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Following the human point: Research with nonhuman animals since Povinelli, Nelson, and Boysen (1990)

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Abstract

For this special issue in honor of Dr. Sarah (Sally) Boysen's career, we review studies on point following in nonhuman animals. Of the 126 papers that we documented on this topic published since the publication of Povinelli, Nelson, and Boysen (1990, *Journal of Comparative Psychology, 104*, 203–210), 94 (75%) were published in the past 15 years, including 22 in the past 5 years, indicating that this topic is still an active area of interest in the field of animal behavior and cognition. We present results of a survey of publication trends, discussing the species tested and the sample sizes, and we note methodological considerations and current multilaboratory approaches. We then categorize and synthesize the research questions addressed in these studies, which have been at both the ultimate level (e.g., questions related to evolutionary adaptiveness and phylogenetic differences) and proximate level (e.g., questions related to experiential and temperamental processes). Throughout, we consider future directions for this area of research.

Keywords Comparative cognition · Social learning · Communication

In the early 1990s, four chimpanzees in Sarah (Sally) Boysen's laboratory, at The Ohio State University, participated in a study that would prove to be seminal in the field of animal cognition. The study (Povinelli et al., 1990; hereafter "PNB") garnered interest not because of particularly robust results, but rather because the results were mixed. The procedure was elegantly simple. On test trials, a chimpanzee would observe two experimenters, one who watched food being hidden in one of four containers (the "Knower"), and one who could not see the food being hidden (the "Guesser"). The Knower then pointed to the baited container while the Guesser pointed to an empty one, and the chimpanzee could choose a container to obtain whatever was inside. If the chimpanzees had consistently chosen the baited container, following the information provided by the only experimenter who had knowledge of the correct food location, their behavior would have been much like that of young children tested in a similar manner (Povinelli & DeBlois, 1992), and the study would have been hailed as a strong demonstration of theory-of-mind abilities in a nonhuman species. Instead, the chimpanzees required more than 100 trials until choices showed a statistically significant preference for the Knower's information. Further, performance on a follow-up transfer task was not compelling in that chimpanzees were not immediately successful. Together, the results suggested to some that the chimpanzees were most likely learning a behavioral rule such as "follow the points of individuals who did not have their eyes covered" rather than attributing mental states (e.g., Cheney & Seyfarth, 1992; Povinelli & Eddy, 1996).

Still, the study was foundational for at least two lines of research. In one line, the ability of nonhuman animals to attribute mental states to others was further examined, with modifications to theory and experimental procedures inspired by PNB. For example, to address proposals that chimpanzees may be more likely to show mental state attribution when placed into *competitive* scenarios with conspecifics—rather than scenarios in which humans provided cooperative cues to food locations—some study paradigms omitted human-provided pointing and instead observed chimpanzees as they obtained or avoided food in the presence of ignorant or knowledgeable dominant group members (e.g., Hare et al., 2001). Similar research continues to this day, across species (for reviews, see Krupenye & Call, 2019; Penn & Povinelli, 2007). In the second line of research, the

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focus has been the manual pointing behavior itself. Research has examined whether nonhuman animals produce referential, declarative points and whether animals that follow points understand them to be intentionally communicative (for a review, see Krause et al., 2018). This research line thus examines the evolutionary origins and cognitive underpinnings of the pointing gesture, a gesture that is one of the earliest developing communicative behaviours in human infants (e.g., Butterworth, 1998).

For this special issue in honor of Dr. Sally Boysen's career, we focus on this second line of research, particularly studies published since PNB that examined whether and when nonhuman animals (hereafter, "animals") follow human pointing behavior. Our review paper offers an update and extension of previous reviews by Miklósi and Soproni (2006) and Krause et al. (2018), which considered studies published up to 2005 and 2016, respectively, though our current paper focuses solely on point following rather than combining this behavior with point production as the Krause et al. review did. Of the 126 papers that we documented on this topic published between 1991 and 2021, 94 (75%) were published in the past 15 years, including 21 in the past 5 years, indicating that this topic is still an active area of interest in the field of animal behavior and cognition. The research questions addressed in these studies are posed at both the ultimate level (e.g., questions related to evolutionary adaptiveness and phylogenetic differences) and proximate level (e.g., questions related to experiential and temperamental processes). We will review these themes and highlight promising future directions in the second section of this paper. First, though, we present results of a survey of publication trends, examining the number of papers published, the species tested, and the sample sizes, and we note methodological considerations and current multilaboratory approaches.

Publication trends

A survey of publication trends can provide a bird's-eye view of the development of a specific research topic (e.g., animal pointing production and comprehension: Krause et al., 2018), the interest in a particular target species (e.g., dogs; Aria et al., 2021), and even the evolution of a broader field of study (e.g., comparative cognition; Beach, 1950; Dewsbury, 1998; Shettleworth, 2009). Here, we report the results of a survey of peer-reviewed journal papers published between 1991 and 2021 on the topic of point following—specifically, animals following human pointing. The aim of this survey is to evaluate trends in the field, which, in turn, can provide a resource for researchers by highlighting missing elements and challenges.

This survey does not, however, include a meta-analysis or quantitative comparison across the studies. Although, as described below, we focused on a specific type of study design, the procedural details and data analytic approaches differ enough to preclude quantitative analysis of, for example, effect sizes for point following behaviour across species (see Krause et al., 2018; Miklósi & Soproni, 2006; Mulcahy & Hedge, 2012, for similar concerns). Experimental procedures vary in relation to initial familiarization trials, the number of test trials, the eye direction and vocalizations of the pointer, the distance of the pointer's index finger to the referent, among other differences. Further, results in the published papers can be reported at the individual level or at the group level. However, as noted later, at least one current project may allow for a strong meta-analytic approach in the near future, specifically for point following in dogs and considering, for example, breed and human socialization experience.

Methods

Inclusion criteria

Four criteria were used for papers to be included in the survey. (1) The primary aim of the reported study was to examine an animal species or multiple species. Comparison with humans could be included, though human behavior was not the main focus of the research question. (2) The primary measurement was of comprehension of a human point, not point production or following of a conspecific's point. That is, at least one condition included a human pointing to a location or object, and the dependent measure was a subject's subsequent search and/or physical contact with that location or object. This procedure is typically referred to as an object-choice task (Fig. 1). (3) Related to criterion #2, the purpose of the study was to examine point following. Studies that included an experimenter pointing to a location as part of a broader procedure were not included. For example, papers on chimpanzee scale model comprehension (e.g., Kuhlmeier et al., 1999), in which an experimenter pointed to and placed a marker at a location in a scale model of a room prior to the chimpanzee searching the real room, were not included. (4) The paper was published in English in a peer-reviewed journal between 1991and 2021.

Literature search

The search of published papers was conducted in three phases. In the first phase, we extracted papers that fit our criteria from the extensive list provided in Krause et al. (2018); search procedures they used for their list are detailed in their paper. In the second phase, we extended the publication dates to 2021 from the earlier study's end date of 2016.

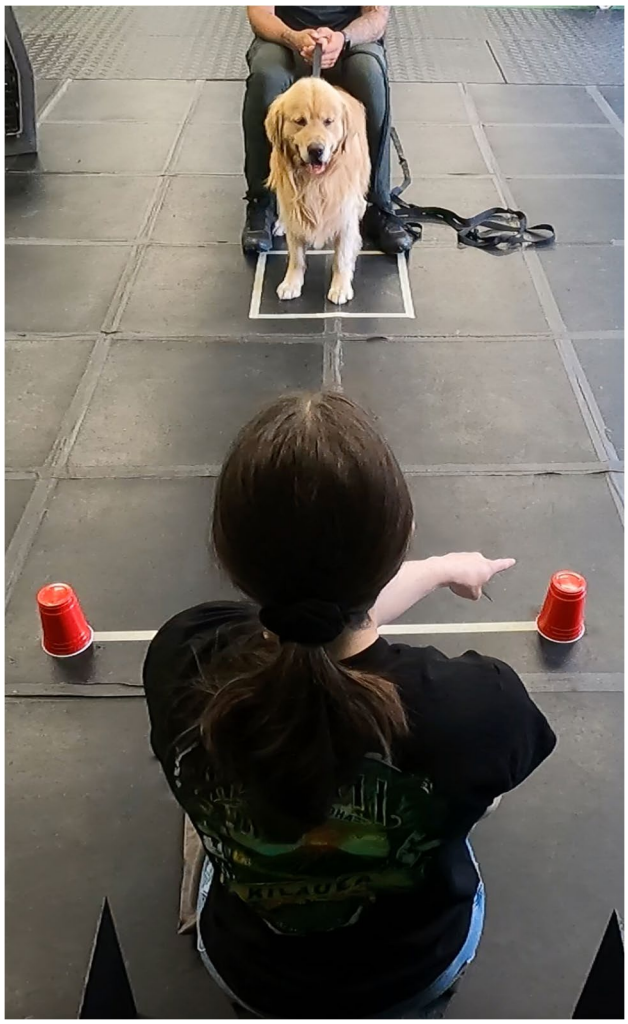

Fig. 1 The object-choice task. Typically, the experimenter points to one of two or more cups or containers, and subjects are then released to search. The first location searched or physically contacted is coded as a "choice." Here, for example, the experimenter (Dr. Sally Boysen's "academic granddaughter") has shown a dog a treat, and then placed it under one of the cups while they are occluded. The cups are revealed, and the point is given. Where appropriate, odor cues are controlled, and the point direction is pseudorandomized so as to reduce the number of sequential trials at one location

Searches were conducted in both PsycINFO and Google Scholar. In the last phase, we compared our list to the reference sections of the papers published in the past five years as well as that of two reviews of canine cognition (Aria et al., 2021; Project ManyDogs, 2021).

Results and interim conclusions

Number of papers, subjects, and species

A total of 126 papers were found that met the inclusion criteria. The majority of these papers (75%) were published in the second half of the time range, with a notable increase occurring after 2007 (Fig. 2). The papers appeared in specialist journals (e.g., *Animal Cognition*, *Journal of Comparative Cognition*), discipline-specific journals (e.g., *Current Biology*), and generalist journals (e.g., *Science*). A table with sortable details of these papers is available as supplementary material (https://osf.io/phzrg/?view_only=b4cd19006c8845bbbc1778ad59c3ca6f).

Figure 3 displays the sample sizes reported in each of the papers as well as the taxonomic order of the subjects tested. We chose to group by order for clarity of visualization; however, species-level information may be found in the full table. For studies that tested multiple species or orders, the sample size was determined by the sum of all subjects tested. Visual inspection of the scatter plot suggests that by the year 2006, the diversity of species began to increase, with the introduction of multiple bird species, bats, and elephants beginning in 2008. Yet, as seen in the bar chart, the majority of species tested are in the order carnivora. Of the 75 publications focused on carnivora, 67 were specifically studying canids. Though primates initially constituted the majority of species studied in early years, they became less represented (and are absent from the studies published from 2016 to 2021).

The number of subjects tested in any one study also increased over time, though, again, carnivora represents the largest contribution. The mean sample size in studies testing members of the order carnivora was 91 subjects across 75 studies, though after excluding one "citizen science" study with a sample size of more than 4,000 dogs (Watowich et al., 2020), the mean is 48 subjects. In general, we note that the increase in sample size over time is strongly influenced by studies testing domestic dogs; studies with other members of the order, such as ferrets and seals, report small sample sizes. The sample sizes for other species in other orders such as primates and Passeriformes also remain consistently low over time.

These publication trends are consistent with the findings reported by Krause et al. (2018), with two notable exceptions. First, our survey contained about 15 fewer studies with primates, making the contrast with the number of studies examining carnivora all the more prominent. This difference in the number of primate studies between the present survey results and those of Krause et al. (2018) is likely due to the broader criteria of the earlier review, which included papers reporting on the production of pointing, a topic often examined with species with fingers. Second, though both surveys found an increase in the number of species over time, the present survey shows that since the 2016 end date of the previous survey, the diversity of species has decreased. The study of point following has become primarily the study of the domestic dog.

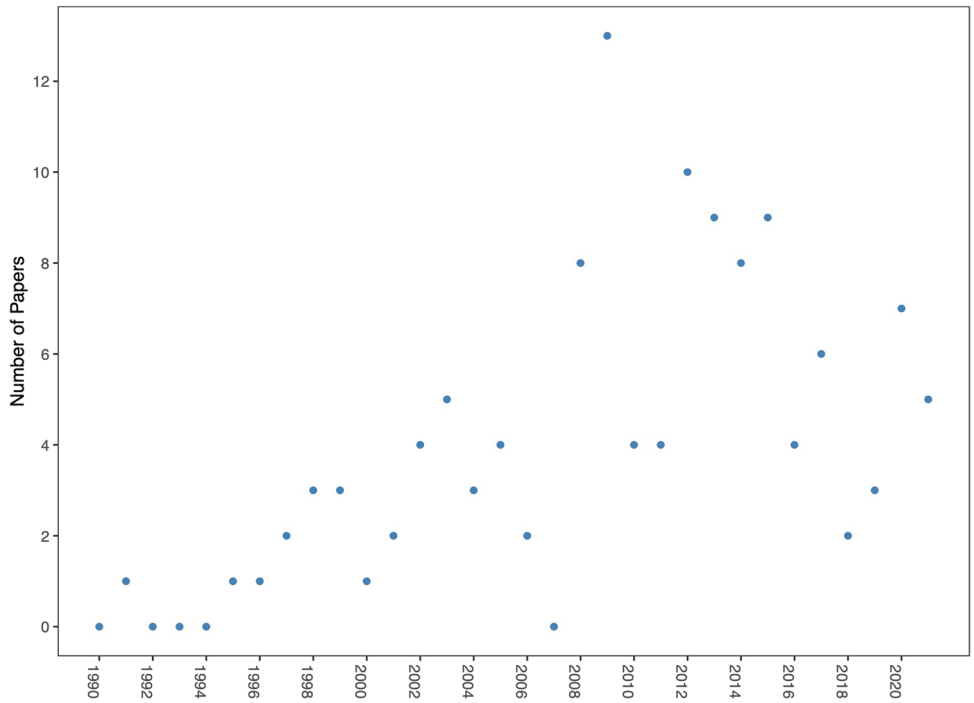

Fig. 2 The number of published, peer-reviewed journal papers reporting on animals following human pointing to a location or object, by year

The focus on dogs in research on point following reflects, in part, the general increase in studies with dogs in the field of comparative cognition, a trend that has been seen at least since 2005 (Aria et al., 2021). The feasibility of conducting animal cognition research with dogs surpasses that of other species; the subjects are often pets that are brought to the lab, negating housing and veterinary costs. In some cases, dogs have been tested at large training facilities; in the current survey, two of the three papers with the largest sample sizes were conducted with dogs being trained as assistance or explosive detection dogs (Bray et al., 2021; MacLean et al., 2017). The prevalence of dogs in research on point following, however, is also likely due to the research questions underlying the studies, which have shifted (with some exception) from the topic of mental state attribution to that of attention to human communicative cues, for which the domestic dog is a particularly appropriate subject. These research questions are described in more detail below.

Methodological and analytic considerations

As noted above, the studies included in the current survey differ in relation to methodology and analytic practices. This is to be expected, as the studies typically have different underlying research aims, such as examining the effect of looking toward the referent while pointing (e.g., Smith & Litchfield, 2009), ostensive cues such as looking at the subjects and using their names (e.g., Kaminski et al., 2012), or the knowledge state of the pointer (e.g., Guesser/Knower object-choice task; Kuroshima et al., 2003).

Yet a particularly notable methodological difference is the type of point given by the experimenter and the distances between the point and the referent, and the referent and the participant (see Miklósi & Soproni, 2006, for an earlier review). For example, among canids, Virányi et al. (2008) found that for 4-month-old wolf and dog puppies, only the latter followed distal pointing (e.g., the index finger is 50 cm from the target), though with proximal pointing (10 cm from the target), both followed the cue (see Elgier et al., 2009a, b, for further discussion). A similar concern about methodology has been made for studies with great apes. Mulcahy and Hedge (2012) examined the methodology of 63 object-choice studies with a range of species and found that the method that is most commonly used with apes—a proximal point made to an object that is on a small table between the human and ape—will typically yield low point following. In contrast, when apes are tested with a distal/peripheral method similar to that used with dogs (Fig. 1), more point following is observed. These methodological differences, and potentially resultant differences in point following, can inform the conclusions we make about how animals learn about and interpret points (discussed below), but for now we note that they may also present challenges to our ability to compare across species. For example, in studies that have directly compared point following in dogs and apes, and which typically conclude that dogs share a

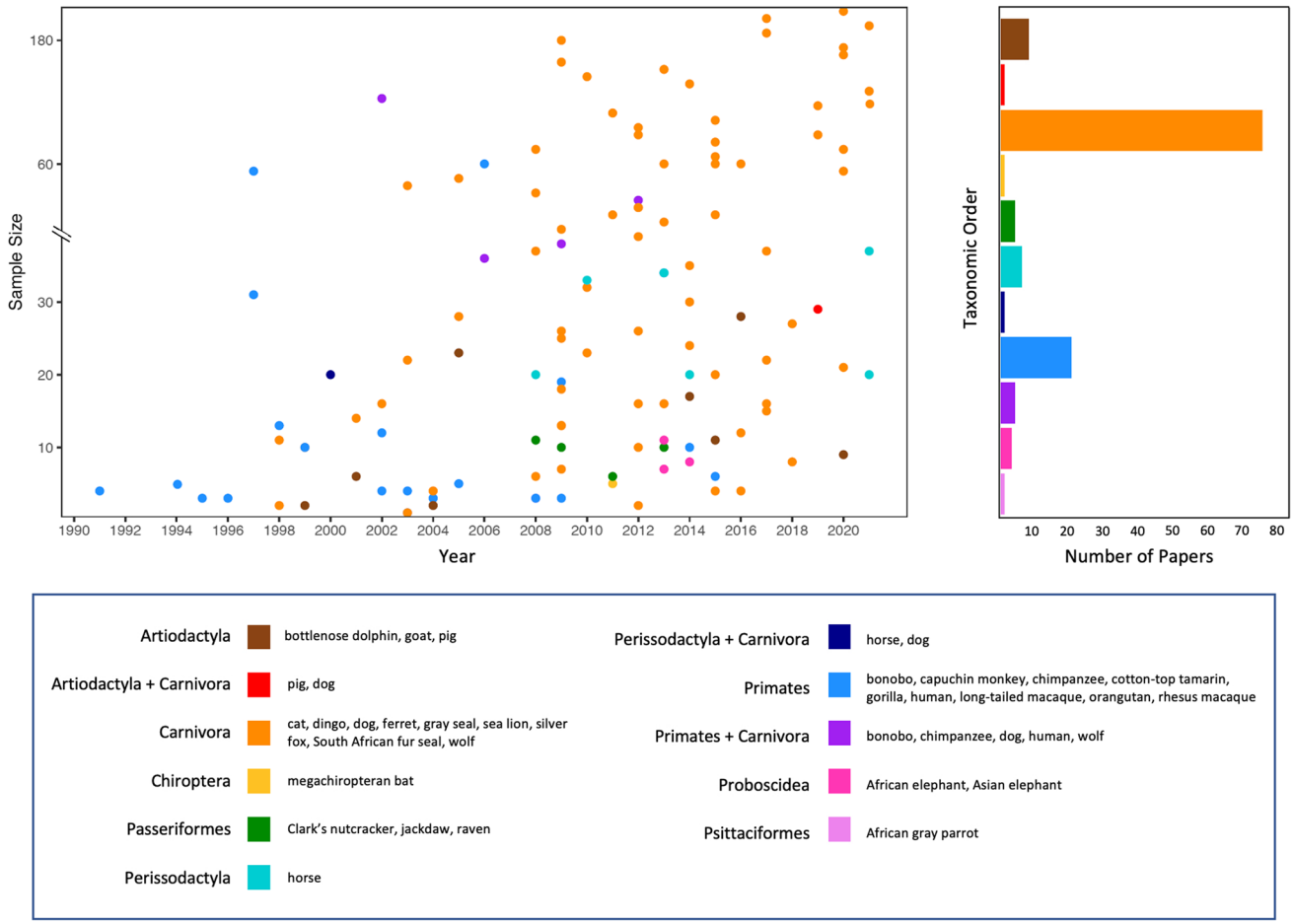

Fig. 3 The number of papers, sample sizes, and publication year by taxonomic order. *Note.* Each dot represents a published paper, with color indicating taxonomic order. Papers that compared point following between species of different orders are noted as such (e.g., "Primates + Carnivora"). Due to the wide range of sample sizes, and in order to provide visual clarity, the *y*-axis on the scatterplot is depicted by a ratio scale up to 40, then becomes ordinal. (Color figure online)

propensity to follow human pointing cues in a manner that apes do not, the apes are tested with the more proximal style of the object-choice task and the dogs with the more distal style (e.g., Bräuer et al., 2006; Hare et al., 2002; MacLean et al., 2017). One solution is to develop more standardized procedures for cross-species tests, though constraints exist; for one, apes and humans typically must be separated by caging, while dogs typically do not require a barrier (see Clark & Leavens, 2019).

It is easier to design standardized procedures for within-species comparisons. Though it may seem unintuitive to propose that dogs be the focus of such studies, as already so much research has been conducted with them to date, many have proposed that this work is necessary. As noted by Krause et al. (2018), if papers such as Lazarowski and Dorman (2015, working dogs) and Udell et al. (2010, shelter dogs) had been published prior to those demonstrating the success of pet dogs in object-choice tasks, a different conclusion regarding dogs may have been made, and the publication trends reported here might have looked quite different. There is within-species variability among dogs in terms of point following, yet it is presently unclear why. One current methodological approach designed to address this question is the first study of Project ManyDogs, an international consortium of researchers. Laboratories and dog training facilities will contribute data using identical object-choice procedures and owner questionnaires, allowing for a sample that is large and diverse in attributes such as age, breed, living environment, temperament, and training history (Project ManyDogs, 2021). This procedure will allow for a systematic analysis of genetic, developmental, and environmental factors that may be related to point following in the domestic dog. In relation to cross-species comparisons, it may be possible for future "ManyX" big team science projects to combine—such as ManyDogs and ManyPrimates (Many et al., 2019)—to develop consistent procedures and analyses.

Research themes: Past, present, and future

The research themes underlying studies on point following can be placed into at least six categories, though we note that these categories have some conceptual overlap. Additionally, some of these research themes have been considered from both ultimate (evolutionary and phylogenetic) and proximate (mechanistic) perspectives. Though many of these themes are now well-considered—and debated—in the literature (and could have been the sole topic of a review paper or monograph!), we include others that we believe will receive increased attention in future research.

Domestication

Perhaps the most discussed theme within research on point following has been the role of domestication, the process of evolution by "artificial," or human, selection. An integral moment in point following research came in the early 2000s, when a study reported in *Science* (Hare et al., 2002) suggested that dogs were more likely than chimpanzees to follow human points. A logical conclusion was made that dog domestication led to selection for sociocognitive abilities that support cross-species communication. Further, these sociocognitive abilities did not evolve in chimpanzees in the same manner or to the same extent, and, in fact, evolutionary pressures favored competitive social behaviors that could even contraindicate point production and point following (Hare et al., 2001). It is likely that this proposal was the key factor in the increase in published papers on point following and the increased focus on dogs and other canids.

Studies with other domesticated species were conducted, such as domestic goats, horses, ferrets, and pigs, often with some individual subjects showing point following, even if group-level analyses did not always support it (e.g., Hernádi et al., 2012; Kaminski et al., 2005; Lansade et al., 2021; Nawroth et al., 2014). Thus, studies have been mixed, but this is not unexpected. As Miklósi and Soproni (2006) noted, "domestication is not a unified process, and the behaviour selected for depends not only on the selection process, but also on the species in question" (pp. 89–90); that is, humans have not selected for the same traits across all domesticated animals. Another approach has been to compare dogs with wolves, though again, results have been mixed. In early studies, dogs, even as puppies, seemed more likely to follow points than wolves (e.g., Hare et al., 2002), but later studies found evidence for point following in even young wolves (Gácsi et al., 2009a, b, c; Miklósi et al., 2003; Udell et al., 2008a, b; Udell et al., 2012). Thus, an explanation for point following in dogs based on domestication would, at best, require further nuance which, we suggest, can be found in the other, related research themes described below.

Cooperative versus competitive social ecologies

Some species show more intra-specific competition than others. As an extension of proposals related to domestication, another research theme has considered that phylogenetic differences in point following may result from species differences in the propensity for cooperation versus competition. Chimpanzees, for example, are relatively competitive regarding resources, and do not readily share food or inform others of food in the wild (e.g., de Waal, 1989). Indeed, as described in the introduction to this paper, it was when chimpanzees were tested in a competitive scenario that they showed more effective social navigation than in the cooperative pointing scenario of PNB (e.g., Hare et al., 2001). Thus, by this argument, the emphasis on competitive behaviors would make point following unexpected in this species. By contrast, characteristics that support cooperation with humans were selected for during dog domestication. The proposal has been taken further recently, with proposals that the less-aggressive bonobos and humans might be best described as "self-domesticated" (e.g., Hare et al., 2012; Hare & Woods, 2020).

In support of this idea, bottlenose dolphins, for which cooperative behaviors have been documented in the wild, do show some evidence of point following (Herman et al., 1999). Yet other findings complicate this argument. First, as noted above when discussing methodological differences in the object-choice task, it is not clear that chimpanzees are truly less likely to follow points than dogs, or if the differences that are seen are related to procedural differences. Second, chimpanzees do show some cooperative behaviors in the wild, such as cooperative hunting (e.g., Boesch, 2002), and in captivity have been shown to share food in some instances (e.g., Silk et al., 2013). Third, it is unclear where wolves fit into the argument if one considers them to be less likely to follow points than dogs, as wolf hunting behaviour is described as being cooperative, and experimental tasks suggest that they are more likely to cooperate with conspecifics in problem-solving tasks than dogs (e.g., Marshall-Pescini et al., 2017). Thus, domestication may promote characteristics that support point following, but we find it currently difficult to make strong claims that connect a species' broader social ecology to their propensity to follow human pointing.

Socialization and enculturation

A counterargument to the proposal that selection during domestication can lead to increased point following, at least

in dogs, was that dogs receive more experience with humans, often starting at birth, than other animal species, and thus have more opportunity to learn human communicative cues. Udell et al. (2012) proposed that domestication should not be a prerequisite for canid responsiveness to human cues; rather, life experience and human socialization may be more important predictors of success. Such arguments were made based on studies with wolves noted above, in which wolves with human experience as puppies tended to follow human pointing. Consistent with this claim, dogs raised in kennels with limited human interaction were less likely to follow points than pet dogs that had lived with humans since they were puppies (D'Aniello et al., 2017). Finally, a recent study by Mastellone et al. (2020) found that goats with different levels of human socialization performed differently in the so-called "impossible task" in which subjects attempt to open a container that cannot be opened, and then tend to either persist in trying or look to a nearby human. Though not a pointing comprehension study, the results indicate that higher socialization correlated with increased interaction with humans during the task, which may predict an improved ability to attend to human-given cues.

In a similar manner, studies of cognitive abilities with chimpanzees in the 1990s were often considered in relation to the level of "enculturation," referring to being reared with intensive human contact (Call & Tomasello, 1996). It is possible that chimpanzee point following may also be influenced by this early exposure to humans, though currently there is no clear support for this proposal, likely due in part to the difficulty in quantifying human experience (Miklósi & Soproni, 2006).

When considering the role of socialization or enculturation on the propensity to follow human communicative cues, however, it is best not resort to a "nature versus nurture" debate. Behavior that develops with the input of socialization can still have genetic underpinnings. It may be that considering interactions between genetic predispositions and social experience advance our theories the most. For example, some species may have developmental systems that are predisposed to process certain types of environmental cues associated with food or other resources, and these systems may have critical or sensitive periods in which they operate most efficiently.

Training history

In the literature on point following, a specific form of socialization is training, which itself can range from the general (e.g., basic dog obedience) to more intensive (e.g., dog sport, hunting, policing; marine mammals in entertainment or military), but can also include conditioning of behaviors in the laboratory setting. As an example of the latter, studies using the Guesser/Knower object-choice task of PNB have traditionally included multiple trials and considered learned associations between the behavioral or featural characteristics of the knowledgeable experimenter and the location of reward. Kuroshima and colleagues (2003), for example, found that a capuchin monkey learned to use the "inspecting" action of the knower as a discriminative cue, following the points of this experimenter more than the guesser's points.

There is great variability in the training experience of dogs, and to date, some studies have begun to examine possible relationships with point following. In Cunningham and Ramos (2014), however, dogs with basic training did not differ in point following from those with training for competitive sport (e.g., flyball) or hunting, yet the degree of training or ability was not considered in the analysis. More recently, Lazarowski et al. (2020) found no difference in point following between pet dogs and dogs in a scent detection training program, though the latter exhibited less gazing toward humans in the "impossible/unsolvable task," likely due to the selection or training for detection work which encourages persistence and independence. Relatedly, the object-choice task is being applied by some trainers as part of a battery of tests used to determine good detection dogs early in development, particularly when it is of interest to determine whether a dog is more likely to use its own olfactory sense or the cuing of a handler (Ford, 2019, May 24). At least with dogs, then, we may soon know more about specific training experiences that can encourage or discourage point following, which, in turn, may have implications for both basic and applied science approaches.

Temperament and motivation

Other approaches have considered point following in relation to temperament and motivation, which can vary at the species and individual level. By our reading, this research theme is currently less elaborated than the previous two, but we believe it to be gaining attention. Interest in temperament may have roots in earlier claims related to domestication in that selection for "tameness" was found to be sufficient to induce the correlated changes in morphology and physiology that are typical of domestication (Belyaev et al., 1985; Wheat et al., 2019). There is also a growing interest in the relationship between temperament and cognitive development in humans; temperament is related to behaviour on social and cognitive tasks (e.g., prosocial behaviour: Karasewich et al., 2019; theory of mind: Wellman et al., 2011), suggesting that traits such as aggressiveness or shyness may affect either the development of cognitive processes (competence) or the display of such processes (performance). Similarly, some have emphasized the importance of considering the interaction between temperament and cognition in dogs, showing individual differences in problem-solving

based on measures of approach/exploratory behavior and reactivity (Bray et al., 2017). Project ManyDogs described above includes measures of dog temperament, which may shed light on individual differences that support, or discourage, point following.

Consideration of motivation as a factor influencing point following on object-choice tasks has focused primarily on methodology. For example, Krause et al. (2018) note that stimulus preferences for certain objects hidden in the task will likely impact performance, citing work by Vitale Shreve et al. (2017). Further, when points are directed toward hidden food items, natural foraging or predatory behavior may influence motivation and, subsequently, performance (Udell et al., 2014), though we note that extreme arousal may serve to decrease performance (e.g., the "Yerkes-Dodson Law"; Yerkes & Dodson, 1908). Methodological features such as the number of trials may also interact with motivation and influence performance; Krause et al. (2018) raise the intriguing possibility that animals that scavenge or graze, engaging in food gathering repetitively over time, may perform better than other species when multiple test trials are required. Again, though, like temperament, little research to date has examined motivational factors.

The interpretation of the human point

The previous research themes are related to the last theme we will consider here: The interpretation of the human point. Commonly, point following is said to reflect attention to human "cooperative communication", but both "cooperative" and "communication" can be discussed in relation to different cognitive processes, ranging from higher order, more complex processes that include representations of others' mental states, to those that are relatively simpler. By our reading, the current research on point following offers limited discussion of these underlying mechanisms. In an attempt to synthesize current arguments with our own proposals, we will address both cooperation and communication in turn.

The focus on domestication and the cooperative or competitive social ecologies of a species implies that some species, like dogs, perceive the point as cooperative. For sure, the human signaler is intentionally engaging in cooperation when pointing, but it is presently unclear how to accurately describe the receiver's interpretation. Many species are thought to distinguish cooperative from uncooperative behaviors, and the mechanisms supporting this can range from highly constrained innate predispositions (e.g., when fish choose to interact with "cleaner" fish that more cooperatively remove their ectoparasites) to more flexible individual and social learning processes and rational inference (e.g., Bshary & Noë, 2003; Kuhlmeier et al., 2014). Relatedly, evaluating a behavior as cooperative need not include the representation of the cooperator's intent to be prosocial; a behavior may simply be functionally cooperative, benefitting the receiver.

A similar consideration can be made with the term *communication*. In the fields of animal behavior and comparative cognition, communication is a broad term used to describe instances when signals are produced by a sender to a receiver (e.g., Olmstead & Kuhlmeier, 2015). Communication can, thus, include the coloration of a poison dart frog as well as human language. In the pointing task, the human has the intention to communicate, but it is unclear whether receivers perceive the point as the intentional and referential act of a knowledgeable informant (i.e., that it is *about* a particular object or location: Povinelli et al., 1997). We agree with earlier conclusions made by Miklósi and Soproni (2006), that point following cannot easily be explained by "simple conditioning processes" (e.g., Shapiro et al., 2003). In Kaminski et al. (2012), for example, dogs showed more point following when points were preceded by ostensive cues such as making eye contact and saying "Look, [dog's name]!" than when points were preceded by other sounds, such as a light cough. It could be argued that this finding demonstrates that when ostensive cues are present, dogs will interpret a point as an intentional act meant to convey important information. Further, there is some suggestion that dogs may avoid following the points of individuals who did not have visual access to the baiting of a location and individuals who point to a location opposite of a location in which the dog has seen an object placed (Johnston et al., 2018; Pelgrim et al., 2021; Szetei et al., 2003), indicating a level of flexibility in point following based the likelihood of the pointer to provide accurate information. Yet it is also possible that no attribution of intention is made, and instead, dogs have a cognitive system that allows for past experience of others' behavior to be organized by heuristics (or sets of related rules) that allow them to recognize causally relevant aspects of current behavior (eye gaze, use of "names") and respond in a way that optimizes reward (see Penn & Povinelli, 2013, who present this model in relation to theory of mind).

It is notoriously difficult to determine the cognitive mechanisms that underlie social behavior like cooperation and communication. As a field, we typically subscribe to Morgan's Canon, eschewing interpretations based on higher cognitive mechanisms if other mechanisms (historically, the learning of stimulus–response associations) can adequately explain behavior. Since then, though, models of cognition have been developed that construe operant conditioning in relation to the forming of cause–effect representations, and ones that consider how experiences can be generalized to produce predictions for future behavior.

As such, it is possible that as new studies focus systematically on social experiences, training, and temperament, new ideas regarding the mechanisms that underlie point following will be proposed.

Conclusions

Pointing is a foundational human communicative act. The comprehension of points occurs early in development, followed quickly by the production of points (e.g., Butterworth, 1998). It is unsurprising, then, that points are the means by which we so frequently attempt to communicate with other species. As reviewed here, this attempt at interspecies communication has led to fruitful discussions on topics at the heart of comparative cognition more broadly, including biological predispositions for certain cognitive processes, social and asocial learning, perception, reasoning about others' perception, and cooperation. Additionally, consideration of how different methodological procedures can encourage (or discourage) the production of behaviors within and across species has been made.

Several interim conclusions were presented throughout this review. Here, we condense these to two main conclusions. First, though there have been other species tested and more studies since the previous reviews by Miklósi and Soproni (2006) and Krause et al. (2018), the diversity of species tested in variants of the object-choice task has decreased in recent years. Now, dogs have become the primary focus. We noted that one reason for this is feasibility of comparative work with pet dogs, but large sample sizes may also be possible through multilab projects such as those conducted by ManyPrimates (https://manyprimates.github.io/) and ManyBirds (http://themanybirds.com/). In future work, however, standardized procedures would be necessary. Second, focus on within-species differences in socialization, training, and temperament, as well as some not discussed in this paper, including neurodevelopment and general cognitive processes such as inhibitory control, may shed light on underlying cognitive mechanisms that support point following. Future studies will benefit from quantifiable measurement of these factors as well as large sample sizes. In sum, though we still feel some of the "frustration" felt by Miklósi and Soproni over 15 years ago regarding the challenge of making sense of results in this field, we retain optimism for the future based on the studies that have occurred since.

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