Symbolic, Indexical, and Iconic Communication with Domestic Dogs

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ABSTRACT

Recent studies in canine communication are reviewed using Deacon's framework of iconic, indexical, and symbolic reference. The presented analysis examines these studies using Deacon's notion of interpretant, taking into account the evolutionary and perceptual capacities of the dog. By taking these dispositions and capacities into account, the conclusions that have been drawn in current studies of canine communication with respect to Deacon's framework are critically evaluated. The analysis proceeds by investigating clusters of studies that align with symbolic, indexical, or iconic reference.

KEYWORDS: Zoosemiotics; Icon; Index; Symbol; Dog.

1. Introduction

The problem of reference, or how words refer to things, has a long history in the study of philosophy and language. Modern work distinguishes between a term's sense, a mental representation of meaning, and a term's reference, the object to which the term refers (Frege, 1892). Others have applied similar notions to study communication and the transmission of information, the so-called theory of signs. For example, de Saussure (1959) distinguishes between the signifier and the signified; that is, the form of the sign and sense of the sign. Likewise Peirce (1958) distinguishes between representamen, interpretant, and object; these are the form, sense, and referent, respectively. In some respects, Peirce's triadic system of form, sense, and reference, can be viewed as

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a bridging of Frege's ideas (which minimize the role of form) and de Saussure's ideas (which minimize the role of referent).

Peirce's triadic system continues to be influential, particularly with regard to efforts comparing the referential and communicative capabilities of humans to those of other animals. These efforts are often undertaken in the context of *zoosemiotics*, the "scientific study of signaling behavior in and across animal species," (Sebeok, 1968, p. 142), which has a strong biological- and information-based approach (Martinelli, 2012). Perhaps the most well-known, cross-species comparative work contextualizes Peirce's triadic signs in a modern understanding of psychology (Deacon, 1998). Following Peirce, Deacon emphasizes the importance of the interpretant in defining reference, stressing that an interpretant is a cognitive process that infers the referent for a sign in a given context. The structure of this cognitive process determines the nature of the relationship between form and referent. In other words, Deacon sees the interpretant as key to the problem of reference.

Borrowing additional terminology from Peirce, Deacon identifies three kinds of relationships between form and referent and their associated cognitive processes. By aligning reference with cognitive processes, Deacon redefines the problem of uncovering the communicative capabilities of animals to finding evidence for the associated cognitive processes. In this framework, higher level referential relationships are hierarchically built upon lower level referential relationships. The first and simplest relationship is iconic reference. Iconic references derive from cognitive-perceptual processing of similarity. Two things which are similar are processed similarly and so have a similar interpretant. Another way of describing iconic reference is that it is categorization. Two non-identical (but similar) items are placed into the same category and treated as equivalent. Iconic references are perhaps so simple that any organism generalizing recognition of a stimulus can be said to possess iconic reference.

Second, indexical references derive from the correlational structure between two things, for example *smoke* and *fire*. In Deacon's framework, both *smoke* and *fire* are icons, i.e. categories. An indexical reference contains two icons and a generalized relationship between them, which itself can be viewed as an icon. In other words, *smoke* and *fire* have a consistent causal relationship that generalizes to many different kinds of smoke and fire. As a result this causal relationship is a categorical relationship, i.e. an icon. Deacon equates indexical references with the type of conditioned response commonly found in trained animals.

Third, symbolic references derive from a system of relationships between indexes, for example *justice*, *crime* and *punishment*. Typical indexical relationships have observable component icons like *smoke* and *fire*. When many indexical relationships like this exist, indexical relationships between their indicating stimuli may be learned. For example, the words *crime* and *punishment* are indicating stimuli for the real-world events of crime and punishment, both of which are at least partially observable. The word *justice*, is an indexical relation between *crime* and *punishment*, is less directly observable, and is in a sense distributed between these two indexical relationships.

In Deacon's framework, symbolic reference generalizes relationships between indices into higher level categories and combinations of these categories, i.e. proto-syntax. The hallmarks of symbolic reference are that it (1) allows acquisition of new knowledge without repeated trials for learning, (2) is not extinguished in absence of reinforcement, (3) takes place in a hierarchical system of semantic relationships, and (4) exists in combinatorial organization with other symbols. In contrast, indexical references are learned independently of one another and are subject to extinction, i.e. will disappear if the association between indicating stimuli and object of reference is not maintained. Symbolic references are thought to be resistant to extinction because the interdependency of symbols maintains associations even in the absence of objects of reference like *unicorns*, c.f. Harnad (2002). In the same way, symbolic references are built upon indexical references but exist independently of them as well.

Deacon's framework of iconic, indexical, and symbolic reference provides a convenient rubric for evaluating recent studies in canine communication. By focusing on these three levels, greater insight may be gained into the larger significance of these studies. However, it is equally important to consider the domestic dog in a broader context, including its evolutionary and perceptual capacities. This broader examination is warranted because the interpretant, which is so key in Deacon's framework, is determined by the cognitive dispositions and capacities of the organism in question. By taking these dispositions and capacities into account, this paper critically evaluates the conclusions that have been drawn in current studies of canine communication with respect to Deacon's framework. The analysis proceeds by investigating clusters of studies that align with symbolic, indexical, or iconic reference.

2. The origin of dogs

A recent review of the evolutionary and domestication history of dogs outlines a longstanding relationship with humans (Galibert et al., 2011). Human and wolf bones have been found together as early as 300,000 BP (before present). Co-mingling of bones indicate some kind of close contact, minimally a pre-domestication overlap of human and wolf territories. By at least 31,700 BP, the skull shape of dogs had differentiated from that of wolves, indicating that distinct dog and wolf populations existed. Although some level of domestication likely took place in order to promote such structural changes, it is not clear if dogs at this time occupied the same place in human culture as dogs do today. Such evidence was uncovered in a human tomb dated 12,000 BP, where the body of a puppy was found buried next to a human skeleton with the human hand positioned in contact with the puppy. Arguably by this time the dog and the affectionate bond between dogs and humans was sufficiently established in human culture as to be marked in a ritual burial.

Genetic analyses of dogs and wolves show a complex relationship (vonHoldt et al., 2010). While dogs appear to be most related to grey wolves from the Middle East, analyses reveal repeated crossings between dogs and wolf populations all over the world. Additionally, there is strong genetic similarity within functional groupings associated with dog breeds such as herding dogs, retrievers, and toy dogs. As a result, modern dog breeds are more distantly related to wolves than to each other, and each breed grouping has genetic markers that clearly distinguish it from other breed groups. The level of genetic distance between dogs and wolves is in some senses surprising given the fact that wolves and dogs can successfully interbreed and produce offspring (Iljin, 1941). Indeed, some modern day efforts have promoted such crossings to produce new domestic dog breeds (Seidler, 1999). The general lack of recent crossings between dogs and wolves may be in part due to problematic issues in training and controlling such hybrids (Humphrey & Warner, 1934) and the general observation that the introduction of wolf genetic material into domestic dog lines appears to confer no new advantages to the offspring (Stephanitz, 1921).

While archaeological and genetic evidence give some indication of the history of dog domestication, they leave open many questions about the selective pressures that man exerted on the development of the dog. However, a remarkable 50 year experiment in Russia suggests that selection for *tamability* may be sufficient to drive many, if not all, of the behavioral and morphological changes that distinguish dog from wolf (Trut, 1999, 2001). Beginning with a wild type canid, the silver fox (*Vulpes vulpes*), researchers created a selective pressure for tamability by only allowing the most tame foxes to mate. In each generation, foxes were tested for tamability by offering them food with one hand and attempting to pet them with the other. Only most tamable foxes of each generation (10% females and 4% males) were allowed to breed. By the sixth generation, researchers observed a new level of tameness they called the *domestication elite*, in which foxes would proactively seek human contact by whimpering and licking like dogs. Over time the percentage of the fox population in the elite category increased, from 35% in the 20th generation to 75% in the 40th generation.

In addition to increased tamability, foxes began to exhibit a variety of morphological changes that parallel the differences between dogs and wolves, including variegated coat color with white patches, curly tails, shorter and wider skulls, shorter tails, and floppy ears. Curly tail and white patches were more than a thousand percent more frequent in the experimental foxes than in control foxes. Many of these morphological attributes are associated with adolescence and disappear in adulthood in the wild-type fox, suggesting that selecting for tamability might result in changes that prolong or freeze adolescence. Development of the startle response in the experimental foxes was accordingly delayed by 50% relative to the control foxes. The delay in the startle response corresponds to a drop in the hormone production of the adrenal gland in the experimental foxes. It should be noted that these changes in behavior have a strongly genetic basis. Multiple studies investigated cross-fostering newborn experimental foxes with control fox mothers (and vice versa) as well as transplanting embryos between these experimental groups. These studies found that 35% of the variation in the tamability tests was due to genetics rather than how the foxes were raised.

Although these fox domestication experiments are not direct evidence for dog domestication, they do establish intriguing parallels in a close relative of the wolf. Of particular interest is the rapidity in which domestication can occur in controlled environments with a rather simplistic selective pressure. These experiments provide an existence proof for how hominids with comparatively low technological and cultural sophistication might have successfully domesticated the wolf, not once but in multiple geographic locations independently. The key result is that selecting for tamability brings about a number of genetic changes that affect behavior towards humans. As a result, even though the domesticated and wild-type animals are genetically compatible, behaviorally they are remarkably different. From the perspective of the present article, the question is whether corresponding behavioral differences between dogs and wolves constitute a different level of interpretant when it comes to their understanding of human communicative behavior.

3. Perceptual capacities

It's important to review the perceptual capabilities of dogs for the obvious reason that perceptual capabilities underlie the interpretive processes that establish referential relationships. As discussed in Section 1, iconic relations are perceptual at the most basic level. However, there is another important reason to review the perceptual capabilities of dogs, namely anthropomorphism. Typically anthropomorphism is identified as attributing human-like reasoning to a non-human. Perceptual anthropomorphism is somewhat more pernicious, as it represents an implicit bias to assume that the perceptual inputs of other animals are approximately equivalent to human perceptual inputs. In the case of the dog, and likely most other animals, such an assumption could not be farther from the truth. Although there are many dimensions to perception, only vision and olfaction will be considered here.

The salient differences between human and dog visual perception include differences in color, acuity, and motion sensitivity, as reviewed by Miller and Murphy (1995). While humans are trichromatic, having cone cells responsive to red, green, and blue, dogs are bichromatic, having cone cells responsive to only green and blue. As a result, red, green, and yellow colors are relatively indistinguishable to dogs.

In addition to being more sensitive to variations in color, humans are also more sensitive to differences in spatial resolution, also known as visual acuity. Greater visual acuity implies a greater ability to see details of an object as opposed to those details blurring together. Although visual acuity may be assessed and described in various ways, a relatively intuitive measurement is based on the ability to perceive vertical bars.

Figure 2: The difference between human (above) and dog (below) visual acuity. From Péter (2012).

Figure 2 displays the relative difference between human and dog visual acuity. Although for humans, the left side of the image is still distinguishable as vertical bars, for a dog this part of the image would appear as a grey blur. Recent work has created an algorithm to map photographs into the corresponding image perceived by dogs, using the color and acuity results for dogs described in the literature (Péter, 2012). Figure 3 displays a photograph of a dog toy as seen from the viewpoints of humans and dogs. Although color differences between human and dog viewpoints are lost in grayscale, Figure 3 illustrates how dogs are less able to see the fine details of objects and the sharp boundaries of objects.

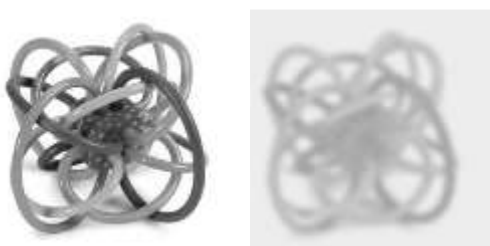

Figure 3: Composite differences between human and dog perception of a static image.

In addition to having different visual perception of static images relative to humans, dogs also perceive motion differently. So-called *flicker fusion* describes the point at which a rapidly flashing object is perceived as a continuous object in motion. Humans achieve flicker fusion at relatively low rates, which is why 24 and 30 frames per second are commonly used in video and animation. In comparison, dogs achieve flicker fusion at 70 frames per second or more, meaning that typical video displays may appear to a dog to be flickering. Dogs are also highly sensitive to motion and can use it to identify objects more easily, such that moving objects reliably identified at 900 meters must be 300 meters closer to be identified when the object is stationary. Although more research is needed in on this subject, it may be that motion is an integral component of visual object recognition in dogs and helps dogs compensate for their lack of visual acuity.

Of course a well-known component of object recognition for dogs is smell. Dogs have both a larger number of olfactory cells than humans (200 million vs. 5 million, approximately) and a larger number of cilia per cell than humans (125 cilia vs. 7 cilia, approximately) (Pearsall &Verbruggen, 1982). Cilia of the olfactory cells are individually sensitive to specific odorous molecules. Unlike vision, in which patterns of light across the retina must be recognized as a specific object despite changes in orientation, distance, and illumination, olfaction is based on chemoreception. In chemoreception, a specific molecule binds onto a sensory receptor and triggers a nerve impulse, so there is no need for pattern recognition to recognize odors at the molecular level. Dogs can easily detect human odor and are widely trained to find missing persons. Their olfactory sensitivity is such that microscopic flakes of skin or the perspiration and oil in a fingerprint are sufficient for the reliable detection and tracking of a specific human (Pearsall &Verbruggen, 1982).

Thus, while human vision may exceed dog vision in most respects, dog olfaction is several orders of magnitude more sensitive than human olfaction, such that dogs are acutely aware of odors that are completely imperceptible to us. From the perspective of the present article, it appears reasonable to assume that the cognitive processing used by dogs when they interpret referential relationships are more highly biased towards processing motion and odor than would be assumed from an anthropomorphic perspective.

4. Symbolic reference

As indicated in Section 1, Deacon’s framework of referential relationships is hierarchical, such that symbolic reference is based on indexical reference which in turn is based on iconic reference. This section reviews a recent study whose results are suggestive of symbolic reference in dogs (Pilley & Reid, 2011). In a remarkable multi-year study, the owner/experimenter trained a border collie (a herding breed) to recognize the proper names of objects, recognize noun-verb combinations, learn common/category nouns, and reason by exclusion.

The first experiment in the study examined the ability of the dog, named Chaser, to correctly associate a proper name with a specific object. Over the course of several years, the experimenter trained proper names for 1,022 different objects. Chaser was said to have mastered the name when she correctly selected the target item from a set of eight items, eight times in a row, without making an error. Every month, all the items Chaser had mastered were tested in groups of 20 with the experimenter in the room. Each item was called without replacement. In all 838 of these trials, Chaser correctly retrieved the item 18 times out of 20 or better. Also monthly, 100 items were randomly selected and evaluated in sets of 20. For these trials, items were placed in another room so that the experimenter could not non-verbally cue the dog to the correct answer. In all 145 of these trials, Chaser correctly retrieved the item 18 times out of 20 or better. These results indicate that highly trained dogs can have an extensive vocabulary of proper nouns.

In Deacon's terminology, these proper noun associations constitute indexical references. The indicating stimulus of the indices is a proper noun spoken by the experimenter, and the object of reference is the retrieved object. Because the retrieved objects were motionless, it appears likely that Chaser was identifying them based on their visual appearance and smell as described in Section 3. Given the vast variety of objects and the relatively poor visual acuity of dogs, it would seem difficult for Chaser to accomplish the indexical reference based solely on vision. Although the experimenter notes that the objects were washed periodically, thus blunting acquired odors, it is possible that the compositions of the objects themselves, i.e. various compositions of plastic, rubber, and fabrics, were such that they released distinctive odors that could be used during recognition.

The second experiment in the study investigated Chaser's ability to correctly apply proper noun/verb pairings. Each of the proper nouns, *lamb*, *lips*, and *abc*, were independently learned during the first experiment. In parallel, three verbs/commands, *take*, *paw*, and *nose*, were independently learned with a different set of objects. The second experiment investigated Chasers ability to correctly interpret novel combinations of these three nouns and three verbs. In 14 blind trials, the experimenter issued a verb/noun command, for example *take lamb*, and in all 14 trials Chaser correctly performed the action with the object in question. This experiment demonstrates that Chaser is interpreting the command as a composition of two elements rather than a single element. Chaser's sensitivity to structure allowed her to perform this action correctly the first time on novel items. Thus this experiment demonstrates two of the hallmarks of symbolic reference discussed in Section 1. First, it shows the acquisition of new knowledge without repeated trials for learning because Chaser was able to correctly respond to novel verb/noun combinations. Second, it shows that the verb/noun interpretations are organized as combinatorial relationships because Chaser is sensitive to the verb/noun structure of the commands.

The third experiment assessed Chaser's ability to create common noun categories. As described earlier, Chaser had already learned the proper names of 1022 objects. In this experiment she learned additional labels for the same objects, forming subgroups. The first subgroup was formed with the common noun *toy*, consisting of all 1022 objects. The second subgroup was formed with the common noun *ball*, consisting of 116 objects. And the last subgroup was formed with the common noun *frisbee*, consisting of 26 objects. As a result, objects in the last two subgroups had three labels: *toy*, the subgroup label *ball* or *frisbee*, and the proper noun labeling the object. During training, Chaser was said to have learned a label when she correctly applied it successfully on eight generalization trials (where all objects were of the same category) and eight discrimination trials (where half of objects were of the same category and half were not). In eight blind trials for each category, Chaser correctly identified all target items in every trial. For *toy* and *ball*, the categories were sufficiently large that the objects used in testing were not used in training; however, for *frisbee* some items were used in training and testing. These results clearly indicate that Chaser formed categories for these three subgroups and could correctly extend these categories to proper nouns that she had not been trained on. Moreover, she was able to learn multiple subgroup labels for some of these items without unlearning the other labels.

As in the second experiment, these results further support Chaser's use of symbolic reference because she has acquired new knowledge without repeated trials for learning by extending the subgroup labels to untrained objects. Although resistance to extinction was not explicitly measured, no extinction was observed even when multiple labels were learned for a given item. In addition, the correct multiple labels per item show Chaser has established three levels of hierarchical semantic relationships, for example *proper name* ® *ball* ® *toy*. The demonstrated ability to apply multiple labels to subgroups of objects is particularly interesting in light of the perceptual abilities of dogs. The largest category *toy* is composed of highly heterogeneous objects in terms of appearance and smell, and according to the experimenter is distinguished functionally by the goal of play, c.f. Barsalou (1985). Therefore it seems unlikely that Chaser organized the category *toy* around shared perceptual properties. In contrast it is possible that Chaser organized *ball* and *frisbee*, which share properties of shape as well as properties of motion, around perceptual properties.

The fourth experiment evaluated Chaser's ability to learn proper name labels for novel objects using reasoning by exclusion. After first establishing that Chaser had no baseline preference for novelty that might bias results, the investigators conducted reasoning by exclusion trials followed by delayed retention trials. In the reasoning by exclusion trials, a novel object was placed together with seven familiar objects. Chaser correctly retrieved the novel object when given a novel label in all eight blind trials. In the delayed retention trials, a labeled-by-exclusion object was placed with three novel objects and four familiar objects at three delay intervals (immediate, 10 minutes, 24 hours). Chaser correctly identified the labeled-by-exclusion object in eight of eight immediate trials, five of eight 10 minute delay trials, and one of eight 24 hour delay trials. These results suggest that Chaser understood that the novel label applied to the novel object and thus was able to acquire new knowledge without repeated trials. However, this new knowledge was quickly extinguished without repetition, which indicates that interdependency between the novel label and existing labels was weak. In Deacon's framework, this tendency towards rapid extinction makes sense because the label-by-exclusion was not related to any other symbol.

Taken together, these four experiments suggest that Chaser is capable of forming a full symbolic system, with all the hallmarks proposed by Deacon, but they fall short of demonstrating it conclusively. The most illuminating experiments were the second and third experiment. The second experiment shows acquisition of new knowledge without repeated trials and a combinatorial organization with other symbols, because the verb/noun commands required correctly interpreting novel combinations of verbs and proper nouns. The third experiment shows an absence of extinction when multiple labels are learned for the same object and a hierarchical system of semantic relationships in those labels, because the labels described nested subgroups of objects. However, no experiment demonstrated all the hallmarks of symbolic reference together. To do so, Chaser would need to correctly interpret verb/noun syntax applied to subgroup labels, for example *take toy*, and execute these commands correctly for novel objects. Another unanswered question is the extent to which Chaser's abilities generalize to other dogs. As discussed in Section 2, herding dogs are genetically distinct from the other major functional breed groups. Thus it is possible that Chaser's abilities derive from an interaction of genetically-determined ability and a high level of training (4–5 hours daily for several years).

5. Indexical reference

In contrast to the high degree of training required by Chaser, a number of studies have indicated that dogs are able to interpret various cues to determine the location of food without training (Hare et al., 2002; Bräuer et al.; 2006; Riedel et al., 2006). Typically these studies use eye gaze, pointing, a physical marker, or some other indicating gesture to draw an animal's attention to one of two opaque containers that is hiding food. Given the discussion of dog's perceptual capabilities in Section 3, there are some immediate concerns with this type of experiment. First, the containers may not be odor-neutral, meaning that each container is not equally marked with human scent or the scent of food. If so, the dog is not interpreting the gesture as a communicative indexical reference, but is instead using a foraging strategy to locate the food. Second, even if the containers are odor-neutral, the dog may be interpreting the gesture not as a communicative act but rather as a non-cooperative act of a conspecific. By orienting toward the indicated container, the dog would then be competing with the experimenter for the food in the cup rather than interpreting a cooperative communicative act. Third, dogs are very sensitive to motion and so might perceive a weak motion-based cue, for example a slight lean that would be non-perceptible to a human, so the dog may be responding to that cue rather than overt cues like pointing.

Many of these concerns are addressed in a series of experiments performed by Hare et al. (2002). Their first experiment compared the ability of domestic dogs versus the ability of chimpanzees to attend to social cues of pointing, gaze, and a physical marker to indicate the baited container. Nine of eleven dogs used the cues, whereas only two of eleven chimpanzees used the cues.

This finding supports the hypothesis that dogs are not attending to the cues as a competitive act (which chimpanzees should also be able to interpret). A second experiment compared the ability of domestic dogs versus the ability of wolves to attend to the cues of gaze, pointing, and tapping. All dogs performed above chance when given any one cue, but no wolf performed above chance with any one cue. Both dogs and wolves performed at chance when no cue was given. These results further support the hypothesis that dogs are not attending to cues as a competitive act but as a social communicative act. Apparently dogs, by virtue of domestication, are biased to interpret these cues as indexical references without repeated learning trials, and wolves are not biased to interpret the cues as indexical. Furthermore, since both dogs and wolves performed at chance in the no cue condition, it is likely that the containers were effectively odor-neutral; otherwise both groups would be able to detect the food in the absence of cues. The third experiment further confirmed the equivalence of dogs and wolves at foraging in the absence of clues. However, it is possible that the experimenter (who was not blind to condition) also unconsciously produced some subtle movement cue to dogs but not wolves. This alternative explanation assumes that some subtle movement cue would be more salient to dogs than eye gaze, pointing, or tapping, and thus this alternative explanation is somewhat unintuitive. The fourth experiment examined whether age or upbringing of puppies affected their ability to use gaze and pointing cues. Puppies reared by families or reared in a kennel, ages 9–24 weeks, were given gaze or gaze with pointing cues. Neither rearing nor age affected the puppies' ability to perform the task: both rearing groups performed equivalently and all age groups performed equivalently. These results suggest that dogs are either born with an innate bias to interpret human gaze and pointing as indexical references, or they acquire these interpretants before the age of nine weeks.

Hare et al. (2002)'s experiments indicate that domestic dogs are biased towards interpreting human gestures as indexical references. A natural conclusion is that the process of domestication itself somehow gave rise to this bias. An additional set of experiments investigated the effect of domestication using foxes from the 40-year domestication experiment described in Section 2 (Hare et al., 2005). In the first experiment, domesticated fox kits and dog puppies were equally successful at interpreting point with gaze cues. Fox kits in the control group were not exposed to gaze and point cues and performed at chance, indicating that the containers were odor-neutral. In the fourth experiment, adult domesticated foxes and control foxes (from the same facility rather than wild-type foxes) were found to both utilize gaze with point cues to identify the baited container, but the domesticated foxes were significantly better at interpreting the cues than the control foxes.

What is most remarkable about these experiments is that the domesticated foxes were not selected based on their ability to interpret human communicative cues, but rather based on their tamability as described in Section 2. It appears that selecting for tamability in domestic foxes has induced a bias to interpret human gestures as indexical references, and that this bias is equivalent to the bias found in domestic dogs. Thus it appears that for canids in general, tamability is a key ingredient for interpreting human indexical references. Because symbolic references are built upon indexical references, it may be the case that this bias is the foundation for Chaser's abilities described in Section 4.

6. Iconic reference

From one point of view, it may seem nonsensical to discuss dogs' capability for iconic reference after their capabilities for symbolic and indexical reference have been discussed. Both symbolic and indexical references are hierarchically built upon iconic references, so it may be assumed that dogs are equally capable of iconic reference. Moreover, it is assumed that iconic reference is innately specified and so does not require training. However, this question has been investigated in one study with mixed results and so is worthy of discussion (Kaminski et al., 2009).

The dogs in this study were all border collies (a herding breed). Three were highly trained to retrieve objects by name in previous studies while the other two were not so trained. None of the dogs were trained to retrieve objects by iconic reference. All dogs were familiar with the target objects (toys) after several weeks of casual exposure. The study investigated the dogs' ability to retrieve the target objects when presented with one of three alternative indicating stimuli: an identical object, a miniature version of the object, or a life-sized photograph of the object. Dogs were exposed to eight blind trials for each of these three conditions, in order of identical, miniature, and photo. Dogs were praised for returning with the correct object and were given up to three attempts when they returned with the incorrect object. The three experienced dogs correctly used the identical and miniature object at above chance levels, though not necessarily on the first attempt. The other two dogs were not able to use the identical objects, but one of the two was able to use the miniature objects. Only one of the experienced dogs used the photo above chance, but she was correct on the first, second, and third attempts with equal frequency.

Under the present analysis, these results are highly mixed. First, only the experienced dogs correctly used the identical object as an indicator of the target object without training. This finding implies that their ability was based on prior training with proper name labeling of objects. However, if this is true, then the experienced dogs used a previous indexical reference of proper name to object and substituted the icon of proper name with the icon of the identical object. If this is the case, then what the experiment shows is a flexibility of substituting the indicating stimuli of an indexical reference (generating new knowledge – a symbolic hallmark) rather than anything about icons per se. Second, the results of the miniatures are hard to interpret because the miniatures were sometimes (but not always) made of the same material as the identical objects. Thus the olfactory signature of the miniature did not always match the olfactory signature of the target object, which should undermine the dogs' ability to use the miniature as a cue. However, all the experienced dogs and one inexperienced dog used the miniature as a cue at above chance levels. A possible explanation for this contradictory situation is that the experimental design did not control for learning effects across trials. In fact, the experimental design implicitly supports learning by allowing positive reinforcement for correct trials, by allowing negative punishment for incorrect trials (absence of praise), and by ordering the presentation of stimuli from the most similar (identical) to the least similar (photograph). Thus it is difficult to conclude that the more experienced dogs would have correctly used the miniature object as a cue if they had not been immediately presented with (and rewarded for using) an identical object as a cue. Accordingly, the one experienced dog that used a photograph at above chance levels might not have done so without the previous exposure to and implicit training for identical and miniature objects.

While there can be little doubt that dogs are capable of iconic reference by virtue of their ability to perform indexical reference, this study suggests that demonstrating iconic capability experimentally may require rethinking the experimental procedures described in Sections 4 & 5. In object labeling experiments, a given dog has learned an indexical relationship between the spoken proper name and a specific object, but in addition the dog demonstrates this understanding by retrieving the object on cue. Thus the interpretation of the indexical reference is intertwined with the extraneous behavior of demonstrating that interpretation to the experimenter by retrieving the object. Likewise the interpretation of indexical reference in the food hiding experiments with untrained dogs is intertwined with the extraneous behavior of demonstrating that interpretation by taking the food from the baited container. In this later case, very careful controls and comparison conditions are needed to show that the human cue is interpreted as a communicative and indexical reference rather than in some other way. It may be the case that further work on iconic reference with untrained dogs requires a correspondingly simple task, controls, and comparison conditions.

7. Conclusions

The present article reviewed recent studies in canine communication using Deacon's framework of iconic, indexical, and symbolic reference. These studies individually situated their results with respect to the theoretical and philosophical problem of reference. The analysis presented here examined these studies using Deacon's notion of interpretant, taking into account the evolutionary and perceptual capacities of the dog. For the most part, the present analysis confirmed the original interpretation of results in these studies while simultaneously addressing their larger significance to the question of reference in canine communication.

Section 4 described four experiments with the border collie Chaser. In these experiments, Chaser exhibited remarkable capabilities to associate a large number of objects with individual names, to learn additional labels for nested subgroups of objects, to extend verb/noun commands combinatorially to new items, and to learn new labels for objects via exclusion. These capabilities individually address all the hallmarks of symbolic reference, which (1) allows acquisition of new knowledge without repeated trials for learning, (2) is not extinguished in absence of reinforcement, (3) takes place in a hierarchical system of semantic relationships, and (4) exists in combinatorial organization with other symbols. However, no one experiment demonstrated all of these hallmarks simultaneously. For example, Chaser never applied verb/noun combinations to novel objects using nested subgroup labels as in *take ball*. Without additional evidence showing all four hallmarks simultaneously, Chaser's abilities are only strongly suggestive of symbolic reference.

A conservative interpretation of Chaser's abilities is warranted because in isolation, these hallmarks are only indicative of hierarchical indexical reference (Deacon 1998). For example, when Chaser applied the three verbs/commands, *take*, *paw*, and *nose*, to novel objects, she may merely have been generalizing an indexical association. This would be achieved if Chaser recognized the iconicity between a trained command like *take turkey* and the novel command *take lips*. An iconic interpretation of a known indexical relationship would allow a novel stimulus, like *take lips*, to be correctly interpreted as an index. This phenomenon is related to the transference of *learning sets* (Harlow 1949), where animals can learn patterns in a series of learning tasks and become faster at learning similar tasks in the future. However, an important distinction is that the iconic interpretation of an index, a so-called hierarchical indexical reference, can not only speed learning but also lead to acquisition of new knowledge without additional learning. Although the above discussion has focused on Chaser's three verb/commands, a similar line of reasoning applies to her learning of nested subgroups of objects. Because these results might be explained by hierarchical indexical reference, it is imperative that future work demonstrate all four of Deacon's hallmarks simultaneously in a single experiment.

Section 5 reviewed various experiments that examined ability of dogs to interpret human gestures as indexical references without training and compared this ability to that of chimpanzees, wolves, domesticated foxes, and puppies. Perhaps surprisingly, domesticated foxes and domesticated dogs appear to be equally able to interpret human gestures as indexical references from as early as nine weeks of age. Thus it appears that domestication imparts a genetic bias towards interpreting human gestures as indexical references, as similar ability was not observed in chimps or wolves. This bias toward interpreting human gestures as indexical references may explain why dogs are so easily trained to respond to verbal and nonverbal commands. It may also lay a foundation for more sophisticated indices, like proper names for objects, and the other abilities demonstrated by Chaser.

The studies in Sections 4 & 5 are well aligned with the central notion of interpretant in Deacon's framework. In both cases the dogs' interpretation of the reference was clearly indicated by the dogs' behavior in a given task. In contrast, the study in Section 6 is not well aligned with the notion of interpretant because the dogs which performed correctly appear to be substituting proper name icons with physical object icons in an already known indexical relationship. Thus applying Deacon's framework to this study is instructive because it helps identify the conceptual flaw in the design of the associated experiments.

In conclusion, these studies and corresponding analysis suggest that the domestic dog may be capable of symbolic reference and furthermore might be a valuable model for further studying the development of symbolic reference. Unlike chimpanzees and other primates, dogs present no ethical or safety concerns when family-reared to study the development of symbolic reference. Domestic dogs naturally and easily integrate into a highly social human environment that is rich with communicative cues. It is perhaps ironic that a great deal of research has focused on primate referential communication because of our shared genetic heritage, rather than canine referential communication that has a shared sociocultural heritage. When it comes to symbolic reference in communication, domesticated apes may have more in common with domesticated dogs.

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