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Visual Illusion Susceptibility in Dogs using the Ebbinghaus-Titchener Illusion in a Spontaneous Choice Task

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by

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Abstract

In recent years, dogs have been a popular test subject when studying visual illusion susceptibility. Multiple studies have investigated whether animals perceive illusions as humans do, but few studies have evaluated dogs' perception of illusory stimuli. In this thesis, we studied if dogs are visually susceptible to the Ebbinghaus-Titchener illusion when presented in a spontaneous choice task. Subjects were presented two visual images on a board, which had bologna pieces embedded in the stimuli. In control trials, two different sized bologna pieces were placed in the center of the images. In these control conditions, dogs were expected to choose the larger piece of bologna. In test trials, two identical sized bologna pieces were placed in the in the images. If dogs perceive the illusion the way humans do, they were expected to choose the "larger" appearing piece of bologna, which was surrounded by smaller inducer circles. Dogs selected the larger stimulus significantly above chance levels when presented with Control A, however they performed at chance when selecting between the differently sized stimuli in Control B. When presented with the illusion condition, dogs performed at chance indicating null susceptibility of the illusion. These findings suggest that dogs are not susceptible to the Ebbinghaus-Titchener illusion in a spontaneous choice task, contrary to previously observed findings in a training-based paradigm. However, the slightly above chance performance in Control A and at chance performance observed in Control B suggest these results should be interpreted with caution. Additional research should evaluate the suitability of the spontaneous-choice paradigm when evaluating dog illusion susceptibility.

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Are Dogs Visually Susceptible to the Ebbinghaus-Titchener Illusion in a Spontaneous Choice Task?

Dogs play a significant role within human society as companion animals, service dogs, guide dogs, police dogs, and more. Dogs also represent the most morphologically diverse species on the planet, with over 300 recognized dog breeds and even more mixed breeds (Fédération Cynologique Internationale, 2018). As dogs are becoming more than household pets within our society, it is imperative that we understand the way they perceive things such as objects and sizes, in order to properly train and cohabitate with them. Therefore, a better understanding of how dogs see the world can increase our understanding of canine learning, effective training methods, and structure the way dogs behave in our society, as well as improve their relationship with their owner in the home.

The domestic dog (*Canis lupus familiaris*) has recently become a popular test subject for canine cognition tasks (Bensky et al., 2013). There has been a surge of published research on dog cognition over the last 20 years, largely driven by the recent interest in canine social cognition (Bensky et al., 2013). The majority of the experimental tasks, approximately 74%, are conducted using visual stimuli, an astounding number given there are few empirical assessments of canine visual perception and visual processing (Miller & Murphy, 1995; Byosiere, 2018). Dog vision and visual processing of information is an understudied area of research, and there is still much to learn about how dogs perceive their external environment.

One way to evaluate perception in dogs, is to evaluate misperception to visual illusions. However, before evaluating visual illusion susceptibility, it is important to understand canine visual perception to optimally design and evaluate the suitability of visual experimental stimuli. A foundational understanding about the neurobiological process of dog’s visual perception is available (Miller & Murphy, 1995; Byosiere, 2018). These reports suggest the retina of the dog is largely composed of rod photoreceptor cells, which are extremely helpful in dim light, as they function in less intense light conditions (Kemp & Jacobson, 1992). Moreover, research suggests dogs process figures and objects at a global level, much like humans, meaning that they interpret an object as a whole, and not by its individual parts (Mongillo et al., 2016; but see Byosiere et. al, 2017). Specifically, global level processing is the act of processing a visual stimulus holistically. Taken together, these findings suggest that there are similarities and differences between how humans and dogs may view their environment.

Morphological variation in dogs, and potential breed differences in visual perception, is another factor that may skew results in a visual susceptibility test. Although dogs represent one species, different breeds have different evolutionary traits and adaptations, which can show us that one type of dog breed might see things in a variety of ways differently than other dog breeds (Boyko et al., 2010). These variations might affect depth perception, distance perception, color perception, visual acuity, as well as the ability to see in dim light (Lind et al., 2017). For instance, brachycephalic dog breeds, such as Pugs or Bulldogs, have an eye position that is often more laterally directed than in dolichocephalic breeds, such as the German Shepherd or Poodle. Ultimately, brachycephalic dogs have less binocular overlap than dolichocephalic dogs because they are more flat-faced, therefore, they are not able to see as much of what is around them (Helton et al., 2010). On the other hand, brachycephalic dogs have trouble with seeing what is next to them (peripheral vision) as their eyes are sunk into their faces, whereas dolichocephalic breeds have their eyes closer to the outer edges of their face allowing them to see more of the environment around them. There are also mesocephalic dog breeds, such as the Golden Retriever or Border Collie, whose eye placement falls in the middle of the two extremes (Helton et al., 2010). Due to the immense morphological within species diversity, it is challenging to assess breed differences in vision.

The concept of visual perception of geometric illusions is a topic of interest in psychology, animal neuroscience, and biology. Geometric illusions allow us to investigate how the perceptual systems of different species integrate local stimulus features within global stimulus information (Sovrano et al., 2014). Animal susceptibility to geometric illusions can tell us more about the way they see their environment and how it relates or differs from the way we see our environment. Through a series of complex transformations, the input to the retina is converted into rich visual perceptions that constitute an integral part of visual recognition (Blumberg & Kreiman, 2010). A visual illusion occurs when the brain misrepresents physical reality, adapting reality based off of preconceptions rather than accurately processing retinal information (Gregory, 2015). This retinal information "tricks" the brain into visually revising an image when a revision is not necessary. The mechanism underlying this process applies this correction automatically, meaning that humans and possibly other animals cannot stop themselves from falling susceptible to illusory effects (Pylyshyn, 1999).

Visual illusions have been found to occur in both human and non-human species. In fact, recent research suggests illusion susceptibility is more prevalent in nonhuman animals than previously thought (Kelley & Kelley, 2014). In the animal world, illusion susceptibility can be advantageous for survival, mating, and food competition. For example, a study of fiddler crabs (*Uca mjoebergi*) found that the females choose their mate based on their perception of males' claw length (Callander, Jennions, & Backwell, 2011). Other studies have evaluated illusory motion in rhesus monkeys and in cats (Agrillo, Gori, & Beran, 2015). There has also been research with the Ponzo illusion in pigeons and primates (Fujita, 1997; Fujita, Blough, &

Blough, 1991), as well as the corridor illusion in baboons (Barbet & Fagot, 2002). However, the results across these many studies are mixed and inconsistent. Some results show the species' responses to visual illusions are parallel to those of humans, but other results show the opposite or null susceptibility. The mixed results from previous studies indicate that this area of research requires further insight.

The Ebbinghaus-Titchener illusion, a well-studied illusion in humans, is known as a size distorting visual geometric illusion (Jaeger & Klahs, 2015; Todorovic & Jovanovic, 2018). This illusion consists of two circles of equal size, but perceptually one looks larger (Figure 1). A center circle (orange), often labelled a target, is surrounded by smaller circles, also known as inducers. The other center circle is surrounded by large inducers. When presented in tandem, the center circle surrounded by smaller inducers appears larger to humans (Takao et. al, 2019).

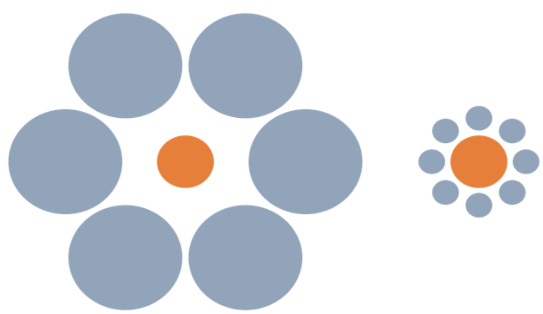


Figure 1. The Ebbinghaus-Titchener illusion. This Photo by Unknown Author is licensed under CC BY-SA

There are many theories that explain how and why humans are susceptible to this illusion. The inappropriate constancy scaling theory (Gregory, 1963) states that the inducer circles surrounding the target are perceived as depth cues, where none exist. Depth cues are the reason we can see a 3D image on a flat surface, for example. This results in the two target circles being perceived at different distances, and therefore as different sizes. The contour interaction theory (Jaeger, 1978) states that the inducer circle contours that are close to the target perceptually attract, while the contours of inducer targets that are further away perceptually repel. This results in the target stimuli being perceived as different sizes, when they are actually the same size. Assimilation theory (Pressey, 1971) states that the inducer circles are grouped with their respective target circle, perceptually rescaling the target circles to be more like the inducers. The angular size contrast theory (McCready, 1985) states that the eye position is altered by depth cues, causing misperception of the apparent distance of the inducer circles, making the target appear different in size. The size contrast theory (Coren & Enns, 1993) states that the inducer circles are viewed as a standard and the target size is misperceived in relation by comparison. The small inducers result in an overestimation of the target, while the large inducers cause an underestimation of the target (Fujita, 2004). While these theories explain human visual perception to the Ebbinghaus-Titchener illusion, it is unknown if these theories apply to non-human animals' visual perception, or which theory is more accurate.

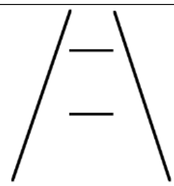
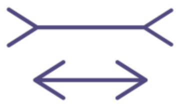
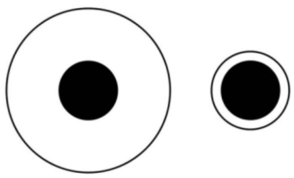
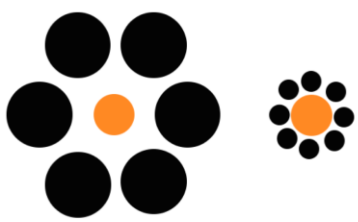
Researchers have investigated how different animals perceive the Ebbinghaus-Titchener illusion, with varying results. Baboons and the gray bamboo shark were found to have no susceptibility to the Ebbinghaus-Titchener illusion (Parron & Fagot, 2007) (Fuss et al., 2014). Homing pigeons and bantam chickens were found to have reversed susceptibility to the Ebbinghaus-Titchener illusion, which means these animals perceived the circle surrounded by small inducers as larger than the circle surrounded by big inducers. (Nakamura, Watanabe & Fujita, 2008) (Nakamura, Watanabe & Fujita, 2014). The bottle-nose dolphin (Murayama, Usui, Takeda, Kato & Maejima, 2012), the redtail splitfin fish (Sovrano, Albertazzi & Salva, 2014), and the Teleost damselfish (Fuss et al., 2014) were all found to have susceptibility similar to humans to the Ebbinghaus-Titchener illusion. Taken together, these results suggest that different species may use differently perceptual processing mechanisms to interpret stimuli in their environments (Kelley & Kelley, 2014).

To date, there have been multiple studies assessing visual illusion susceptibility in dogs, generally employing two different types of methodological paradigms (Table 1). Using training-based paradigms, in which dogs are trained to select the larger between two stimuli, researchers have evaluated canine susceptibility to the Ebbinghaus, Delboeuf, Ponzo, and Müller Lyer illusions. The Delboeuf illusion has been studied in dogs using a spontaneous choice paradigm, and no susceptibility was found (Petrazzini et. al, 2016). The Ebbinghaus-Titchener illusion has been previously studied with dogs using a trained two-choice discrimination procedure (Byosiere, Feng, Woodhead, et al., 2017). This study reported that dogs had reverse susceptibility to the Ebbinghaus-Titchener illusion. Visual illusion susceptibility of dogs using the Ebbinghaus-Titchener illusion should be studied to further investigate how dogs see the world around them. Evaluating 6 illusory contexts, Byosiere et. al (2017) and Byosiere et. al (2018), found little evidence to suggest any type of canine susceptibility to the illusion. More recently, Keep et al. (2018), investigated dog susceptibility to the Müller-Lyer illusion and observed human-like susceptibility.

Table 1

Review of literature and illusion susceptibility observed in dogs

Illusion	Type of paradigm used to assess susceptibility	Type of susceptibility observed	Citation
Ponzo	Trained two choice discrimination	Null	Byosiere, S. E., Feng, L. C., Wuister, J., Chouinard, P. A., Howell, T. J., & Bennett, P. C. (2018). Do dogs demonstrate susceptibility to a vertically presented Ponzo illusion? *Animal*

			*Behavior and Cognition*, *5*(3), 254-267.
Müller-Lyer 	Trained two choice discrimination	Null	Keep, B., Zulch, H. E., & Wilkinson, A. (2018). Truth is in the eye of the beholder: Perception of the Müller-Lyer illusion in dogs. *Learning and Behavior*, *46*, 501-512.
Delboeuf 	Spontaneous Choice	Null	Petrazzini, M. E. M., Bisazza, A., & Agrillo, C. (2016). Do domestic dogs (Canis lupus familiaris) perceive the Delboeuf illusion? *Animal Cognition*, *20*, 427-434.
Ebbinghaus 	Trained two choice discrimination	Reversed	Byosiere, S., Feng, L. C., Woodhead, J. K., Rutter, N. J., Chouinard, P. A., Howell, T. J., & Bennett, P. C. (2017). Visual perception in domestic dogs: Susceptibility to the Ebbinghaus-Titchener and Delboeuf illusions. *Animal Cognition*, *20*, 435-448.

An alternative methodology to training subjects is to investigate illusion susceptibility through spontaneous behavior (Petrazzini et al., 2016). This methodology emphasizes natural behavior and can more easily be conducted across a wide variety of subjects and allows for investigation into whether animals' sensitivity to illusory phenomena reflects a natural perceptual bias of the visual system that affects subjects' behavior in their environment (Petrazzini et. al, 2016). This method, often called a spontaneous choice task, has been conducted in a wide variety of species (Murayama et. al, 2012; Fujita, 1997) but more recently has been applied to dogs. Petrazzini et al. (2016) evaluated canine susceptibility to the Delboeuf illusion, where dogs were presented with a choice between two equal size food quantities on two different size plates. While dogs, as a group, demonstrated above chance performance on controls (a size discrimination task) dogs were not susceptible to the illusion. These findings parallel those observed by Byosiere et al., 2016, in which null susceptibility to the Delboeuf illusion was observed in a training-based paradigm.

Given the generalizability of the spontaneous-choice task, and the parallels observed in the results of canine susceptibility to the Delboeuf illusion when compared to a trained task, additional research is needed to evaluate the suitability of this paradigm. While dogs' visual perception has been investigated through many different illusions, the Ebbinghaus-Titchener illusion represents a unique stimulus in which to do so. First, it is a relatively strong illusion (Nakamura et. al, 2014), and second, its properties are similar to the Delboeuf illusion (Petrazzini et. al, 2016). As null susceptibility to the Delboeuf illusion was observed in both a spontaneous choice task and training-based study (Petrazzini et. al, 2016; Byosiere et. al, 2017), the Ebbinghaus-Titchener, with its stronger illusory effects, could represent an ideal model to evaluate the spontaneous-choice paradigm. Therefore, the aim of this thesis is to further the current understanding of canine illusion susceptibility, by evaluating whether dogs demonstrate susceptibility to the Ebbinghaus-Titchener illusion. More specifically, when dogs are presented with a spontaneous-choice task, do they demonstrate reversed illusion susceptibility, as has been observed in a training-based paradigm (Byosiere et. al, 2018).

Method

The Hunter College Institutional Animal Care and Use Committee (IACUC) approved of the study on December 12, 2018, titled "DR-Dog Percept 11/21".

Participants

31 owned pet dogs were selected through the Thinking Dog Center (TDC) Hunter College database to participate in the study, however only 29 dogs either partially or completely participated in the study.

Owners voluntarily signed up their dogs online at tinyurl.com/thinkingdogcenter, where they submitted basic information about their pet dog. For example, questions included does your dog have any dietary restrictions, etc. Based on their answers and, if the dog was qualified to visit the center (healthy, up to date on vaccinations, safe, people-friendly), they were invited through email to participate in a 1-hour session at the Thinking Dog Center in Midtown, NYC. All dogs were required to eat bologna for the study; however, one subject had a dietary restriction and turkey deli meat was used as a substitute.

Upon arrival at the Center, owners completed a consent form acknowledging their dog's participation in the study. Owners were always welcome to withdraw their dog from participation at any time. At the center, the dogs acclimatized to the space, off-leash, to explore their new surroundings. Multiple toys were scattered throughout the center for the dog to play with and get more comfortable. We provided water and other treats, based on owner's preference. Once dogs were comfortable with the space, they were brought into the testing room.

The sample included 22 Mesocephalic dogs, 7 Brachycephalic dogs, and 0 Dolichocephalic dogs. Facial morphology was determined using an online facial cephalic index. If a dog was mixed, and contained 2 different dog facial types, it was labeled as mesocephalic.

Apparatus

Figure 2. Apparatus used for the study.

The apparatus was a hand-made poster board that was angled upwards 5-7 cm to facilitate ease of viewing. The Ebbinghaus-Titchener illusion can be presented in numerous ways, but since the subjects were dogs, it was important to present it in a way that was best suited for their perception. For example, past studies using the Ebbinghaus-Titchener illusion presented the stimuli on the floor, for dogs to look down at, much like the way they eat food. In an attempt to correctly adjust this presentation for more accurate results, the stimuli were instead propped up directly in front of them. Velcro was placed on the poster board and the back of the laminated illusion printouts to center the stimuli and have each at an equal distance from each other. Bologna pieces were cut using 5.99 cm and 4.97 cm cookie cutters. The specific diameter measurements of 5.99 cm and 4.97 cm have a 40.65% difference, a finding that research by Byosiere (2017) suggests is feasible for dogs and other animals to discriminate.

In the illusion condition, two identical pieces of bologna were used. For this, we used the 5.99 cm piece of bologna within each illusory display.

Measurements

The board was 1.05 m across and 0.51 m in height. The two stimuli, from center to center, were displayed 0.55 m apart. The board was placed 1.52 m from the starting position line, where the dog sat. The owner was placed behind the dog, 1.82 m away. The testing room was 3.40 m wide and 7.54 m long. The left wall of the room was 1.22 m from the board, and the right side of the wall was 1.12 m from the board. Pictured below is a sketch of the testing room.

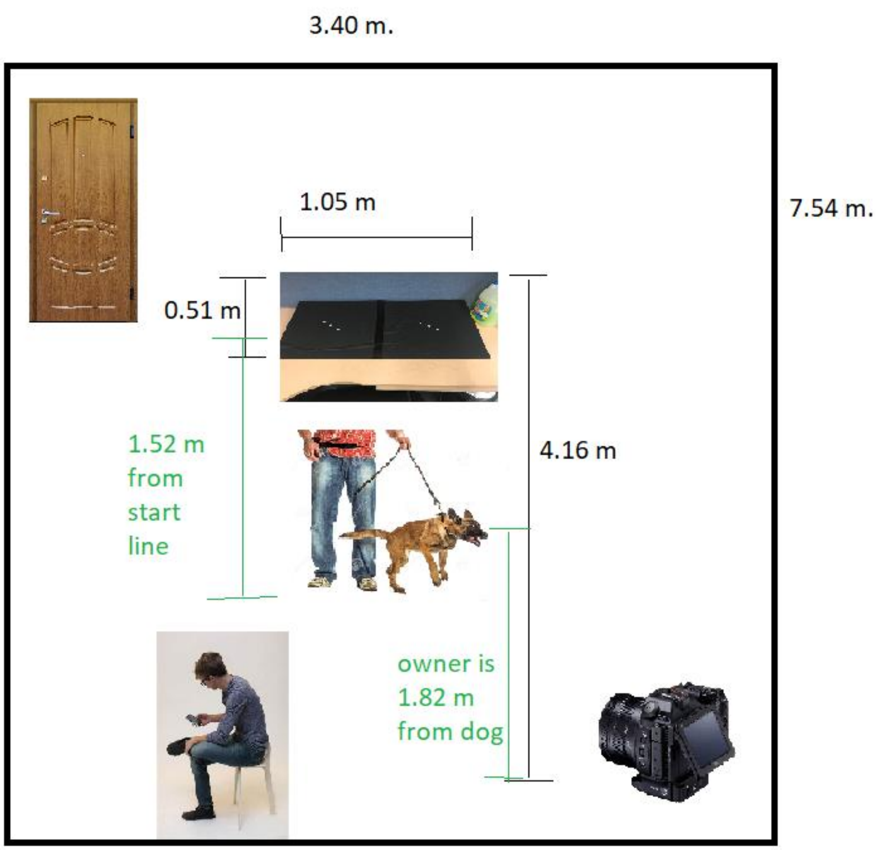


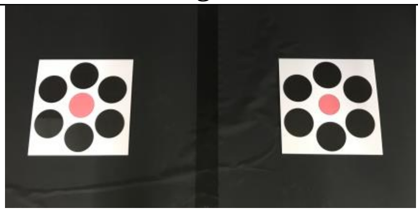
Figure 3. Sketch of testing room at the Thinking Dog Center.

Procedure

In order to ensure the dogs enjoyed eating bologna, and to demonstrate bologna was available on both sides of the board, two familiarization trials were conducted. In these trials, the Experimenter (E) placed a plain white board on the floor, first on the left and then the right side, with a single circular piece of bologna on it. This was to get the dog's attention and introduce them to a food reward that they would be eating from a propped-up board. After the dog successfully managed to obtain the food reward in the two familiarization trials, the test began. Table 2 depicts the stimuli for this experiment, where the pink centered circles represent the bologna pieces.

Table 2

Control and Test conditions for Spontaneous Choice Test

Condition	Figure	Description
Control A		The left stimulus has a 2.36-inch diameter of food lump size (bologna) and the right stimulus has a 1.96-inch diameter. Both food sizes are surrounded by identically sized large inducer circles.
Control B		The left stimulus has a 2.36-inch diameter of food lump size (bologna) and the right stimuli has a 1.96-inch diameter. Both food sizes are surrounded by identically sized small inducer circles.
Test (Illusion)		Both illusions have a food diameter of 2.36-inches, however the left stimulus has small inducer circles and the right stimulus has large inducer circles.

Note: All stimuli with "larger" appearing center circles are placed on the left side in this table.

The experimenter arranged stimuli behind the board before beginning trials, separating Control A stimuli, Control B stimuli, and illusion stimuli. Before the testing began, bologna pieces were placed on each stimulus to control for odor. E placed stimuli on a platformed board that sat at an angle. E made minimal eye contact with the dog, only using gaze to assess the dog's attention before placing the stimuli on the ground. During the test, E looked down into her lap. The Handler (H), holding the dog on a short leash, was asked to look down and/or close their eyes during the trials to prevent unintentional cues or biases. Once the bologna pieces were placed on the stimuli, the dog was given 3 seconds to view the stimuli while being held at the start line. After the 3 seconds of viewing the stimuli, E gave the release command, "Okay!", at which point H released the dog to make a choice. The dog had 30 seconds to choose one of the two sides. The dog's choice was considered to be whichever side they ate the piece of bologna from. As soon as the dog began to eat their chosen bologna, E removed the other choice off the board to ensure they could only obtain one food reward per trial. Dogs always ate the piece of bologna they initially chose.

A total of 18 trials were conducted per dog, including 12 control conditions (6 of Control A, and 6 of Control B) and 6 test conditions. The sequence of conditions and which side the "larger" bologna piece went on for that condition, was randomized. Each subject always began the experiment with a control condition, and the same side placement was never repeated more than twice. It is important to note that as bologna is easily filling, especially for smaller dogs, fewer trials per subject were conducted. However, to date, no study of dog illusion susceptibility has used more than 13 dogs. Therefore, this study represents more than double the sample compared to previous studies (Petrazzini, M.E.M, Bisazza, A., & Agrillo, C. (2017); Byosiere et. al (2017); Byosiere et. al (2018) and Keep et. al (2018)).

Table 3

Individual descriptive (age, sex, and breed) and quantitative (results of number of correct trials per condition indicated by a binomial test) data

Dog	Age	Sex	Breed	Facial Morphology	Control A	Control B	Test trials
Aesop	2	M	Pomeranian	Meso	3/6, P= 1.312	3/6, P= 1.312	2/6, P= 0.687
Bindi	4.5	F	Aussie Mix	Meso	3/6, P= 1.312	4/6, P= 0.687	3/6, P= 1.312
Boss	3	M	Brindle German Shepherd/ Lab	Meso	2/6, P= 0.687	4/6, P= 0.687	2/6, P= 0.687
Bunky	10	M	Chihuahua	Brachy	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Cora	5	F	Pit/Sato	Meso	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Dani	8 months	F	Pomeranian & Havanese	Meso	4/6, P= 0.687	2/6, P= 0.687	4/6, P= 0.687
Dolce	6 months	F	Beagle	Meso	5/6, P= 0.218	4/6, P= 0.687	5/6, P= 0.218
Evie	1	F	Mixed	Meso	4/6, P= 0.687	2/5, P= 1.000	3/5, P= 1.000
Fate	9.5	F	Shih Tzu, Bichon Frise, Maltese, Havanese	Meso	3/6, P= 1.312	3/6, P= 1.312	3/6, P= 1.312
Ginny	3	F	German Shepherd Mix	Meso	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Hobbes	2	M	American Staffordshire Terrier Mix	Meso	2/6, P= 0.687	4/6, P= 0.687	3/6, P= 1.312
Hudson	8 months	M	Duck Tolling Retriever	Meso	3/6, P= 1.312	3/6, P= 1.312	3/6, P= 1.312
Indigo	7	M	Cocker Spaniel Poodle	Meso	3/6, P= 1.312	4/6, P= 1.312	3/6, P= 1.312
Julius	2	M	Beagle/ German Shepherd	Meso	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Kaycee	4	F	American Staffordshire Terrier	Brachy	3/6, P= 1.312	4/6, P= 0.687	3/6, P= 1.312
Leo	1	M	Chi-weenie	Brachy	2/6, P= 0.687	4/6, P= 0.687	4/6, P= 0.687
Loki	2	M	Pointer/Boxer	Meso	4/6, P= 0.687	5/6, P= 0.218	3/6, P= 1.312
Lucie	4	F	Black Mouth Cur and Treeing	Meso	2/6, P= 0.687	3/6, P= 1.312	4/6, P= 0.687

			Walker Coonhound				
Maury	6	M	Cocker Spaniel Poodle	Meso	3/6, P= 1.312	3/6, P= 1.312	3/6, P= 1.312
Mochi	2	F	Mixed	Meso	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Mochi Tamale	1	F	Havanese	Meso	1/2, P= 1.500	1/3, P= 1.000	0/2, P= 0.500
Moose	2	M	Australian Shepherd	Meso	4/6, P= 0.687	4/6, P= 0.687	3/6, P= 1.312
Penny	11 months	F	Pitbull mix	Brachy	4/6, P= 0.687	3/6, P= 1.312	3/6, P= 1.312
Perl	9	F	Pitbull	Brachy	3/6, P= 1.312	4/6, P= 0.687	3/6, P= 1.312
Pogacs	8.5	F	Puli	Meso	4/6, P= 0.687	2/6, P= 0.687	3/6, P= 1.312
Quarter	5	F	Boxer/Pit	Brachy	3/6, P= 1.312	3/6, P= 1.312	4/6, P= 0.687
Sunny	5	F	Border Collie	Meso	4/6, P= 0.687	3/6, P= 1.312	3/6, P= 1.312
Teddy	8	M	Shih Tzu	Brachy	2/3, P= 1.000	3/4, P= 0.625	1/6, P= 0.218
Telly	3	F	Miniature Poodle and Portuguese Water Dog	Meso	5/6, P= 0.218	3/5, P= 1.000	2/4, P= 1.375

Note: The correct choice for the test condition is indicated as correct per the bologna appearing larger in the illusion as humans see it.

Results

Control Trials

As a group, a one sample two-tailed t-test on the number of choices for the larger food reward, indicated that dogs selected the larger piece bologna in Control A significantly more than chance (57.47 ± 13.79, $t(28) = 2.917$, $P= 0.0069$; Cohen's $d= 0.5417$). A one sample, two-tailed t-test on the number of choices for the larger food reward for dogs as a group suggested that they did not select the larger piece of bologna in Control B significantly more than chance

(52.8 ± 15.19, *t*(28) = 0.914, *P*= 0.3682, Cohen's *d*= 0.1702). No significant difference in performance between Control A and Control B was observed, *t*(56) = 1.2836, *P* = 0.2046, therefore, Control A and B were combined. When control performance was combined, dogs, as a group, did not perform significantly above chance, (55.02 ± 14.49, *t*(56) = 1.3474, *P* = 0.1833, Cohen's *d*= 0.3464) according to a one sample, two-tailed t-test on the number of choices for the larger food reward.

Test Trials

In the test trials, where the illusion was presented, dogs as a group, did not select the larger bologna (as perceived larger by humans) more often than chance (proportion of choices for the bologna piece on stimulus with smaller inducer circles (49.77 ± 15.22, *t*(28) = 0.0814, *P* = 0.9357, Cohen's *d* = -0.0151). Moreover, no significant difference, as a group, was observed between the controls (Control A and Control B combined) and the illusion conditions, *t*(56) = 1.3474, *P* = 0.1833, Cohen's *d*= 0.3467.

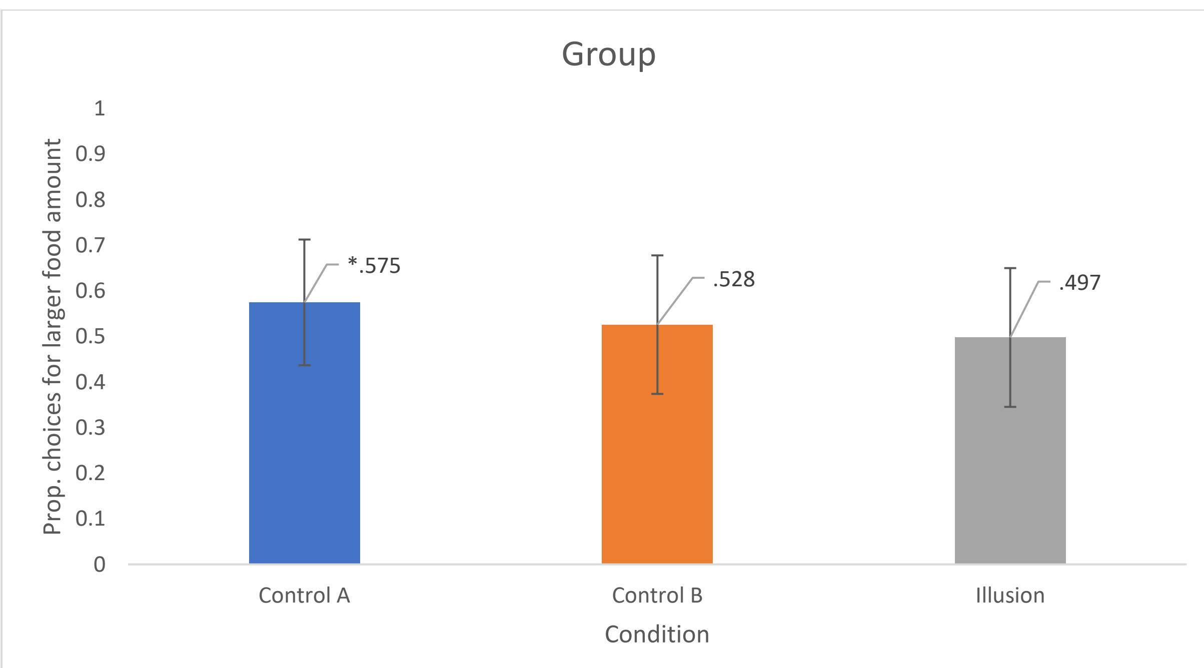


Figure 4. Average group performance on control conditions A, B, and trials. Asterisks above bars represent performance above chance levels.

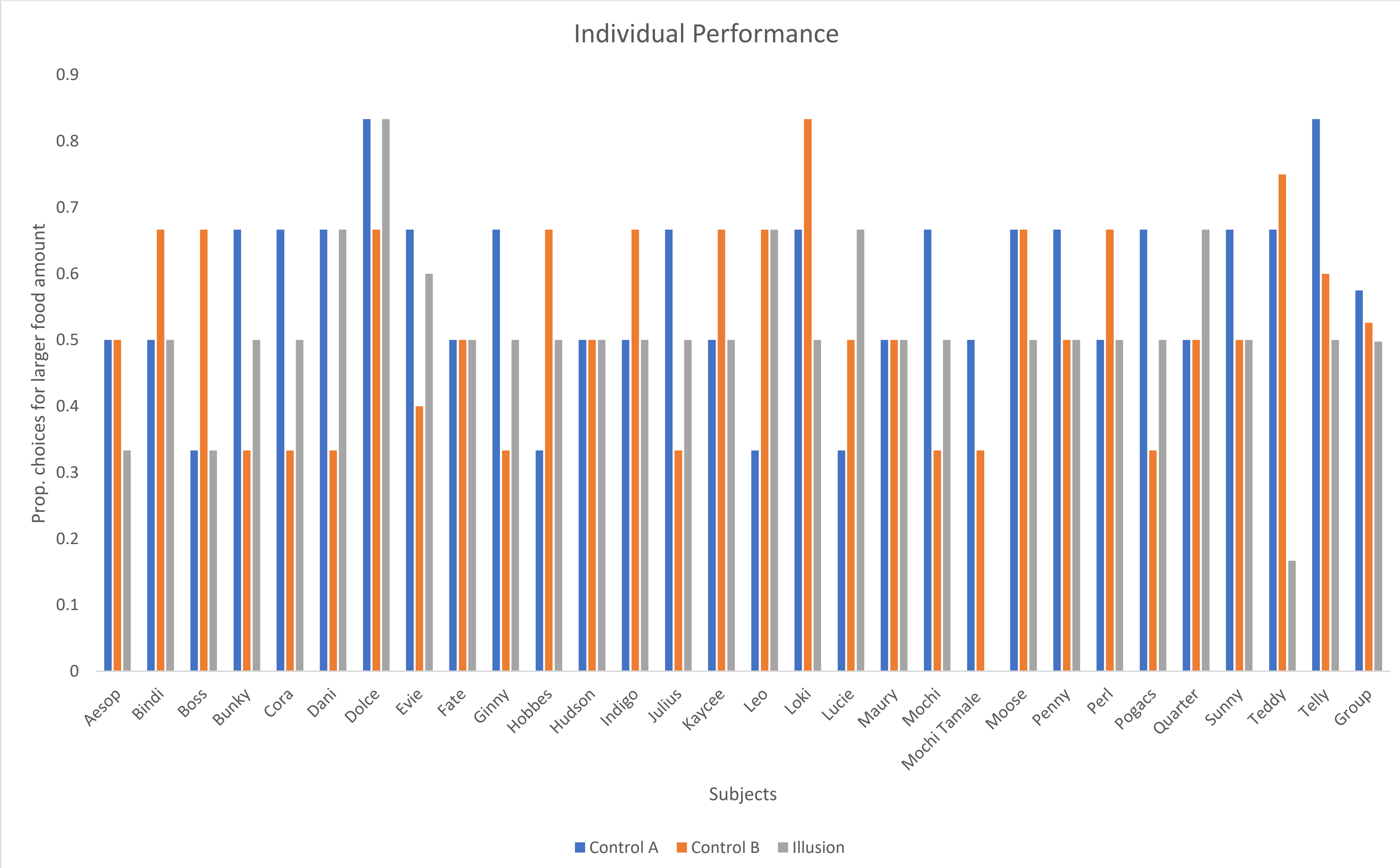


Figure 5. Individual performance on control conditions A, B, and illusion trials.

Table 4

Side preference for each individual dog, specifically the number of trials the dog went to the left or the right

Dog	# of Trials Selected on L	# of Trials Selected on R
Aesop	1/18	17/18*
Bindi	9/18	9/18
Boss	5/18	13/18
Bunky	2/18	16/18*
Cora	0/18	18/18*
Dani	1/18	17/18*
Dolce	11/18	7/18
Evie	15/16*	1/16
Fate	0/18	18/18*
Ginny	0/18	18/18*
Hobbes	18/18*	0/18
Hudson	0/18	18/18*
Indigo	17/18*	1/18
Julius	0/18	18/18*
Kaycee	17/18*	1/18
Leo	7/18	11/18
Loki	11/18	7/18
Lucie	12/18	6/18
Maury	2/18	16/18*
Mochi	0/18	18/18*
Mochi Tamale	3/7	4/7
Moose	6/18	12/18
Penny	1/18	17/18*
Perl	1/18	17/18*
Pogacs	0/18	18/18*
Quarter	17/18*	1/18
Sunny	1/18	17/18*
Teddy	4/11	7/11
Telly	2/16	14/16*
Group	**5**	**15**

Note: *denotes a side bias.

Side Bias

Table 4 shows all the dogs' number of left and right-side choices. Any dog who chose 14/18 or above on either the left or right side is marked with an asterisk. For the dogs who did not get to a total of 18 trials, we calculated what would demonstrate significant above chance bias for the side. Overall, more dogs were going to the right than the left, or at least there is a bias for them to go to the right. However, the left and right directions are from the point of view of the experimenter, therefore, more dogs were going to their left as opposed to their right. There could be many interpretations for why 15 dogs out of the total 29 were going to their left side more. For instance, their left side was closer to the testing room door, so it could be that they were more comfortable with that side of the room. In our familiarization tests, the first 15 dogs were familiarized with the bologna piece first on the left side, then the right side (experimenter's POV). The second round of dogs, which were the following 14 dogs, were familiarized first on the right side and then the left side. The familiarization task was not shown to influence side bias throughout testing.

Morphological Variation

Unpaired one sample two-tailed t-tests were conducted on group performance in Control A (53.44 ± 16.36, $t(28) = 1.291$, $P = 0.207$; Cohen's $d = 0.153$), B (53.26 ± 15.03, $t(28) = 0.950$, $P = 0.350$, Cohen's $d = 0.163$) and the Illusion condition(47.80 ± 18.36, $t(28) = 0.525$, $P = 0.603$, Cohen's $d = 0.183$) comparing brachycephalic (N=7) and mesocephalic (N=22) breeds. No significant difference in discrimination abilities and illusion susceptibility in a spontaneous choice paradigm was observed as a factor of facial morphology.

Discussion

The current study used a spontaneous choice paradigm to test whether dogs demonstrate susceptibility the Ebbinghaus-Titchener illusion. The results suggest that dogs are not susceptible to the Ebbinghaus-Titchener illusion, when presented in a spontaneous choice paradigm. Dogs performed above chance on control A but not on control B. No significant difference was observed between the control groups, so they were combined. Dogs performed at chance on the illusion test, suggesting null susceptibility to the Ebbinghaus illusion. When we compared combined controls and test performance, no significant difference was observed. As previous literature and research tell us, dogs have mixed results when viewing illusory stimuli. For example, Petrazzini et. al (2016) found that dogs had null susceptibility to the Delboeuf illusion when using a spontaneous choice task, and we found similar results when we presented the Ebbinghaus illusion using the same paradigm. However, it is important to note that we cannot interpret these findings completely as dogs did not perform above chance on their combined controls. Therefore, the findings say more about the methodology of this task, rather than the results obtained.

The spontaneous choice paradigm is known to be faulty, and at times unreliable (Santacà et.al, 2017). While the spontaneous choice task allows for natural behavior (Petrazzini et. al, 2016), it can encourage preferences and biases as any and all choices are rewarded. By allowing the dog to continuously make a choice and get rewarded with food, even if it is an incorrect choice, the dog may grow to develop a different understanding about the “goal” of this task. This may instill a behavior where the dog may be comfortable with going towards one side (having a left or right side-bias) and getting rewarded with food each trial. Given this task’s current popularity in animal cognition studies, it is important to point out its weaknesses and provide alternative methods and models to use in future research.

A specific area of dog research that can provide insight into how dog's see their environment is quantity discrimination. Research suggests that dogs are capable of quantity discrimination with food sums, however, that capability decreases when the numerical ratio becomes greater (Petrazzini & Wynne, 2016). For example, dogs can discriminate one piece of kibble from ten pieces of kibble, but have a harder time discriminating ten pieces of kibble in comparison to twenty pieces (Petrazzini & Wynne, 2016). Previous research has found that dogs can successfully discriminate sizes when making food judgments between large proportional differences, whereas wolves can successfully discriminate sizes with both large and small proportional differences (Petrazzini & Wynne, 2016). A possible explanation for this could be a result of wolves hunting in packs, whereas dogs more often live independently and do not have to hunt for food, as they are provided food and water by a human caretaker. Therefore, canine dependence on humans may have led to variation in necessary skills such as size discrimination. It may be more relevant to evolve traits helpful to human communicative understanding and less important to focus energy on maximizing food rewards. Due to dogs and wolves having a different social ecology, their results on quantity and size discrimination are different. Domestic dogs have also been successful in numerical task discriminations (Macpherson & Roberts, 2013). It has been shown that dogs successfully discriminate large circles and small circles by learning a size discrimination rule to novel stimuli (Byosiere et al., 2017). This research provides evidence that dogs are capable of not only seeing a difference in size between stimuli, but they are also able to learn a rule and apply it to a test paradigm. However, it is unknown if dogs are able to discriminate food-size discrepancies in the Ebbinghaus-Titchener visual illusion, which the current study aimed to discover.

A possible adaptation to the spontaneous choice task could be to implement a size discrimination learning task, which involves training dogs to comprehend the rule that the “larger” circle results in getting a food reward. The dogs would be presented with differently sized stimuli and would be trained to learn and discern the concept of small and large. This paradigm requires more effort and engagement and, therefore, it is not as practical as the spontaneous choice task. However, it is imperative to evaluate size discrimination capabilities in order to make conclusions about illusion susceptibility. If dogs are not performing above chance in the spontaneous choice task when presented with the control conditions, it is impossible to interpret their performance on the illusion conditions. Can we then teach them how to see this illusion and possibly perform better in a post-test? This experiment will give us findings in not just dog vision, but dog learning, memory and perception.

There are some differences between these two paradigms. The size discrimination task involves more experimenter control over attention, learning and memory. The spontaneous choice task offers a non-trained alternative, giving the dog freedom to indicate a natural food/quantity preference. Each of these experimental designs have strengths and weaknesses. For example, the spontaneous choice paradigm might be more exciting for dogs because they see the food in front of them, however, this may invoke an inhibitory control problem rather than capturing any real evidence that dogs can even see the illusion presented to them. In other words, it could be the case that the dogs are just too focused on the food reward in front of them to recognize a size discrimination between the stimuli. Future directions in this area include investigating inhibitory control, such as how to get a dog to concentrate on stimuli without the distraction of a highly motivating food reward. On the other hand, the size discrimination task incorporates learning, where decisions can be controlled and evaluated. Only subjects that learn a size difference can participate in test trials. However, although this task can provide researchers with more concrete results, it is more tedious and requires constant and regular training.

The generalizability of these paradigms, also brings into light the differences between dog breeds, raising the question of which is better to study: a vision task with subjects of one specific dog breed, or a vision task with subjects of multiple dog breeds? As one paradigm gives us more concrete evidence as to how one type of dog perceives their environment, the latter gives us a more generalized foundation on how dogs perform or visualize a certain stimulus or task. Both participant populations are significant to consider when researching canine visual susceptibility tests. However, we cannot assume based on average collection of data, that all dogs behave and visualize in the same way. The morphological differences between breeds, which are many to account for, such as face-shape, eye placement, height of the dog, snout length, overall body size, ear shape and size, body structure, stamina, and more, do affect the behaviors and choices dogs make. There is limited research evaluating morphological variation within dog cognition tasks (Gácsi et. al, 2009), therefore it is possible that morphological differences can skew and/or affect the accuracy of results.

The sample for this study was composed of a population of New York City pet dogs, which does not generalize to the world's population of dogs. New York City has an incredible high human population and is also full of many apartment buildings containing small rooms. One can imagine that most dogs in New York City live in an apartment and their only interaction with the outside world is when taken for a walk or a trip to the park. These dogs are not like rural dogs, who on the contrary may live on wide open land, are able to roam freely, perhaps unleashed, and might even co-exist with farm animals. Therefore, New York City dogs are an interesting sub-group to have for a visual susceptibility study because these dogs exist in a different habitat than many other dogs. Domestic dogs living in New York City do not run around outside as freely, hunt for prey, or leave their owners for great distances. Due to this type of existence, it may be the case that New York City dogs perform differently on this visual task than other dogs. These issues and possible confounds may yield mixed results compared to previous research on canine visual susceptibility to illusions.

Theoretically, if these findings are reflective of a canine inability to perceive the Ebbinghaus-Titchener illusion, it may provide valuable insight into the differences underlying dog and human visual perception. In other words, these findings could mean that dogs do not see the world as humans do. Therefore, when it comes to training and social interaction, humans must be mindful of how their visual system varies. What we see and understand clearly, may not hold true for our canine companions. Interestingly, the domestication of dogs might have hindered their ability to visually perceive in general. Studies in the dog's closest evolutionary ancestor have found that wolves are able to make quantity discriminations (Macpherson & Roberts, 2013). It could, therefore, be the case that there is a potential discontinuity, evolutionarily speaking, from the wolf to the dog.

However, if dogs are susceptible to this illusion, but not in this specific task, then this could mean that dogs perceive the environment similarly to humans, in relation to objects and size. If this is true, this might mean that training dogs may be easier for humans, because visual processing and perception between humans and dogs would be the same. Although, if dogs are only able to demonstrate susceptibility to this illusion in a trained paradigm, then that means dogs are not naturally seeing illusions in this manner. That would then mean that dogs may have the capability to see the illusion when they are trained, however, when dogs are first presented with the illusory stimuli, they would not be susceptible in the same way that humans are. The biases observed in this study provide additional insight into canine problem-solving capabilities. In the case presented here, dogs may not rationalize their decision making acting simply on impulse. If this is true, then a lack of inhibitory control may be the explanation of dogs' performance in the study as well as other using visible food rewards. Additional studies are needed to clarify this possibility.

If dogs are viewing this illusion reversed, as in the opposite direction from humans, then that could mean that dogs have a different level of visual processing than we once thought. For instance, dogs are known to have global processing (Mongillo et al., 2016), like humans, but if they are consistently viewing this illusion and have reversed susceptibility, then future research may have to study visual global processing in dogs and see if there is a possibility of dogs having a different visual processing system. There could also be the possibility that different breeds have different visual systems as well, and that could be useful to look into.

In conclusion, there was limited evidence to suggest that dogs are susceptible to the Ebbinghaus illusion when presented in a spontaneous choice task. At chance performance on controls make it particularly difficult to interpret the null findings observed within the test. It is, therefore, recommended that future research study visual illusion susceptibility using a different methodology, possibly integrating a training-based paradigm within the spontaneous choice task to obtain more accurate measures of canine illusion susceptibility. With more knowledge on dog vision, we can find out if dogs are susceptible to illusions, and furthermore, how dogs see the world both similarly and differently than humans do.

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