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Methodological Challenges in the Assessment of Dogs' (*Canis lupus familiaris*) Susceptibility of the Ebbinghaus-Titchener Illusion Using the Spontaneous Choice Task

Nicolette Becker, Sasha Prasad-Shreckengast*, and Sarah-Elizabeth Byosiere

Thinking Dog Center, Department of Psychology, Hunter College, City University of New York

*Corresponding author (Email: sasha.prasad82@myhunter.cuny.edu)

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Abstract – Visual illusions represent an innovative method to investigate animal visual perception. One well known geometric illusion is the Ebbinghaus-Titchener illusion, which consists of two identically sized target circles with one surrounded by large inducer circles and the other surrounded by small inducer circles. Humans are susceptible to this illusion, underestimating the size of the target circle surrounded by larger inducers and overestimating the size of the target circle surrounded by smaller inducers. In the present study, we investigated whether pet dogs (*Canis lupus familiaris*) perceive the Ebbinghaus-Titchener illusion in a spontaneous choice task by adapting and replicating the methodology of Miletto Petrazzini et al. (2017). Twenty-five pet dogs were presented with two stimuli in which a food reward was embedded. Each subject participated in 18 total trials, 12 size discrimination control trials (where one food reward was larger than the other) and six illusion trials (where identically sized food rewards were presented). Dogs, as a group, failed to demonstrate a significant preference for the larger food reward in control trials, and demonstrated null susceptibility, performing at chance, in the illusion trials. The chance performance on controls prevents further interpretation regarding canine illusion susceptibility; however, it invokes a discussion regarding the methodological challenges associated with conducting spontaneous-choice tasks. In an attempt to provide guidance for future research, we provide a review of canine illusion susceptibility to the Ebbinghaus-Titchener illusion and detailed recommendations to help mitigate extraneous factors to help further research of animal illusion susceptibility.

Keywords – Canine cognition, Spontaneous choice task, Visual illusions, Visual perception, Ebbinghaus-Titchener illusion

Recently, the study of visual illusion susceptibility in nonhuman animals (hereafter animals) has dramatically increased (Agrillo et al., 2020), providing unique insight into the cognitive processes underlying visual perception (Kelley & Kelley, 2014). Visual illusions occur when retinal information is adapted to fit preconceptions, misrepresenting the physical properties of a stimulus (Gregory, 2015). In other words, the brain is "tricked" into revising a visual scene when a revision is not necessary. Visual illusion assessments can be used to evaluate broader theoretical mechanisms underlying visual perception; however, given their suitability and adaptability, they also represent an ideal method to evaluate similarities and differences in visual perception comparatively across animals (Feng et al., 2017; Kelley & Kelley, 2014; Sovrano et al., 2014) without reliance on language (Byosiere et al., 2020; Feng et al., 2017; Kelley & Kelley, 2014).

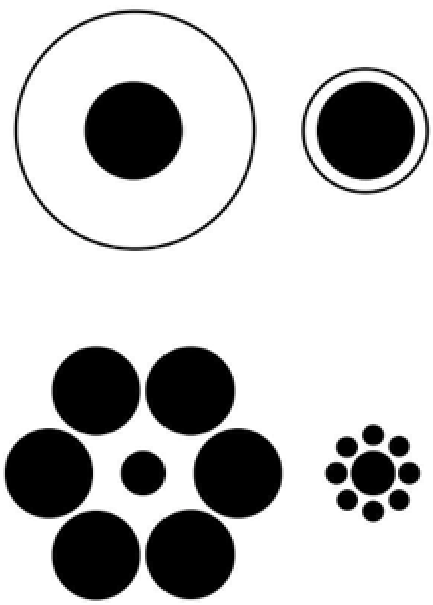
Two well-studied visual geometric illusions are the Delboeuf and Ebbinghaus-Titchener illusions (e.g., de Fockert et al., 2007; Jaeger, 1978). The Delboeuf illusion traditionally consists of two identically sized target circles, each encompassed by differently sized inducers in the shape of rings (Figure 1a). When presented together, humans perceive a size difference between the target circles, underestimating the target enclosed by the larger inducer ring and overestimating the target enclosed by the smaller inducer ring (Parrish, 2020). While typically illustrated with circles and inducer rings, the Delboeuf illusion can also be presented with any equally sized shapes or objects on two differently sized backgrounds (Howard et al., 2017; Li et al., 2020), though the shape used affects the strength of the illusion (Li et al., 2020). The Ebbinghaus-Titchener illusion also consists of two identically sized target circles surrounded by differently sized inducers. However, instead of rings, they are surrounded by multiple inducer circles (Figure 1b). When presented with this illusion, humans underestimate the size of the target when it is surrounded by larger inducer circles and overestimate the size of the target when it is surrounded by smaller inducer circles (Kelley & Kelley, 2014; Parrish, 2019).

Figure 1

The Delboeuf illusion and the Ebbinghaus-Titchener Illusion

a)

b)



Note. The Delboueuf illusion (a) consists of two identically sized target circles with one surrounded by a larger inducer ring and the other surrounded by a smaller inducer ring. Humans tend to overestimate the size of the target circle encompassed by the smaller inducer ring. The Ebbinghaus-Titchener illusion (b) consists of two identically sized target circles with one surrounded by large inducer circles and the other surrounded by small inducer circles. Humans tend to overestimate the size of the target circle surrounded by the smaller inducer circles.

Various theoretical explanations exist to interpret, typically, human-like illusion susceptibility. Susceptibility to the Ebbinghaus-Titchener illusion is often explained by the size contrast theory (Coren & Enns, 1993) while susceptibility to the Delboeuf illusion is often explained by the contour interaction (Jaeger, 1978; Jaeger & Lorden, 1980) and assimilation theories (Pressey, 1971; for a review of the theories underlying canine illusion susceptibility see Byosiere et al., 2020). In humans, the Ebbinghaus-Titchener has been proposed to be more robust, having a stronger illusory effect than the Delboeuf illusion (Nakamura et al., 2014). However, illusion susceptibility also invokes a discussion of visual processing precedence, specifically the perceptual processing mode of the species. Species that demonstrate human-like susceptibility are generally believed to process visual stimuli at a global level (Byosiere et al., 2020; Kelley & Kelley, 2014; Nakamura et al., 2008, 2014), meaning they integrate and perceive stimuli as a whole composition rather than as individual components (Navon, 1977). Conversely, those that demonstrate null or reversed susceptibility are believed to process these stimuli at a local level (Byosiere et al., 2020; Kelley & Kelley, 2014; Nakamura et al., 2008, 2014), prioritizing the individual components rather than the whole composition (de Fockert et al., 2007).

To date, susceptibility to the Ebbinghaus-Titchener and Delboeuf illusions has been studied in a variety of vertebrate species, with a great deal of variability in the type of illusion susceptibility observed (Table 1). Importantly, unlike assessments of the Delboeuf illusion, all assessments of the Ebbinghaus-Titchener illusion have been conducted using training-based paradigms. In total, nine studies evaluating the Ebbinghaus-Titchener illusion have been published. The current findings suggest that bottlenose dolphins (Murayama et al., 2012), bantam chickens (Rosa Salva et al., 2013), redtail splitfin fish (Sovrano et al., 2014), and teleost damselfish (Fuss et al., 2014) demonstrate human-like susceptibility, perceiving a size difference between the target stimuli and overestimating the stimulus surrounded by smaller inducer circles. Baboons (Parron & Fagot, 2007) and gray bamboo sharks (Fuss et al., 2014) exhibit null susceptibility, meaning they do not perceive any difference in size between target circles in illusory contexts. Finally, homing pigeons (Nakamura et al., 2008), bantam chickens (Nakamura et al., 2014), and dogs (Byosiere et al., 2017) demonstrate reversed susceptibility, meaning they perceive a size difference between the target stimuli, however, in an opposite manner compared to humans, identifying the stimulus humans perceive as being larger as smaller.

Domestic dogs (*Canis lupus familiaris*) have become popular test subjects in cognition research; yet, the current understanding of dog vision, visual processing, and perception remains understudied (Byosiere et al., 2018; Miller & Murphy, 1995). Though limited, the current literature regarding canine illusion susceptibility indicates dogs might process visual information as local processors (e.g., Byosiere et al., 2017; Looke et al., 2020; Miletto Petrazzini et al., 2017), suggesting they may perceive the visual world quite differently from humans. As such, further research into canine perception will allow researchers to create more suitable experimental paradigms and, indirectly, can help improve many ways in which humans interact with dogs. Recently, susceptibility to the Ebbinghaus-Titchener and Delboeuf illusions has been evaluated in dogs utilizing two different testing paradigms, the spontaneous choice task (Miletto Petrazzini et al., 2017) and a training paradigm (Byosiere et al., 2017). While previous research suggests that the two methodologies produce reliable results (Byosiere et al., 2017; Miletto Petrazzini et al., 2017), the spontaneous-choice task, which involves the observation of spontaneous behavior when an untrained animal is presented with biologically relevant stimuli (such as food), has not been used to test susceptibility to the Ebbinghaus-Titchener illusion in any species (Table 1). As such, the original intent of this study was to evaluate perception in dogs through misperception of the Ebbinghaus-Titchener illusion in order to further our knowledge of pet dog perception. To achieve this, we aimed to replicate the findings of Miletto Petrazzini et al. (2017) using complementary spontaneous choice methods. However, despite our original intent, several complications were encountered during the course of experimentation. Therefore, the aim of the present publication is to highlight methodological challenges that may occur when conducting illusion susceptibility research using the spontaneous choice task and to provide detailed recommendations for future studies.

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.”

Table 1

A Review of Susceptibility to the Delboeuf and Ebbinghaus-Titchener Illusions in Vertebrates

Illusion	Species	Susceptibility	Paradigm
Delboeuf	Chimpanzees (*Pan troglodytes*) (Parrish & Beran, 2014)	Human-like	Spontaneous Choice
	Rhesus monkeys (*Macaca mulatta)* (Parrish et al., 2015)	Human-like and reversed, depending task	Training
	Capuchin monkeys (*Cebus apella)* (Parrish et al., 2015)	Human-like and reversed, depending task	Training
	Gray bamboo shark (*Chiloscyllium griseum*) (Fuss & Schluessel, 2017)	Null	Training
	Teleost damselfish (*Chromis chromis*) (Fuss & Schluessel, 2017)	Human-like	Training
	Ring-tailed lemur (*Lemur catta*) (Santacà et al., 2017)	Null*	Spontaneous Choice
	Dogs (*Canis lupus familiaris*) (Miletto Petrazzini et al., 2017)	Null	Spontaneous Choice
	Dogs (*Canis lupus familiaris*) (Byosiere et al., 2017)	Null	Training
	Guppies (*Poecilia reticulata*) (Lucon-Xiccato et al., 2019)	Reversed	Training, Spontaneous Choice
	Red-footed tortoise (*Chelonoidis carbonaria*) (Santaca et al., 2019)	Null*	Spontaneous Choice
	Bearded dragon (*Pogona vitticeps*) (Santaca et al., 2019)	Human-like	Spontaneous Choice
	Domestic cat (*Felis silvestris catus*) (Szenczi et al., 2019)	Human-like	Spontaneous Choice
	Siamese fighting fish (*Betta splendens*) (Santaca et al., 2020)	Reversed	Spontaneous Choice
	Redtail splitfin (*Xenotoca eiseni*) (Santaca et al., 2020)	Reversed	Spontaneous Choice
	Angelfish (*Pterophyllum scalare*) (Santaca et al., 2020)	Reversed	Spontaneous Choice
	Zebrafish (*Danio rerio*) (Santaca et al., 2020)	Null	Spontaneous Choice
	Three-spot gourami (*Trichopodus trichopterus*) (Santaca et al., 2020)	Null	Spontaneous Choice
Ebbinghaus-Titchener	Baboons (*Papio papio*) (Parron & Fagot, 2007)	Null	Training
	Homing pigeons (*Columba livia*) (Nakamura et al., 2008)	Reversed	Training
	Bottlenose dolphin (*Tursiops truncates*) (Murayama et al., 2012)	Human-like	Training
	Bantam chickens (*Gallus gallus*) (Rosa Salva et al., 2013)	Human-like	Training
	Bantam chickens (*Gallus gallus*) (Nakamura et al., 2014)	Reversed	Training
	Redtail splitfin fish (*Xenotoca eiseni*) (Sovrano et al., 2014)	Human-like	Training
	Gray bamboo shark (*Chiloscyllium griseum*) (Fuss et al., 2014)	Null	Training
	Teleost damselfish (*Chromis chromis*) (Fuss et al., 2014)	Human-like	Training
	Dogs (*Canis lupus familiaris*) (Byosiere et al., 2017)	Reversed	Training

Note. *Did not demonstrate above chance performance on controls.

Participants

A total of 29 pet dogs of various breeds and ages initially participated in this study. This sample size was determined using a power analysis (G*Power) based on the reported effect size presented for illusion trials in Miletto Petrazzini et al. (2017). For an effect size (Cohen's d) of 0.48 with an alpha probability of .05 and power of .8, the total sample size required would be 30 participants. However, due to additional constraints we were able to test only 29 dogs – more than double the subjects tested by Miletto Petrazzini et al. (2017).

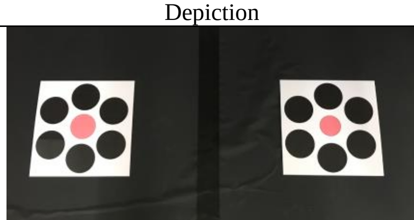
Four dogs failed to complete all trials, as they did not meet our criteria for making a choice by consuming the entire piece of bologna (a type of sausage) and were therefore excluded. The final sample consisted of 25 pet dogs, more than double the sample used in previous studies (Byosiere et al., 2017, 2018, 2020; Keep et al., 2018; Miletto Petrazzini et al., 2017). All dogs were recruited from the Thinking Dog Center (TDC) Hunter College database and were volunteered to participate in the study by their owners. Owners were asked not to feed their dogs for 3 hours prior to testing. Dogs were required to eat bologna for the study; however, one subject (Dolce) had a dietary restriction and turkey deli meat was used instead. None of the subjects had previously participated in size discrimination tasks at the TDC.

Stimuli and Apparatus

Laminated stimuli of the Ebbinghaus-Titchener illusion were adhered to either the left or right side of a propped up (~25 degrees) poster board and held in place using Velcro. Table 2 depicts examples of the stimuli for all three trial types: Control A, Control B and Illusion. Pre-sliced Oscar Mayer Bologna (regular thickness) was cut using cookie cutters and was placed in the center of a laminated stimulus to represent the target circles of the Ebbinghaus-Titchener illusion.

Table 2

Depictions and Descriptions of Stimuli Presented in the Control and Illusion Trials

Trial Type	Depiction	Description
Control A		The left stimulus has a 5.99 cm diameter of bologna and the right stimulus has a 4.97 cm diameter. Both food sizes are surrounded by identically sized large inducer circles.
Control B		The left stimulus has a 5.99 cm diameter of bologna and the right stimuli has a 4.97 cm. diameter. Both food sizes are surrounded by identically sized small inducer circles.
Illusion		Both illusions have a bologna diameter of 5.99 cm. The left stimulus has small inducer circles and the right stimulus has large inducer circles.

Note: All stimuli with larger or larger-appearing target circles are placed on the left side.

Control trials, represented by Control A and Control B, were set up to assess whether the dogs were able to select the larger portion of food in a non-illusory context. Two controls were presented as the illusion is invoked through a simultaneous presentation of the two control types. In both control trial types bologna pieces of 5.99 cm (large) and 4.97 cm (small) diameters were presented simultaneously. The ratio between the smaller and the larger pieces of bologna was equal to 0.66, which is consistent with spontaneous quantity discrimination of non-primate species (Agrillo et al., 2012), as well as size discrimination ratios (15-20% difference in surface area) observed in studies of dogs (Byosiere et al., 2017; Miletto Petrazzini et al., 2017). The differently sized bologna pieces could be surrounded by either large inducers (Control A) or small inducers (Control B). During the Illusion trials, two identically sized pieces of 5.99 cm bologna were presented simultaneously; however, the surrounding inducers varied in size (Table 2). One target stimulus was surrounded by large inducer circles (identical to the inducers presented in Control A) while the other target stimulus was surrounded by small inducer circles (identical to the inducers presented in Control B).

The food type used (bologna) and the angled presentation of stimuli differed from the original methods of Miletto Petrazzini et al. (2017). In their study, small biscuits were used as a reward and stimuli were displayed on the floor, requiring dogs to look down. Because this viewing angle might make it difficult for dogs to view the stimuli from a distance, we opted to utilize an angled presentation in an attempt to more clearly present the stimuli to our subjects. Due to the need to have a sticky reward that could easily be placed on the laminated stimuli without sliding off, bologna was selected as the food reward instead of biscuits.

Procedure

All subjects were individually tested in a room at the TDC at Hunter College in New York City (Figure 2). Before starting the experiment, and to ensure the dogs would eat bologna from both sides of the apparatus, a short familiarization phase of two trials was conducted. During this phase, the experimenter placed a plain white board (with no illusory figures) on the floor with a piece of bologna, once on the left and once on the right side (counter-balanced by subject). After the dog successfully managed to obtain the food in the two familiarization trials, the spontaneous choice task began.

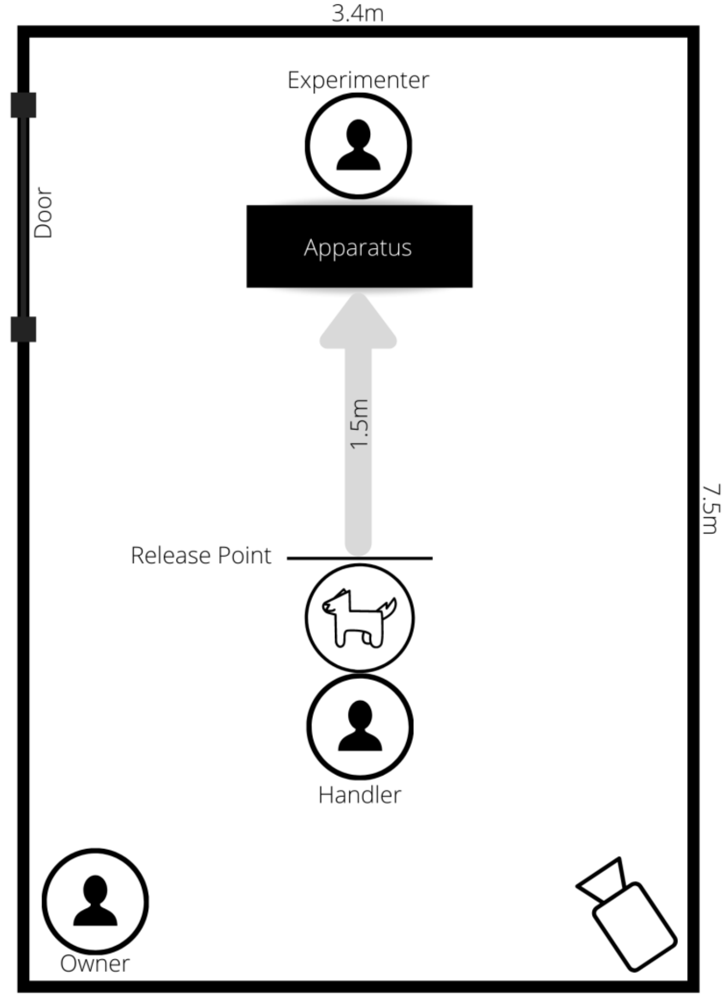
In the spontaneous choice task, the experimenter arranged the stimuli behind the poster board out of the dog's sight. At the beginning of each trial, she placed the laminated stimuli onto the poster boards. During each trial, the experimenter looked down into her lap to avoid any unintentional cuing of the dog. The handler held the dog on a short leash at the beginning of each trial and looked down at the ground during the trial. Once the stimuli were in place, the dog was given 3 s to view the stimuli. They were then released by the handler and allowed to make a choice of one of the two stimuli. A choice was considered made once the dog began to eat one of the pieces of bologna. Consequently, the experimenter immediately removed the alternative choice. Dogs had 30 s to choose one of the two sides. They were always permitted to eat the piece of bologna that they chose, regardless of whether the piece of bologna was larger, smaller, or equally sized. If a dog did not make a choice within 30 s, the handler would guide the dog back to the starting line and the experimenter would repeat the trial. If no choice was made on three consecutive trials, the experiment was terminated and the dog was excluded from analysis.

Each dog completed a total of 18 trials during their visit consisting of 6 Control A, 6 Control B, and 6 Illusion trials. Control and Illusion trials were then pseudo randomly dispersed across the 18 total trials, with no trial type being presented more than two times in a row. The side that the "larger" bologna piece was placed was counterbalanced within and across trial types and randomized. Each subject always began the experiment with a Control trial and the same side placement was never repeated more than twice in a row.

Statistical analyses were conducted using Microsoft Excel/SPSS 26. Two-tailed binomial tests were used to assess whether dogs were able to discriminate the two sizes in Control A and B, and whether dogs were susceptible to the Ebbinghaus-Titchener illusion above chance (0.50). 95% confidence intervals (CI) were calculated using the Clopper-Pearson method. A two-tailed binomial test was also used to evaluate the side biases at the group level.

Figure 2

Sketch of Testing Room at the Thinking Dog Center



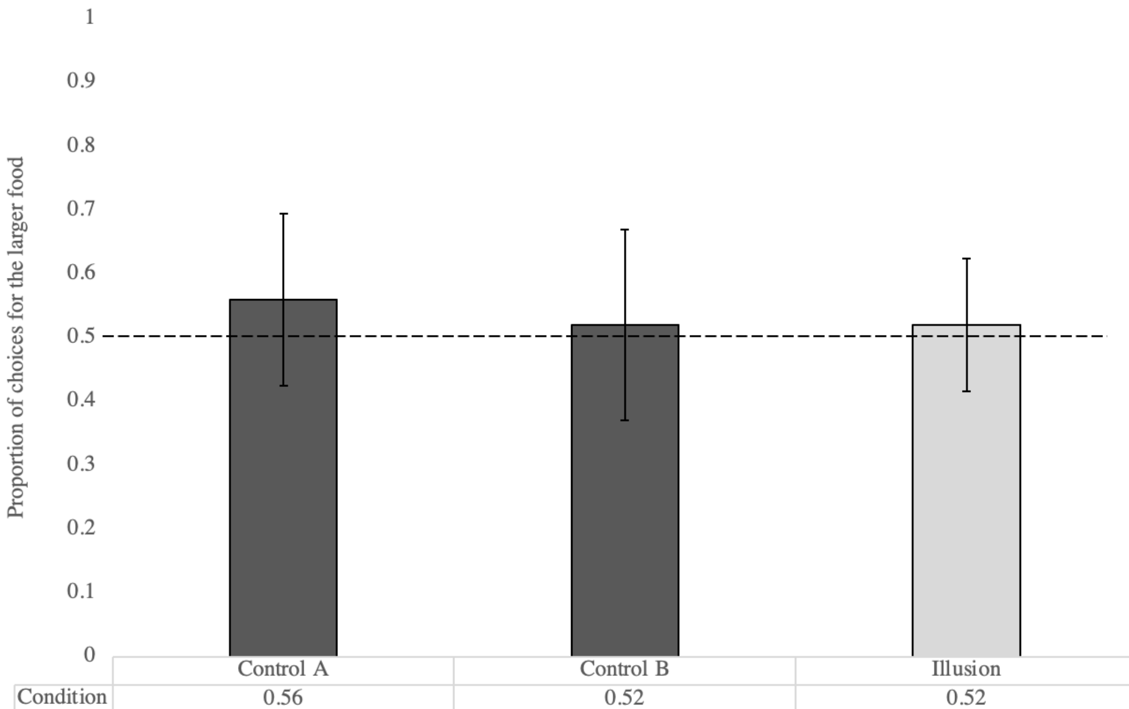
Note. The apparatus was 1.0 m across and 0.5 m in height. The two stimuli, from center to center, were displayed 0.6 m apart. The owner was sitting in a chair 1.8 m behind the dog. The left wall of the room was 1.2 m from the board, and the right side of the wall was 1.1 m from the board. The dog's owner sat behind the dog in a chair facing the wall. A video camera was placed in the other corner behind the dog and recorded all trails.

Results

As a group, the dogs (n = 25) did not select the larger piece bologna in Control A significantly more than chance (two-tailed binomial test; p = .17), performing at 56% ± 13.5% (95% Clopper-Pearson CI of 47.7% to 64.1%) (Figure 3). The dogs also did not select the larger piece bologna in Control B significantly more than chance (two-tailed binomial test; p = .57), performing at 52.6% ± 14.9% (95% Clopper-Pearson CI of 44.4% to 60.6%). In the Illusion trials, as a group, dogs did not select the piece of bologna within the smaller inducer circles (and therefore, perceived as larger by humans) more often than chance (two-tailed binomial test; p = .57), performing at 52.6% ± 14.9% (95% Clopper-Pearson CI of 44.4% to 60.6%).

Figure 3

The Average Group Performance on Control and Illusion Trials for All Subjects



Note. Dashed line represents chance (0.50). Bars represent standard deviations. Dogs did not select the larger piece of food significantly above chance in any condition.

It is important to note that 19 of the 25 subjects demonstrated a significant side bias (two-tailed binomial test; p = .15) by choosing a preferred side on 13 or more of the total 18 trials (Table 3). Fifteen subjects demonstrated a preference for the stimulus presented on the left, four demonstrated a preference for the stimulus presented on the right, and six demonstrated no side bias.

Discussion

The current study originally sought to investigate whether dogs are susceptible to the Ebbinghaus-Titchener illusion. In an attempt to achieve this, we replicated and adapted a spontaneous choice paradigm used by Miletto Petrazzini et al. (2017), which found that dogs demonstrated null susceptibility when presented with the Delboeuf illusion. We hypothesized that pet dogs would demonstrate reversed susceptibility to the Ebbinghaus-Titchener illusion when presented in a spontaneous choice task. These results would be consistent with the reversed findings observed by Byosiere et al. (2017) and support the existing literature that suggests dogs are local processors (Byosiere et al., 2020).

Although previous studies have shown dogs are able to spontaneously select the larger quantity of food above chance (Looke et al., 2020; Miletto Petrazzini et al., 2017; Miletto Petrazzini & Wynne, 2016), our analysis suggested that dogs were not able to discriminate between the two quantities in the size discrimination task (Controls A and B). During our Control trials, dogs performed at chance when choosing between the small and large pieces of bologna. This prohibits us from interpreting the findings for the Illusion trials as a primary assumption of the spontaneous choice task is the successful size discrimination in Control trials. Therefore, we cannot make any definitive conclusions about Ebbinghaus-Titchener illusion susceptibility in dogs.

Table 3

Descriptive Information and Individual Results for Each Subject on Control and Illusion Trials

Dog	Age (Yrs)	Sex	Breed	Control trials	Illusion trials	Side Bias (L/R)
Aesop	2	M	Pomeranian	6/12	2/6	L
Bindi	4	F	Mixed (Australian Shepherd)	7/12	3/6	No bias
Boss	3	M	Mixed (German Shepherd, Labrador Retriever)	6/12	2/6	L
Bunky	10	M	Chihuahua	6/12	3/6	L
Cora	5	F	Mixed (American Staffordshire Terrier)	6/12	3/6	L
Dani	<1	F	Mixed (Pomeranian, Havanese)	6/12	4/6	L
Dolce	<1	F	Beagle	9/12	5/6	No bias
Fate	9	F	Mixed (Shih Tzu, Bichon Frise, Maltese, Havanese)	6/12	3/6	L
Ginny	3	F	Mixed (German Shepherd)	6/12	3/6	L
Hobbes	2	M	Mixed (American Staffordshire Terrier)	6/12	3/6	R
Hudson	<1	M	Duck Tolling Retriever	6/12	3/6	L
Indigo	7	M	Mixed (Cocker Spaniel, Poodle)	7/12	3/6	R
Julius	2	M	Mixed (Beagle, German Shepherd)	6/12	3/6	L
Kaycee	4	F	American Staffordshire Terrier	7/12	3/6	R
Leo	1	M	Mixed (Chihuahua, Dachshund)	6/12	4/6	No bias
Loki	2	M	Mixed (English Pointer, Boxer)	9/12	3/6	No bias
Lucie	4	F	Mixed (Black Mouth Cur, Treeing Walker Coonhound)	5/12	4/6	No bias
Maury	6	M	Mixed (Cocker Spaniel, Poodle)	6/12	3/6	L
Mochi	2	F	Mixed (Unspecified)	6/12	3/6	L
Moose	2	M	Australian Shepherd	8/12	3/6	No bias
Penny	<1	F	Mixed (American Staffordshire Terrier)	7/12	3/6	L
Perl	9	F	American Staffordshire Terrier	7/12	3/6	L
Pogacs	8	F	Puli	6/12	3/6	L
Quarter	5	F	Mixed (Boxer, American Staffordshire Terrier)	6/12	4/6	R
Sunny	5	F	Border Collie	7/12	3/6	L

Note. The age, sex, and breed of each subject is included, as well as their individual results on both Controls (A and B Combined) and Illusion Trials, including acknowledgment of a side bias and its directionality. The correct choice for the Illusion is indicated as correct per the bologna appearing larger in the illusion as humans see it (with smaller inducer circles).

Whereas the findings of the present investigation are equivocal and bar interpretation of canine susceptibility to the Ebbinghaus-Titchener illusion, they are still informative for future studies. These results suggest that the spontaneous choice task may not be an ideal task to evaluate illusion susceptibility in pet dogs. This conclusion is not unique to this study or this species, as confounds and limitations regarding the paradigm and its suitability have been noted in other animals (ring-tailed lemur: Santacà et al., 2017; red-footed tortoise: Santacà et al., 2019). This is largely due to the nature of the paradigm and the assumptions that are made. The spontaneous choice task relies on the assumption that the subjects will prefer a larger quantity of food over a smaller quantity when presented with both. However, it is possible that an individual may not try to optimize caloric intake if 1) they are well and frequently fed (as pet dogs living in homes generally are) and 2) food is always obtained during trials. Under these conditions, a dog might struggle to ascertain the objective of the task when they are rewarded for every choice, even in instances that are deemed 'incorrect.'

As a result, alternative strategies like win-stay-lose-shift and side-bias may occur. In the present investigation, 19 of our 25 subjects exhibited a significant side bias, with the majority of participants favoring the left side (Table 3). This left-side preference may have been influenced by a door in the room, located on the dogs' left side (Figure 1), which, while closed, may have affected the subjects' initial preferences. Further, dogs have been shown to preferentially choose food dishes that allow them to orient in a north-facing direction and show a strong directional turning preference (Adamkova et al., 2021). Although our experiment was set up in an east-west orientation, it is possible that the dogs' directional turning preference contributed to this pervasive side bias. Anecdotally, it is worth noting that 6 of our 25 subjects did not demonstrate a side bias, and four of those individuals appeared to discriminate between control trials above chance. This might indicate that some dogs were able to discern the goal of the task, suggesting that, with modifications, the spontaneous choice task might be a suitable paradigm and allow for meaningful conclusions to be drawn about pet dog susceptibility to visual illusions.

In addition to the challenges related to side bias outlined above, other issues to the present investigation exist. For instance, it is possible that the choice of food stimuli (bologna) was an overly high-value reward which could have led to inhibitory control effects in our subjects. Miletto Petrazzini et al.'s (2017) choice of food (biscuits) seemed to allow dogs to maintain levels of inhibitory control necessary to discriminate between choices during control trials. Although past studies indicate that dogs can still make quantity discriminations between different amounts of other high-value food item (like the sausage slices used by Looke et al., 2020), we suggest that future research utilize biscuits or another type of food that is rewarding enough to keep the dogs engaged for all trials while avoiding over arousal. If researchers determine that high-value food items are the most appropriate for their study, given their salient nature, we suggest that researchers prepare smaller food portions when implementing a spontaneous choice task. Although the two food portions we used during control trials differed by a ratio of 0.66, the same ratio as used by Miletto Petrazzini et al.'s (2017), both sizes of bologna could have been enough to satiate some dogs, especially those of smaller breeds like Pomeranians and Chihuahuas. Satiation is a known limitation of the spontaneous choice task using food rewards. Even the smaller stimuli (4.97 cm diameter) could have led to a loss of motivation in many of the dogs. Thus, it is important to consider the size of the food and satiation when designing a spontaneous choice task. We recommend that future studies utilizing high-value or large quantity portions in spontaneous choice tasks with dogs evaluate ways in which to deliver smaller quantities of food without altering the perceptual experience of the illusion.

Beyond issues related to site-specific variation and differences in testing methodology, it is important to highlight that the shortcomings observed in replication studies, such as the study presented here, can also plague original research studies. When results of animal cognition studies fail to replicate, as seen here, it can often be attributed to small, poorly representative samples and/or study site-specific differences in factors that were not accounted for. This represents a major constraint and limitation in replicating and generalizing the findings of animal behavior and cognition assessments (Farrar et al., 2021). However, another possibility should also emerge: is the original testing methodology suitable? Considering this, we present the following modifications to the spontaneous choice paradigm that, though they remove an element of spontaneity, may produce more representative findings and, thus, could be considered for both original and replications studies.

One modification to the spontaneous choice task methodology would be to adopt a semi-training-based approach by rewarding only correct choices during control trials. Since previous research indicates that dogs are capable of quantity discrimination with food (Looke et al., 2020; Miletto Petrazzini et al., 2017; Miletto Petrazzini & Wynne, 2016), and that dogs can successfully discriminate large and small circles after learning a size discrimination rule (Byosiere et al., 2017), we believe that dogs can successfully discriminate between control stimuli when they understand the objective of the task. Rewarding only correct choices during control trials might more clearly communicate the objective of the task, enabling dogs to perform above chance. This could be done by placing the stimuli behind a plexiglass barrier so the experimenter could control when a reward is given. Whereas this removes an element of the spontaneity in the spontaneous choice task, it may represent a more effective methodology, a less confusing paradigm for the participants, and avoid extraneous issues of satiety.

A second suggested modification is to present and/or analyze a subset of the control trials prior to conducting the illusion trials. In the present study, Control A, Control B, and Illusion trials were presented pseudorandomly across all 18 trials and all analysis took place after all data were collected. While this methodology is consistent with previous spontaneous choice studies (e.g., Miletto Petrazzini et al., 2017), it presents great difficulty when attempting to analyze the findings. Specifically, in the case of the spontaneous choice task, should there be a stringent criterion regarding which subjects should be included in the group analysis based on control performance? To date, there is no such criteria utilized within the spontaneous choice task; however, the current methodology may represent a major constraint for replication and generalizability. We leave this question open to further debate, exploration, and investigation, but highlight that at least two other studies evaluating illusion susceptibility via a spontaneous choice task have questioned the adequacy of this methodology (Santacà et al., 2017, 2019). In the interim, a possible solution to mediate the issue regarding control trial performance, is to set criteria that subjects must meet before moving on to illusion trials or until study exclusion criteria is met. This could be done through increasing the number of familiarization trials or by presenting a subset of the control trials before the illusion trials. This approach has been previously implemented in training paradigms (Byosiere et al., 2017) and would allow researchers to evaluate whether participants demonstrate the behaviors required for meaningful interpretation in the subsequently administered illusion trials. Once again, this adaptation removes an element of spontaneity but might result in more meaningful interpretations of illusion trials.

Conclusion

In conclusion, given the increasing popularity of the spontaneous choice task in cognition research, we recommend that future studies evaluate the suggestions outlined here to avoid these specific methodological challenges. Although the original aim of this study was to investigate pet dog visual perception by testing their susceptibility to the Ebbinghaus-Titchener illusion in a spontaneous choice task, the at-chance performance on control trials prohibited interpretation of the Illusion trial results. Therefore, we are unable to draw conclusions regarding pet dog susceptibility to the Ebbinghaus-Titchener illusion and additional research into canine illusion susceptibility and perceptual processes is needed. Our detailed recommendations outlined above may help mitigate extraneous factors when administering the spontaneous choice task and, ultimately, allow future studies to obtain more representative findings. Thus, we recommend that our suggestions for improvement be considered for any study using this paradigm to investigate dog susceptibility to visual illusions.

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Ethical Statement

All procedures performed and approvals obtained were in accordance with the Hunter College CUNY Institutional Animal Care and Use Committee (IACUC) which approved of the study on December 12, 2018 (DR-Dog Percept 11/21).

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Data Accessibility

All data are provided in the manuscript and any additional data will be provided by contacting the authors.

Authors' Contributions

NB: contributed to the conception, study design, acquisition of data, interpretation of data, drafting and correction of the manuscript.
SP-S: contributed to the interpretation of data, drafting and correction of the manuscript.
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