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Point Topography and Within-Session Learning Are Important Predictors of Pet Dogs' (*Canis lupus familiaris*) Performance on Human Guided Tasks

Udell, Monique A.R. [*a]; Hall, Nathaniel J. [b]; Morrison, James [b]; Dorey, Nicole R. [b] & Wynne, Clive D.L. [b]

[a] Department of Animal and Rangeland Sciences, Oregon State University. United States.
[b] Department of Psychology, University of Florida. United States.

Psicología Comparada y Cognición Animal

Abstract

Pet domestic dogs (*Canis lupus familiaris*) are generally considered successful on object choice tasks, reliably following human points to a target. However, defining the specific topography of the point types utilized and assessing the potential for dogs to generalize their responses across similar point types has received little attention. In Experiment 1, we assessed pet dogs' performance on an object choice task utilizing nine different point types that varied across the dimensions of movement, duration, and distance. These dimensions reliably predicted the performance of pet dogs on this task. In Experiment 2, pet dogs presented with nine different point types in the order of increasing difficulty performed better on more difficult point types than both naive dogs and dogs experiencing the nine points in the order of decreasing difficulty. In Experiment 3, we manipulated the attentional state of the experimenter (as in perspective taking studies) and found that human orientation was not a strong predictor of performance on pointing tasks. The results of this study indicate that dogs do not reliably follow all point types without additional training or experience. Furthermore, dogs appear to continuously learn about the dimensions of human points, adjusting their behavior accordingly, even over the course of experimental testing. These findings bring claims of pet dogs' spontaneous success on pointing tasks into question. The ability to learn about, and respond flexibly to, human gestures may benefit pet dogs living in human homes more than a spontaneous responsiveness to specific gesture types.

Key Words:
Canis Lupus Familiaris; Dog; Domestication; Learning; Generalization; Communication; Pointing.

Resumen

Los perros domésticos son generalmente considerados exitosos en la tarea de elección de objeto, siguiendo fiablemente señales humanas hacia el lugar correcto. Sin embargo, tanto el definir la topografía precisa de las señales así como el evaluar la capacidad de los perros para generalizar sus respuestas a través de claves similares, ha recibido poca atención. En el Experimento 1, evaluamos el rendimiento de los perros en la tarea de elección de objeto, utilizando nueve diferentes tipos de señalamientos que variaron a través de tres dimensiones: movimiento, duración, y distancia. Estas dimensiones fueron predictores confiables del desempeño de los perros en esta tarea. En el Experimento 2, los perros a los cuales se les presentaron las nueve formas de señalamiento en un orden de dificultad creciente, tuvieron un mejor rendimiento en las claves complejas que los perros que no fueron expuestos a ninguna clave, o aquellos a los que se les presentaron las mismas señales en orden dificultad decreciente. En el Experimento 3, variamos el estado de atención del investigador (como en los estudios de toma de perspectiva) y encontramos que la orientación del cuerpo de la persona no fue un buen predictor del desempeño de los perros en respuesta al señalamiento. Los resultados de esta investigación indican que los perros no siguen todos los tipos de señalamientos sin tener entrenamiento adicional o experiencia. Más aun, los perros parecen aprender continuamente acerca de estas dimensiones de movimiento, duración, y distancia, ajustando su comportamiento de acuerdo a ello, aun durante la prueba experimental. Estos hallazgos cuestionan las afirmaciones de que los perros sean espontáneamente exitosos en las pruebas de señalamiento. La habilidad de aprender acerca de los gestos humanos y responder flexiblemente a ellos, puede beneficiar a los perros que viven en hogares humanos aún más que la capacidad espontánea de responder a un tipo de gesto específico.

Palabras Claves:
Canis Lupus Familiaris; Perro; Domesticación; Aprendizaje; Generalización; Comunicación; Señalar.

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1. Introduction

Over a decade of research has established that many pet domestic dogs, *Canis lupus familiaris*, can reliably follow a variety of human points to a target for food reward (for a review see Udell, Dorey & Wynne, 2010a). In fact, pet dogs' reputation for success in human-guided tasks has made them a model species for

* Send Correspondence to: Udell, M.A.R.
E-mail: moniqueudell@gmail.com

investigating the origins of human socio-cognitive behavior, especially with respect to point following and sensitivity to attentional state (Miklósi, Topál & Csányi, 2004, 2007). Some have asserted that dogs are a good model species for evolutionary reasons, arguing that domestication or convergent evolution over the last 14,000 years (Nobis, 1979) can explain dogs' human-oriented behaviors (Hare, Brown, Williamson & Tomasello, 2002). Others have proposed that in addition to the dogs evolutionary history, ontogeny is also critical for the development of dogs' social behavior, including human-oriented social behavior (Bentosela, Barrera, Jakovcevic, Elgier, & Mustaca, 2008; Dorey, Udell & Wynne, 2010; Udell & Wynne 2010; Wynne, Udell & Lord, 2008), and that both evolutionary and lifetime considerations should be taken into account when interpreting dogs' response to human behavior (see the Two Stage Hypothesis, Udell et al., 2010a). Indeed, a wide range of studies have demonstrated that pet dogs show improvement on point following tasks with age and experience (Dorey et al., 2010; Miklosi et al., 1998; Wynne et al., 2008). Dogs also readily learn about the relationship between human actions and availability of reinforcement for acting in accordance with them. Pet and shelter dogs can learn to follow novel or challenging human gestures to a target with repeated exposure- often in less than 15 trials (Udell, Dorey, & Wynne, 2010b; Udell, Giglio, & Wynne, 2008) and can learn to move towards a target opposite of the one pointed to when that is the reinforced response (Elgier, Jakovcevic, Mustaca, & Bentosela, 2009). Dogs can also learn to increasingly gaze at a human who provides treats and stop gazing when reinforcement is no longer available (Bentosela et al., 2008), and gain knowledge about novel occluders that predict human attention or inattention, as well as the relative likelihood of reinforcement for behaviors such as begging, with experience (Udell, Dorey, & Wynne, 2011). The domestic dogs' proclivity for learning about human behavior (Udell et al., 2011a), as well as their ability to flexibly adapt to different environments and relationships with humans worldwide (Coppinger, & Coppinger, 2001), may be an important factor in their success as a species, as well as their success in human homes (Udell & Wynne, 2008). This may also be a contributing factor to the growing number of working roles dogs are now found in: from search and rescue, to guide dogs for the blind, therapy dogs, sniffer dogs, herding and livestock guarding dogs, hunting dogs, competitive athletes and the list goes on.

While much attention has been given to the possible evolutionary (Hare et al., 2002; Miklósi, Topál & Csányi, 2004, 2007) and lifetime (Dorey et al., 2010; Udell & Wynne 2010; Wynne, Udell & Lord, 2008) origins of these behaviors in recent years, less attention has been given to unprogrammed learning that could be occurring during the course of experimental testing. It is also unclear whether there are physical elements (or stimulus properties) of human points that might increase or decrease the salience of these stimuli in the context of a choice task. Therefore the purpose of the current study is not to further investigate the origins of pet dogs responsiveness to human pointing. Instead this study has three goals: (1) To provide a systematic comparison of different forms of the basic human pointing gesture by manipulating stimulus properties along the dimensions of movement, duration and distance (2) To investigate how experience and generalization during the course of experimental testing influences object choice task performance and (3) To determine whether human attentional state acts as a reliable independent predictor of dogs' success on a pointing task.

Experiment 1: What Is a Human Point?

Miklósi and Soproni (2006) compiled 24 studies where non-human animals were required to utilize a point in an object choice task. Based on the description of stimuli used in these studies, the authors broke the basic pointing gesture into three temporal categories (static, dynamic, or momentary). Each of these categories could be broken down further into five spatial designations (at target/ touching, proximal, distal, cross body, or asymmetric) and then divided again into three attentional state categories (no gazing, gazing at target, gazing at subject, gaze alternation). As a result, over 60 different point-type topographies were possible given the dimensions introduced by different experimenters (Udell et al., 2010a), and this is no longer a comprehensive list, as many additional point types have been used since that time.

What's more, individuals and populations of dogs do not appear to respond to the 60+ variations of the human point currently found in the literature as a unified stimulus. Variability is regularly found across 'point' types with different topographies as well as between individuals or populations of dogs experiencing the same point type (e.g. Gácsi, Kara, Belenyi, Topál, & Miklósi, 2009; Lakatos, Soproni, Dóka, & Miklósi, 2009; Udell, Giglio, et al., 2008;

Udell, Spencer, Dorey, & Wynne, 2012). For example, a series of experiments demonstrated that roughly 93% of dogs living in a shelter initially failed to follow a momentary distal point, where the human arm and hand was more than 50 cm from the target at full extension and returned to a neutral position before the dog was released to make a choice (Udell, Dorey & Wynne, 2008, 2010b). However these same dogs, as well as shelter dogs in other studies, have been found to follow simpler forms of human pointing, such as a dynamic proximal point, which comes within 10 cm of the target and is left in place until a choice has been made (Hare et al., 2010; Udell et al., 2010b).

While many studies have suggested that pet dogs as a group are more proficient at following momentary distal points to a target (Gácsi et al. 2009; Udell, Dorey et al., 2008), many individual pet dogs also initially fail to follow this point type. Instead pet dogs that do perform above chance on this gesture often do so with perfect, or near perfect accuracy (bringing up the population average to above chance levels), allowing many of those that fail the test to go undetected. In fact, most studies looking at pet dogs' responsiveness to a wide range of human gestures find different levels of success across gesture types and between individuals, independent of whether the average performance of the subjects is above or below chance levels (Udell et al., 2010a).

In other words after two decades of declarations that domestic dogs follow points, we have yet to answer a simple but important question: What is a point?

The large amount of variability in pet dog performance across point types suggests that there may not be a single answer. However, it may be possible to identify common features of point types that the majority of pet dogs follow (and also common features of point types dogs often struggle with). If so it might be feasible to identify point types that are more prototypical than others (and also point types that are less so). This could aid in future experimental designs and interpretations of data that may be especially relevant to cross-lab and cross-species comparisons.

While prior studies and meta-analyses have looked at differences in pet dog performance on object choice tasks in the presence of different gesture types (e.g. Dorey et al., 2009; Miklósi, et al., 1998; Miklósi & Soproni, 2006; Soproni, Miklósi, Topál & Csányi, 2001, 2002; Udell, Giglio et al., 2008), a systematic experimental manipulation of stimulus dimensions making up the basic human point with the extended arm and hand has not yet been achieved to our knowledge. Therefore, in our first experiment we look at a continuum of related but distinct point types, common to the literature, to assess how successful experimentally naive pet dogs might be on point types that systematically vary along dimensions of movement, duration (role of memory), and distance from the target (table 1).

Table 1. Point type conditions identified by combinations of relevant stimulus dimensions. All nine point type conditions were utilized in Experiments 1 and 2. Black cells indicate point types also tested in Experiment 3 where attention was removed during stimulus presentation.

		Movement/Duration		
		Dynamic	**Static**	**Momentary**
Distance	**Touch/Tap:**	**Dynamic Tap**	Static Touch	Momentary Tap
	Proximal (≤ 10cm):	Dynamic Proximal	**Static Proximal**	Momentary Proximal
	Distal (≥ 40cm):	Dynamic Distal	Static Distal	**Momentary Distal**

2. Materials and Methods

2.1. Subjects

Seventy-two pet dogs (41 male, 30 female) reported in good health comprised the study. Dogs ranged from six months to eleven years of age (M = 2.7

years, SD = 3) and represented a wide range of breeds and mixes. While developmental factors have been implicated in point following performance (Dorey et al., 2010; Wynne et al., 2008), no age-based decrement in performance has been reported for dogs over the age of four months (Dorey et al., 2010). Therefore all recruited subjects were not only over this age, but had been residing in their current home for at least 4 months. All dogs were naive to experimental pointing tasks at the time of testing and were tested indoors by an unfamiliar experimenter.

To prevent generalization across point types, each subject only experienced ten trials of a single point type, or in other words participated in only one condition of the nine possible point type conditions tested (see table 2 for descriptions of each point type). Therefore each condition required eight experimentally naive dogs. Dogs were randomly assigned to a condition before testing began.

Table 2. Point type definitions.

Point Type	Definition
Static touch	The experimenter touches the target container with one finger while the dog's view of the testing area is blocked. The dog is then allowed into the testing area while the experimenter maintains his touching position until the dog makes its choice.
Dynamic tap	The experimenter extends his arm toward the target container while the dog watches and continually taps the container with one finger until the dog makes its choice.
Momentary tap	The experimenter extends his arm toward the target container while the dog watches and taps four times on the top of the container with one finger. The experimenter then returns to a neutral position and the dog is released to make its choice.
Static proximal point	The experimenter begins pointing towards the target container, with his finger 10 cm from the container, while the dog's view of the testing area is blocked. The dog is then allowed into the testing area and the experimenter maintains his pointing position until the dog makes its choice.
Dynamic proximal point	The experimenter extends his arm toward the target container while the dog watches and maintains a point with his finger 10 cm from the container until the dog makes its choice.
Momentary proximal point	The experimenter extends his arm toward the target container while the dog watches and maintains a point with his finger 10 cm from the container for 4 seconds. The experimenter then returns to a neutral position and the dog is released to make its choice.
Static distal point	The experimenter begins pointing towards the target container, with his finger 50 cm from the container, while the dog's view of the testing area is blocked. The dog is then allowed into the testing area and the experimenter maintains his pointing position until the dog makes its choice.
Dynamic distal point	The experimenter extends his arm toward the target container while the dog watches and maintains a point with their finger 50 cm from the container until the dog makes its choice.
Momentary distal point	The experimenter extends his arm toward the target container while the dog watches and maintains a point with their finger 50 cm from the container for 4 seconds. The experimenter then returns to a neutral position and the dog is released to make its choice

2.2. Testing materials and layout

Two empty paint cans (15 cm diameter, 22 cm tall) with lids tightly fastened served as response objects. During experimental testing food was not present in or on either can until the subject made a correct response. This was done to control for smell given off by hidden food, which could guide the dog's response independent of experimental stimuli. Although sham baiting, or smearing/false baiting both choice objects with food prior to testing, has also been used to address this potential confound in the past (e.g. Miklósi et al., 1998; Riedel, Schumann, Kaminski, Call, & Tomasello,

2008) at least one study has demonstrated that sham baiting alone is an insufficient olfactory control for some canine subjects (see Udell, Dorey et al., 2008). Another study demonstrated that dogs are capable of using olfactory cues to locate hidden food in an object choice task (Szetei, Miklósi, Topál, & Csányi, 2003) although dogs may sometimes continue to favor visual human stimuli to olfactory cues.

The target cans were placed 0.5 m on either side of the experimenter (E1) and remained there throughout testing. At the start of each trial an assistant (E2) held the subject 2.5 m back from the center-line of the experimenter (see figure 1). All distances were measured prior to testing and marked with masking tape on the floor.

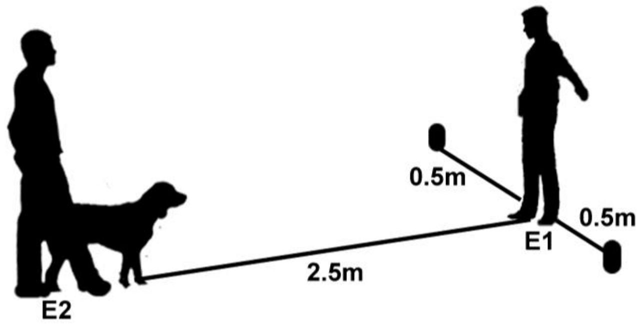

Figure 1. Testing Layout.

During testing dogs were rewarded with a preferred type of commercially available dog treat. To ensure food motivation and absence of fear in the experimental setting, dogs were required to readily eat this treat from the experimenter's hand prior to testing to be included in the study. The correct container or target was determined pseudorandomly before sessions, subject to the constraints that no one location was designated correct more than three times in a row and each location was correct for 50% of the trials.

2.3. Motivation Test

All testing began with a motivation test (MT) to familiarize the dog with the response objects and ensure that the dogs were motivated to eat food off the cans when given freely. This consisted of the experimenter (E1) calling the dog's name to gain its attention. He then placed a treat on top the designated paint can in view of the dog. The dog was allowed to approach the can and consume the treat. Experimental trails began after a subject successfully completed this motivation test four times (two MT for each can). Dogs then immediately moved on to experimental testing.

2.4. Experimental Testing

During experimental trials the dog was held 2.5 m back from the empty cans by the assistant, E2; the experimenter E1 called the dog's name to gain its attention. The experimenter then administered the designated stimulus (one of the nine possible point types described in table 2) indicating the previously determined target can. The assistant released the dog, which was then allowed to approach one of the two cans. A choice was recorded when the dog's muzzle came within 10 cm of either can or when the dog touched the can with any part of its body. If the dog chose the correct can first, the experimenter placed a treat on top the correct can for the dog to consume. To minimize any effects of delay between the subject's response and receipt of food, the experimenter also marked a correct response by saying "good dog" while placing the treat on the can. The only response considered correct during analysis was approach of the target –the can pointed to- during the one minute maximum duration of a trial; if the alternative can was approached first or any other response was made this was considered incorrect. If during testing the dog made three incorrect responses in a row, two additional MTs were given, one to each can. Loss of motivation, as indicated by failure to approach a can and take the food during a MT, resulted in as suspension of testing. No dog ever failed a test of motivation.

Each subject experienced a total of ten experimental trials, only witnessing a single assigned point type.

2.5. Control trials

A control trial followed every two experimental trials, with an additional control trial at the end of testing. In total each subject received six control trials. Control trials were carried out in an identical way to experimental trials, except that after calling the dog, the experimenter remained in a neutral position facing the dog (no point was given). This neutral position was held until the subject made a choice or until one minute had passed indicating that the trial had timed out. Just as in experimental trials, a correct or target can was predetermined (the correct can was pseudo-randomly assigned so that each can was correct 50% of the time) before testing and the experimenter was aware of which can was the target. Just like experimental trials, subjects were allowed to eat food from the target can after correct choices and did not receive food if an incorrect response was made. This was done to detect the presence of extraneous stimuli that could be controlling the dog's behavior beyond the designated point in experimental trials (including unintentional movements on the part of the experimenter).

Dogs did not perform above chance in the absence of a pointing stimulus (Mean of 1.99 correct responses out of 6; 95% CI [1.73, 2.25]), suggesting that successful point following performance during experimental trials was not a product of other available stimuli within the experimental setting. In fact in the absence of a point (as in the case of control trials) many dogs choose neither can (this response was more common after a dog had already experienced one or more control trials), instead they engaged in exploratory activities, waited at the starting point, or approached the experimenter often sitting neutrally or begging near by. This might suggest that dogs come to use human points not only as a stimulus predicting the location of food, but also a stimulus indicating the beginning of a choice trial. It is also possible that in comparison to simple point types, where dogs often reliably earn food > 80% of the time, control trials may offer too little payoff (on average 50%) to ensure a response is made on each of these trials, suggesting that dogs may learn to discriminate between experimental and control trials over the course of testing. However such outcomes still suggest that dogs are responding to the point, and not other external environmental stimuli, during experimental trials.

2.6. Statistical analysis

Performance analysis was based on correct responses. An individual was considered successful on the task if it made eight or more correct responses out of ten trials (binomial test, $p < .05$). A one-sample t-test was used to determine if a group of eight dogs followed a point type to the target more often than would be expected by chance. To determine if differences in performance existed across point types a single factor ANOVA was utilized. Performance between point types differing in designated point dimensions - movement, duration and distance- were then compared using corrected t-tests.

All statistical tests were two-tailed and had alpha set at .05 unless otherwise noted.

3. Results

3.1. Performance across point types

Each group of dogs was successful in following its assigned point type at above chance levels (one sample *t*-tests, t (7) = 6.00, $p < .001$) with the exception of the static distal point group (t (7) = 2.27, p = .06) and the momentary distal point group (t (7) = .34, p = .75). Mean performance scores and number of individual successes for each group can be found in figure 2. When comparing group performances for the different point types, a highly significant difference in the average number of correct responses between the nine point types arose (between-subject single-factor ANOVA, F (11, 84) = 8.03, $p < .001$).

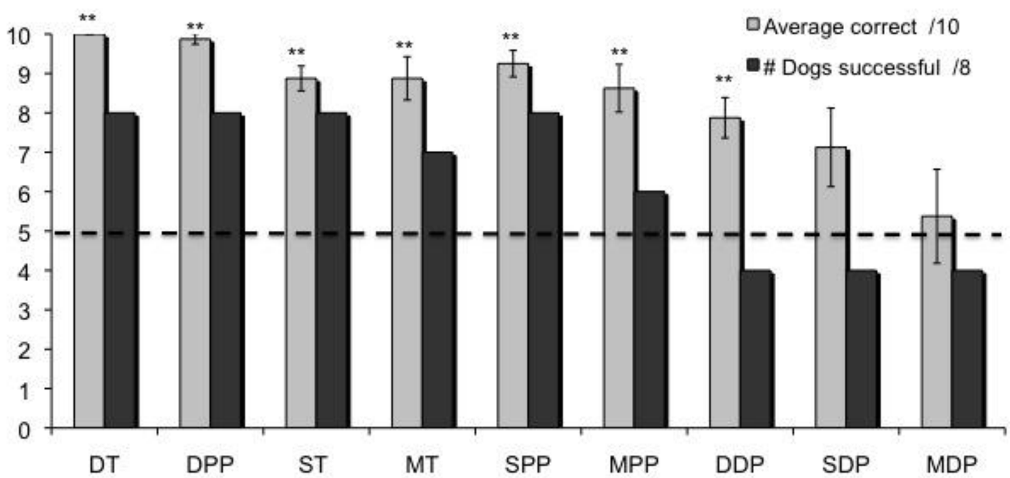

Figure 2. *Mean number of correct responses and number of successful individuals across point types in Experiment 1*. Point types are abbreviated as follows: DT (Dynamic tap), DPP (Dynamic proximal point), ST (Static touch), MT (Momentary tap), SPP (Static proximal point), MPP (Momentary proximal point), DDP (Dynamic distal point), SDP (Static distal point), MDP (Momentary distal point). Error bars represent +/- SEM. ** indicates one sample t-test, t (7) > 6.00, $p < 0.001$. Individuals were considered successful with a point type if they made eight or more correct responses out of ten (binomial test, $p < 0.05$). Dashed line at chance.

3.2. Stimulus dimensions

Our original prediction was that the source of such differences between groups would be related to the stimulus dimensions of movement, duration, and distance (as measured between the end of the stimulus and target container), therefore two additional analyses were conducted:

1) Movement/duration could be broken into three categories based on the point-types utilized in this study: dynamic (movement, point in place at time of choice), static (no movement, point in place at time of choice), and momentary (movement, point no longer in place at time of choice). Using corrected two-sample t-tests (corrected alpha, .02), we found a significant difference between pet dog performance on dynamic points [in place at time of choice] versus momentary points [absent at time of choice] (t (46) = 2.70, p = .01), with dogs making more correct choices on average when presented with dynamic points. We found no significant difference between momentary [containing movement] and static points [containing no movement] (t (46) = 1.19, p = .24) nor between dynamic [containing movement] and static points [containing no movement] (t (46) = 1.82, p = .08). Therefore point duration (or presence at the time of choice) seemed to have a larger influence than movement alone. At the individual level, more dogs were successful in static or dynamic conditions (20/24 each) than in momentary conditions (17/24), however this difference was not statistically significant (two-way Fisher's exact test, p = .49). See figure 3A.

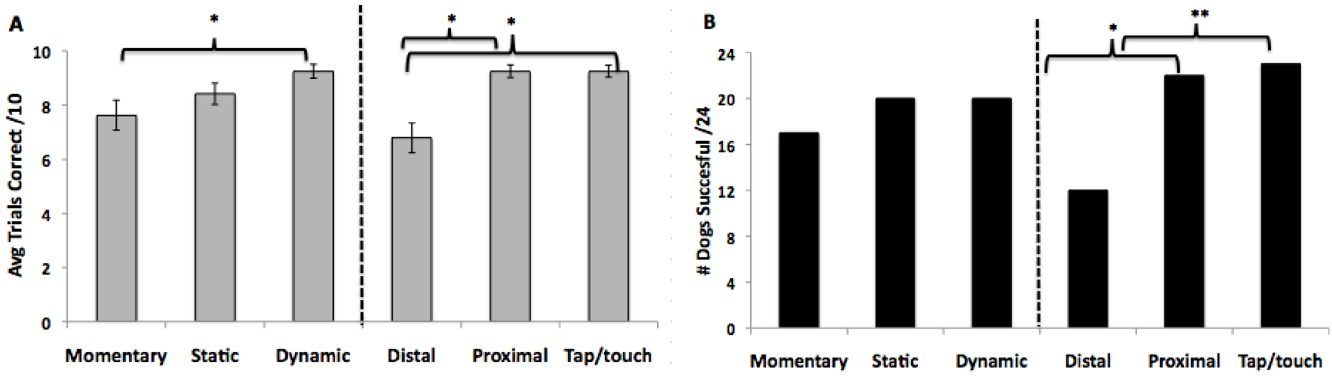

Figure 3. *Group and individual performance by dimension*. (A) Mean number of correct responses (out of 10) for each dimension. (B) Number of dogs successful in following point types categorized under each dimension (out of 24). Error bars represent +/- SEM. ** p < 0.001, * p < 0.05. Individuals were considered successful with a point type if they made eight or more correct responses out of ten (binomial test, p < 0.05).

2) Distance between the end of the pointing finger and the target could also be broken into three categories: tap/touch (direct contact made with the target), proximal points (10 cm from target), and distal points (50 cm from target). Using corrected t-tests (corrected alpha, .02) we found a significant difference between pet dog performance when comparing distal points with proximal points (t (46) = 4.21, p < .001) and between distal points and tap/touch (t (46) = 4.25, p < .001). In both cases dogs performed more accurately when the human point came closer to (or touched) the target. There was no difference between tap/touch and proximal points (t (46) = 0, p = 1.00). At the individual level, significantly more dogs were successful in proximal conditions (22/24) compared with distal (12/24) (two-way Fisher's exact test, p < .01), and in tap/touch conditions (23/24) compared to distal (two-way Fisher's exact test, p < .001). A significant difference between proximal points and tap/touch was not found. See figure 3B.

Experiment 2: Learning & Generalization

Experiment 1 suggested that both the duration (favoring points that remained in place until a choice was made) and distance (favoring points coming close to or touching the target) of a human point can significantly influence the likelihood that a dog will be successful in following a human point to a target. Point types lacking both long duration and proximity, such as the momentary distal point, appear to be the most difficult for experimentally naive dogs to respond to. General failure to follow the static distal point may suggest that the absence of movement, coupled with increased distance, could also make some gestures more difficult to follow.

Yet prior studies have reported that pet dogs do sometimes follow points lacking movement, made from a distance, or presented briefly at higher levels, and can in some cases perform well on point types that combine these elements – including the momentary distal point. Certainly individual dogs might have adequate experience (possibly beyond that of the general population) allowing them to perform well using these more difficult point types (for example dogs with agility training or even those who spend most of the day with their owner might be at an advantage over pet dogs with little to no training and those that spend much of the day home alone). Indeed in most studies at least a few individuals perform successfully even when more subtle gestures are used. It is also possible that some breeds may be more sensitive to specific stimulus properties than others (Dorey et al., 2009). However another important factor may be the methods used to assess dogs' 'spontaneous' responsiveness to human points; including the number of trials or point types a dog will experience over the course of experimental testing. While all of these factors are of potential importance, here we intend to focus specifically on the latter.

Many previous studies have presented a single group of dogs with a large number of point types over the course of a single experiment (e.g. Soproni et al., 2001, 2002; Udell et al., 2012). While this approach is not inherently problematic (it can be used to assess a dogs capacity to follow a variety of point types), elevated success rates in studies using this methodology may indicate that subject performance is not truly spontaneous (even if the dog could be considered naive at the start of the experiment), but instead influenced by experience gained during testing itself. After all, research has demonstrated that pet and shelter dogs can learn to follow a novel or challenging human gesture to a target with repeated exposure- often in less than 15 additional trials (Udell et al., 2010b; Udell, Giglio et al., 2008).

On the other hand, it might be argued that while repeated exposure to the same human point type improves canid performance on an object choice task (Udell et al., 2010b; Udell, Giglio et al., 2008; Virányi et al., 2008), studies presenting dogs with a string of topographically distinct human points are not subject to the same criticisms. Whether exposure to physical properties of one point type, sharing characteristics with more difficult or unusual point types, might allow dogs to generalize their response to novel gestures has remained untested. In Experiment 2 we directly test and measure the effect of experimental exposure on pet dogs' point following performance.

4. Materials and Methods

4.1. Subjects

Sixteen additional pet dogs reported in good health comprised the study. Subjects ranged in age from nine months to nine years (M = 4.3 years, SD = 2.5), eight were male and eight female, and represented a range of breeds and mixes. All subjects had been residing in their current home for at least 4 months. All dogs were naive to the task at the time of testing and were tested indoors by an unfamiliar experimenter.

Each subject experienced the full series of nine point types, as defined in table 2. Testing was broken into three sessions; each dog experienced three point type conditions per session. Breaks between sessions were determined by participant availability but were never shorter than one day and never longer than two weeks. Half of the subjects experienced the point type conditions in the order of increasing difficulty (easy to difficult), as established by Experiment 1 and additionally confirmed by independent difficulty ratings made by eleven anonymous researchers in the field naive to the purpose of the study (these measures were highly correlated: Pearson's correlation coefficient, rating x performance, R = 0.94). The remainder of the subjects experienced each point type in order of decreasing rank difficulty (difficult to easy). See figure 4 for point types in order of increasing/decreasing difficulty. Before testing began, dogs were randomly assigned to their respective conditions with one exception: if two dogs from the same household participated in the study each was assigned to a different condition to avoid potential confounds between condition assignment and living environment.

4.2. Testing materials, layout, MT, and experimental trials

Materials, layout, motivation tests, and experimental trials were identical to those in Experiment 1, with the following exceptions:

As in Experiment 1 subjects experienced MT at the beginning of testing. Since subjects in Experiment 2 were required to complete three point-type conditions per session (a total of 30 experimental trials, compared to 10 in Exp 1) an additional two MT, one to each side, were conducted after the first and second conditions of each session to ensure the dog was still food motivated before proceeding to the next condition. No subject failed a test of motivation within the course of a session.

Each subject received a total of 90 experimental trials over the course of testing; 10 trials per point type condition.

4.3. Control trials

A control trial followed every ten experimental trials, resulting in three control trials per session and nine control trials per dog. Control trials were carried out in the same manner as in Experiment 1. Dogs did not perform above chance on control trials, mean of 3.44 (95% CI [2.71, 4.17]) control trials correct out of 9, suggesting that point following performance was not influenced by other stimuli within the experimental setting.

4.4. Statistical analysis

Performance analysis was based on correct responses. An individual was considered successful on the task if it made eight or more correct responses out of ten trials (binomial test, $p < .05$). A one-sample t-test was used to determine if a group of eight dogs performed better on a point type than would be predicted by chance.

A two-factor within subject ANOVA was used to determine if there were significant differences in performance across point types and between the two subject groups (difficult to easy; easy to difficult). For each group, we also compared the performance between point types differing in designated point dimensions (movement, duration and distance) using corrected t-tests.

All statistical tests were two-tailed and had alpha set at .05 unless otherwise noted.

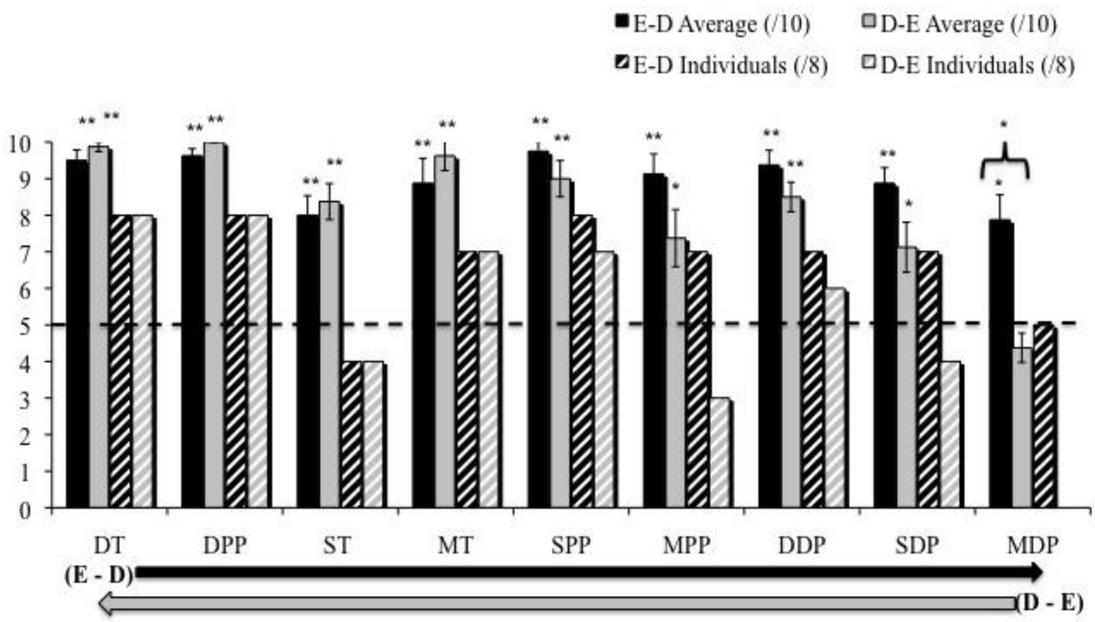

Figure 4. *Mean number of correct responses and number of successful individuals across point types in Experiment 2*. Point types abbreviations are the same as in figure 2. Dog subjects in the Easy to Difficult (E-D) condition experienced all point types in order from left to right. Dog subjects in the Difficult to Easy (D-E) condition experienced all point types in order from right to left. Error bars represent +/- SEM. ** indicates one sample *t*-test, $t\ (7) > 6.00$, $p < 0.001$; * indicates one sample *t*-test, $t\ (7) > 3.25$, $p < 0.05$. *** Located over the momentary distal point bracket indicates a significant difference between groups (t-test, $t\ (7) = 4.72$, $p < 0.0006$). Individuals were considered successful if they made eight or more correct responses out of ten on a point type (binomial test, $p < 0.05$). Dashed line at chance.

5. Results

Experiment 2 was designed to determine if dogs would learn about human point types over the course of experimental testing. We were interested in the possibility of stimulus generalization across point types. Specifically, we looked for improved performance on novel point types sharing some but not all the stimulus properties with previously experienced point types. Each subject received ten trials of all of the nine different point types (90 trials total). Eight of the subjects experienced the point type conditions in the order of increasing rank difficulty (easy to difficult); the other eight experienced the point types in order of decreasing rank difficulty (difficult to easy).

Dogs in the easy to difficult condition were successful on each of the nine point types as a group (one sample *t*-tests, t (7) > 4.50, p < .01). At the individual level at least half the subjects performed significantly above chance (binomial tests, p < .05) on each point type. Dogs in the difficult to easy condition were successful on eight of the nine point types as a group (one sample *t*-tests, t (7) > 3.25, p < .01), failing to reach above chance performance only on the momentary distal point (one sample *t*-test, t (7) = 1.67, p = .14). No dog in the difficult to easy condition was individually successful on the momentary distal point (binomial tests, p > .05), and fewer than half of the subjects experiencing point types in order of decreasing difficulty were successful on the momentary proximal point (see figure 4).

5.1. Experience and learning

A significant difference was found between the mean performances of dogs in the easy to difficult condition compared to dogs in the difficult to easy condition, with the former outperforming the latter on the series of object choice tasks (two-factor within subject ANOVA, F (1, 14) = 5.97, p = .03). There was also a highly significant difference in performance between point types (F (8, 112) = 15.3, p < .001), as well as a significant interaction between condition and point type (F (8, 112) = 5.66, p < .001). Because dogs were least successful on the momentary distal point in Experiment 1 we predicted that the effect of experience would be most apparent for this point type, therefore we directly compared the average performance of dogs experiencing this point first (difficult to easy condition) with dog who experienced this point last (easy to difficult condition). A highly significant difference was found between the mean performance of dogs experiencing eight simpler point type conditions prior to encountering the momentary distal point (mean = 7.89 correct out of 10), and those without prior experience (mean = 4.38 correct out of 10) (t-test, t (7) = 4.72, p < .001). At both the group and individual level, dogs with more pointing experience performed significantly better on the momentary distal point, even though they had not previously encountered this specific gesture type earlier in testing.

5.2. Stimulus dimensions

As in Experiment 1, two additional analyses were conducted to compare the salience of our focal stimulus dimensions (movement, duration, and distance) based on the performance of pet dogs on the object choice task. This was done separately for the two subject groups because prior analyses indicated that order of point exposure influenced performance, especially for the most difficult point types. We wanted to determine if each group's overall pattern of response across stimulus dimensions was different as well.

1. As in Experiment 1, movement/duration could be broken into three categories based on the point types utilized in this study: dynamic, static, and momentary. Using corrected two-sample t-tests (corrected alpha, .02), we found no significant difference in mean trials correct between dynamic (9.5/10 correct), static (8.9/10) and momentary (8.6/10) points for dogs in the easy to difficult condition (t (46) < 2.28, p > .03). On the other hand, dogs in the difficult to easy condition chose the correct target significantly more often on average when the pointing stimulus was dynamic (9.5/10 correct) as opposed to static (8.2/10) (t (46) = 3.37, p < .01) or momentary (7.1/10) (t (46) = 4.13, p < .001). No significant difference was found between static and momentary points (t (46) = 1.66, p = .11).

2. Distance between the point and the target could also be broken into three categories: tap/touch, proximal points, and distal points. Using corrected t-tests (corrected alpha, .02), we found no significant differences in mean number of trials correct between tap/touch (8.8/10 correct), proximal (9.5/10) and distal points (8.7/10) for dogs in the easy to difficult group (t (46) < 2.02, p > .03). However dogs in the difficult to easy condition performed significantly better on average with tap/touch stimuli (9.3/10 correct) (t (46) = 5.21, p < .001) and proximal points (8.8/10) (t (46) = 3.73, p < .001) when compared with distal points (6.7/10). No significant difference was found between tap/touch and proximal points (t (46)= 1.17, p = .24).

Therefore experiencing points in order of increasing difficulty may have allowed dogs to overcome decrements in performance associated with greater pointing distance and shorter point duration (or the need for memory, given that in momentary points the point it removed prior to the dog making a choice) initially identified in Experiment 1 and also seen in the difficult to easy condition of Experiment 2. This strongly suggests that experience acquired during the course of experimental testing can have a significant impact on the performance of dogs across different point types utilized in human-guided object choice tasks. This effect can be influenced by the testing order itself and in some cases could lead to performances that appear to support spontaneous success on a novel gesture type, but are really the by-product of learning and generalization from earlier testing.

Experiment 3: Does Human Attentional State Matter

Point following behavior is often considered a measure of joint attention and has been associated with healthy socio-cognitive development, language formation and even theory of mind in the human developmental literature (Carpenter, Nagell & Tomasello, 1998; Goldin-Meadow, 2007; Tomasello, Carpenter & Liszkowski, 2007). To some, following the point of another individual implies a deep understanding of communicative intent or even knowledge of the mental states of others (Gómez, 2007; Tomasello et al., 2007). In the same tradition, domestic dogs have been tested for their responsiveness to human gestures, including pointing. However it is far from clear what point following behavior can tell us about a dog's understanding of a human pointer's intentions, if anything (including whether dogs actually treat points as inherently cooperative gestures).

Perspective taking tasks have traditionally come closer to addressing this type of question. Indeed, pet dogs have been recognized for their ability to discriminate between a person looking towards them and one looking away (or with obscured vision) (E.g. Forbidden food tasks: Bräuer, Call & Tomasello, 2004; Call, Bräuer, Kaminski & Tomasello, 2003; Begging tasks: Cooper et al., 2003; Gácsi, Miklósi, Varga, Topál, & Csányi, 2003, Udell, Dorey, & Wynne, 2011). Although occluders, or barriers of attention, used in both tasks can vary substantially (e.g. reading a book, bucket over the head, blindfold over the eyes and even portable wall placement) in the most straight-forward version of the begging task, a dog is given the choice to beg from either an attentive experimenter facing the dog or an inattentive experimenter whose back is turned. Across studies, dogs have shown sensitivity to the cooperative nature of begging tasks and the importance of experimenter attention; reliably approaching the person looking at them when begging for food – not approaching the individual with her back turned (Cooper et al., 2003; Gácsi et al., 2003, Udell et al., 2011).

On the other hand, the forbidden food task is clearly not cooperative; instead human attention serves a competitive or preventative role. For this task, a piece of food is placed within the dogs reach, and the owner instructs the dog not to take it. The human is then either attentive, watching the dogs actions, or inattentive. In this case dogs' sensitivity to attentional state has been demonstrated by dogs increased willingness to steal food when the human's back is turned (or when one of many other possible occluders is used to block the human's view of the food or dog), thereby increasing the dog's chances of obtaining the food and avoiding punishment for doing so. Therefore dogs have not only demonstrated a sensitivity to cues that predict to attentional state, but also discriminate between contexts where human attention will facilitate reinforcement (cooperative scenarios) from contexts where the absence of human attention is most beneficial (non-cooperative scenarios).

To date the knower-guesser paradigm provides one of the few examples of where human pointing and attentional state measures are combined into a single task. In this task one experimenter, the 'knower', witnesses the hiding of a piece of food. The subject is not able to see where the food is hidden, however they do have visual access to the 'knower' during the baiting phase. The other experimenter, the 'guesser', is prevented from seeing where the food was hidden. Afterwards both individuals point at a location where the food might be. The correct response is for the subject to choose the location indicated by the 'knower', and dogs have performed successfully on several versions of this task (Cooper et al., 2003; Maginnity, 2007). While interesting in its own right, this particular methodology is designed to assess what the dog is knows about the attentional state of the experimenter with relation to the baiting process; or, in other words, the experimenter's knowledge about the location of the food, not the location of the dog. Therefore from the dog's perspective both experimenters might be attempting to engage in 'cooperative behavior', even if one can only provide his best guess about the location of the food. Begging and forbidden food tasks are inherently different from the knower-guesser task in an important way: the human always knows where the food is (in some cases they are holding it), the question is whether the person is attending to the behavior of the dog and whether or not this is beneficial or problematic for the dog depending on the nature of the task (cooperative or not). In this case, behaviors requiring human cooperation, like begging, should decrease when a human turns her back (a signal of inattention), conversely behaviors that compete or conflict with human goals (e.g. human guarding or forbidding a piece of food), should increase when a human turns her back. Other behavioral responses to human-attentional state likely fall somewhere in between these two ends of the approach-avoidance continuum; human attention should have less influence on a dog's response when the human action is not perceived as inherently cooperative or competitive.

In Experiment 3 we borrow this perspective taking methodology to assess whether point following in dogs is influenced by the attentional state of the human. If pointing is strictly viewed as a cooperative activity by dogs, then a cue of inattention (such as turning one's back) might be expected to reduce responsiveness to typically salient gesture types as it does in other cooperative tasks. On the other hand, dogs may learn that points can be useful independent of human cooperative intent (or may not rely on perceptions of communicative intent or cooperation at all). If this is true the human's attentional state may not have reliable predictive value for point following behavior, but instead may simply serve as one of many possible stimulus dimensions that contribute to the overall salience of the human point.

To test this we revisited three of the point types from Experiment 1 (dynamic tap, static proximal point, momentary distal point) comparing dogs' performance when the human experimenter faced forward or had his back turned.

6. Materials and Methods

6.1. Subjects

All subjects were pet domestic dogs reported to be in good health at the time of testing. Dogs ranged from 6 months to eight years in age (M = 3.4 years, SD = 2.4 years), 16 were male and 16 female, and consisted of a range of breeds and mixes. All subjects had been residing in their current human's home for at least 4 months and were tested indoors by an unfamiliar experimenter.

Two groups of dogs participated: The experienced group (E) - made up of eight dogs from Experiment 2, having previously experience 90 trials of the object-choice task over the course of all nine forward facing point types, and the no experience group (NE) - 24 naive dogs, split into three sets of eight dogs- one set assigned to each back-turned point type.

As in Experiment 2, subjects in the experienced group (E) experienced all three point types utilized in Experiment 3 (presented in the following order: dynamic tap, static proximal, momentary distal). Dogs experienced these three point types within one 20-30 minute session on a single day. As in Experiment 1, each dog in the no experience group (NE) only received 10 trials of a single point type during testing to reduce the possibility of generalization.

6.2. Testing materials, layout, MT, and experimental trials

Materials, layout, MT, control and experimental trials were identical to those in Experiment 2, with the following exceptions:

Only three point type conditions were included in Experiment 3: Dynamic tap, static proximal point, and momentary distal point. These conditions were selected because each point possessed different combinations of the stimulus dimensions investigated in Experiments 1 and 2 (see table 1), together representing a comparatively easy, moderate, and difficult form of the pointing stimulus.

The most significant change to the methods in Experiment 3 was the shift from forward facing to backwards facing point presentations. During experimental and control trials, the testing layout depicted in figure 1 was utilized, however E1 faced away from the dog, looking towards a back wall for the duration of testing. Since the experimenter could not see the dog from this position, the assistant began the trial by saying "point," to indicate that the dog had oriented towards the experimenter. Once the point had been presented the dog was released. The assistant was also responsible for alerting the experimenter once the dog had made a choice: "yes" indicated a correct response, "no" indicated an incorrect response, and "time" indicated that the one-minute timeout period had passed. Scoring was based on the same choice criterion described in Experiments 1 and 2. The experimenter only provided the food reinforcer to the dog if the assistant indicated a correct choice. This was done to ensure that a prompt and consistent response was made to the dog's behavior during testing even if it occurred outside of the experimenter's field of vision.

6.3. Control trials

Control trials were carried out in an identical manner to Experiments 1 and 2, only the experimenter's back was turned during them. Overall, dogs in both the experienced group (mean of 4.13 out of 12 trials divided between three sessions; 95% CI [3.24,5.02]) and no experience group (mean 2.08 out of 6 trials presented during the course of their only session; 95% CI [1.57,2.59]) did not perform above chance on control trials.

6.4. Statistical analysis

Performance analysis was based on correct responses. An individual was considered successful on the task if it made eight or more correct responses out of ten trials (binomial test, $p < .05$). A one-sample t-test was used to determine if a group of eight dogs performed better on a point type than would be predicted by chance.

A two-factor ANOVA (one within, one between), was used to determine if there were significant differences in performance across back-turned point types and between the two subject groups (experience, no experience). We also independently compared the mean performance scores of experienced and inexperienced dogs for the back-turned momentary distal point using a t-test. Based on the outcomes of Experiments 1 and 2, we predicted that the momentary distal point would be the strongest independent indicator of the effect of prior experience on performance.

Finally the influence of attentional state in the context of an object choice task was evaluated comparing naive dogs experiencing back-turned dynamic tap, static proximal, and momentary distal points with the experimenter in a forward facing orientation (from Experiment 1) with naive dogs experiencing those same point types with the experimenter in a back-turned orientation (a cue of inattention).

All statistical tests were two-tailed and had alpha set at .05 unless otherwise noted.

7. Results

Dogs in the experienced group (E) performed above chance on all three of the back-turned point types (one-sample t-tests, t (7) > 7.17, $p < .001$). Individually, out of eight dogs, a total of seven successfully used the dynamic tap, six dogs used the static proximal point, and six dogs used the momentary distal point to locate the target at above chance levels (individual binomial tests, $p < .05$). Dogs in the no experience group (NE) were also successful in using the back-turned dynamic tap and static proximal point as a group (one sample t-tests, t (7) > 13.75, $p < .001$), but did not perform above chance on the back-turned momentary distal point condition (one sample t-test, t (7) = .31, $p = .77$). See figure 5. Individually, out of the eight dogs in each condition from the no experience group, all eight performed above chance (individual binomial tests, $p < .05$) on the back-turned dynamic tap and static proximal point conditions, while only two dogs performed above chance (individual binomial tests, $p < .05$) on the back-turned momentary distal point condition. Differences in dogs' average performance by point type (two-factor ANOVA, F (2, 28) = 19.1, $p < .001$) and in interactions between point type and prior experience (two-factor ANOVA, F (2, 28) = 8.32 $p = .001$) were identified, however no significant difference was found between groups (experience vs no experience) when point types were pooled (two-factor ANOVA, F (1, 14) = 3.03 $p = .10$). However, when the mean group performances were compared for the back-turned momentary distal point alone, the group of dogs with prior experience (8.25/10 correct) performed significantly better than the naive dogs (5.25/10 correct) (t-test, t (7) = 3.21, $p < .01$).

To assess performance differences predicted by the orientation of the experimenter, the mean performances of inexperienced dogs witnessing a dynamic tap, static proximal point, and momentary distal point in Experiment 1 (forward facing) and Experiment 3 (back-turned) were compared using a two-factor between-subject ANOVA. Although differences between the point types themselves were found (F (2, 42) = 33.1 $p < .001$), with dogs performing worst on the momentary distal point independent of human orientation, a significant difference was not found between the performance of dogs in the forward-facing versus back-turned groups (F (1, 42) = .064, $p = .80$). See figure 5. A significant interaction effect between point type and experimenter orientation was also lacking (F (2, 42) = .192, $p = .82$).

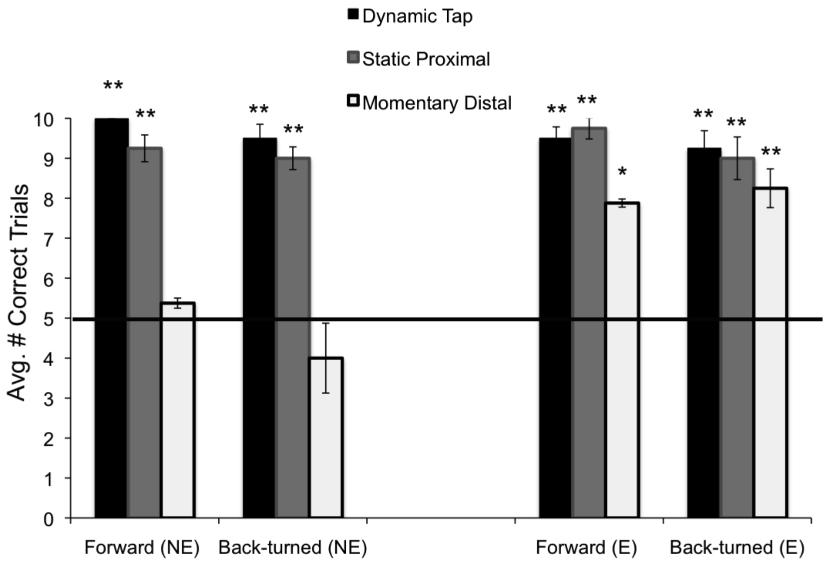

Figure 5. *Role of experimenter attentional state on point-following performance in nieve and experienced dogs*. The mean number of correct choices out of ten for each back-turned point type and its forward facing counterpart are shown. NE indicates groups of dogs with no prior experience on the task; these dogs only experienced the single point type indicated. E indicates groups of dogs with prior experimental Experience; these dogs experienced all point types from Experiments 2 & 3, however the data shows their first exposure to each particular point type. Solid line indicates 50% chance; error bars represent +/- SEM. ** indicates one sample *t*-test, t (7) > 7.17, p < 0.001; * indicates one sample *t*-test, t (7) = 4.50, p = .002.

Therefore the attentional state of the experimenter did not appear to significantly influence pet dog performance in the context of the human- guided object choice task. Dogs with no prior experience were likely to succeed on the dynamic tap and static proximal point conditions and fail on the momentary distal point condition independent of experimenter orientation. Dogs with more pointing experience were likely to succeed on all point types independent of experimenter orientation. This suggests that dogs do not rely on traditional cues of cooperative intent (e.g. eye contact) when responding to human points.

8. General Discussion

It has been suggested that pet dogs' responsiveness to human action, including their ability to follow a point to a target, may contribute to their success in human environments (Udell & Wynne, 2008). Our results suggest that while many pet dogs can follow a wide range of points made with the human arm and hand, they also show different levels of responsiveness to points that vary along dimensions of distance and duration (and possibly to a lesser degree movement). Therefore different forms of human point should not be considered interchangeable, as small differences in topography can have a significant impact on performance (in some cases predicting success or failure on the task). Likewise, individual variation between dogs suggests that it may be equally problematic to describe 'dogs' as proficient on point following tasks; instead it would be more appropriate to describe dogs (and other relevant species) as having the capacity to succeed –or even excel- on human-guided tasks assuming other lifetime variables (developmental stage, life experience, home environment, and even prior experimental exposure) are compatible with such a response.

The momentary distal point was identified here as the most challenging point for pet dogs to follow in an object choice task, a finding that is widely supported in the literature for the performance of pet dogs (Gásci et al., 2009), shelter dogs (Udell et al., 2010b) and wolves (Virányi et al., 2008). The fact that momentary points eliminate the dog's ability to view the point, or discriminative stimulus, at the time of choice, adds a memory component to the task. This might make the task more challenging in ways that could be systematically varied by an experimenter, allowing for tests of the influence of memory on pointing tasks as well as another method for assessing short term memory in domestic dogs (and possibly other species as well). Therefore momentary points may provide interesting opportunities for additional study.

Additional experimental manipulations exploring the effect of distance between the stimulus (human point) and the target might also be made. While a change of just 40 cm in distance appeared to make an significant difference for the performance of dogs in this study (dogs performed better on points within 10 cm of the target, and worse on those 50 cm from the target), it would be interesting to know what the maximum limit for making a connection between the point and a target might be and whether this could vary by context or breed.

While the *combination* of the momentary and distal components of a point led to the most challenging point type across all three experiments, dogs were successful in utilizing a range of other point types possessing either the momentary or distal component in other combinations. Therefore predicting the degree of salience associated with a pointing stimulus may not be as easy as calculating the sum of its parts.

In Experiment 2 we demonstrated that experience acquired over the course of an experimental study can prepare pet dogs to outperform naive dogs on an object choice task utilizing human points (even when prior experimental exposure was limited to points containing some but not all of the stimulus properties associated with more difficult points). This suggests that dogs can and do rapidly learn to assimilate new gestures into their behavioral vocabulary, and can acquire appropriate responses to new gestures through the process of generalization. It is possible that dogs might also develop a learning set with respect to point following tasks, and that with enough experience dogs may quickly and seamlessly appear to be proficient at responding appropriately in the presence of any gesture within the context of an object choice task (where any new discrimination can be learned on the first trial). Determining if this is the case however, will require further research.

Independent of the type(s) of learning taking place, within-subject research intended to survey the domestic dog's *spontaneous* success on human-guided tasks (for examples see Soproni et al., 2001; Virányi et al., 2008) should carefully consider the effects of learning that occur over the course of testing, not to mention a lifetime of learning opportunities present in the pet dog's natural environment- the human home. Post-hoc tests that compare a small portion of trials at the beginning and end of an experiment after the fact may not always be sufficient to accurately measure the influence of learning within the course of an experiment (Udell et al., 2010b).

It should be noted, however, that generalization over the course of an experiment may be less likely in studies utilizing stimuli that differ greatly from one another (E.g. Miklósi et al., 1998; Udell et al., 2012; Udell, Giglio et al., 2008). For example, conditions utilizing a momentary distal point towards a target followed by a condition using a foot point or a head turn. While it is possible that subjects may still learn something about the task (for example, that they should generally attend to the experimenter's behavior and minimally approach one of the target objects each trial), a drastic shift in stimulus form or location could potentially decrease performance on the task in this case (e.g. a dog may still attend to the experimenter's neutrally placed hand when the solution is to be found by looking at the movements occurring with the experimenter's foot or head). In contrast, for Experiment 2, the solution could always be found by looking at the experimenter's arm and hand. Indeed a recent study by Elgier, Jakovcevic, Mustaca, and Bentosela (2012) demonstrated that dogs who were first allowed to follow proximal points later performed above chance when presented with a novel cross-point (both made with the experimenters arm and hand); conversely dogs who instead had previous experience with body position cues (where the experimenter stood behind the target container) did not perform above change when later presented with the cross-point. As in the current study, this finding suggests that dogs can show improved performance on novel gesture types due to generalization (i.e. reinforced prior exposure to simpler point types or gestures from earlier in testing); however the degree of similarity between the stimuli also seems to be relevant.

Interestingly, in Experiment 3, the attentional state of the experimenter did not alter the performance of dogs on the pointing task. This does not imply that dogs are insensitive to attentional state or cooperative actions. To the contrary, there is ample literature demonstrating that dogs are more likely to approach an attentive experimenter in tasks that are inherently cooperative, such as begging tasks (Cooper et al., 2003; Gácsi et al., 2003; Udell et al., 2011) and are more likely to steal forbidden food when humans, who might stop or punish the behavior, are inattentive (Bräuer et al., 2004; Call et al., 2003). Instead dogs do not appear to treat point following as a behavior requiring the attention of the human, or in other words, the responses of the dogs in Experiment 3 are not consistent with the hypothesis that dogs view human points as an inherently cooperative gesture. Alternatively, dogs may learn that human points are often useful even when not intended for them, for example when a human points out a ball to another dog at the park.

A related study recently found that when a pointing human experimenter called a dog's name in a "cooperative tone of voice" dogs were more likely to reliably follow their point to a target than when the experimenter gestured towards the target "uttering a forbidding command in a prohibitive tone of voice" (Pettersson, Kaminski, Herrmann, & Tomasello, 2011, p. 236). This finding suggests that additional cues, such as tone of voice, may allow dogs to discriminate between contexts where following a point might lead to reward or punishment. However, while dogs' performance fell to chance levels in the overtly competitive situation presented by Pettersson et al. (2011), the current study suggests that overt cooperative cues (like eye contact) are unnecessary for above chance performance.

From a learning perspective, it makes sense that dogs display flexible point following behavior independent of human attentional state. Payoff within the human home may be available for following a point even when the dog is not the intended recipient. Pointing used to reprimand a child for dropping food on the floor is no less laden with information than a point intended by the human to alert the dog to the location of the food. This sort of eavesdropping would allow vigilant dogs to focus their attention on interesting or important aspects of the environment as signaled by humans, even when the intended recipient may be another individual (dog, human, or otherwise). Eavesdropping may play an especially important role when interpreting the behavior of dogs who would likely benefit most by responding to human gestures in ways counter to the goals of the human (e.g. feral dogs avoiding capture or harm at the hands of humans, or a pet dog trying to avoid a bath or shot). This form of response would not require the dog to understand or even perceive the intent of the gesture – responding in accordance with the outcomes of prior context specific experiences may be sufficient to explain this behavior- however the possibility that dogs understand the intent of a gesture but ignore or act counter to it in cases where it might be beneficial to do so cannot be ruled out without further research.

While it is possible that some foundational stimulus properties are necessary for any dog to utilize a human point as a stimulus- for example, adequate stimulus size given an individual's visual acuity (Udell, Giglio, et al., 2008), or sufficient contrast with a given background (Lakatos, Dóka, & Miklósi, 2007)- differences in individual experience with humans and specific gesture types may account for much of the variability seen in the literature to date. It is also possible that the degree to which certain stimulus dimensions are important could vary by developmental factors, breed, or population. For example movement as a stimulus dimension may be more relevant when testing herding breeds (which have been bred for their attentiveness to moving stimuli) and less important for livestock guarding breeds (which are bred for an inhibited response to movement) (Dorey et al., 2009). However, these are important empirical questions for future research.

Ultimately the findings of this study are consistent with the broader literature on point following and the use of referential stimuli not only by canids but also by humans. There is ample evidence that both human children and dogs learn and develop the ability to respond to the stimuli of their social companions with age and experience, both within species (e.g. children: Carpenter et al., 1998; Mundy et al., 2007; dogs: Fox, 1969; Scott & Fuller, 1965) and between species (e.g. Bentosela et al., 2008; Elgier et al., 2009; Dorey et al., 2010). In fact, stimulus type predicts the performance of young human children in object-choice tasks as well (Lakatos et al., 2009). Considering the wide variety of gestures that could be made with the human body, and the impact that culture, environment, health, growth, and coordination could have on a human's gesturing behavior, flexibility ¬– including the ability to learn and modify responses to different human stimuli - could provide many short and long term benefits compared with a static ability to respond to specific gesture types. However, more direct acknowledgment and study of the impact that life experience, environment, and specific stimulus properties have on the social behavior of pet dogs may allow us to better appreciate and explain individual differences as well as species or breed trends. Additional systematic research on the proximate variables that influence social behavior may also help provide a better understanding of how other species, including humans, develop a sensitivity to the gestures of others within their lifetime – or even during the course of experimental testing. A goal that can and should fit hand in hand with the important research being done from an evolutionary perspective.

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