarly to adult humans (Abdai et al., 2017), by showing equal initial attention to both patterns and favoring the independent pattern later. Detailed analysis also revealed that both species increasingly favored to look at the chasing pattern even within the first trial, although not reaching overall preference during the trial. These changes in visual attention were in line with those reported by Rochat et al. (1997) in five-month-old human infants and adults, who considered these shifts as indicating sensitivity to the specific movement information, animacy in our case. Accordingly, we interpreted our results as indicating that dogs, similarly to humans, perceive animacy based on simple motion cues (Abdai et al., 2017).

Changes in the characteristics of the chasing pattern influence human animacy perception. Whereas some of these facilitate the perception of the pattern (e.g. chaser moving directly toward the chasee; Gao et al., 2009), others impair the detection of the object as animate (e.g. interruption of chasing pattern with random motions; Gao & Scholl, 2011). Heading alignment, that is, when the main axis of objects is always aligned with the direction of their motion, is an important cue to animacy, perhaps due to the constraints by the bilateral body-structure on the motion. The anteroposterior axis defines several aspects of the behavior, thus spontaneous encoding of the axis of an agent is advantageous, for example in foraging (e.g. attacking the head of the prey), communication (e.g. accumulation of perceptual organs toward the anterior end) or predicting future behavior (e.g. motion direction) (Hernik et al., 2014; Morikawa, 1999; Rosa-Salva et al., 2018).

Recent findings indicate that human and non-human species might be sensitive to heading alignment (Ewert et al., 1983; Gao et al., 2009; Hernik et al., 2014; Morikawa, 1999; Rosa-Salva et al., 2018; Tremoulet & Feldman, 2000). Adult humans consider moving objects maintaining heading alignment more likely to be animate, than objects without heading alignment (Tremoulet & Feldman, 2000). Also in adult humans, this aspect of motion facilitates perception of a chaser agent, compared to cases when the axis of the object and its motion are uncorrelated or when the principal axis of the object is always perpendicular to its motion direction (Gao et al., 2009). Human infants at six months of age already show the spontaneous encoding of the anteroposterior axis of a moving object in a short, chasing-like scenario (Hernik et al., 2014). Regarding non-human species, Ewert et al. (1983) described that toads (*Bufo*) and *Periophthalmus koelreuteri* prefer when the main axis is aligned with the motion direction, compared to when it is oriented perpendicular to the direction of movement. Visually naïve chicks also show preference toward a moving object with heading alignment over objects without it (Rosa-Salva et al., 2018). Based on these findings, heading alignment alone seems to be an important cue for animacy detection across many species, though we only have limited information on this in non-human species.

Although in our earlier study dogs resembled humans in overall pattern of visual attention to chasing vs. to independent displays (Abdai et al., 2017), it remained unclear whether the same spatiotemporal and physical features (e.g. shape) drove this behavior in both species. In the current study the same method was applied as previously in (Abdai et al., 2017); however, isosceles triangles were used as moving objects instead of dots. The main axis of the triangles was always aligned with the direction of their motion, equipping the moving objects with heading alignment that has been shown to facilitate animacy perception (e.g. Gao et al., 2009; Rosa-Salva et al., 2018; Tremoulet & Feldman, 2000).

We hypothesized that using heading alignment facilitates animacy perception both in dogs and adult humans, and we expected that the more rapid perception of animate motion would shift subjects' attention to the independent motion pattern earlier, i.e. subjects' looking time would gradually increase toward the independent motion from the beginning of the test (cf. Abdai et al., 2017).

Methods
Ethics
Dogs
Ethical approval was obtained from the National Animal Experimentation Ethics Committee (PEI/001/1492-4/2015). Owners provided written consent indicating voluntarily allowing their dogs to participate in the study.

Humans
Ethical approval was obtained from the Institutional Psychological Ethics in Research Committee (EPKEB-2017/13). Participants (all of legal age) provided written consent indicating voluntarily participation in the study.

Subjects
Testing was conducted with 53 dogs and 32 university students; of these, data were analyzed for 30 dogs (different breeds; 15 females; *mean age* = 4.1 years, *SD* = 2.8) and 30 students (22 women; *mean age* = 21.7 years, *SD* = 1.2). Twelve dogs were excluded because they looked at the stimuli for less than 1 s in either trial, seven because their faces were not captured by the camera for the entire duration of the trials (conceptualized as >3 s in either trial; non-capture duration for excluded dogs: Trial 1, *mean* = 5.74 s, *SD* = 3.57; Trial 2, mean = 7.27 s, *SD* = 2.96; *min* = 3.8 s, *max* = 10.0 s), and four due to technical problems with the recording system. Two human participants were excluded because of poor quality of the recording.

Apparatus
Participants were tested at the Department of Ethology, Eötvös Loránd University, in a 5.2 m x 3 m testing room. Trials were recorded by two cameras; one was a 25 frame/s (fps) zero lux camera (Panasonic NV-DS28), appropriate for recording in low light density. This camera was mounted on a compact tripod placed before the screen, equidistant from its sides and was focused on the face of subjects. Infrared LEDs placed next to the camera were directed toward the subjects to improve eye visibility. The second camera was a synchronized camera mounted on the ceiling, behind subjects and was focused on the video displays. The projector was also mounted on the ceiling behind subjects. Audio was displayed by two speakers centered behind the screen to avoid possible asymmetric cues.

Procedure

Subjects sat on the ground, 2.8 m away from the stimulus-projecting screen (Figure 1). Owners sat on a chair and held the dog in front of them, by a collar or its chest. Owners were instructed to look towards the ground during the test, to avoid unintended human influence (Pfungst, 1911). Human participants sat on a pillow that was placed on the floor before they entered the testing room, so that the height of their eyes was closer to the height of the dogs' eyes. The experimenter adjusted the focus of the zero lux camera to capture subjects' face and turned off the lights in the room. The experimenter left the room and started the video from outside. We repeated 10 s long stimuli to subjects twice in a row (Trial 1 and 2) by using a video that consisted of the following: (1) 2.32 s long audiovisual attention grabber directing subjects' attention to the center of the screen, (2) 10 s stimulus, (3) 3 s long black screen, (4) 2.32 s long audiovisual attention grabber, and (5) 10 s stimulus. All subjects saw one unique video, and we used the same set of stimuli (overall 30 unique videos) for dogs and humans. Videos displayed to excluded subjects were used again later for new subjects. The study thus included 30 videos for 30 dogs and 30 human participants (see supplemental materials for an example video).

Stimuli were dependent (henceforth 'chasing') and independent movement patterns of two white isosceles triangles presented side-by-side, over a plain black background separated by a white vertical line. Videos were generated by the ChasingDots program (Abdai et al., 2017). Independent patterns were compiled from two chasing patterns selected randomly; from one of them the program used the chaser, and from the other, the chasee. Thus, the dynamics of the chasing and independent patterns were the same. The sides of the chasing and independent patterns were counterbalanced between trials and subjects. See supplemental materials for further details.

Data analyses

All tests were recorded and subjects' behavior was analyzed with Solomon Coder 17.03.22 (developed by András Péter: http://solomoncoder.com). All videos were coded frame by frame (25 frames per second); for each frame, gaze direction (independent, dependent, away) was determined. Looking duration (at the patterns) was coded based on eye movements. Looking duration was normally distributed in both species (see supplemental material). Inter-coder reliabilities on random subsamples (20% of dog and 20% of human recordings) indicated acceptable reliability (mean ± *SD* Cohen's kappa for dog recordings: 0.820 ± 0.082; human recordings: 0.789 ± 0.149; see supplemental material).

Generalized Linear Mixed Model were used (GLMM; adjusted with sequential Sidak) in IBM SPSS 22 to estimate the fixed effect of motion pattern, trial and species (three-way interactions) on looking duration. Subject was included as a random effect variable to control for within-subject comparison across trials. Contrast estimates (β ± SE) are reported for significant explanatory variables.

Looking-time curves were created for dogs and humans separately for each trial, to investigate within-trial dynamics of looking. The relative proportions of time spent looking at the chasing and at the independent stimuli were calculated for every three consecutive frames, to represent a single point. As at the onset of the trials neither dogs nor humans looked at the stimuli, data points preceding their looking at the stimulus with looking proportions <80% of their respective averages were disregarded in the analyses. Linear regression was applied to the data to capture overall trends and estimate slopes (β ± SE).

Frequency of gaze shifts between patterns (irrespective of delays in between) were counted. AIC values indicated the Poisson distribution fit the data best, thus loglinear GLMM was used for analyses (*AIC* = 175.386; model with the lowest AIC value was kept, a model was

considered better whenever ΔAIC was ≥2). For significant explanatory variables, contrast estimates ($\beta \pm$ SE) are provided.

Results

Significant three-way interaction was found between species, trial and pattern (linear GLMM of looking duration: Species x Trial x Pattern, $F(1, 232) = 6.418$, $p = .012$). In Trial 1, dogs looked longer at the chasing, whereas in Trial 2, they looked longer at the independent pattern (Dogs, Chasing vs Independent: Trial 1, $F(1, 232) = 4.604$, $\beta = 0.952$, $SE = 0.444$, $p = .033$; Trial 2, $F(1, 232) = 20.457$, $\beta = -2.007$, $SE = 0.444$, $p < .001$). Humans looked marginally significantly longer at the independent pattern in Trial 1, but looked at it longer in Trial 2 (Humans, Chasing vs Independent: Trial 1, $F(1, 232) = 3.642$, $\beta = -0.847$, SE = 0.444, $p = .058$; Trial 2, $F(1, 232) = 12.231$, $\beta = -1.557$, $SE = 0.444$, $p = .001$). In Trial 1, humans looked longer at the independent pattern than dogs (Independent pattern, Dogs vs Humans: Trial 1: $F(1, 232) = 7.778$, $\beta = -1.237$, $SE = 0.444$, $p = .006$), and in Trial 2, humans looked longer at the chasing pattern than dogs (Chasing pattern, Dogs vs Humans: Trial 2: $F(1, 232) = 6.028$, $\beta = -1.089$, $SE = 0.444$, $p = .015$). However, significant difference was not found between species in Trial 1 regarding the chasing (Chasing pattern, Dogs vs Humans: Trial 1: $F(1, 232) = 1.601$, $p = .207$), or in Trial 2 regarding the independent pattern (Independent pattern, Dogs vs Humans: Trial 2: $F(1, 232) = 2.081$, $p = .151$). Although in humans difference was not found between trials in looking at either of the patterns (Humans, Trial 1 vs 2: Chasing pattern, $F(1, 232) = 0.966$, $p = .327$; Independent pattern, $F(1, 232) = 0.383$, $p = .536$), dogs looked at the chasing pattern less in Trial 2 than in Trial 1 (Dogs, Trial 1 vs 2: Chasing pattern, $F(1, 232) = 22.120$, $\beta = 2.087$, $SE = 0.444$, $p < .001$; Independent pattern, $F(1, 232) = 3.863$, $\beta = -0.872$, $SE = 0.444$, $p = .051$) (see Figure 2 and Table S2 in the supplemental material).

Within-trial dynamics of looking at stimuli

Dogs' looking increased toward the chasing pattern during Trial 1, while it decreased toward the independent motion (Dogs, Trial 1: Chasing, $\beta = 0.012$, $SE = 0.002$, $p < .001$; Independent, $\beta = 0.009$, $SE = 0.002$, $p < .001$; Figure 3a). Dogs' decreased attention toward the stimuli in Trial 2 (see supplemental material) was driven by decreased looking at the chasing pattern, while their looking at the independent pattern did not change (Dogs, Trial 2: Chasing, $\beta = -0.011$, $SE = 0.002$, $p < .001$; Independent, $\beta = 0.003$, $SE = 0.002$, $p = .154$; Figure 3a). Human participants' looking time decreased toward the chasing, while increased toward the independent pattern during Trial 1 (Humans, Trial 1: Chasing, $\beta = 0.017$, $SE = 0.004$, $p < .001$; Independent, $\beta = 0.025$, $SE = 0.004$, $p < .001$; Figure 3b). In Trial 2 there was no change in the dynamic of humans' looking at either of the patterns (Humans, Trial 2: Chasing, $\beta = 0.003$, $SE = 0.002$, $p = .238$; Independent, $\beta = -0.005$, $SE = 0.003$, $p = .130$; Figure 3b).

Alternation of looking between patterns

There was a two-way species by trial interaction effect on frequency of between-pattern gaze alternation (loglinear GLMM: Species x Trial, $F(1, 116) = 4.077$, $p = .046$). Humans shifted gaze more often than dogs, in both trials (Dogs vs Humans: Trial 1, $F(1, 116) = 18.073$, $\beta = 3.389$, $SE = 0.797$, $p < .001$; Trial 2, $F(1, 116) = 35.378$, $\beta = 4.135$, $SE = 0.695$, $p < .001$). Dogs exhibited more frequent gaze alternation in Trial 1 than in Trial 2 (Trial 1 vs 2: Dogs, $F(1, 116) = 10.609$, $\beta = 1.597$, $SE = 0.490$, $p = .001$). In humans, there was no difference in this regard between trials (Trial 1 vs 2: Humans, $F(1, 116) = 1.502$, $p = .223$) (see also Table S3 in the supplemental material).

Discussion

Consistent with earlier findings (Abdai et al., 2017), spontaneous recognition of the chasing pattern increased attention toward the independent pattern in both species, suggesting

animacy perception. As predicted, humans exhibited gradual increases in looking duration toward the independent pattern already in Trial 1 (suggesting more rapid perception of the chasing pattern). Dogs, however, looked preferentially at the chasing pattern throughout Trial 1 in contrast to Abdai et al. (2017) where dogs did not show a marked preference toward either pattern. Thus both species are sensitive to changes in the shape of moving objects and/or to the heading alignment in the movement of such objects, but dog and human looking patterns show different dynamics. In what follows, we propose ecological and sensory explanations that may point to different causal factors, the roles of which may be warranted to clarify in future behavioral experiments.

Ecological differences between species can affect how they process environmental information. For example, chimpanzees, relying on shorter fixations, scan naturalistic scenes faster than humans, but the location of such fixations are similar across these species (Kano & Tomonaga, 2011). It was suggested that as the dense forests that are the natural habitat of chimpanzees have low predictability, these animals have to employ rapid visual scanning to efficiently detect other individuals. Analogously, one could argue that dogs, being a predator species, are highly sensitive to chasing motion (cf. sign stimulus), which might control their initial looking preference and result in an extended interest in this pattern. In contrast, in humans, rapid perception of chasing led to faster habituation to this pattern and they turned their look toward the "unrecognized" independent pattern.

Dogs have good peripheral vision along a horizontal plane (approx. 250°), supported by the horizontally elongated visual streak consisting of relatively large amounts of ganglion cells in the retina (McGreevy et al., 2004; Peichl, 1992). In contrast, humans have a narrower visual field (approx. 180°) and use the fovea for focused vision. Therefore, dogs are able to perceive motions in a wider visual field, whereas humans have to change the focus of the eye frequently for active exploration of their environment (Hoppe & Rothkopf, 2016). It has been found that humans rapidly adjust the temporal eye movement to the regularity of changes in the surrounding (Hoppe & Rothkopf, 2016). Taken together, this suggests that humans switch more frequently between the two patterns, and thus they have a greater chance to get drawn into looking at the "unrecognized" independent pattern. In contrast, dogs may have been able to look at both patterns without the need to alter the orientation of their gaze.

Interestingly, three-month-old human infants, relative to older human children, behave more similarly to dogs. Rochat et al. (1997) reported that three-month-olds, relative to five-month-old human infants, alternate more often between looking at chasing and independent patterns, potentially reflecting more frequent comparison of the stimuli. However, these between-group differences may also be explained by visual stimulus processing differences. For example, Helo et al. (2016) found that duration of fixation on visual scenes decreases from three to twelve months of age in infants (see also Colombo & Mitchell, 2009). Longer fixation duration has been explained by the speed with which visual stimuli are processed in a perceptual-cognitive task (e.g. Colombo et al., 1991). It also cannot be excluded that younger infants may be more sensitive to the sign stimulus aspect of the coherent pattern (cf. chasing).

Regarding the behavioral difference of chimpanzees and humans, Kano & Tomonaga (2011) also suggested that the different processing of the retrieved information in the two species might account for their results. The heading alignment, which is an important cue for animacy may have increased the complexity of the motion (qualitatively or quantitatively) that could also have led to differences in the processing of the stimuli used in this experiment.

Thus, we suggest that basic differences in the visual system and visual strategies of animals should be taken into account in future comparative studies on visual perception of moving patterns. These aspects can lead to different behavior in species irrespective of the perception of animacy *per se*. Findings of this study may lead to novel directions in the research

on animacy perception. For example, it has been suggested that animacy perception has a specialized processing in the visual system (for further details see Scholl & Gao, 2013).

Throughout this paper, we use the term *animacy* instead of *agency* as the latter implies goal-directedness in the agent (e.g. Blakemore et al., 2003; Luo et al., 2009; Rosa-Salva et al., 2016). Although the chasing pattern has often been interpreted as a visual display of goal-directed motion, it would have been difficult to determine in the context of the current design, whether looking behavior was influenced by the goal-directedness, or by other characteristic(s) of motion (e.g. correlation in the motion of the objects). Rosa-Salva et al. (2018) also discussed that heading alignment alone could be a cue for agency, or a constraint on motion by the bilateral body-structure that is linked to animacy. Heading alignment and other animacy-related motion cues together may lead to *agency* attribution; however, considering the uncertainty of how specific cues and their combination affect the attribution of animacy or agency to moving objects, we do not want to argue that our chasing stimuli convey the former or the latter.

In summary, dogs and humans both exhibit evidence of animacy perception, and changes in motion (or shape) similarly influence their behavior. Yet, it is not possible to determine whether the across-species difference found in the present study, i.e., initial preference for gazing at the chasing pattern in dogs, and at the independent motion in humans, relates to animacy perception and thus reflects ecological differences between dogs and humans, or is the result of visual strategy differences between two to species. Accordingly, we suggest that factors beyond motion parameters (e.g. differences in looking strategies) should be taken into account in comparative studies on animacy perception.

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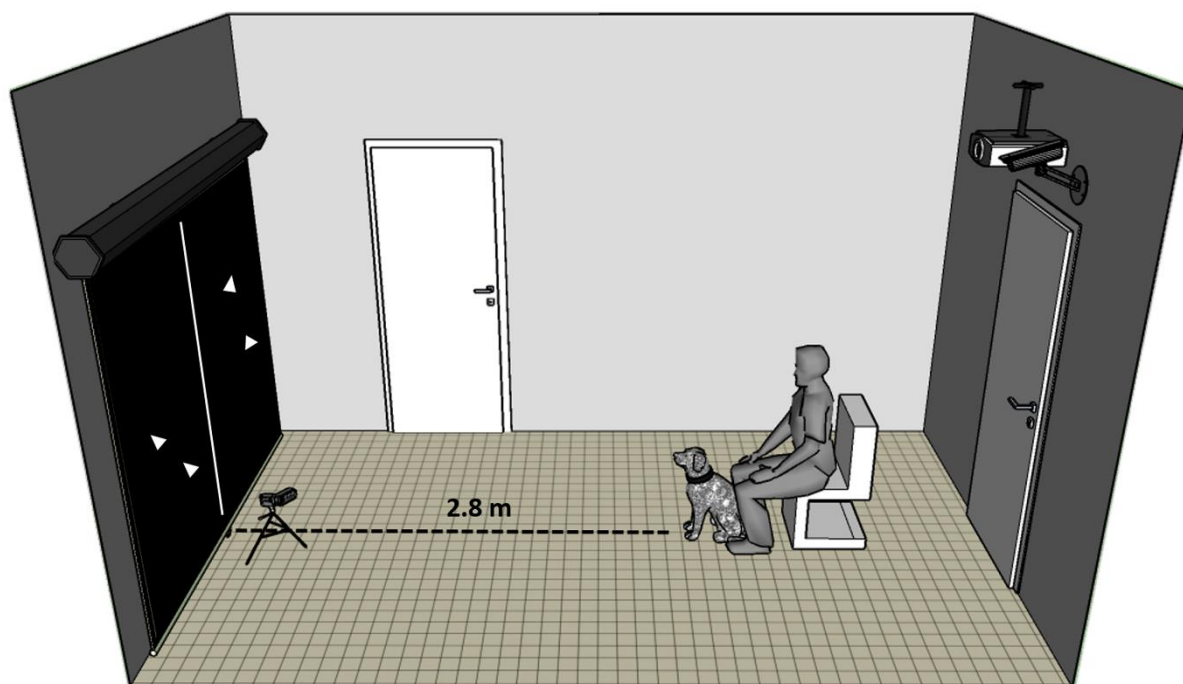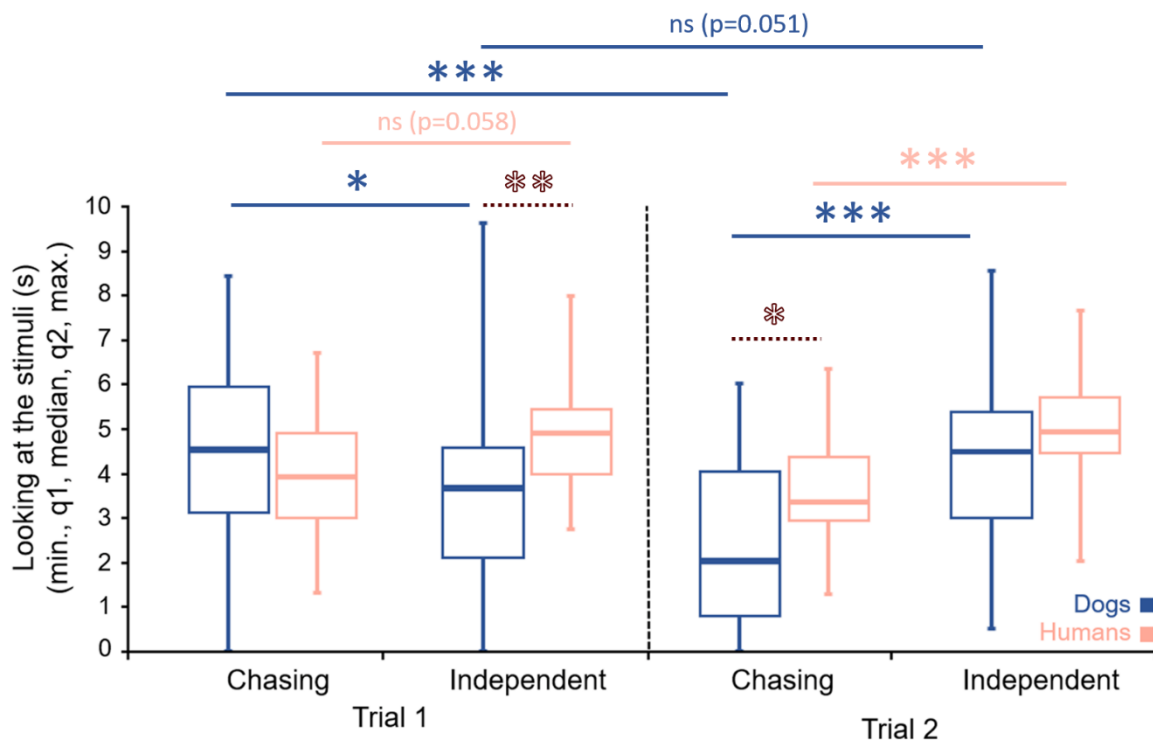
Figure 1

*Experimental Set-up.*

Figure 2

Median Duration of Looking at the Chasing and Independent Patterns.

Note. Median duration of looking at the chasing and independent patterns in Trial 1 and 2 by dogs (blue/ dark grey) and humans (pink/ light grey) (minimum, first quartile, median, third quartile, maximum). ns – non-significant, * $p < .05$, ** $p < .01$, *** $p < .001$; blue/ dark grey lines indicate within-subject differences in dogs, pink/ light grey lines indicate within-subject differences in humans, and dashed lines indicate between-species differences.

Figure 3

Proportions of Looking at the Chasing and the Independent Stimuli in (a) Dogs and (b) Humans.
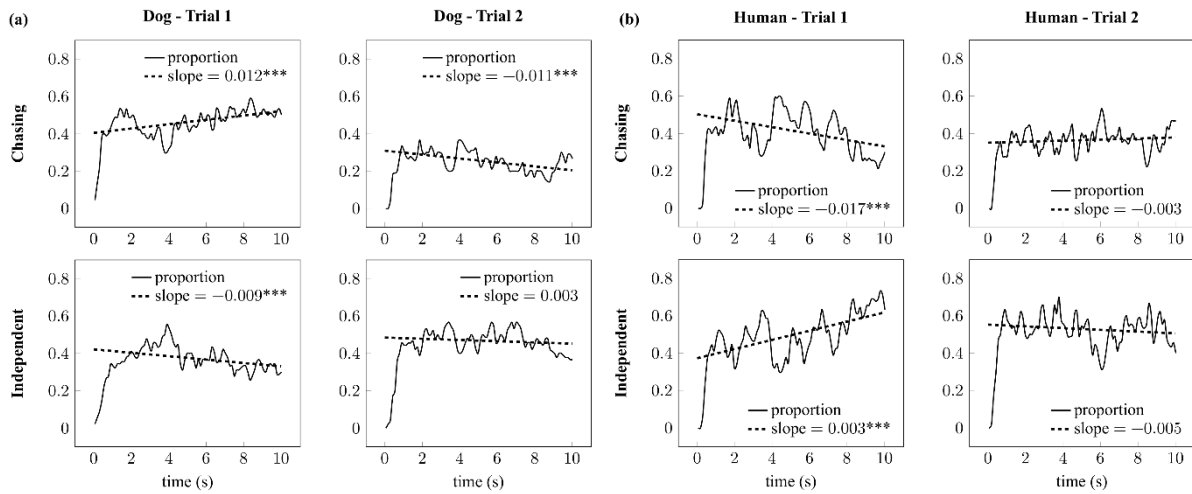
Note. Regression lines were fitted using data after the proportion values reached the 80% threshold computed from the average proportion of looking time at stimuli during the trial for the subject (see supplemental material). *** $p < .001$