The Social Cognition of Domestic Dogs (*Canis familiaris*) During Cross-Species Interactions with Humans

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ABSTRACT

Domestic dog (*Canis familiaris*) research has revealed an impressive cognitive skillset within the species; however, little research is conducted in naturalistic settings. Thus, much of what is currently known about dog cognition comes from laboratory trials. This thesis explores the dog cognitive skillset, investigating their social cognition during cross-species interactions with humans in their homes. I examine five areas: 1) the gestural and vocal repertoire of dogs used during cross-species interactions; 2) the targeted solicitation and use of social companions through communication; 3) the understanding of human verbal phrases; 4) the understanding causal reasoning; and 5) whether hemispheric emotional processing in the brain is associated with ear temperature.

I investigated the communicative repertoire of dogs using a citizen science approach, thus maximising the data collection potential. The research revealed dogs possess a broad gestural and vocal repertoire that they use in cross-species communication. New evidence for intentionality and referential signalling in dog communication is also revealed. I then report how dogs use their cross-species communicative repertoires to employ humans to achieve inaccessible goals and discuss new terminology for this type of communication.

Using an experimental procedure comparable to naturalistic studies on non-human primates, I reveal that dogs understand human receive-request verbal phrases; an ability not previously demonstrated. I then report that dogs understand causality and reveal a new simple, inexpensive method for recording canine emotional hemispheric brain activity during behavioural trials.

Overall this thesis sheds light on important areas of dog behaviour including social cognition, the evolution of cross-species communication, and the dog-human bond. It is one if the first to fully embrace the citizen science principle to reveal the naturalistic behaviours that dogs use in the context of their daily lives. Taken together, these results demonstrate that dogs are a highly skilled socio-cognitive species.

1. INTRODUCTION

1.1 ANIMAL COMMUNICATION AND SOCIAL COGNITION

Social cognition refers to how an individual processes, stores and applies information about other individuals and social situations (Shettleworth, 2010). Some species possess increased cognitive abilities which help them to anticipate, correctly respond to and understand the social behaviour of their group mates (Holekamp, 2007). Social species perform many new and intriguing patterns of behaviour evolved specifically for the maintenance and regulation of group living (Byrne & Whiten, 1988; de Waal, 1988; Dunbar, 1998; Engh et al., 2005; Pongrácz, 2014) and sociality would be near impossible without the ability to effectively communicate with fellow group mates.

The evolution of communication and language in humans has been a topic of interest for many years (Stam, 1976) and communicative interactions between organisms have been documented in all domains (Witzany, 2014). When we consider a species' interactions they would struggle to function in the absence of communication (Hauser, 1996). Communication is essential for animals who navigate through complex societies as it is the mechanism by which they interact with each other and organise their status and function (Shorey, 1976). Communication is therefore playing an important role in social interactions and reproductive events, as well as being a vital component to the ecology of the habitat (Hauser, 1996).

Communicating successfully with group-mates requires much more than sending and receiving cues (Roloff, 2012). Individuals must also possess socio-cognitive abilities to understand how their intended receiver interprets the cues (Roloff, 2012). These socio-cognitive abilities influence the behaviour of individuals as well as assist in the development of communication (Roloff, 2012). Investigating communication systems is essential to understanding the social cognition and behaviour of animals, as interactions between individuals tend to be mediated by olfactory, vocal and visual signals (Bradbury & Vehrencamp, 1998). Today social cognitive researchers view the communicative abilities of non-human species as a privileged source of insight into an animal's mind (Rendall & Owren, 2002).

1.1.1 Vocal Communication

Vocal communication is utilised by numerous species in a variety of contexts as a means of social signalling (Ploog, 1992). One form of vocal communication in non-human species that is frequently investigated by researchers is alarm calling. Research has revealed in titi monkeys (Cäsar et al., 2012) and several species of guenon the evolution of a complex system of alarm calls to warn group mates of the presence of specific predators or to signal the approach of conspecific aggressors (Struhsaker, 1967; Seyfarth et al., 1980: vervet monkeys [*Cercopithecus aethiops*]; Zuberbühler et al., 1997; Diana monkeys [*Cercopithecus diana*]; Zuberbühler, 2001; Campbell's mona monkey [*Cercopithecus campbelli]*).

Alarm calling and contact calling is also seen in non-primate species. Juvenile Richardson's ground squirrels (*Spermophilus richardsonii*) (Hare, 1998), Adélie penguins (*Pygoscelis adeliae*) (Speirs & Davis, 1991) and Magellanic penguins (*Spheniscus magellanicus*) (Clark et al., 2006) discriminate among callers and respond differently to the alarm calls of neighbours and strangers (Hare, 1998). Similarly, female African elephants are able to distinguish between the calls of close and distant associates (McComb et al., 2000), and red deer (*Cervus elaphus*) hinds can discriminate between the mating calls of individual stags (Reby et al., 2001), thus influencing mate-choice in the species.

The production of alarm calls is affected by the presence and composition of the audience (Seyfarth & Cheney, 2012). An individual is more likely to produce an alarm call whilst in the presence of conspecifics than when they are alone and are more likely to produce these calls in the presence of kin and preferred group mates than in the presence of non-kin or rivals (Seyfarth & Cheney, 2012). For example, female rhesus macaques (*Macaca mulatta*) respond significantly faster and longer to the contact calls of matrilineal relatives (Rendall et al., 1996).

Alarm calls are also abundant in semantic information, i.e. class of predator, threat posed by predator and physical attributes (Hare, 1998). Therefore, individuals are required to decipher the meaning behind the alarm call in order to respond appropriately (Hare, 1998). Interestingly, researchers have also demonstrated that individuals are also able to identify the sender of the call (Seyfarth & Cheney, 2012). This, in turn, has fitness benefits as recipients can adjust their responses according to the caller's reliability (Cheney & Seyfarth, 1988) and avoid expending energy responding to calls from an unreliable source, i.e. sucker's payoff (Axelrod & Hamilton, 1981). It also enables them to respond according to their spatial relationship with the signaller as calls from family members or preferred group mates would signal an impending threat compared to those from distant conspecifics and non-kin (Hare, 1998). This fitness benefit is also apparent between mothers and their offspring; for example, captive Mexican free-tailed bat (*Tadarida brasiliensis Mexicana*) mothers can recognise the vocalisations of their presumptive pups (Balcombe, 1990) and domestic sheep (*Ovis aries*) ewes and their lambs recognise each other's calls from a distance (Searby & Jouventin, 2003) enabling the mothers to restrict their maternal investment.

When played the scream of an unrelated infant, female vervet monkeys (*Cercopithecus aethiops*) are more likely to look towards the mother of the infant than towards other females in the group (Cheney & Seyfarth, 1980). This demonstrates that vervet monkeys not only possess knowledge of one's own relationship to other group members but also of the relationships formed between other group members (Borgeaud et al., 2013). This 'third-party' knowledge is of interest to researchers as it requires an animal to recognise other individuals and frequently observe them interacting with other group members in a variety of contexts (Seyfarth & Cheney, 2015). By obtaining this knowledge an individual animal is then able to make appropriate deductions regarding the close associates other group members have formed. From this, individuals can then place other group members into categories such as, close social bonds and linear dominance ranks. Therefore knowledge of other individual's social relationships also requires an animal to form social categories (Seyfarth & Cheney, 2015).

Researchers investigating vocal communication in animals (especially non-human primates) will inevitably use their findings to better understand the origins of human language. However, comparisons between human and non-human primate vocalisations are rarely drawn from great apes as their vocal communication is not especially complex or human-like (Tomasello & Camaioni, 1997). Further research into the vocal communication of other non-human primates revealed limitations in the use of representational vocalisations to flexibly communicate with various recipients, in different psychological states, in a variety of social situations (Cheney & Seyfarth, 1992; Tomasello & Call, 2018). Non-human primates therefore must rely on another form of communication (Tomasello & Camaioni, 1997): gestures.

1.1.2 Gestural Communication

In its simplest form a gesture is defined as "a movement of part of the body to convey a meaning or intention" (Oxford English Dictionary, 2018). In great apes gestural communication is more flexible and under greater voluntary control than vocal communication (Tomasello & Zuberbühler, 2002; Genty et al., 2009) and a number of studies have demonstrated that the gestural communication of chimpanzees is similar to that seen in pre-linguistic human infants (Tomasello et al., 1985; Tomasello & Camaioni, 1997). As a result, most researchers now subscribe to the idea of a gestural origins-of-language hypothesis (Armstrong et al., 1995) and an increasing amount of research is being conducted on non-human primate gestural communication.

Studies have shown that gestures performed by several monkey and ape species play an important role in communication between conspecifics and are used flexibly in numerous functional contexts (Liebal et al., 2006). For example, pigtail macaques (*Macaca nemestrina*) (Maestripteri, 1996); siamangs (Liebal et al., 2004); gorillas (Pika et al., 2003); chimpanzees (Tomasello et al., 1985, 1994, 1997); and bonobos (Pika et al., 2005b) have all demonstrated that the gestures they use vary as a function of context, such as sexual, affiliative behaviour and bonding and dominance/submission. The significance of gestural communication in chimpanzees (*Pan troglodytes*) has been demonstrated when researchers have attempted to teach a form of human language to them. When home-raised by a human with the intent of teaching language almost no change occurs in the vocal repertoire of chimpanzees (Hayes, 1951). However, when assisted by humans great apes are able to acquire a repertoire of tens or hundreds of non-species-typical gestures (Patterson, 1978; Patterson & Linden, 1981; Gardner et al., 1989). These studies, however, have caused controversy (discussed further) in the scientific community and should be viewed with caution.

Investigating gestural repertoire is an important step to understanding cognitive processes as it helps us to grasp the breadth and depth of traits in a species' communicative system (Altmann, 1967). A communicative gestural repertoire is defined as a collection of signals or actions that are used to cause a change in the behaviour of a potential recipient (Altmann, 1967). Indeed, research has revealed that great apes have a large repertoire of manual and bodily gestures (Smith, 1977); for example, Genty et al. (2009) reported a repertoire of 102 gestures in one wild and three captive gorilla (*Gorilla gorilla*) groups. The gestural repertoire of chimpanzees (Tomasello et al., 1994) and gorillas (Tanner & Byrne, 1996; 1999) is used flexibly and many gestures are used in multiple contexts and across a wide variety of situations. For example, a recent study by Hobaiter and Byrne (2014) reported that out of 66 gestures used by chimpanzees only 10 were used in a single context.

An individual requires skills to read and understand the gestures produced by conspecifics, and making correct inferences is an integral part of social regulation within a group (Smith, 1977). Gestures are mainly used in intimate social contexts such as grooming, play, nursing, and agonistic and sexual encounters (Pika et al., 2005a), and thus play an important role in the formation and maintenance of social relationships (Hobaiter & Byrne, 2014).

1.1.3 Intentional Cross-species Communication

Numerous studies have investigated the conspecific communicative abilities of a variety of different taxa; however, there is little evidence for intentional cross-species communication. Indeed, anecdotal evidence exists for cross-species communication between humans and various species, i.e. a person identifying a bird as being distressed through hearing it alarm call means cross-species communication has taken place. The communication, however, is not considered intentional as the caller is not sensitive to the state of the human receiver (Leavens, 2004). Perhaps call production was to warn conspecifics (who provide an appropriate behavioural response) but the cross-species recipient is simply an eavesdropper.

The ability to intentionally communicate cross-species is potentially more cognitively demanding for an individual as they are required to understand and learn how to successfully communicate with another species. To do this, an individual needs to adapt their communicative style to one that will enable the intended heterospecific recipient to understand their behaviours. Moreover, for bi-directional cross-species communication an individual will also have to learn how to understand the communicative actions of the other species as well.

More anecdotal evidence exists which demonstrates cross-species communication between humans and non-human primates, such as the controversial 1973 research project involving Nim the chimpanzee. Its aim was to reveal if a chimpanzee living in a human family could be taught American Sign Language to communicate with humans (Gardner et al., 1989). Similarly, a gorilla named Koko was taught American Sign Language from the age of one and now knows over 1,000 signs and understands around 2,000 verbal words (Patterson, 1978). Even parrots have demonstrated the ability to communicate with humans. The famous Alex the African grey parrot (*Psittacus erithacus*) could identify various shapes and colours and knew over 100 English words (Pepperberg, 1987).

All three individual cases represent examples of successful cross-species communication. Scientific rigour, however, has been questioned. In all cases, communication was artificially induced by human experimenters. Little data has emerged for scrutiny from the long-running study of Koko and independent verification of claims has seldom been allowed which makes the results that are reported difficult to support (thediscoveryofinteresting, 2012). Despite considerable resources, in both ape studies there has been a failure by the subjects to form a syntactically-correct sentence. In all three cases, trainer imitation is prevalent with trainer confirmations of 'correct' answers; this suffers the problem of Clever Hans effects and unconscious prompting potentially taking place (Miles, 1991; Smith, 1999). In addition, despite claims of impressive performance, the subjects have been shown to make a greater number of incorrect than correct signs and the evidence from these studies should therefore be viewed with caution.

Naturally occurring cross-species communication is sparse as most species do not need to communicate or understand another species. This however, is not the case for domesticated species. Domestic animals and humans share the anthropogenic environment and so have developed the ability to understand and communicate with each other. They provide some of the best evidence of naturally occurring cross-species communication, and arguably the best cross-species communicators are domestic dogs. The process of domestication has had a profound effect on the cognitive abilities of dogs (Hare & Tomasello, 2005), enabling them to understand, communicate and form a bond with humans in ways that other species cannot. Therefore, the socio-cognitive and communicative abilities of domestic dogs are uniquely adapted to humans and the anthropogenic environment, making dogs an interesting animal to study.

1.2 THE STUDY SPECIES: THE DOMESTIC DOG (*Canis familiaris*)

1.2.1 A Brief History

Dogs belong to the order Carnivora in which there are 16 extant families, the suborder Caniforma ("dog-like") and the family Canidae (Figure 1.1) which contains 35 species in 13 genera. Domestic dogs (including working dogs) are listed in the wolf-like clade (blue) in figure 1.1, also referred to as the tribe Canini ("true dogs") and the genus *Canis* which includes the grey wolf (*Canis lupus*), dingo (*Canis lupus dingo*), coyote (*Canis latrans*), Ethiopian wolf (*Canis simensis*), golden jackal (*Canis aureus*), side-striped jackal (*Canis adustus*) and black-backed jackal (*Canis mesomelas*). In 1993, through mitochondrial DNA (mtDNA), it was shown that the domestic dog is an extremely close relative of the grey wolf with only 0.2% of their mtDNA sequence differing (Wayne, 1993).

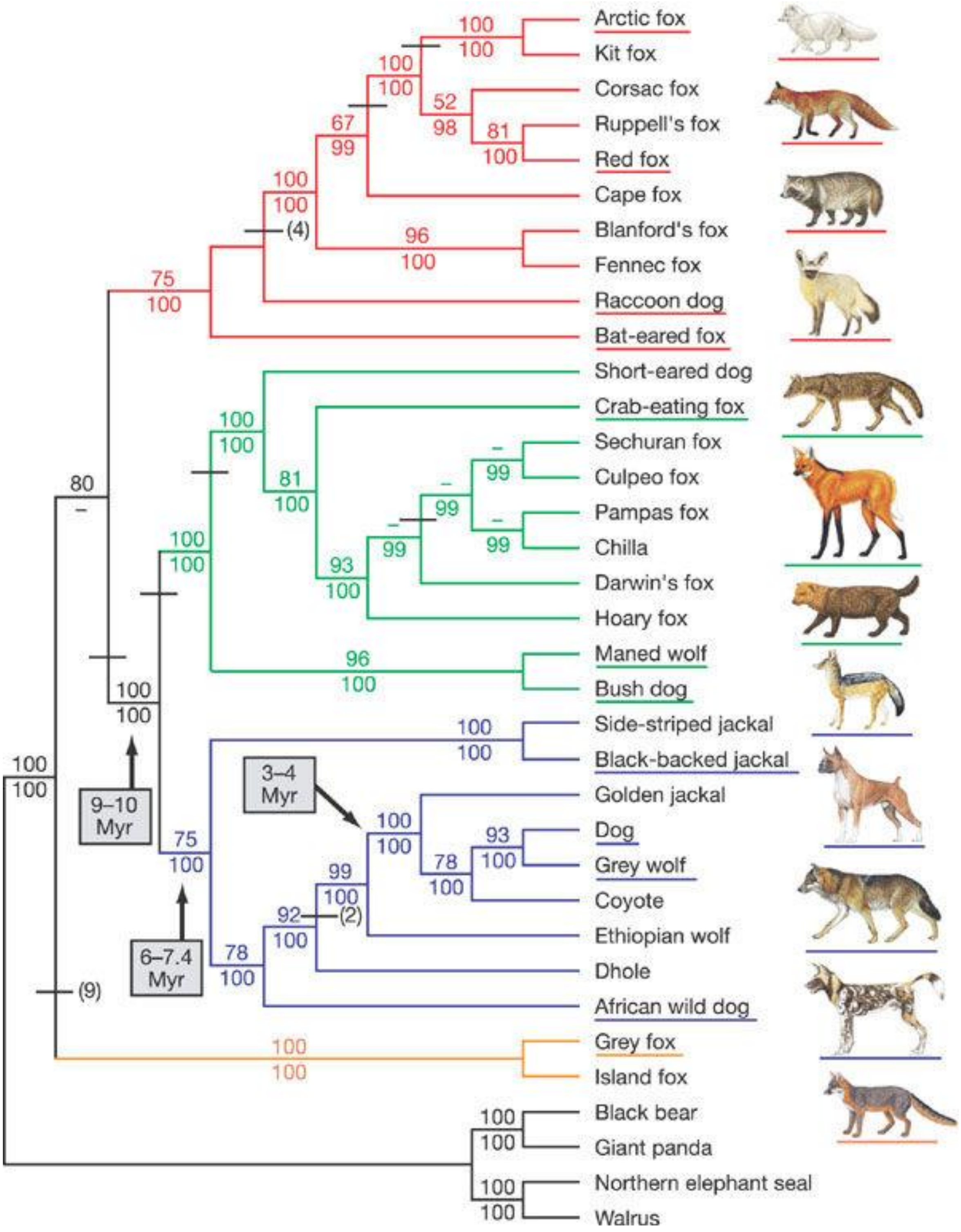


Figure 1.1 Phylogenetic tree drawn from a sequencing of the domestic dog genome, images of a selection of the species listed are shown and the corresponding species name is underlined. The branch colours identify the red-fox-like clade (red), the South American clade (green), the wolf-like clade (blue) and the grey and island fox clade (orange). (Lindbald-Toh et al., 2005).

1.2.2 The Domestication Process: Causes, Changes and Benefits

It is commonly thought that dogs' divergence from wolves happened around 130,000 years ago (Vilá et al., 1997) and that by at least 15,000 years BP dogs had veered morphologically from wolves with the first signs of domestication taking place (Miklósi, 2007). Dogs are the first domesticated animal and their domestication predates the advent of agriculture (~10,000 years BP) and the domestication of agricultural animals (Galibert et al., 2011).

Human and canid remains have been found together at several locations which suggest that their habitats overlapped for a long period of time in the Pleistocene age (Nowak, 2003; Mech & Boitani, 2010). The earliest archaeological evidence assigned to domestic dogs comes from the Goyet cave in Belgium, dated c.31, 700 BP (Germonpré et al., 2009). Also, a recent study using genetic sequencing by Druzhkova et al. (2013) found that a 33,000 year old Pleistocene dog specimen from Altia was more closely related to domestic dogs than extant wolves. It is difficult to ascertain an exact date for the start of the wolf domestication process (Druzhkova et al., 2013), but the consensus is that it occurred ~30,000 years ago (Miklósi, 2007).

Due to this domestication process domestic dogs have often been thought of as an 'artificial species' (Macpherson & Roberts, 2013). However, dogs are adapted to human society, and the anthropogenic environment represents their natural ecological niche (Miklósi, et al, 2003a). By living within human society dogs have developed specific mental adaptations that have allowed them to successfully integrate themselves into our culture (Cooper et al, 2003). Moreover, the domestication process has led to the creation of a unique cross-species bond that is still prevalent today.

1.2.3 The Dog-Human Bond

The dog-human relationship is built on a deeply ingrained and complex bond (Siniscalchi et al., 2013). People value the relationships that they form with their pets and often describe the relationship as being similar to a parent-child bond (Berryman et al, 1985; Sable, 2013). Indeed, various studies have reported that owners: use dogs for social support (Allen et al., 1991; Beetz et al., 2011); substitute dogs for human comfort when emotionally distressed (Kurdek, 2009); and use dogs as social facilitators (Messent, 1985; Guéguen & Ciccotti, 2008).

Owners place tremendous value in the relationship they have with their dog and believe that they are capable of exhibiting emotions (Fox, 1981) and aim to improve and achieve goals in the relationship they have (Sanders, 1993). But in order to fully understand this bond we need to explore how dogs view their human (and canine) social partners.

1.2.4 The Attachment Bond

Attachment refers to a specific type of bond that develops between an infant and its mother (the primary caregiver) (Bowlby, 1958). It has been suggested by researchers that the bond between humans and dogs is similar to that of infantile attachment which, for dogs, extends into adulthood (Palmer & Custance, 2008). In order to examine attachment bonds, investigators perform a strange situation test. These tests involve conducting a behavioural experiment in a novel environment to investigate the behaviours of an individual towards a familiar person as opposed to a stranger (Ainsworth & Bell, 1970). Strange situation tests were originally used to investigate the mother-infant bond and have since been modified to explore the dog-human relationship.

A number of studies have documented that dogs form strong attachments to their human companions (Palmer & Custance, 2008; Miklósi & Topál, 2013) and that these attachments are stronger than the ones formed towards conspecifics (Berns et al., 2015). It has been shown that adult dogs react in a similar way to human infants during strange situation tests and show a preference for their owner (*vis a vis* parent) over an unfamiliar person (Topál et al., 1998). Furthermore, in the presence of a familiar person, dogs show behavioural preferences such as comfort, proximity maintenance and the 'secure base effect' (Horn et al., 2013a). Subsequent research has also demonstrated that dogs can form attachments with humans multiple times and later in life, even after only three short interactions with a specific individual (Gácsi et al., 2001).

The type of attachments which dogs form with humans in strange situations has not been documented between dogs and conspecifics. Research has shown that conspecifics, even the mother, cannot attenuate stress responses as efficiently as a human-being can, and puppies show no preference for their mother over an unfamiliar female in stressful situations (Pettijohn et al., 1977; Tuber et al., 1996). Contrastingly, when puppies are placed in a moderately stressful environment with a human they developed strong attachment behaviours towards that person, but this preference has not been found in hand-raised wolf puppies of a similar age (Topál et al., 2005).

The prevalence of these behaviours in dog puppies, and the absence of them in wolf puppies, suggests that specific selection processes may be the driving factor behind the emergence of human attachment behaviours in domestic dogs. Therefore, domestication has played a crucial part in the evolution of attachment behaviours and provided a basis for the development of all interactions and relationships that dogs have formed with humans (Topál et al., 2005; Miklósi & Topál, 2013). Without the presence of a bond between humans and dogs neither species would have developed their impressive socio-cognitive and cross-species communicative abilities.

1.3 DOG-HUMAN CROSS-SPECIES INTERACTIONS: A BRIEF OVERVIEW

Domestic dogs' social behaviour is of interest to researchers because of a unique species-specific characteristic: their special cross-species relationship with humans (Pongrácz, 2014). Dogs' communicative, social, attachment and cooperative behaviours towards humans have all changed because of the domestication process (Miklósi et al., 2003b). Moreover, domestic dogs present a good model for investigating communication and socio-cognitive processes as three factors have influenced their high sociality (Cooper et al., 2003). Firstly, dogs evolved from an ancestral wolf, a species which engages in co-operative behaviour and forms stable social groups (Miklósi, 2007); secondly, dogs were selectively bred due to their high sociality during the domestication process (Coppinger & Coppinger, 2001); and thirdly, dogs live in the anthropogenic environment which facilitates the development of social skills (Cooper et al., 2003).

Indeed, research has shown that dogs are more skilled their closest relative, the wolf, in using human social cues to locate hidden food (Hare et al., 2002). In fact, many studies into dog cognition have focused on the ability of dogs to understand human-given social cues. When completing the so-called object choice test (locating hidden food using a social cue) dogs understand several different human-given social cues: (1) a human pointing at the food location; (2) a human orientating their gaze to the target location; and (3) a human bowing or nodding at the target location (Hare et al., 1998; Miklósi et al., 1998). However, when the cues given by humans involve unfamiliar pointing gestures, such as elbow-cross pointing and pointing with a knee, dogs are unsuccessful at understanding them as directional cues (Lakotos et al., 2009).

Despite this, dogs’ abilities to use human-given social cues are superlative when compared to those of other animal species (Kaminski & Nitzschner, 2013). Their performance in the object choice paradigm is significantly better than non-human apes (Bräuer et al., 2006) who tend to fail when given gaze direction cues (Tomasello et al., 1997; Povinelli & Eddy, 1996; Call et al, 1998). Also, although chimpanzees have a natural ability to use gestures (Hobaiter & Byrne, 2014) they show low levels of performance when relying on human pointing signals (Povinelli et al., 1997; Itakura et al., 1999).

Unlike apes, dogs have developed a set of skills which allow them to use and understand human-produced directional cues (Agnetta et al., 2000); they out-perform other domesticated animals, such as horses, in communicative signal tasks (McKinley & Sambrook, 2000), but the ability to understand human pointing gestures is similar in both domestic cats (*Felis catus*) and dogs (Miklósi et al., 2005). Despite this, when it comes to informing naïve humans about the location of hidden food, cats lack the attention-getting behaviours that dogs possess. Dogs can inform owners about the location of hidden food by communicating through barking and orientating the body towards the goal location (Hare et al., 1998), it is not, however, currently known if cats are able to do this.

From an early age (six weeks) puppies can follow a human pointing gesture (Hare et al., 2002; Riedel et al., 2008). This suggests that the long evolutionary history that dogs have shared with humans lies at the root of dog-human communication (Hare & Tomasello, 2005; Udell et al., 2010). This shared evolutionary history can explain why dogs outperform wolves when responding to human-given pointing gestures (Miklósi et al., 2003b; Topál et al., 2009). When compared to wolves, dogs have a genetically based advantage when it comes to understanding human gestures (Miklósi et al., 2003b). Dogs also perform at above chance levels when using social cues produced by unfamiliar humans (Hare & Tomasello, 1999) and are successful in following the pointing gesture given by an artificial hand (Kundey et al., 2014).

Dogs can also distinguish the communicative intent of humans (Kaminski et al., 2012) and will not blindly follow a pointing gesture but will consider contextual information (Scheider et al., 2011). The understanding of social cues given by humans is consistent throughout an individual’s life, further suggesting that the domestication process has played a vital role in the development of dog-human communication (Riedel et al., 2008). These communicative abilities allow dogs to successfully predict the behaviours of and communicate with humans (Hare et al., 2002).

Research has also revealed that some dogs can learn and understand human-given vocal cues, and there have been cases of several individual dogs around the world who have demonstrated this (Warden & Warner, 1928; Pilley & Reid, 2011; Griebel & Oller, 2012; Pilley, 2013). For example, a border collie named Betsy could fetch a specific object out of a set of hundreds when prompted through photographs and verbal cues (Kaminski et al., 2009). More recently, over a period of three years, another border collie named Chaser learned and remembered the names of thousands of objects and used words to represent categories of objects (Pilley & Reid, 2011; Pilley, 2013). Additional research, on a mongrel named Sofia, has shown that dogs can extract and integrate information contained in complex messages (Ramos & Ades, 2012).

Most of this research, however, should be viewed with caution as it is easy to assume the same word knowledge in dogs is of the same quality of that seen in humans (van der Zee et al., 2012). These studies also involved the testing of a single subject, all of varying ages and breeds which may lead to differences in results (Griebel & Oller, 2012). Owners have reported, however, that their dogs had a very developed understanding of words and vocal commands are frequently used by dog trainers to produce and control behaviours (Ramos & Ades, 2012). Therefore it can be assumed that dogs do possess some understanding of human- given vocal cues but the depth of this ability has yet to be explored in the field (Bensky et al., 2013).

The majority of dog-human cross-species interaction research is conducted outside of the dogs' natural environment. This means that currently we have little or no evidence of the naturally occurring cross-species communicative and social cognitive abilities of dogs. Given that the study of dog cognition and dog-human communication attracts a large volume of public interest compared to comparable fields (Macpherson & Roberts, 2013), the citizen science approach could provide us with an insight into the naturally occurring abilities of domestic dogs.

1.4 CITIZEN SCIENCE

1.4.1 The Evolution of Citizen Science

Prior to the 20th century the majority of researchers, including Charles Darwin, were self-funded 'gentlemen scientists'; amateur researchers who held a job in a non-scientific profession (Silvertown, 2009). It was not until the late 19th century that science became a paid profession and by the mid-20th century research was dominated by government employees and university academics (Silvertown, 2009). Citizen scientists, although still active, were ignored.

In more recent years science has become more accessible and a large number of professional researchers collaborate with citizen scientists on specifically designed projects (Slivertown, 2009; Lewandowski & Oberhauser, 2015). It is thought that the first true citizen science project is the Christmas bird count which started in the early 1990s by the National Audubon Society in the USA (Silvertown, 2009) to monitor the bird population in North America. To date, a variety of disciplines have adopted citizen science approaches including astronomy, cestology, entomology, meteorology and botany.

Within behavioural and cognitive research, citizen science is a relatively new phenomenon and currently only research concerned with domestic dogs has adopted this approach, for example, Dognition® (https://www.dognition.com/) and The Canid Howl Project (http://howlcoder.appspot.com/). Over the years domestic dog research has relied heavily on the general public with regards to recruitment and participation in studies (Bensky et al., 2013). This is due to the fact that dogs and people have intricate and intertwining lives (Hecht & Spicer-Rice, 2015), and because of this the public show a keen interest in dog behavioural and cognitive research (Macpherson & Roberts, 2013).

1.4.2 Citizen Science: Definitions

Citizen science involves the general public collaborating with professional scientists to collect and analyse data for a specific research project (Lewandowski & Oberhauser, 2015). However, there is some confusion amongst researchers regarding what defines a citizen science project. Some state that citizen science can include any type of participation in research (Raddick et al., 2010; Hecht & Spicer-Rice, 2015) such as completing questionnaires, whereas others state that the citizen scientists need to be involved in explicit data collection and/or analysis (Trumbull et al., 2000; Evans et al., 2005; Dickinson et al., 2012; Bonney et al., 2014; Stewart et al., 2015).

In 2015, the White House hosted an open science forum on the topic of citizen science. As part of the forum they released an electronic federal crowdsourcing and citizen science toolkit which they adapted from previous research, such as Bonney et al. (2009).

The toolkit defines citizen science as:

> The voluntary public participation in the scientific process to form research questions, conduct scientific experiments, collect and analyze data, interpret results, make discoveries, develop technologies and applications, and solve complex real-world problems (Federal Crowdsourcing, 2015).

The toolkit also provides another definition for the term crowdsourcing which:

> Involves an open call for volunteers to provide information or help solve a particular problem. A large group of either unknown or trusted individuals ('the crowd') responds (Federal Crowdsourcing, 2015).

If we follow the definitions set out by the federal toolkit then citizen science cannot include any type of participation (Raddick et al., 2010; Hecht & Spicer-Rice, 2015) as this conforms to the definition of crowdsourcing. In order to be classified as a citizen science project participants must be actively involved in the collection of data and/or assist in the analysis of the data and the methods used in this thesis will conform to this definition.

1.5 OVERALL AIM AND THESIS OUTLINE

1.5.1 Aim of the Thesis

The overall aim of this thesis is to explore dogs' socio-cognitive and communicative abilities during cross-species interactions with humans in their natural environment i.e. the family home. Domestic dogs are an ideal species to use to investigate this area due to their shared history and unique relationship with humans, which has helped to shape their cognitive outlook. As seen in the literature discussed previously, most of the dog-human cross-species communicative research to date has placed its focus on human-given social cues during dog-human interactions. There is therefore a lack of data investigating the ways in which dogs communicate with humans and use their communicative abilities during cross-species interactions. Moreover, little research exists investigating dogs' communicative responses to naturally occurring, untrained human vocal cues.

This thesis will address these gaps in knowledge by exploring the cross-species communicative abilities of domestic dogs by investigating: the intentional and referential gestural and vocal repertoire of dogs used during cross-species interactions with humans; the recruitment of social companions through communication; the understanding of untrained human verbal phrases; the ability to understand causal reasoning; and whether a dogs' ear temperature is a good proxy for emotional hemispheric brain activity during behavioural trials.

From communicating intentions and understanding human words to recruiting humans in order to achieve unobtainable goals and understanding cause and effect, investigating these areas will reveal the variety of ways dogs utilise their impressive cross-species communicative and socio-cognitive abilities. Additionally, by bringing together these areas this thesis will provide us with a rounded view of the cross-species communicative abilities of domestic dogs. Furthermore, using a combination of the citizen science and "experimental" methods conducted in the natural environment, this thesis will document the everyday cross-species interactions between humans and dogs. The use of these methods will reveal the naturally occurring socio-cognitive abilities of dogs during interactions with humans.

The results from this thesis will broaden our understanding of domestic dogs and their uniquely adapted communicative and socio-cognitive abilities. By placing emphasis on ecological validity this thesis will be one of the first to document and analyse the naturally occurring abilities of domestic dogs during cross-species interactions with humans. This thesis will test dogs' cross-species communicative abilities in a variety of contexts, providing us with a new insight into the socio-cognitive world of domestic dogs.

1.5.2 Thesis Structure

This thesis is organised into six chapters. In chapter 1 I introduce the topics of social cognition and communication. A description of the study species is provided, their domestication and bond with humans is discussed and I explain why they are an ideal candidate for the study of social cognition and cross-species communication. Then I introduced the topic of citizen science and briefly discussed its background and identified the definition which will be used to study the naturalistic behaviours of domestic dogs in this thesis. Chapter 1 concludes with the overall aim of the thesis.

Chapter 2 provides an overview of the research aims and introduces the five objectives that were tested in order to achieve the aims of the research. A combination of citizen science observations and experimental techniques were adopted for the data collection and these are outlined for the five objectives within the chapter. A summary of key outcomes is discussed.

Chapters 3, 4 and 5 are research chapters, which investigate the objectives and address the overall aim of the thesis. In chapter 3 I investigate the gestural and vocal repertoire of domestic dogs during cross-species interactions with humans using a citizen science approach. Chapter 4 also utilises a citizen science approach and explores how dogs are using their cross-species communicative abilities to recruit social companions to achieve an otherwise inaccessible goal. Chapters 5 and 6 are concerned with the final three objectives, understanding of human verbal phrases, the ability to understand causality and whether ear temperature corresponds with emotional hemispheric activity, all of which used experimental procedures to investigate them. Each research chapter presents a literature review for the objective being investigated, specific methods and analyses, the obtained results and a discussion of the findings.

Finally, Chapter 7 brings together all of research findings in a general discussion. I provide a discussion of the cross-species communicative and social cognitive abilities of domestic dogs investigated in this thesis. I then discuss the pros and cons of the methods used in the thesis and recommendations for further research.

2. RESEARCH AIMS, OBJECTIVES, METHODS AND KEY OUTCOMES

2.1 AIM OF THE RESEARCH

The overall aim of this research is to test dogs’ social cognition during cross-species interactions with humans. Unlike other species of animals, dogs can be easily tested in their natural environments (Miklósi et al., 2004). Today cognitive researchers are using a combination of both naturalistic and experimental methods and adopting an ethological approach (Miklósi et al., 2003a). Research concerned with the social cognition of primates has seen a move towards these methods, by combining the use of (1) an ecologically valid setting and (2) proper control(s) to maximize the validity of experiments (Hare, 2001). However, this move has not been seen in domestic dog research.

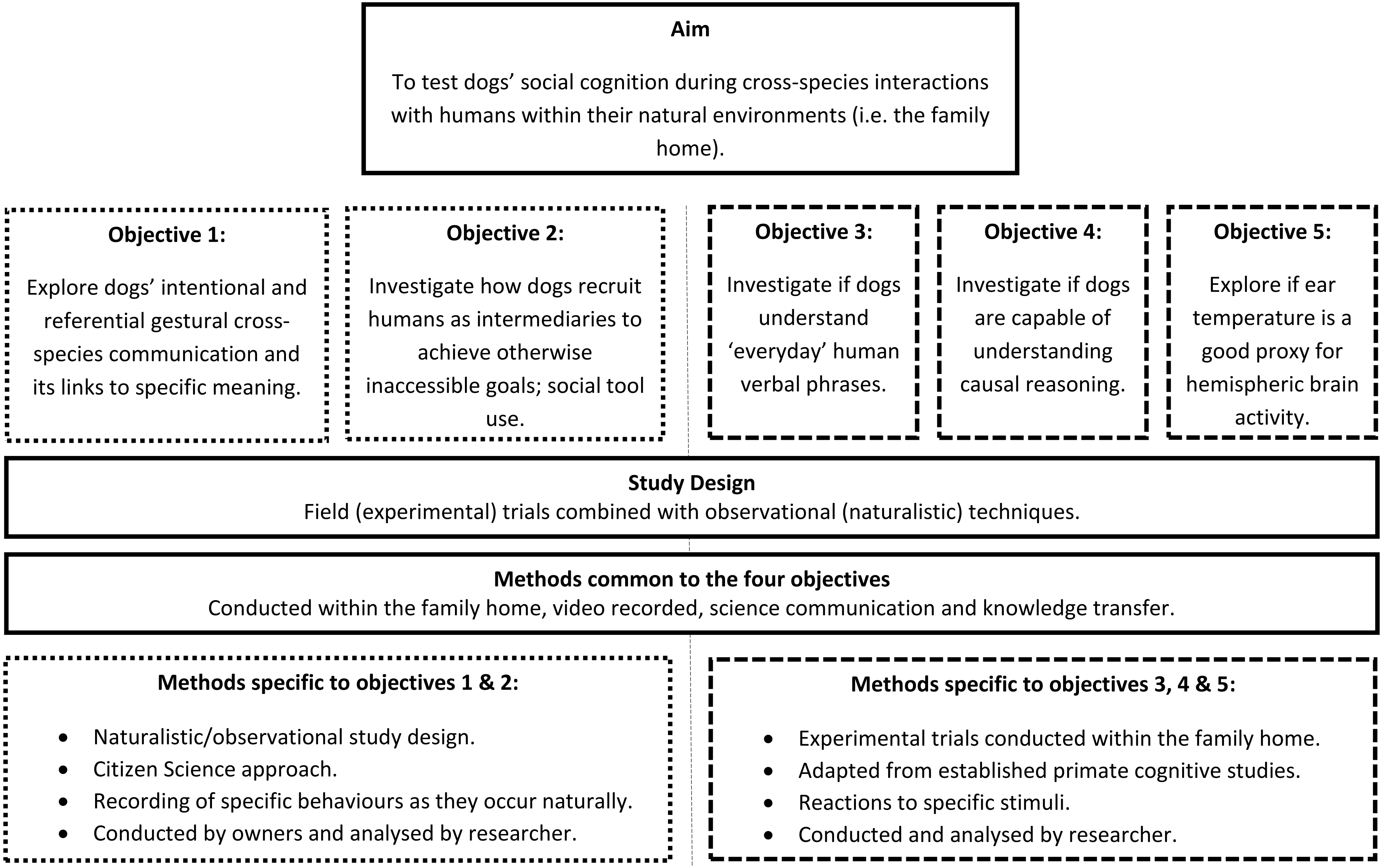
This study will use a combination of naturalistic techniques and experimental trials to study dog cross-species communicative abilities and social cognition in an attempt to reveal the range of behaviours that dogs use in the context of their daily lives in the shared human environment. This research will also be one of the first to fully embrace a 'citizen science' principle whereby members of the public are themselves engaged in the research and are responsible for collecting the data used in the project.

In order to achieve this aim I will test five research objectives:

1. That dogs have a gestural and vocal repertoire that is linked to specific meaning and is used in intentional and referential cross-species communication.
2. That, through their cross-species communicative abilities, dogs can recruit humans as intermediaries to achieve otherwise inaccessible goals; social tool use.
3. That dogs can understand human verbal phrases.
4. That dogs demonstrate an understanding of causal reasoning.
5. That ear temperature is a good proxy for emotional hemispheric activity in domestic dogs during behavioural trials.

2.2 METHODS

A flowchart outlining the methods common to the objectives and the methods specific to each objective can be seen in figure 2.1.



Aim

To test dogs’ social cognition during cross-species interactions with humans within their natural environments (i.e. the family home).

Objective 1:

Explore dogs’ intentional and referential gestural cross-species communication and its links to specific meaning.

Objective 2:

Investigate how dogs recruit humans as intermediaries to achieve otherwise inaccessible goals; social tool use.

Objective 3:

Investigate if dogs understand ‘everyday’ human verbal phrases.

Objective 4:

Investigate if dogs are capable of understanding causal reasoning.

Objective 5:

Explore if ear temperature is a good proxy for hemispheric brain activity.

Study Design

Field (experimental) trials combined with observational (naturalistic) techniques.

Methods common to the four objectives

Conducted within the family home, video recorded, science communication and knowledge transfer.

Methods specific to objectives 1 & 2:

- Naturalistic/observational study design.
- Citizen Science approach.
- Recording of specific behaviours as they occur naturally.
- Conducted by owners and analysed by researcher.

Methods specific to objectives 3, 4 & 5:

- Experimental trials conducted within the family home.
- Adapted from established primate cognitive studies.
- Reactions to specific stimuli.
- Conducted and analysed by researcher.

Figure 2.1 Description of the methods used common to each objective and the methods specific to each objective.

The research for this thesis was conducted in accordance with ASAB/ABS guidelines for the use of animals in research. Research approval was granted by the institution's ethics panel (REP reference: CST 15/07). In addition, written and informed consent was obtained from participants.

2.2.1 Objectives 1 and 2: Gestural and Vocal Communication and Social Tool Use

Subjects

Many participants were already known to the researcher (family, friends etc.) and so were recruited through word of mouth, whereas other participants responded to advertisements in local newspapers and websites. Thirty-seven domestic dogs, 17 female and 23 male of a variety of breeds, and their owners participated in this study. All dogs had lived with their owner for a minimum of five months before the observational period took place. The ages of the dogs who participated ranged from 1.5 – 15 years. The dogs and their owners were located around the Greater Manchester area with the majority falling within the Salford and Bolton catchments (see table 2.1 for more information on the participants).

Table 2.1 Information about the canine subjects who participated in objectives 1 and 2.

Individual (Name)	**Sex**	**Age (Y)**	**Breed**	**People who live with dog (*n*)**	**Where the dog came from**	**Length of time with current owners**	**Videos (*n*)**	**Data collection time (weeks)**
Betty	F	4	Lhasa Apso X	2	Rescue	2 years	12	4
Emma	F	5	Saint Bernard	2	Breeder	5 years	8	4
Florence	F	7	English Cocker Spaniel	4	Breeder	7 years	15	4
Izzy	F	5	Cavalier King Charles Spaniel	2	Breeder	5 years	5	6
Jenko	F	1	German Shepherd X Akita	2	Re-homed	11 months	9	6
Lola	F	7	Border Terrier	3	Breeder	7 years	13	4
Lyla	F	6	Cavalier King Charles Spaniel	2	Internet Advert	2.5 years	9	6
Mandy	F	4	Yorkiepoo	4	Kennel	4 years	12	2
Peggy	F	5	Border Terrier	3	Breeder	5 years	12	4
Phoebe	F	1	Cockerpoo	4	Breeder	5 months	17	4
Pudding	F	2	Pug	2	Breeder	1 year	4	6

						10 months		
Sula	F	11	Labrador	4	Breeder	10 years	9	8
Tess	F	8	Border Terrier	3	Breeder	8 years	9	6
Tilly	F	8	Border Terrier	3	Breeder	8 years	9	6
Yoshi	F	2	Jack Russell X Lhasa Apso	4	Re-homed via Internet advert	21 months	15	6
Aaron	M	7	Mixed Breed	2	Breeder	7 years	5	8
Archie	M	1.5	Cairn Terrier	3	Breeder	1.5 years	8	10
Barley	M	4	Border Collie	3	Farm	3.5 years	18	6
Bobby H	M	12	West Highland Terrier	4	Breeder	12 years	7	4
Bobby L	M	9	German Shepherd	2	Breeder	9 years	3	2
Dexter	M	4	West Highland Terrier	3	Breeder	3 years 10 months	8	4
Dug	M	2	Golden Retriever	2	Breeder	2 years	6	2
Jaffa	M	2.5	Cocker Spaniel	2	Breeder	2 years	22	6
Jenson	M	3	Beagle	3	Rescue Centre	2.5 years	10	6
Kyp	M	5	Beagle	2	Breeder	5 years	14	6
Leroy	M	9	Staffordshire Bull Terrier	2	Adopted from a family member	7 years	4	4
Max B	M	9	Jack Russell X Border Terrier	4	RSPCA	8.5 years	14	8
Max W	M	5	Short Legged Jack Russell	3	Adopted from a family member	3 years	13	4
Mickey	M	3	Border Collie X	1	Gumtree Advert	2.5 years	15	4
Onslow	M	7.5	Lhasa Apso	2	Breeder	7 years 3 months	10	4
Oscar	M	7	Cocker Spaniel	4	Breeder	7 years	11	6
Patch	M	4.5	Jack Russell X	3	Farm	4.5 years	21	2
Rupert	M	4	German Pointer X French Spaniel	5	Breeder	3 years	20	8

Sherlock	M	3	Miniature Poodle X Chinese Crested Powder Puff	4	Breeder	3 years	13	4
Star	M	15	Patterdale Terrier	4	Breeder	15 years	52	2
Toby	M	4.5	Shih Tzu X Toy Poodle	2	Breeder	4 years 2 months	10	6
Watson	M	3	Miniature Poodle X Chinese Crested Powder Puff	4	Breeder	3 years	15	4

Procedure and Design

To maximise the quantity of data accumulated, a citizen science method was used to collect data on the communicative abilities of dogs. This citizen science approach was founded on the method used by Horowitz and Hecht (2016) in their ‘play with your dog’ study. In that study, Horowitz and Hecht asked owners to record themselves playing with their dogs and upload the video clips to a specifically designed website. The researchers then behaviourally coded the video clips to identify the characteristics of everyday-occurring dog–human play (Horowitz & Hecht 2016).

In this thesis, participants were asked to film their dogs in ‘everyday’ scenarios, such as feeding, stroking, playing, letting outside etc., using their mobile phone whenever behaviours naturally occurred, for a minimum of two weeks (see table 2.1 for actual data collection time). Owners were also asked to film both successful (outcome achieved) and unsuccessful (outcome not achieved) communicative bouts performed by their dog(s). To orientate owners to the *kinds* of things I was looking for them to record, all participants were shown pre-collected footage of the researchers own dog in the ‘everyday’ scenarios listed above, to ensure behaviours would be identified and to increase internal and external validity (*sensu* Brink, 1993). There was no limit placed on collection and the same kinds of communicative bouts could be recorded multiple times.

The citizen science approach here involved the owner(s) performing observations of their dog in their home. The aim was to employ a procedure somewhat analogous to field studies of primates (and other free-ranging animals). It is important to note that some behaviours may have been missed in some subjects. Citizen science relies on the public collecting the data and here it is highly likely that not all gestures have been documented. Nonetheless, this was an acceptable trade off when gaining access to a large corpus of naturalistic data whilst embracing an inclusive approach that benefits owners by providing them with an opportunity to learn more about the cognitive world of their pets (Hecht & Spicer-Rice, 2015) and potentially benefit dogs.

To further increase the validity of this study, participants were provided with a help sheet (Appendix I) to assist them during the observational period and provided with the researchers' contact details in case any help was required. Participants were contacted at two week intervals to ensure data collection was going smoothly.

Video data were transferred onto a supplied USB drive which I then analysed, coding it according to the dog's apparent goal/outcome (food, play etc. this is discussed further in subsequent chapters 3 and 4). Participants were also asked to review their footage and label the dog's apparent goal/outcome. Not all participants completed this part of the study but 98.1% of researcher labels matched the owner labels. The 1.9% which did not match were discussed with the owner and it was revealed that they were initially labelled by the owner as *Unknown* but by reviewing the footage a second time they determined that their initial label was incorrect and identified an apparent goal/outcome which matched the researchers.

Analyses

Specific statistical analyses for these two objectives differ and will be outlined in subsequent sections. However, when it came to analysing the data it was found that windows media player failed to playback several videos recorded on mobile phones. Instead, VLC media player was used to analyse the video data for the study.

2.2.2 Objectives 3, 4 & 5: Understanding Human Phrases, Causal Reasoning and Measuring Ear Temperature

Subjects

Thirty-two domestic dogs (10 of whom participated in the data collection for objectives one and two), 18 female and 14 males of a variety of breeds, and their owners participated in this study. All dogs had lived with their owner for a minimum of five months before the observational period took place and aged from 2 – 15 years. The dogs and their owners were located around the Greater Manchester area with the majority falling within the Bolton, Bury and Radcliffe catchments (see table 2.2 for more participant information).

Table 2.2 Information about the canine subjects who participated in objectives 3, 4 and 5.

Individual (Name)	**Sex**	**Age (Y)**	**Breed**	**People who live with dog (*n*)**	**Where the dog came from**	**Length of time with current owners**
Amber	F	3	German Shepherd	4	Farm	3 years
Bracken	F	3	Border Collie	2	Breeder	3 years
Chispa	F	10	Cross Breed	2	Rescue	10 years
Jett	F	2.5	Barador (Border Collie X Labrador)	2	Farm	2.5 years
Lola	F	8	Border Terrier	3	Breeder	8 years
Lolli	F	5	French Bulldog	3	Breeder	5 years
Mabel	F					
Mandy	F	5	Yorkiepoo	1	Kennel	5 years
Milly	F	9	Lakeland Terrier	2	Breeder	8 years, 10 months
Missie	F	10	Jack Russell	1	Animal rescue centre	3.5 years
Mollie	F	3.5	Border Collie	4	Breeder	3.5 years
Molly	F	2	Mixed	2	Rescue shelter	2 years, 2 months
Pippin	F	10	Labrador	2	Breeder	10 years
Pudding	F	3	Pug	2	Breeder	2 year, 10 months
Ruby	F	9	Labradoodle	4	Breeder	9 years
Sasha	F	6.5	Border Collie	3	Newcastle (N.I.) family reject	6 years
Tess	F	9	Border Terrier	3	Breeder	9 years
Tilly	F	9	Border Terrier	3	Breeder	9 years
Bailey	M	7.5	Cockapoo	3	Breeder	7 years
Barney	M	4	Springer Spaniel	5	Breeder	4 years
Buster	M	9	Labrador	4	Rescue	7 years
Dexter G	M	2	Cockapoo	4	Breeder	2 years
Dexter L	M	5	West Highland Terrier	3	Breeder	4 years, 10 months
Dylan	M	12	Cocker Spaniel	5	Breeder	12 years
George	M	8	Chihuahua	2	Preloved pets website	6 years
Henry	M	6	Cocker Spaniel	5	Adopted from a family member	10 months
Max	M	6	Short Legged Jack Russell	3	Adopted from a family member	4 years
Merrie	M	10	Labrador	2	Breeder	10 years
Patch	M	5.5	Jack Russell X	3	Farm	5.5 years
Romulus	M	1.5	Basenji	4	Breeder	12 months
Star	M	15	Patterdale Terrier	4	Breeder	15 years

Toby	M	5.5	Shih Tzu X Toy Poodle	2	Breeder	5 years, 2 months

Procedure and Design

These objectives involved testing the dogs' reactions by performing playback experiments similar to those conducted in primate cognitive research (Cheney & Seyfarth, 1980; Wittig et al., 2007a, b; Borgeaud et al., 2013, 2015). However, during preliminary investigations it was found that some dogs did not respond to the recorded voices of their owners or the experimenter when they were played back to them. Furthermore, some subjects directed their responses towards the recording device and not the individual who initially produced the call. Therefore, it was determined that to yield accurate data during the experimental trials playbacks would not be used. Instead the human participant would directly speak to the subject (Callback experiments) which eliminated the need for vocal recording equipment.

These preliminary investigations were conducted to determine an appropriate experimental procedure which would yield the best results. The pilot study involved the researcher and the owner each calling a food-related phrase to the dog and recording their reaction following the call. Discussions with owners revealed that when they asked their dog(s) if they would like a treat they would say the phrase multiple times. It was therefore determined that phrases should be called three times during the trials.

Before the start of the experiment, participants were asked to ensure that the trial room was free from any obstacles to allow the subject space to move around. It also reduced the risk of the camera missing any behaviours that the dog may exhibit during the experiment. An example of the experimental setup is shown in figure 2.2.

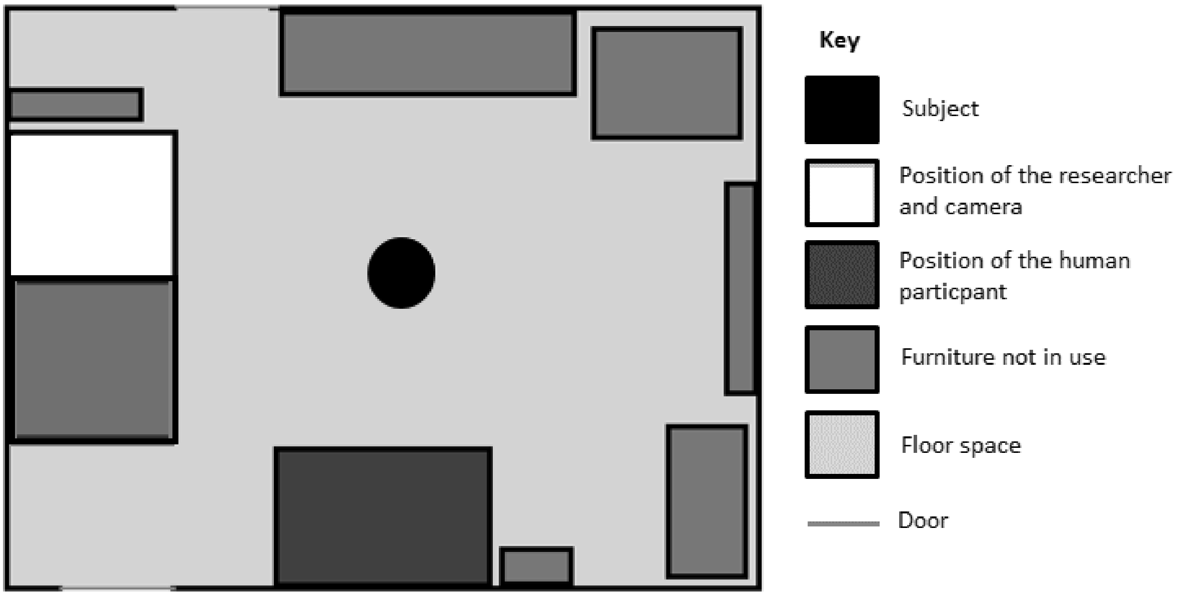


Figure 2.2 An example of an experimental set up to test objectives 3, 4 and 5.

To test objectives 3, 4 and 5, all family members who live with the dog were asked to identify the primary provider for the dog in three daily tasks (e.g. provide treats and/or meals, take for a walk, and letting outside). This was done to determine which human participant would take part in the experiment in households with more than one owner. Filming times differed for each subject as these experiments were conducted at the owners' discretion.

The subject's behavioural responses were recorded during the experimental period using a Sony Handycam DCR-SR58 and ear temperature was taken using a Braun ThermoScan 3 (more detail is provided in chapter 6 p. 115). Following the pilot study, it was determined filming would begin 10 seconds prior to the start of the call once the dog had, of its own accord, moved to the centre of the room. A series of callback experiments, involving calls from an unusual caller (the researcher) and a primary provider (the owner), then took place and three temperature readings were taken from each subject. These experiments differed for the three objectives so will be presented in detail in subsequent sections.

In pilot studies dogs were initially filmed for 20 seconds after the callback but it was found that most subjects gestured for longer. When this was extended to 30 seconds some subjects still gestured for a few seconds longer. It was therefore determined that dogs' behavioural responses would be filmed for 36 seconds after the callback to ensure all relevant behaviours/gestures were recorded. This time period proved sufficient to capture dogs' gestural responses during the trial period. The subject's responses were therefore measured for 36 seconds after the final call/presentation of object. If the subject showed no response 36 seconds after the call the experiment was stopped (=no reaction). The subject (dog), human participant and the experimenter were present in the room during the experimental trial. Any other individuals who were present during the experimental trials were instructed not to interact with the dog during the trial to prevent them from influencing the dog's responses.

If the dogs produced similar reactions to the calls from both the unusual caller and primary provider, it may be inferred that the dogs did not actually understand the call as the caller's identity had no effect on the responses of dogs. It could be suggested that the subjects were merely reacting to the caller speaking and were not reacting to what the caller was saying. A control was necessary to tease this out. Each human caller (primary provider and unusual caller) took part in one trial where they called to the dog and produced a phrase in an unfamiliar language three times (*ven aquí perro*). Failure to respond or a statistically significant reduced reaction time after each caller's control call would imply that the subjects understood the meaning behind the trial calls.

Analyses

The footage collected from the trials was quantified using Media Player Classic Home Cinema (MPC-HC). Specific statistical analyses for the three objectives differed and will be discussed in subsequent sections.

2.3 SUMMARY OF KEY OUTCOMES

The results collected from this research will shed light on important areas of dog behaviour including social cognition and communicative abilities as well as the uniquely successful cross-species relationship that domestic dogs have with human group members. By investigating dogs' ability to understand human phrases and causal reasoning, this study provides an opportunity to document the dog's understanding of human cross-species communicative cues. By identifying the ways in which dogs recruit humans as intermediaries and documenting their intentional and referential gestural repertoires, this research will provide a unique insight into the cross-species communicative abilities of dogs to humans. The research will also demonstrate that the cost-efficient, non-invasive method of measuring ear temperature may be a good proxy for emotional hemispheric brain activity during behavioural experiments.

By adopting a citizen science approach and conducting the research in the participants' homes, this study will give owners the opportunity to learn about animal behaviour and cognition and to actively take part in data collection. Studies conducted on the topic of animal cognition have traditionally been inaccessible to lay audiences and therefore those studies missed out on opportunities to benefit companion animals by enhancing the behavioural and cognitive knowledge/understanding of their owners. This study gives owners the opportunity to understand and think about the cognitive processes and behaviours of their pet. The approach adopted for this research will be beneficial and result in an improvement in the relationship and understanding between owner and dog.

Additionally, conducting the research in the dogs' natural environment allows for the documentation of the 'everyday' relationship and bond that dogs form with their owners. This thesis will influence future research by encouraging investigators in dog cognition to adopt more ecologically valid methods. Furthermore, this research is the first to integrate a variety of topics relating to social cognition and cross-species communication into one collective study, and it is hoped that future researchers will see the benefits of this and utilise it more. The results generated from this research will provide the scientific field with a new insight into the communicative and socio-cognitive abilities of domestic dogs.

3. THE INTENTIONAL AND REFERENTIAL CROSS-SPECIES COMMUNICATIVE REPERTOIRE OF DOMESTIC DOGS

An earlier version of the referential gestures study in this chapter has been published (see Worsley & O'Hara, 2018).

Gestural communication is an important aspect of group living. There are two main types of gestural communication, intentional and referential. Both intentional and referential gestures require an individual to possess socio-cognitive abilities. These socio-cognitive abilities aid in an individual's success in performing these types of gestures and their understanding of them when performed by others. Without socio-cognitive abilities, an animal would struggle to successfully communicate with conspecifics and, in the case of domestic animals, heterospecifics.

> Intentional behaviour is characterized by how an agent responds to difficulties: persistence indicates that the agent has a definite goal, and elaboration when thwarted shows flexibility in reaching that goal (Cartmill & Byrne, 2007, p. 1345).

3.1 Intentional Vocal Communication

I introduced vocal communication in chapter one (p. 1) and discussed alarm calling in monkey species and other animals. The research conducted with monkeys and other animal species suggests that their alarm calls are not influenced by the knowledge of others and are produced for their adaptive value only with no plan in mind (Seyfarth & Cheney, 2003). To date, research has shown that apes are the only non-human species that vocalise in a goal-directed, intentional way (Crockford et al., 2012; Schel et al., 2013). When model snakes are presented by experimenters, chimpanzees are more likely to alarm call in the presence of group members who are unaware of the threat than they are in the presence of aware group members. This suggests they recognise ignorance or knowledge in group mates (Crockford et al., 2012). Attribution of knowledge is a cognitively complex process since it requires an individual to be able to understand and act on another individual's field of vision or intention (Cheney & Seyfarth, 2007; Call & Tomasello, 2008; Fitch, 2010; Crockford et al., 2012). However, vocalisations are not the only signal routinely given by apes in an intentional way; apes have also been shown to perform intentional gestures.

3.2 Intentional Gestural Communication

The gestural modality is heavily reliant on a motivation to understand and share the intentional states of others (Call & Tomasello, 2007). Intentional communication is often defined by its use socially as it requires an audience for the display of the communicative behaviour (Leavens & Hopkins, 1998). To date, the majority of research in this area has concerned itself with the communicative intent of apes. Indeed, the voluntary intentional nature of a gesture is abundantly observed in the 'everyday' behaviour of all the great ape species (Call & Tomasello, 2007; Genty et al., 2009; Byrne et al., 2017). For example, orangutans (*Pongo abelii* and *Pongo pygmaeus*) continually monitor the communicative situation they are in by assessing their recipient's levels of understanding during intentional communicative bouts and produce 40 gestures which have an intentional meaning, with the expectation of specific responses from the intended recipient (Cartmill & Byrne, 2010).

For a gesture to be considered intentional it must be given by an individual in a goal-directed way (Genty et al., 2009). The obtaining of a result provides the motivation for producing a gesture and the recipient's actions must satisfy the signaller (Hobaiter & Byrne, 2014). If the outcome is not satisfactory to the signaller, response waiting is expected to be seen (Tomasello et al., 1994; Call & Tomasello, 2007), followed by repetition of the gesture or incorporation of others in a process referred to as persistence and elaboration (Cartmill & Byrne, 2007; Leavens et al., 2005). A final criterion for an intentional gesture is that it must be directed at an audience (Genty et al., 2009).

There are many indicators of communicative intentionality, but the one most commonly used is gestural flexibility (Cartmil & Byrne, 2007; 2010; Poss et al., 2006). To effectively communicate their intentions, the signaller must have the ability to choose from a repertoire of gestures dependent on the attentive state of the receiver (Poss et al., 2006). Gestural flexibility is viewed by many researchers as a good measure of cognitive ability (Arbib et al., 2008). Intentional communication, however, is not the only mode of gestural communication used by both human and non-human species.

To date, however, none of the intentional gestures of great apes have been shown to go beyond first-order intentionality (Townsend et al., 2016). They demonstrate that, the signaller will work flexibly to achieve an apparent goal and modify or influence the behaviour of a recipient, but no evidence is yet available suggesting that ape signallers intend to change their recipient's mental state (i.e. indicating second-order intentionality) (Byrne et al., 2017). This could be that apes lack the ability to go beyond first-order intentionality or be due to the difficulty of demonstrating second-order intentionality in naturally observed gestures. Cartmill and Byrne (2010) found that orangutans were able to gauge their recipient's understanding of their gestures. When faced with a keeper with 'partial understanding' the apes persisted with the same types of gestures with increased intensity; when faced with a 'complete misunderstanding' keeper the orangutans persisted communicating but elaborated on their gesture types. This finding has provided cautious optimism to primatologists who consider apes are likely capable of second-order intentionality even though to date, this has not been demonstrated in other ape species (Byrne et al., 2017). Nontheless, since first-order intentionality is a necessary precursor to second-order intentionality, and given the difficulties of demonstrating it, Schel et al. (2013) argue apes are likely capable of second-order intentionality based on current knowledge.

A limitation, however, with the research conducted into animal intentionality is that the focus has been on non-human primates, particularly great apes. This is most likely due to investigators placing their focus on uncovering the origin of human language which can lead to an overly anthropogenic approach (Byrne et al., 2017). Some have further stated that no apology need be made for this type of anthropogenic approach as it is what needs to be done (Fitch, 2010; Byrne et al., 2017). This primocentric view has been observed in other areas of animal cognition such as tool use, social learning and mental time travel (Morrison, 2009) and again this focus may be neglecting the possibility that intentional behaviour exists in other animal species.

3.3 Referential Signalling Events

Another form of communicative gesturing frequently investigated by researchers is referential gestures. Referential gestures are produced to direct attention (Leavens, 2004). They are mechanically ineffective movements of the body which are repeated and elaborated on until they elicit a specific response from an intended recipient (Bales et al., 1975; Warneken et al., 2006; Hobaiter & Byrne, 2011; Malavasi & Huber, 2016). From an early age, human infants use gestures to draw a recipient's attention to objects they desire (Bates et al., 1979) and it has been suggested that most communicative events contain both motivational and referential components (Marler et al., 1992; Huber, 1996). Pointing is the most commonly used human referential gesture (Liszkowski et al., 2012) and is thought to be a key component of human language development (Franco & Butterworth 1996) as it strongly predicts language acquisition (Bates et al., 1979; Colonnesi et al., 2010).

For a gesture to be considered as referential in function it must conform to five features. First, it must be directed toward an object or specific area of the signaller's body, e.g., a child pointing towards a specific toy. Second, it is a mechanically ineffective movement, e.g., a gesture that is not designed to act as a direct physical agent such as the human pointing gesture. Third, it is aimed at a potential recipient and fourth, receives a voluntary response from that recipient, e.g., a child repeatedly points at a toy and then looks at/points at their mother who then, of her own accord, retrieves the toy and gives it to the child. Finally, a referential gesture must also demonstrate aspects of intentional production, e.g., a child repeatedly points at a toy then waits for a response from their mother; when no response is forthcoming the child continues to point at the toy but also introduces a new gesture, such as grabbing air, so as to achieve their goal (Pika & Bugnyar, 2011; Vail et al., 2013).

Some argue that mechanical ineffectiveness should not be a criterion for referential communication as although these gestures are usually mechanically ineffective there are cases where sometimes they are not (e.g. Leavens, 2004; 2005). However, if a gesture directly leads to some sort of apparent goal then there would be no need to involve or communicate with another individual. Therefore, in order to referentially communicate the gesture must provide an indicator of the apparent goal to the intended recipient not the goal itself (Pika & Bugnyar, 2011; Vail et al., 2013).

Referential gestures are non-accidental. Therefore, a signaller needs to demonstrate an intention to communicate with their intended recipient (Savilli et al., 2016). There are five attributes of intentional communication (Genty et al., 2009) in contemporary use (see above). According to Malavasi and Huber (2016), to be considered as referential a gesture must show at least some of these attributes of intentionality; in particular persistence and elaboration (Woodruff & Premack, 1979).

In contrast to their frequent use by humans, referential gestures in non-human taxa are relatively rare (Vail et al., 2013). Most research demonstrates the use of referential gestures by great apes in captivity, where subjects gesture to a human experimenter (Woodruff and Premack, 1979; Leavens & Hopkins, 1998; Leavens et al., 2004; 2005; Cartmill & Byrne, 2007). In the wild, chimpanzees use a vocalisation known as the 'rough grunt' (Goodall 1986) as a referent in feeding contexts (Slocombe & Zuberbühler, 2005) and will use directed scratches potentially indicating an area of the body they wish the recipient to groom (Pika & Mitani, 2006).

Referential gesturing, however, is not unique to primates. Ravens (*Corvus corax*), for example, have been observed performing object-orientated behaviours to direct the attention of their conspecifics (Pika & Bugnyar, 2011). Moreover, some species of coral reef fishes, the grouper (*Plectropomus pessuliferus marisrubri*) and coral trout (*Plectropomus leopardus*), use referential gestures to indicate the location of hidden prey (Vail et al., 2013). Interestingly, Vail et al. (2013) also reported that groupers and coral trout use these referential signals to initiate cooperation with hunting partners.

3.4 The Present Study

3.4.1 Dog-Human Communication

Domestic dogs present an interesting case for the study of intentional and referential communication as they spend much of their lives interacting and communicating with heterospecifics as opposed to conspecifics (Miklósi, 2007). Intentional behaviour in dog-human communication has been documented in previous studies (see Hare et al., 1998; Miklósi et al., 2000). However, both of these studies involved a small number of subjects (two in Hare et al., 1998 and 10 in Miklósi et al., 2000). Therefore the results need to be assessed with caution since they may not be representative of the wider population. Additionally, in the Hare et al. study the two subjects used were both raised by the experimenter. Given that the dogs were performing a novel task by following a human pointing gesture to locate hidden food, one cannot rule out the possibility that the experimenter unintentionally gave involuntary cues that led the dogs to the correct location.

Investigations into dog–human communication have revealed that interactions between humans and dogs have referential components (Bensky et al., 2013). Dogs have a set of skills that allow them to use and understand human-produced referential cues (Agnetta et al., 2000), even out-performing other domesticated animals in these tasks (McKinley and Sambrook, 2000). Interestingly, domestic dogs can also perform ‘showing’ behaviours in referential communicative bouts. ‘Showing’ behaviours are defined as communication which contains both a directional element related to an external object and an attention-getting element that directs the attention of the recipient to the signaller (Miklósi et al., 2000).

Investigators have demonstrated that dogs use the position of their body to indicate the location of a goal object (Gaunet & Deputte, 2011) and alternate their gaze between an object of apparent interest and the human while barking (Miklósi et al., 2000), thereby communicating their intentions.

Research in the gestural communication of the great apes has reported a number of idiosyncratic gestures that were not socially learned (Goodall, 1986; Tanner & Byrne, 1996; Genty et al., 2009; Hobaiter & Byrne, 2014). The studies investigating domestic dog gestural intentionality (Hare et al., 1998; Miklósi et al., 2000) involve the subjects taking part in a novel task in an experimental environment. This methodology prohibits the dogs from performing their naturally occurring communicative gestures. Testing in an experimental environment does not allow for the expression of natural behaviours (Bekoff & Jamieson, 1991) and the use of controlled experiments do not make the results collected easy to place into contexts outside of the test situation (Becker, 2005). Therefore, to date, we have no evidence of the naturalistic 'everyday' communicative repertoire of domestic dogs during cross-species interactions with humans.

Previous research has identified eight different vocalisations used by domestic dogs in various behavioural contexts (Table 3.1) and demonstrated that human listeners can identify the situation a bark is performed in regardless of previous experience with dogs (Pongrácz et al., 2005). The majority of research has, however, placed its focus on identifying the acoustic characteristics of dog vocalisations in an attempt to understand the physiological and emotional state of dogs (Bleicher, 1963; Tembrock, 1976; Ohl, 1996, Yeon et al., 1996; Yin & McCowan, 2004; Pongrácz et al., 2006). The vocalisations analysed from those studies tended to be recorded in test situations (e.g. doorbell ringing, isolated from owner). These were set-up to elicit an emotional response from the dog resulting in variable acoustic parameters (Yin & McCowan, 2004). Therefore, how (and if) dogs use these vocalisations in 'everyday' situations to intentionally communicate with humans is still unknown.

Table 3.1 Vocalisations performed by domestic dogs alongside common behavioural contexts (Yeon, 2007).

Name or Type of Vocalization	**Behavioural Contexts**
Bark	Alert/warning
	Territorial defence/rivalry/defence

Name or Type of Vocalization	Behavioural Contexts
	Individual identity
	Social facilitation
	Play solicitation
	Greeting, call for attention
Howl	Territorial maintenance
	Locate group members
	Individual recognition
	Coordinate social activities/hunting
	Attract others
	Reactive (in response to sirens, etc.)
Growl	Offensive and defensive threatening
	Play
	Defence
	Warning
	Threat
Whine	Greeting
	Frustration
	Active submission
	Attention seeking
Yelp	Pain, great stress
Snore	Nasal sound, related with bark
Groan	Acute distress
Grunt	Pleasure

The ability of dogs to successfully communicate intent to humans using gestures and vocalisations develops at a later stage than the ability to respond to human gestures (Bensky et al., 2013). It is therefore predicted that communicative behaviours will differ between households. Previous experimental-only research has not allowed us to determine if this statement is true. Furthermore the experiments only demonstrated dog-human gestural communication in one task and did not show dogs' use of communicative gestures in a variety of tasks. They only document that dogs communicate with humans in one novel task where they request an object of apparent interest. By examining domestic dog gestural communication in a range of tasks, researchers would be able to better document the range and intensity of gestures that dogs possess. To date, no study has attempted this.

Thus far, dog–human communicative research has tended to focus on dogs' ability to understand human-given gestures (Hare et al., 1998, 2002; Miklósi et al., 1998; Hare & Tomasello, 1999; Kaminski & Nitzschner, 2013; Kundey et al., 2014). Knowledge concerning dogs' abilities to produce gestures that humans can understand, by contrast, is lacking. Here I attempt to bridge that gap by observing gestures that pet dogs direct to their owners during everyday communicative bouts to investigate intentional and referential gesturing and humans' ability to understand the gestures performed by dogs. Previous research has also concerned itself with assessing the acoustic characteristics of dog vocalisations (Bleicher, 1963; Tembrock, 1976; Ohl, 1996, Yeon et al., 1996; Yin & McCowan, 2004; Pongrácz et al., 2006; Yeon, 2007). It is therefore not yet known if dogs are capable of producing intentional vocalisations during communicative bouts with humans. In this study, I will attempt to uncover how dogs use their vocal and gestural repertoire to communicate intentionally and referentially with humans.

The present study will be observing the vocalisations and intentional and referential gestures dogs direct to their owners in an ecologically valid context. Instead of the dogs being subjected to a novel task the owners will be asked to film their dogs when gestures naturally occur. Additionally, collecting data in the natural environment and over a week long period will enable me to demonstrate whether gestural and vocal communication differs between individual dogs and households. This will also allow for the documentation of vocal and gestural communication in a variety of situations not just confined to one novel task.

3.4.2 Justifications and Aims

The current study will test the hypothesis that domestic dogs have an intentional gestural repertoire that is linked to specific meaning and identify the types of vocalisations used by dogs during these cross-species communicative bouts with humans. The study will also examine whether dogs perform referential gestures to achieve an apparent goal. Furthermore it has been suggested that biological and environmental factors influence an individual's communicative behaviours (Udell & Wynne, 2008; Genty et al., 2009) . The current study will therefore investigate whether sex, age, size of household and length of time in the household influences an individual dog's repertoire size.

The method adopted for the present study will result in a better understanding of dog-human intentional communication and its first systematic documentation. Should evidence for intentional communication be found in domestic dogs, using this method will demonstrate the experimental benefits a more ecologically valid study can produce. Previous research has focused on the referential signalling events produced by humans and the dog's ability to interpret them, and to date, the referential gestural repertoire of domestic dogs during cross-species interactions with humans has not been documented. Furthermore, the study should also provide evidence of the interpretive abilities of humans to dogs' communicate bouts.

By adopting a citizen science method, the study will enhance owners' knowledge regarding the cognitive world of their pets. By including the owners in the scientific process the study should also help people to better understand and interpret their dog's communication which, in turn could have positive welfare implications.

3.5 STUDY DESIGN

3.5.1 Specific Procedure and Design

A citizen science approach, like that adopted by Horowitz & Hecht (2016), was applied to investigate the intentional and referential communication of domestic dogs in 'everyday' scenarios. This is outlined in detail in the research aims, objectives, methods and key outcomes chapter (p. 16).

3.5.2 Identification of Gestures

Gestures were initially identified as discrete, mechanically ineffective actions (*sensu* Genty et al. 2009; Hobaiter and Byrne 2011; 2014). These actions included limb, head and whole body movements but not facial expressions or static body stances (Hobaiter & Byrne, 2011; 2014). The five features of either intentionality (p. 29) or referential signalling (p. 31) were then applied to determine the frequency of actual referential or intentional gestures observed. Where a portfolio of gestures, each separated by less than one second, was recorded I applied the referential or intentional criteria to each single gesture within the portfolio (Hobaiter & Byrne, 2011; 2014).

The gestures were then categorised as per their apparent satisfactory outcome (ASO). ASOs are deduced from a plausible desire and signaller satisfaction (Hobaiter & Byrne, 2014). They produce an outcome that results in the termination of communication.

3.5.3 Intentional Gestures Analyses

Using the collected data I recorded and catalogued the gestural and vocal repertoire of dogs in a gestural lexicon table to decipher their cross-species communicative intentions. This was achieved by following the five criteria of intentionality (*sensu* Genty et al., 2009). Gestures were documented as: tactile & visual, silent & visual, visual & audible.

The gestural and vocal repertoires of puppies (0 – 1.5 years) and adults (2+ years) were compared using a one-way between-subjects ANOVA. The data collected were analysed using a Shapiro-Wilk test to test for normality with *P* value set at 0.05. Independent samples *t*-test were used to demonstrate if the gestural or vocal repertoires differed between male and female dogs. Goal-directed communication is discussed and a gestural lexicon table produced defining ASOs and listing the gestures and vocalisations which are associated with them.

A table was produced to show the observed vocalisations and gestures and the number of individuals, instances and contexts in which they were noted. Possible evidence for idiosyncrasy (gestures observed in only one individual) in domestic dogs is discussed and any possible idiosyncratic gestures/vocalisations are listed. The flexibility of usage, context specificity and number of instances of a gesture/vocalisation were then explored.

3.5.4 Referential Gestures Analyses

Referential gestures were categorised as per their apparent satisfactory outcome (ASO). I initially identified eight ASOs from the initial analysis of intentional gestures, three of which were excluded from the referential analysis due to low observation frequency (*n*=7). A further ASO, “Play with me!” was also excluded as some gestures used during play are also used with other meanings in other ASOs (Hobaiter & Byrne, 2014). This produced four ASOs which yielded the highest frequency of observations to decipher potential referential gestures.

3.5.5 Influence on Repertoire Size

I collected data on the subject’s sex, age, size of household and length of time in the household. In great apes, repertoire size differs as a function of age class in both chimpanzees (Hobaiter & Byrne 2011) and gorillas (Genty et al., 2009). Sex differences in apes have not been reported, but sex differences in basic cognitive abilities has been reported in domestic dogs, with females performing significantly better than males in simple cognitive tasks (e.g. Müller et al., 2011). Consequently, age and sex could impact the repertoire size of dogs. Furthermore, for domestic dogs an individual’s environment shapes the behaviour they exhibit over their lifetime (Udell & Wynne 2008). Therefore, the number of people that live with the dog and the length of time the dog has lived with those owners each has the potential to impact on repertoire size. I therefore performed a multiple regression analysis after testing the data met the assumptions of linear regression. I looked at what factors influenced the size of the gestural repertoire using sex (categorical variable) and age, number of people who live with the dog and length of time spent with current owners (continuous variables). Volume of data collected (number of videos and length of usable footage) was included as a potential confounding factor as different quantities of data were collected for each subject.

3.5.6 Reliability

Inter-rater reliability analysis using Cohen's kappa was performed to ascertain consistency between observers on a sample of 60 videos for referential gestures and 110 videos for intentional communication. These are equivalent to 25% of the total bouts of communication collected for this study. The secondary observer was trained to identify referential and intentional gestures using the data from one subject (Star). Both observers recorded the gesture and the time at which it occurred, then agreements and disagreements between the two observers were scored (Bateman & Gottman, 1997). Cohen's kappa revealed a good agreement between the coders for the number of referential gestures, kappa=0.642, $P<0.001$ and intentional gestures, kappa=0.614, $P<0.001$ recorded and the times at which they were performed. It is important to note that even though the inter-observer reliability measure produced a good agreement it is on the low side. This is most likely due to the nature of the assessment as it is difficult to identify the individual gestures performed by dogs, especially when they are performed in a portfolio (i.e. one immediately after the other).

3.6 RESULTS

Domestic Dog Intentional Communication

From the footage provided by participants a total of 1091 communicative bouts were seen in 494 human-dog interactions. After an initial analysis of the video data, it was determined that 78 of the 1091 communicative bouts were not suitable for the study. This produced 1013 dog-human communicative bouts which demonstrated gestural and vocal communication. The total video times provided by the owners for each participant can be found in Appendix II.

From the data, 120 gestures defined by the researcher were then identified as potential intentional communication (Appendix III) performed by dogs which conformed to all or some of the five features for intentionality. Once the criteria for intentional communication was applied, this reduced to 103 gestures having intentional properties and 15 vocalisations (the number of vocalisations did not alter between initial and further analysis stages; see Appendix IV for definitions).

The study found that 62 of observed gesture types and 12 of vocalisation types were recorded in more than one dog (see Appendix V for gestures and vocalisations recorded in all subjects). However, three gestures (head turn, head up, head down) (Figure 3.1) and zero vocalisations were observed in all 37 subjects. The remaining three vocalisations and 41 gestures were found in only one subject. It is important to state that absence of certain gestures in individual subjects may be a result of the citizen science method used for this study.

Absence of gestures may also be a result of training factors. If an owner has trained their dog to not jump onto furniture, then that dog will not perform the *jump on* and *jump off* gestures. Furthermore, environmental conditions i.e. the setup of the dog's household, may also have an impact on the types of gestures which a subject can produce; for example, at households were the furniture is not raised off the floor the dog is unable to perform the *paw reach* gesture.

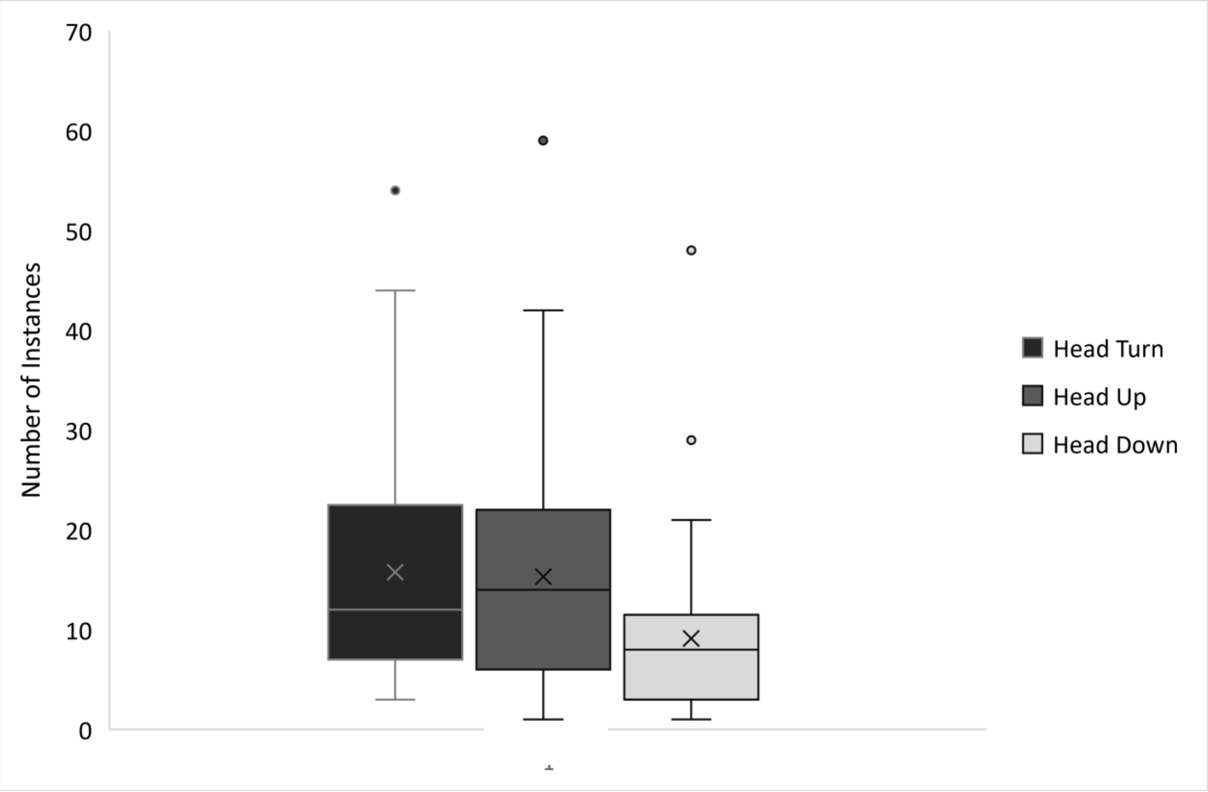


Figure 3.1 Number of instances of the head turn, head up and head down gestures performed by each subject (points above the box and whisker represent the outliers and the x represents the mean marker).

Repertoire Size and Overlap: Differences in Age, Sex and Size

A dog's repertoire size (i.e. number of gesture/vocalisation types) varied with age (Figure 3.2). Adult dogs (2+ years) were responsible, however, for using the highest number of gestures (Figure 3.3) and vocalisations (Figure 3.4) compared to puppies. No significant difference between the age of a dog and both its gestural [$F_{(20,\ 16)}$=2.141, *P*=0.064] and vocal [$F(_{10,\ 26})$=0.984, *P*=0.481] repertoires was found.

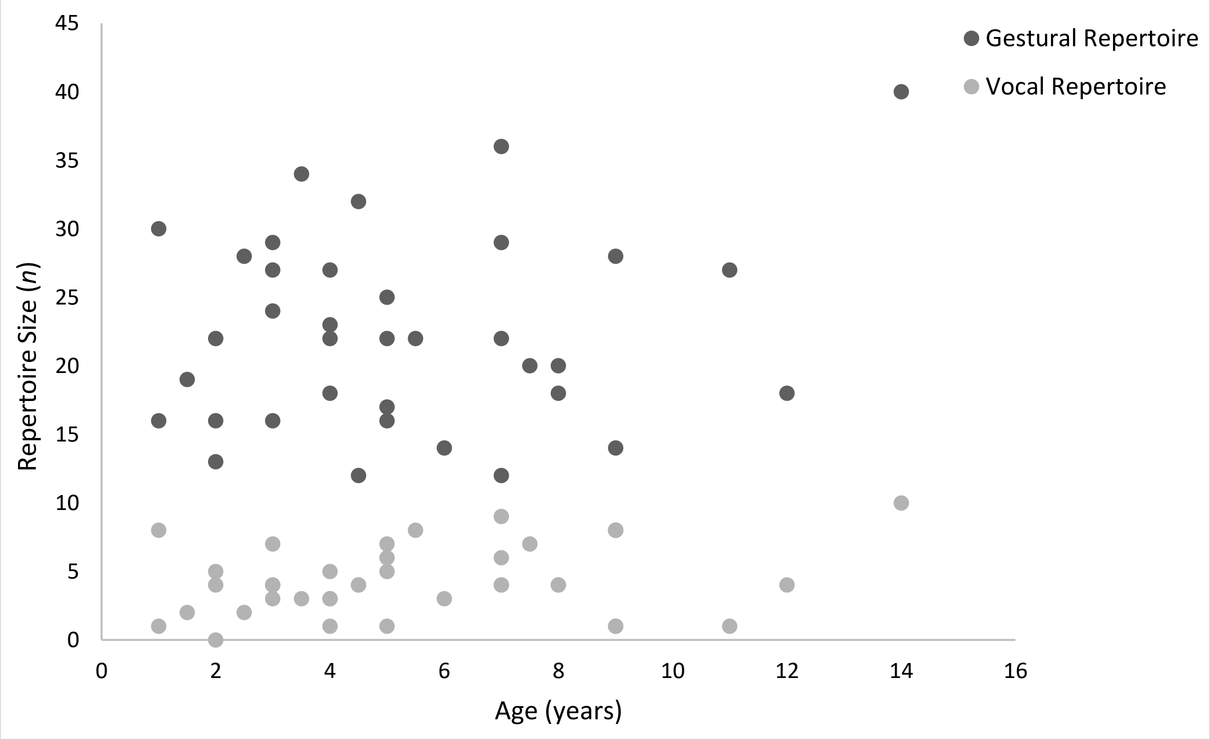


Figure 3.2 Scatter graph showing age of dog and size of vocal and gestural repertoire

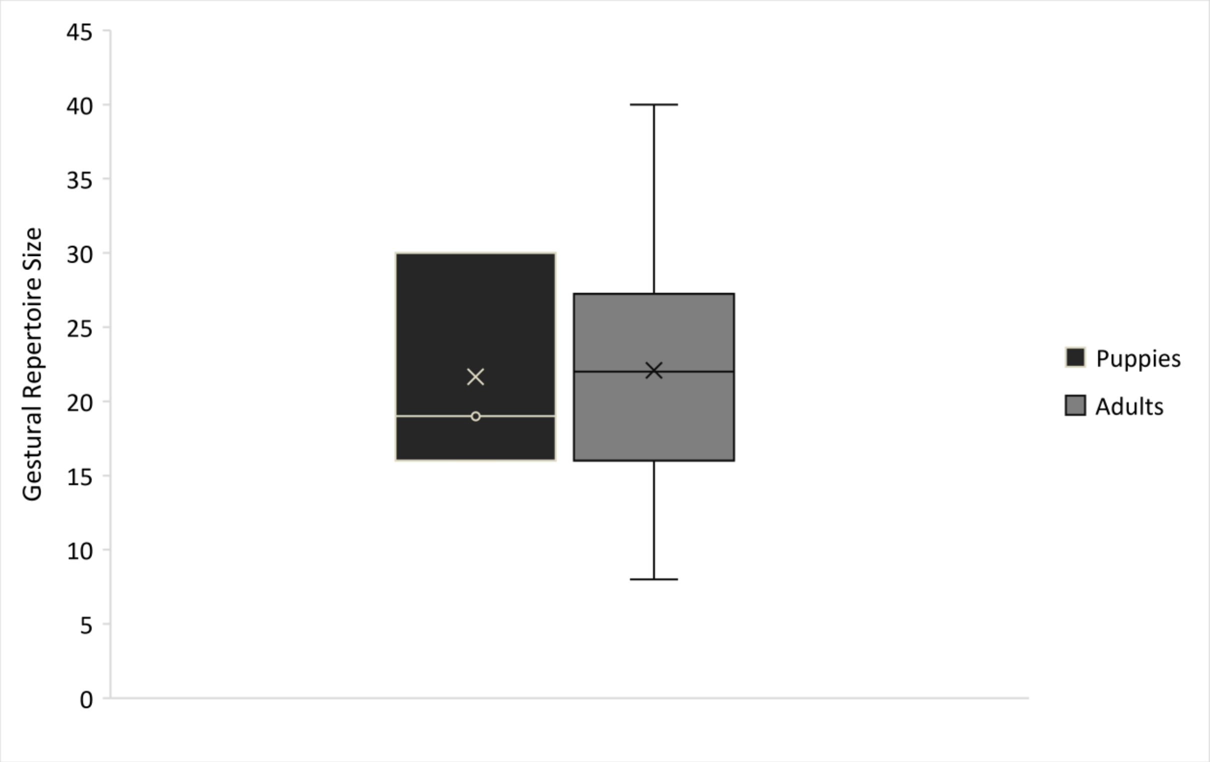


Figure 3.3 Puppy and adult domestic dog gestural repertoire sizes (the x represents the mean marker).

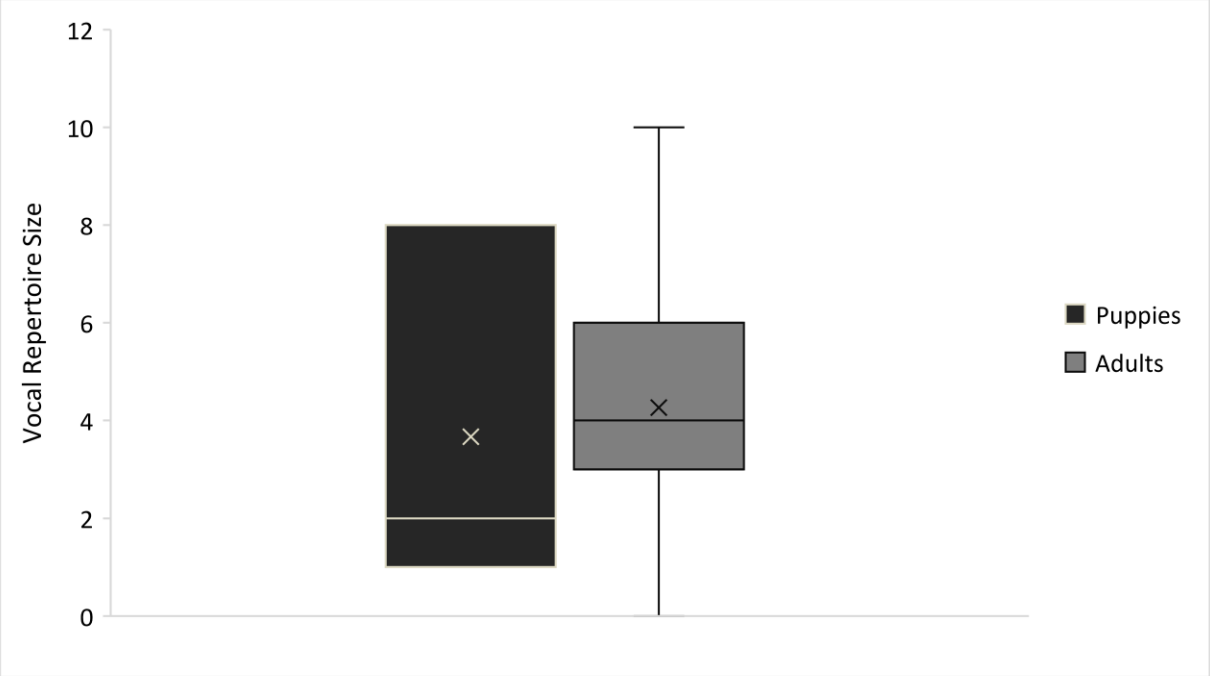


Figure 3.4 Puppy and adult domestic dog gestural repertoire sizes (the x represents the mean marker).

No difference was found between the gestural repertoires of males (M=21.9, SD=8.0) and females (M=22.3, SD=6.5); $t_{(35)}$= -0.189, *P*=0.851, or the vocal repertoires of males (M=4.4, SD=2.8) and females (M=4.3, SD=2.5); $t_{(35)}$=0.085, *P*=0.933.

Individual gestural repertoire was shown to increase with both number of people who live with the dog and the number of videos collected (Table 3.2). Sex, age, amount of time dogs spent with current owners and length of usable footage were found not to be significant predictors of repertoire size.

Table 3.2 Regression output showing the showing the variables which do and do not have an effect on an individual dogs' intentional gestural repertoire.

Coefficients[a]							
	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	*B*	Std. Error	Beta	*t*	Sig.	Lower Bound	Upper Bound
(Constant)	13.080	3.592		3.642	.001	5.754	20.405
Sex	-2.378	1.545	-.162	-1.539	.134	-5.530	.774
Age	-1.289	.973	-.560	-1.325	.195	-3.273	.695
*n*_videos	.612	.102	.686	5.982	.000	.403	.821
*n*_people	2.392	.855	.312	2.797	.009	.648	4.137
*n*_time	1.072	.933	.484	1.149	.259	-.830	2.975
usable footage (*min*)	.001	.003	.086	.377	.709	-.005	.007

a. Dependent Variable: Gestural Repertoire

Individual vocal repertoire was shown to increase with the number of videos collected (Table 3.3). Sex, age, number of people who live with the dog, amount of time dogs spent with current owners and amount of usable footage were found to be not significant predictors of vocal repertoire size.

Table 3.3 Regression output showing the showing the variables which do and do not have an effect on an individual dogs' vocal repertoire.

Coefficients[a]							
	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	*B*	Std. Error	Beta	*t*	Sig.	Lower Bound	Upper Bound
(Constant)	3.121	1.851		1.686	.102	-.654	6.896
Sex	-.806	.796	-.159	-1.012	.319	-2.430	.818
Age	-.443	.501	-.558	-.883	.384	-1.465	.580
*n*_videos	.140	.053	.455	2.646	.013	.032	.247
*n*_people	.134	.441	.051	.305	.763	-.765	1.033
*n*_time	.547	.481	.718	1.138	.264	-.433	1.528
usable footage (*min*)	.002	.001	.420	1.265	.216	-.001	.005

a. Dependent Variable: Vocal Repertoire

Evidence of Idiosyncrasy in Domestic Dog Communication

From the data, 41 gestures and three vocalisations across all 37 subjects are reported as used intentionally by only one subject (Appendix VI). Some of the possible idiosyncratic gestures and vocalisations were observed in only one instance. In these cases, the owners of the dog who performed that gesture were contacted and asked if their dog regularly performed this gesture/vocalisation or if it was a one-off occurrence which happened to be caught on camera. All owners responded back and stated that the gesture/vocalisation in question was something they had seen their dog perform numerous times. This suggests that the gestures/vocalisations in question are not previously unseen behaviours which could have been a result of the presence of a camera but are possibly idiosyncratic.

Flexibility of Usage

To examine the flexibility of usage of each gesture and vocalisation, the procedure set out by primate gestural researchers (Call & Tomasello, 2007; Genty et al., 2009) was followed by recording the range of situational contexts in which a vocalisation/gesture was used (i.e. *Play, Food/Drink, Open, Scratch, Insert & Probe, Attention, Walk, Move, Pick up, Climb* and *Unknown* see table 3.4 for definitions). The majority of gesture (66) and vocalisation (13) types were observed in more than one context with 2 vocalisations and 9 gestures recorded in all 11 contexts (Figure 3.5).

I found that 37 gestures were used in only one situational context, whereas 66 of the observed intentional gestures were recorded in more than one context. This pattern is also seen with vocalisations with 13 vocalisations observed in more than one situational context and only two vocalisations being recorded in one context.

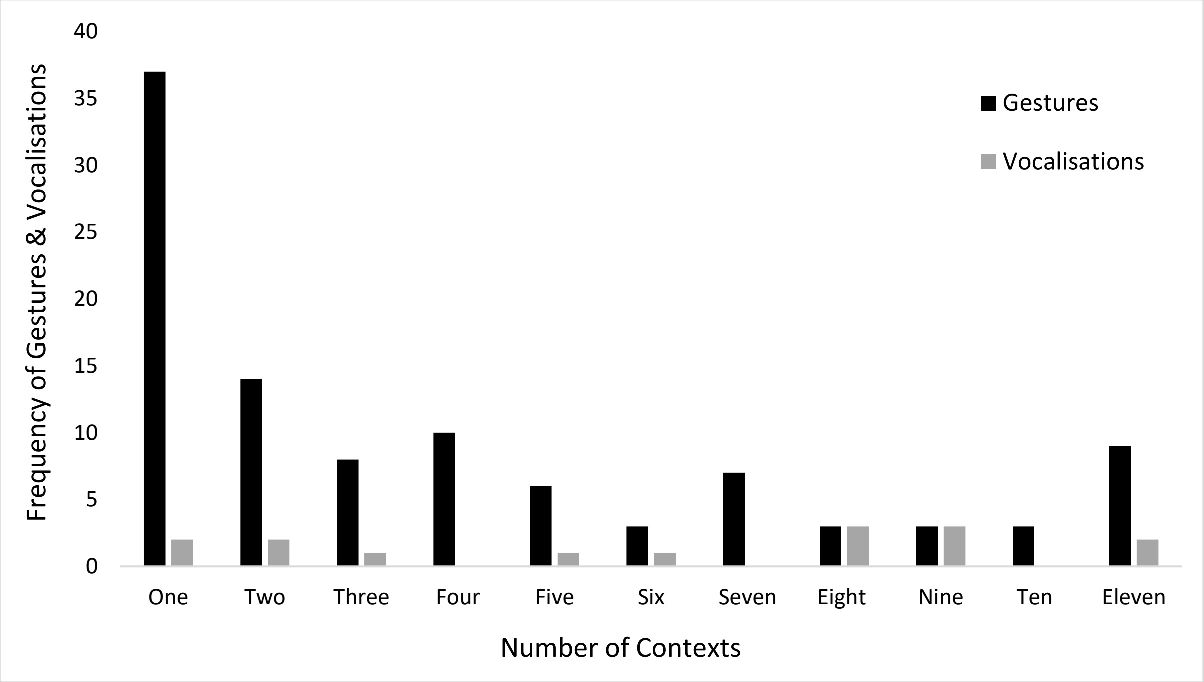


Figure 3.5 Gestural and Vocal flexibility. The frequency of gesture and vocalisation types are plotted according to the number of contexts in which they are used.

This procedure was then used to look into the context specificity of the observed gestures and vocalisations (Figure 3.6). Note that the situational contexts for vocalisations and gestures differ from one another.

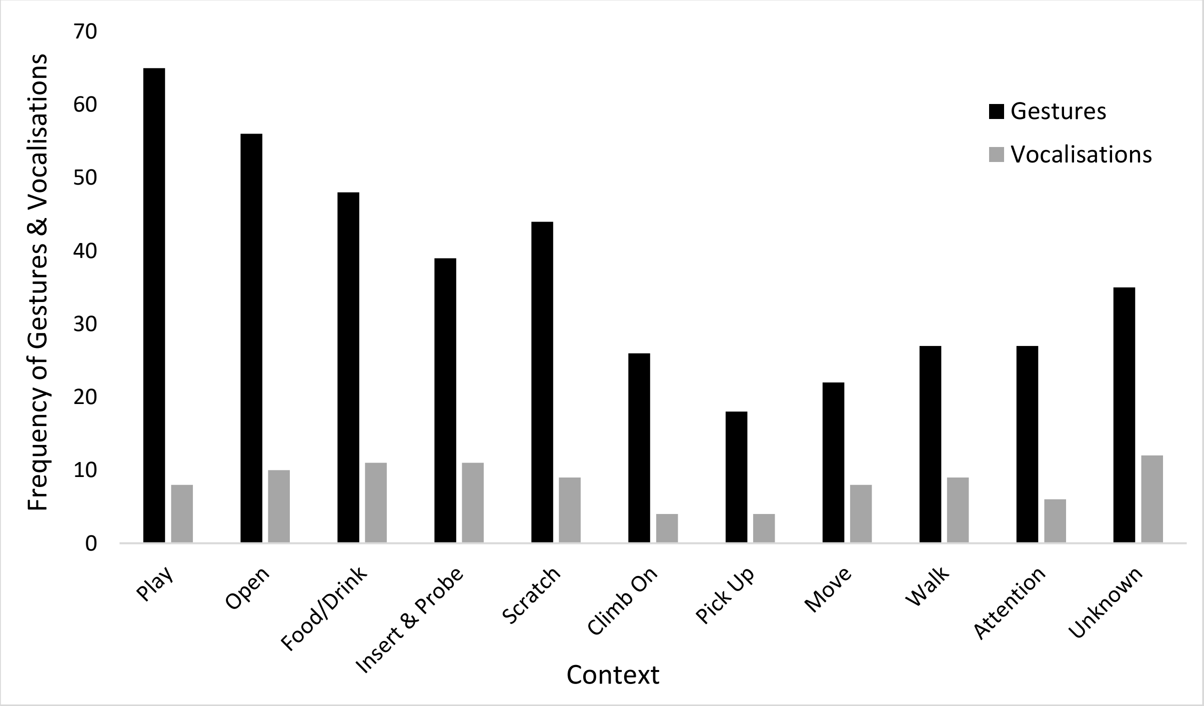


Figure 3.6 Context specificity of gestures and vocalisations. The frequency of gesture and vocalisation types are plotted for each of the situational contexts in which they are used.

The context which elicits the most vocalisation types, however, does not correspond to the contexts with the most gestures. *Unknown* has the largest vocal repertoire with 12 vocalisations. As the *Unknown* data were analysed it became apparent that as the footage progressed the dogs became more active or intense in their communicative acts. The reasoning behind this is most likely due to the lack of understanding from the receiver. As the owners did not know what their dog's apparent goal was in this context, they were not responding appropriately.

Insert & Probe and *Food/Drink* each have a repertoire of 11 vocalisations. These contexts involve dogs receiving or retrieving items of apparent interest and whilst analysing the videos it was noted that as the length of time increased, the dogs became more active and excitable. Considering this, it was expected that a large range of vocalisations would be performed. Overall, the spread of vocalisations across the situational contexts was relatively even. Only *Climb on* and *Pick up* had a lower repertoire of four vocalisations. This, however, is likely due to the amount of data collected for these two contexts.

Goal-Directed Communication

From the data provided I was able to identify 11 apparent satisfactory outcomes (ASOs) in which dog-human communication occurred (Table 3.4).

Table 3.4 Gestural Lexicon. ASOs are defined and listed with the gestures and vocalisations which are associated with them.

ASOs	Definition	Gestures
“Get my toy/bone”	Retrieve a desired object for the signaller which is embedded in a hole or behind a restricted opening.	Lie & wait; Stand & wait; Head under; Sit & wait; Head up; Paw; Head turn; Head down; Paw reach; Head jerk; Jump; Stamp paws; Pounce; Move mouth; Lick lips; Head bob; Front paws on; Hind leg stand; Fetch; Front paws off; Drop ball; Play position; Stretch out; Dodge; Nose; Paw hover; Look behind; Crawl Under; Head out; Circle; Chin rest; Grab toy; Chew/bite toy; Wag; Jump on; Jump off; Runaway; Head tilt.
“Give me food/drink”	Attain food or drink from the intended receiver.	Paw; Head up; Head turn; Lick lips; Look behind; Wag; Head down; Stand & wait; Lick; Nose press; Front paws on; Jump; Sit & wait; Jump on; Jump off; Head forward; Lie & wait; Head sway; Front paws off; Head rest; Hind leg stand; Ear twitch; Head tilt; Stamp paws; Open mouth; Body turn; Tremble; Move mouth; Head bob; Lean forward; Paw hover; Paw down; Begging gesture; Turn; Chin rest; Grab toy; Chew/bite toy; Shake toy; Drop toy; Flick toy; Rest & wait; Chin off; Play position; Jerk forward; Circle; Hover & wait; Sway; Paw shove.
“Let me climb on there”	Permit signaller to climb on the receiver.	Sit & wait; Head up; Stand & wait; Look behind; Drop object; Head turn; Lean forward; Front paws on; Head down; Paw rest; Ear twitch; Lick; Nose; Open mouth; Head rest; Wag; Jump; Jump on; Head tilt; Rock back & forth; Fetch; Stamp paws; Lick lips; Front paws off; Jump off; Head forward.
“Look at me!” **“Follow me!”**	Attract the receiver’s attention to the signaller.	Wag; Paw; Fetch; Play position; Head through; Sit & wait; Head turn; Lie & wait; Stamp paws; Crawl back & forth; Head up; Head down; Jump; Front paws on; Move mouth; Lick; Stand & wait; Lick lips; Body lean; Open mouth; Paw hover; Puppy dog; Turn; Front paws off; Look behind; Ear twitch; Head tilt.
“Move it”	Remove objects or organisms which are in the way of the signaller.	Lie & wait; Ear twitch; Head rest; Head up; Stand & wait; Head forward; Jump; Sit & wait; Paw; Open mouth; Close mouth; Head turn; Head down; Jump on; Nose press; Lick lips; Wag; Chin rest; Rest & wait; Chin off; Look behind; Front paws on.
“Open the door”	Open a door for the signaller so that they can gain access to either a desired object or location.	Nose; Lick lips; Sit & wait; Head turn; Lie & wait; Look behind; Stand & wait; Head up; Lick; Paw rest; Wag; Front paws on; Fetch; Jump; Paw with both; Paw; Hind leg stand; Toy press; Head forward; Head tilt; Ear twitch; Head down; Body turn; Head bob; Move mouth; Stamp paws; Head sway; Open mouth; Close mouth; Front paws off; Tremble; Spin bounce; Rock back & forth; Runaway; Paw hover; Paw down; Front paws up; Front paws down; Side-step; Stretch up; Lean back; Circle; Hop; Turn; Head

		under; Toy in mouth; Stretch out; Chin rest; Rest & wait; Chin off; Rub head; Down-Up; Grab toy; Shake toy; Drop toy; Knock on door.
“Pick me up”	Lift the signaller off the ground.	Wag; Front paws on; Front paws off; Jump; Lick lips; Sit & wait; Lie & wait; Head up; Stamp paws; Stand & wait; Look behind; Head turn; Jump on; Hind leg stand; Paw with both; Open mouth; Close mouth; Lick; Paw rest.
“Play with me!”	Initiate play with the intended receiver.	Play gesture; Wag; Shake toy; Wave toy; Stand & wait; Drop toy; Head up; Head down; Head turn; Sit & wait; Roll over; Jump; Paw with both; Nose press; Paw; Lick; Head rest; Front paws up; Toy press; Head forward; Head tilt; Move mouth; Ear twitch; Parade with toy; Body turn; Jump on; Head sway; Jump off; Look behind; Hind leg stand; Head dodge; Front paws on; Stamp paws; Open mouth; Water bite; Lick lips; Head back; Head jerk; Close mouth; Pounce; Runaway; Chin rest; Chase me; Grab toy; Chew/bite toy; Toy whack; Hunchback; Front paws off; Circle; Paw reach; Pull blanket; Flick toy; Bounce; Lie & wait; Push toy; Body lean; Paw push; Paw hover; Paw down; Hover & wait; Fetch; Sway; Spin; Side jump; Nibble.
“Scratch me!”	Scratch or stroke the signaller.	Head up; Roll over; Head under; Lick; Lick lips; Lean back; Head turn; Look behind; Paw; Head forward; Head down; Paw rest; Ear twitch; Head back; Front paws on; Front paws off; Jump on; Nose; Sit & wait; Stand & wait; Paw with both; Lie & wait; Play position; Wag; Body lean; Front paws down; Front paws up; Shuffle; Paw hover; Lean forward; Fetch; Head rest; Jump; Back leg up; Move mouth; Chin rest; Groaning; Roll back; Jump off; Stamp paws; Puppy dog; Chin off; Chomp; Head rub.
“Walkies!”	Prepare and take the signaller for a walk.	Lean back; Head turn; Look behind; Run & pull; Sit & wait; Head down; Stamp paws; Head up; Wag; Stand & wait; Ear twitch; Jump; Front paws on; Jump on; Jump off; Lie & wait; Fetch; Lick lips; Circle; Front paws off; Head rub; Stretch out; Play position; Grab toy; Shake toy; Drop toy; Chew toy.
Unknown	The receiver does not know or attend to what the signaller wants.	Wag; Head turn; Lick lips; Move mouth; Stamp paws; Sit & wait; Stand & wait; Howl; Lie & wait; Head forward; Front paws on; Spin around; Mouth open; Look behind; Head up; Head down; Roll over; Head twitch; Paw reach; Nose; Jump; Play position; Head under; Head tilt; Paw rest; Paw; Begging gesture; Paws down; Jump on; Lean forward; Turn; Sleepy eyes; Chin rest; Rest & wait; Chin off.
ASOs	**Definition**	**Vocalisations**
“Get my toy/bone”	Retrieve a desired object for the signaller which is	Bark; Whine; Grunt; Whimper; Pant; Cry out; Yawn; Sniff; Yelp; Growl; Exhale.

	embedded in a hole or behind a restricted opening.	
“Give me food/drink”	Attain food or drink from the intended receiver.	Yawn; Cry out; Grunt; Bark; Whimper; Sniff; Whine; Growl; Yelp; Exhale.
“Let me climb on there”	Permit signaller to climb on the receiver.	Grunt; Cry out; Whimper; Growl; Yawn; Sniff.
“Look at me!” **“Follow me!”**	Attract the receiver’s attention to the signaller.	Cry out; Whimper; Growl; Bark; Grunt; Pant; Yawn.
“Move it”	Remove objects or organisms which are in the way of the signaller.	“Sigh”; Yawn; Grunt; Pant; Sniff; Whimper; Exhale.
“Open the door”	Open a door for the signaller so that they can gain access to either a desired object or location.	Yawn; Pant; Bark; Grunt; Sniff; Whimper; Whine; Cry out; Growl; Exhale.
“Pick me up”	Lift the signaller off the ground.	Whimper; Grunt; Growl; Bark; Pant.
“Play with me!”	Initiate play with the intended receiver.	Growl; Bark; Grunt; Yawn; Growl; Pant; Sniff; Yelp; Whimper.
“Scratch me!”	Scratch or stroke the signaller.	Grunt; Growl; Pant; Whimper; “Sigh”; Cry out; Sniff; Yelp.
“Unknown”	The receiver does not know or attend to what the signaller wants.	Whimper; Growl; Bark; Cry out; Howl; Pant; Sniff; Yawn; Whine; Moan; Exhale; Grunt.
“Walkies!”	Prepare and take the signaller for a walk.	Squeal; Bark; Cry out; Whimper; Grunt; Pant; Whine; Exhale; Yawn.

Referential Signalling Events

The four ASOs with the highest observational frequency were “Scratch me!”, “Give me food/drink”, “Open the door” and “Get my toy/bone”, resulting in 242 bouts of communication. Within these 242 bouts we initially identified 47 potential referential gestures (Appendix VII) performed by dogs which conformed to all or some of the five features for referentiality (Appendix VIII). Once I strictly applied the five features for referential communication (Table 3.5), this reduced to 19 gesture types having referential properties (Table 3.6).

Table 3.5 How observed dog gestures conform to the five features of referentiality.

Referential Criteria	**Occurance (yes/no)**	**Description of Findings**
1. Directed Towards an Object or Specific Area of the Signaller’s Body	✓	Most gestures were directed whilst at the location of the desired goal. However, some were performed away from the goal location with the apparent aim of leading the recipient to the ASO.
2. Aimed at a Potential Recipient	✓	The intended recipient was the individual filming as all gestures were performed to the camera. Therefore, all gestures were apparently aimed at an attending recipient.
3. Receive a Voluntary Response	✓	All gestures when performed individually and within a portfolio prompted an apparent voluntary response from the intended recipient.
4. Are Mechanically Ineffective	✓	All gestures were performed in the presence of a recipient with the apparent aim of recruiting them to attain an ASO. If these gestures could be directly used to achieve an ASO dogs would not look to a potential recipient for support but would be able to obtain the ASOs without assistance.
5. Hallmarks of Intentional Production	✓	Gestures were performed in a goal-directed way with the apparent aim of achieving some plausibly desired result (ASOs). Dogs were persistent in their performance of gestures until the desired outcome was achieved and all communication observed was directed to an appropriate audience. Persistence and elaboration of gestures, was exhibited if dogs did not initially achieve the ASO (*n*= 24) and if the receiver was not sufficiently quick to respond (*n*=218).

Table 3.6 Definitions of the 19 referential gestures observed in cross-species domestic dog communication.

Gesture	**Definition**
Back Leg Up	Lifting of a single back leg whilst lay on one side of the body.
Chomp	Involves opening the mouth and placing it over the arm of a human whilst repeatedly and gently biting down on the arm.
Crawl Under	Move entire or part of body underneath an object or a human’s appendage.

Flick Toy	Hold toy in the mouth and throw it forwards, usually in the direction of a human.
Front Paws On	Lifting both paws off the ground and resting them on an object or human.
Head Forward	Move the head forwards and up to direct a human's appendage to a specific location on the body.
Head Rub	Involves rubbing the head against an object or human on which the signaller is leaning on.
Head Turn	Head is turned from side to side on the horizontal axis usually between a human and an apparent object of interest.
Head Under	Plunge headfirst underneath an object or human.
Hind Leg Stand	Lift front paws off the ground and stand on hind legs, front paws are not resting on anything.
Jump	Jump up and down off the ground, human or an object, usually while staying in one location.
Lick	Licking an object or human once or repetitively.
Nose	Pressing nose (or face) against an object or human.
Paw	Lifting of a single front paw to briefly touch an object or human.
Paw Hover	Hold one paw in mid-air whilst in a sitting position.
Paw Reach	Placing a single paw or both paws underneath another object to retrieve an object of apparent interest.
Paw Rest	Lifting a single front paw and resting it on an object or human.
Roll Over	Rolling onto one side of the body and exposing the chest, stomach and groin.
Shuffle	Shuffle whole body along the ground in short movements, performed whilst in roll over position.

I recorded 1136 instances of the 19 listed referential gestures from 242 bouts of communication, however only 1016 of these instances demonstrated hallmarks of intentional production (Table 3.7). These 120 instances were excluded from the analysis due to not conforming to all five criteria for referentiality.

Table 3.7 Total number of referential gestures observed in each ASO alongside the actual number of gestures which also conformed to the criterion of intentional production.

Gesture	***1. "Scratch me!"***	***2. "Give me food/drink"***	***3. "Open the door"***	***4. "Get my toy/bone"***
Back Leg Up	3 (2)	0	0	0
Chomp	5 (5)	0	0	0
Crawl Under	0	0	0	2 (2)
Flick Toy	0	4 (4)	0	0
Front Paws On	12 (11)	22 (17)	28 (26)	4 (4)
Head Forward	12 (10)	16 (16)	6 (6)	0
Head Rub	2 (2)	0	0	0
Head Turn	33 (20)	223 (195)	117 (110)	61 (56)
Head Under	2 (2)	1 (1)	0	54 (54)
Hind Leg Stand	0	5 (4)	1 (1)	2 (2)
Jump	0	16 (11)	19 (17)	2 (1)
Lick	46 (39)	8 (8)	8 (8)	1 (1)
Nose	44 (36)	23 (23)	13 (13)	16 (16)
Paw	33 (32)	51 (43)	36 (35)	102 (98)
Paw Hover	6 (6)	31 (27)	6 (3)	4 (2)

Paw Reach	0	0	0	21 (20)
Paw Rest	11 (9)	0	3 (2)	0
Roll Over	18 (14)	0	0	0
Shuffle	3 (2)	0	0	0
Total	**230 (190)**	**400 (349)**	**237 (221)**	**269 (256)**

The “Scratch me!” ASO produced the largest repertoire with 14 different referential gestures being recorded. Both the “Give me food/drink” and “Get my toy/bone” ASO produced 11 different referential gestures and in the “Open the door” ASO 10 different referential gestures were observed. All 37 subjects were observed using referential gestures in at least one of the four ASOs, but not all dogs performed the same gestures and there was variation between dogs in the repertoire size for each ASO (Appendix IX). Some gestures were used by dogs for more than one ASO in different contexts.

Individual gestural repertoire was shown to increase with the number of people who lived with the dog, the number of videos collected (Table 3.8). Sex, age, amount of time dogs spent with current owners and amount of usable footage were found to not be significant predictors of repertoire size.

Table 3.8 Regression output showing the variables which do and do not have an effect on the size of an individual dogs’ gestural repertoire.

Coefficients							
	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for *B*	
Model	*B*	Std. Error	Beta	*t*	Sig.	Lower Bound	Upper Bound
Constant	2.520	1.709		1.475	.150	-.965	6.006
*n*_people	.850	.407	.296	2.088	.045	.020	1.680
sex	-1.169	.735	-.213	-1.589	.122	-2.668	.331
age	-.060	.463	-.070	-.130	.897	-1.004	.884
*n*_videos	.168	.049	.504	3.448	.002	.069	.267
*n*_time	.113	.444	.136	.254	.801	-.793	1.018
usable footage (*min*)	.000	.001	-.030	-.105	.917	-.003	.003
a. Dependent Variable: Gestural Repertoire							

The most common gesture observed was the gaze alternation (head turn) gesture, recorded 381 times over all four ASOs (Figure 3.7). Thirty five of the 37 dogs were observed to use the head turn gesture.

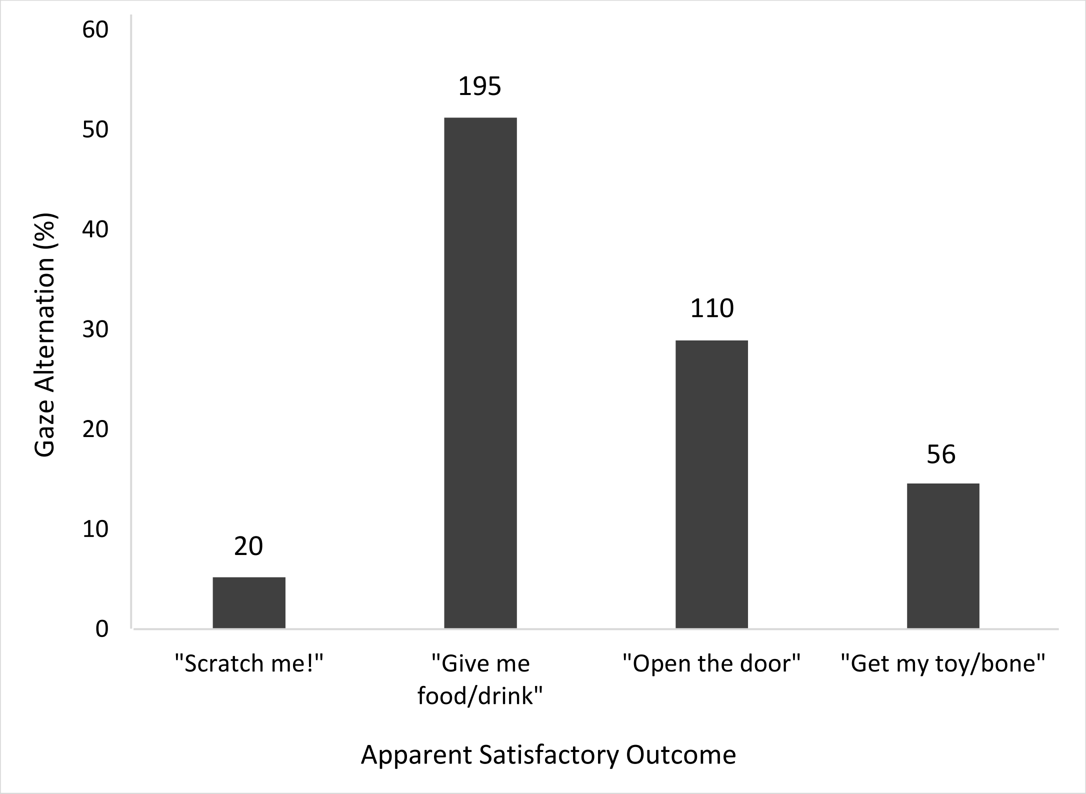


Figure 3.7 Percentage of gaze alternation gestures observed in each ASO with actual number above each bar.

3.7 DISCUSSION

Intentional Communication

These results provide strong evidence for the occurrence of intentional cross-species communication in domestic dogs. I recorded 103 dog gestures that demonstrated hallmarks of intentionality and 15 vocalisations. This study is the first to catalogue the gestural repertoire of dogs so comparisons cannot be drawn with other canine studies. However, a large amount of research is available on the intentional communication of non-human primates. Researchers have identified an intentional gestural repertoire of 20 in bonobos (*Pan paniscus*; Pika et al., 2005b), 66 in chimpanzees (Hobaiter & Byrne, 2014), and 102 in gorillas (Genty et al., 2009), (see table 3.9 for a comparison of great ape and domestic dog intentional gestures).

Table 3.9 Comparison of intentional gestural communication in great apes and domestic dogs.

Species	**Gestural Repertoire (*n*)**	**Contexts (*n*)**	**Flexibility of Use (%)**	**Idiosyncratic Gestures (*n*)**
Chimpanzees	66	19	84.85%	1
Gorillas	102	6	52.94%	1
Dogs	103	11	64.08%	41

Previous research indicates that juvenile and adolescent (3-10 years) gorillas perform a higher number of gestures compared to adults and infants (Genty et al., 2009). The current study found that adult dogs (2+ years) were responsible for using a greater number of intentional gestures and vocalisations compared to puppies. It is important to note, however, in order to participate in the current study the dog needed to have lived with their owner for at least five months prior to the start of the study. This restricted the number of puppies that could be recruited; the results should therefore be interpreted with caution. The majority of participants fell into the adult category (*n*=34), meaning that there was a smaller cohort who fell into the puppy age category (*n*=3). Therefore, unlike primates (see Genty et al., 2009), this study is unable to conclude that repertoire size differs between age groups. In addition, this study found that repertoire size did not differ between sex or breed.

The study found that, unlike gorillas (Genty et al., 2009), dog gestures and vocalisations are not universal across the species as a whole. Only three of the 103 gestures recorded in this study were observed in all 37 dogs: head turn, head up, head down. The occurrence of these three gestures in all subjects points towards these being putative species-typical gestures in dogs. Great apes perform species-typical gestures during communicative bouts with conspecifics (Tomasello & Call, 2018) and the results here suggest that dogs may be similar. More work is required to confirm whether these three gestures are indeed species-typical. This could be achieved by recruiting a larger sample size of dogs from various locations and observing whether these gestures occur.

Idiosyncratic gestures in chimpanzees and gorillas are uncommon, with only one being reported in each species, and tend to arise when an individual is communicating with a human handler (Genty et al., 2009; Hobaiter & Byrne, 2011). However, gestural researchers have reported New and Old World monkeys as inventing novel gestures frequently during interactions with social group members (Perry et al., 2003; Perry & Manson, 2003; Laidre, 2008) and the results here suggest that dogs may also do this. I found evidence of 41 idiosyncratic dog gestures, suggesting that dogs can adapt their repertoire to their particular social group. This high number of idiosyncratic gestures is potentially a result of the citizen science method used in this study but they are still important to the overall picture of domestic dog intentional gestural repertoires. Although the current study checked with owners of the dogs who performed the idiosyncratic gestures whether they were a one-off occurrence or performed regularly, it did not see ask the other owners if their dogs performed these gestures. This means that we do not know if these gestures are truly idiosyncratic or merely not recorded on video. Future research should therefore investigate whether domestic dog communicative repertoires are related to a specific learning disposition which is useful for adapting towards their social group (Tebbich et al., 2001) and if the 41 idiosyncratic gestures observed in this study are truly idiosyncratic.

To be considered as intentional communication the behaviours performed must be directed towards an intended goal (Genty et al., 2009). From the data provided, 11 apparent satisfactory outcomes (ASOs) in which dog-human communication occurred were identified. Tomasello & Camaioni (1997) suggest that chimpanzee communicative intentionality is characterised by their sole use in dyadic contexts and used exclusively for requesting actions from others (Camaioni, 1997; Pika et al., 2005a). Similarly, dog intentionality is also only used to request actions from another individual; however they are not used solely in dyadic contexts.

There was evidence of intentional communicative bouts consisting of one dog and multiple humans. I found that when there was more than one person in the room, dogs would initially direct their gestures towards all of them. Once a potential recipient responded to their actions, the dog would then focus their communicative efforts on that one recipient. Furthermore, unlike chimpanzees I also found that in some cases dogs would also direct their gestures towards multiple recipients.

The ability to communicate with multiple recipients at one given time is more cognitively demanding than communicating with a single individual. In this situation a signaller is required to perform their communicative actions so that the entire group can see (or hear) it alongside understanding the attentional state of the individuals in the group. Moreover, they must understand and recall previous interactions with all present recipients to ensure success. It seems, however, that dogs are able to apply this cognitively challenging process and successfully communicate their intentions with multiple cross-species social partners.

Referential Signalling Events

This study provides strong evidence that pet dogs use referential gestures during everyday communicative bouts with humans. Gestures were performed in a referential way, with the attention of the receiver drawn to an item that was of apparent interest to the signaller. Furthermore, our results show that humans responded to these signals in ways that apparently satisfied the signaller. Kaminski et al. (2011) showed that dogs will gesture towards an object more frequently when it is something of apparent interest to them. Consistent with that assertion, the ASOs identified here all involved an outcome which benefited the dog and not the owner.

Evidence of referential communication in great apes has primarily consisted of pointing gestures performed by captive chimpanzees (Leavens et al., 1996) and orangutans (*Pongo pygmaeus*) (Call & Tomasello, 1994a), and wild bonobos (*Pan paniscus*) (Douglas & Moscovice, 2015) and chimpanzees (Hobaiter et al., 2014); although there is some evidence of wild chimpanzees performing 'directed scratches' gestures to request grooming of specific areas of the body (Pika & Mitani, 2006). It is further reported that one species of monkey, the bonnet macaque (*Macaca radiata*), uses four distinct intentional referential gestures (position change, head/body extension, showing rear, holding body part) during allogrooming (Gupta & Sinha, 2016). Dogs lack the comparable anatomy to easily perform similar overt pointing gestures; however, we did find evidence of dogs directing owners to areas of the body in the 'Scratch me!" ASO (Roll over, Head forward, Back leg up).

We also revealed high occurrences of gaze alternation (Head Turn) in dogs which, moreover, was not limited to one ASO. In the majority of cases (96.1%, *n*=366) of gaze alternation identified in the study, dogs were initially looking at the agent, then switched their gaze toward the apparent goal before turning back to look at the receiver again. Gaze alternation is viewed as one of the best means of referential gesturing (Akhtar & Gernsbacher, 2008) with pre-verbal human infants (Leavens et al., 1996) and great apes (Leavens & Hopkins 1998; Leavens et al. 2004; 2005) regularly performing it. The occurrence of the gaze alternation gesture suggests that dogs are potentially adept at using referential communication.

The study identifies an impressive 19 referential signals in domestic dogs. It is important to note that training may have had an effect on individual dogs' referential repertoire. For example, a dog that has been trained to not jump is less likely to use that gesture as a referent when compared to another dog in which the behaviour has not been extinguished through training. Our results also revealed that dogs call upon a portfolio of referential gestures in order to indicate a single reward. This could have been due to the delay in recipient response created by filming, but it demonstrates that dogs can elaborate on their initial gesture when an appropriate response from the recipient has not been elicited. This suggests that dogs possess repertoire flexibility and are able to still communicate effectively with their owners even when specific behaviours have been expunged through training.

The prevalence of referential communication in dogs suggests that the ability is not as rare as previously thought (Veà & Sabater-Pi, 1998) but could be a common aspect of dog–human communication. Dogs can interpret and understand human-given referential gestures with ease (Kaminski & Nitzschner, 2013) and the evidence from our study suggests humans are also able to successfully interpret and understand canine-given referential gestures. From the age of five weeks, puppies look more toward humans than conspecifics (Gácsi et al., 2005) indicating that the ability to communicate with humans emerges at a very early age. This suggests that the co-habitation process may have resulted in a change in the cross-species communicative abilities of both humans and dogs which may explain how both have become skilled at identifying and understanding each other's referential cues.

Variables on Repertoire Size

Udell and Wynne (2008) have suggested that a dog's environmental history has a major effect on the shaping of behaviour, and interestingly the results here revealed that the size of an individual's referential and intentional gestural repertoire is directly proportional to the number of people who live with the dog. The inference being that dogs with a larger number of people to communicate with possess a greater number of gestures to call upon since they have had more opportunities to learn, and thus increase their repertoire size. This implies dog gestures are not recipient-dependent but that they are performing their portfolio of gestures to their human social partners, ensuring they are understood by the recipient.

The results showed that the length of usable footage does not have an effect on an individual's observed repertoire size. However, a direct relationship between gestural repertoire size and the number of videos collected was revealed, in that repertoire size increased as more data were collected. This is an expected outcome of the data collection procedure, with varying amounts of data collected across participants. It does, however, inform us that the overall estimate of the size of dogs' gestural intentional (*n*=103) and referential repertoire (*n*=19) is likely to be a conservative estimate. Future investigation is likely to lead to the discovery of new gestures in this species.

I further found no effect of age (or sex) on repertoire size in dogs. This is contrast to findings in great apes where repertoire size is negatively related to age (Genty et al. 2009; Hobaiter and Byrne 2011). There it is proposed apes gradually learn which gestures from a portfolio work best and so omit superfluous ones with experience (Byrne et al. 2017). With so-called 'redundancy' taking place adult apes consequently demonstrate fewer gestures. This refinement learning appears to not be evident in dogs who instead continue to throw all gestures at the target individual perhaps in the hope that one will be understood. Longitudinal studies on gestural ontogeny, however, are required to confirm this.

Limitations of the Current Study

Although the current study has identified some interesting results it is not without its limitations, and the citizen science method adopted here has some drawbacks. These are discussed in the general discussion chapter (p. 135). The results revealed here showed no difference between the gestural and vocal repertoire sizes of adult dogs and puppies. The current study, however, only had a small number of puppies (*n*=3) who participated. These results should therefore be viewed with caution and future researchers should consider conducting longitudinal studies whereby they record how dogs' repertoires develop and increase with age. This would also enable us to assess how an individual's repertoire changes and develops over time and if the three gestures (head turn, head down, head up) observed across all 37 dogs in this study form the foundation of dogs' cross-species communicative repertoire.

The current study did not assess whether dogs who live in multi-dog households or spend the majority of the time with other dogs (i.e. doggy day care or spend a large amount of time with another family members dog) differ in their cross-species communicative abilities compared to those dogs who live in single-dog household. Previous research has shown that dogs learn from other dogs, especially in the context of play (Horowtiz & Hecht, 2016). It is therefore possible that dogs who interact with other dogs on a regular basis may differ in their repertoires compared to those dogs who solely live with humans.

The study also failed to investigate if neutering and the age at which it was done has an impact on a dogs' cross-species communicative repertoire. Neutering, particularly in males, has an effect on a dog's aggressive tendencies and makes aggression less likely (Stubbs & Bloomberg, 1995). It has also been suggested that neutering a dog at an early age (before 12 months old) can keep a dog in an almost puppy-like behavioural state (Olsen et al., 2001). Whether this process and the age at which it is done has an effect on repertoire size is not currently known.

Further research is needed in this area to determine how and if neutering has an impact on a dogs' cross-species communicative repertoire by comparing the repertoires of neutered and non-neutered individuals. This can then be further explored by comparing the repertoires of individuals who were neutered at different ages (i.e. before six months, six-12 months, 11-17 months etc.) to see if any differences are present.

Also, communicative repertoire differences between breeds were not investigated in the current study. Although all the dogs who were part of the current study were companion dogs, certain breeds were and still are bred for specific purposes. Patterdale terriers were originally bred for ratting, Beagles are a scent hound bred for hunting hare and Lhasa Apso's were originally used as interior sentinels in Buddhist monasteries (Dorling Kindersley, 2013). Cross-breeds, such as cockapoos, are now bred specifically as companion dogs but they still demonstrate some of the gun-dog cocker spaniel and water-dog poodle traits. How these breed traits impact an individual's cross-species communicative repertoire remains unknown. It is possible that certain breeds, such as Pointers, will have a gestural repertoire that is centred around pointing (Dorling Kindersley, 2013). Breed intelligence may also factor into an individuals' communicative repertoire. German Shepherds, Border Collies and Poodles are often ranked as the top three most intelligent dog breeds as they learn simple tasks quickly obey commands given the first time over 95% of the time (Coren, 1994). Future research should investigate this further to determine if a difference between breeds is present.

The duration (i.e. basic puppy training, regular training class attendee etc.) and type of training (i.e. home trained, professionally trained etc.) the individual dogs had before participating in the study is not explored in the current study. Furthermore, no data has been collected on the type of training model owners have used to train their dogs as this could potentially have an impact on a dogs' repertoire. Almost all companion dogs receive some form of training, and research has shown that training experiences influence a dogs' performance during problem solving tasks (Marshall-Pescini et al., 2008) so it is possible that the amount and type of training dogs are exposed to may affect how they communicate with their cross-species companions.

Methods of dog training can influence how an owner thinks their dog views their relationship and the techniques implemented can form the foundation of the bond between owner and dog (Hiby et al., 2004). The phrase 'the wolf in your living room' has been used as a guide in the development of training methods used to shape dog behaviour, and a vast majority of dog training manuals refer to it. A large number of high-profile dog trainers, such as Cesar Millan, promote the ideology that dogs are pack animals and should be controlled by the dominance model and the use of physical punishment (Bradshaw, 2012). The “wolf pack” theory of training gives owners the impression that dogs view humans as leaders and that if a person does not show leadership over their dog, the dog will strive to dominate them and any other person it comes into contact with (Tennant, 2002). However, the dominance training model is based on flawed assumptions and as a result compromises the welfare of dogs and the relationship their owners have with them (Zimen, 1975; Mech & Boitani, 2003; Bradshaw, 2012). Research has shown that feral dogs do not revert back to a wolf-pack social system and therefore adopting a “wolf pack” model for describing dog behaviour is not supported (Pal et al., 1998). Evidence against the “wolf pack” model has also been reported in domestic dogs. Bradshaw et al., (2009) observed the social behaviour of 19 neutered dogs to determine the dogs’ social unit. They documented that the dogs’ patterns of relationships did not conform to any conventional hierarchical model and therefore did not fit the predictions of the “wolf pack” theory.

Nowadays an increasing number of dog owners are embracing more appropriate training models, such as positive reinforcement training techniques (Hiby et al., 2004). These positive reinforcement techniques have been shown to be more efficient and effective than the dominance training ideology (Herron et al., 2009). This method of training is a more accurate reflection of the social nature of the domestic dog (Bradshaw, 2012). Given that training methods influence our opinions on how a dog perceives his/her human social unit, positive reinforcement training should be adopted more often.

Given that specific training methods influence our opinion of how dogs view us (Bradshaw, 2012) it is possible that they may also affect how a dog learns and develops its communicative repertoire. It is likely that those dogs who have been trained using the ‘wolf-pack theory’ model could have a more submissive or subtle communicative repertoire compared to those who have been trained using positive reinforcement who may be more boisterous or inventive with their repertoires. It is therefore not currently known how training affects the cross-species repertoire of dogs and future researchers should consider conducting further investigations into this.

Conclusions

The results from this study suggest that the domestic dogs' gestural and vocal repertoire is linked to specific meaning and used in intentional cross-species communication. This study documented a repertoire of 103 gestures and 15 vocalisations performed by dogs in intentional communication with their owners. The gestures reported in this study are used intentionally in a flexible, goal-directed way and are therefore not automatic bodily signals (Genty et al., 2009). Domestic dog gestures are a form of non-verbal communication which has been developed, allowing dogs to thrive in the anthropogenic environment.

Research has shown that, unlike any other animal species, dogs have the ability to use human-given gestures in remarkable ways (Kaminski & Nitzschner, 2013). The current study has found that humans are also equally remarkable at using and understanding dog communicative gestures. It would seem that the communicative ability present in both species have developed and converged as a by-product of the domestication process (Hare & Tomasello, 2005). Furthermore, the results from the current study enhance previous research, suggesting that dogs have a strong relationship with their human social partners (Berns et al., 2015) as they are able to successfully communicate their intentions cross-species.

To date the majority of canine referential research has investigated dogs' abilities in response to human-given gestures. The current study is one of the first to record and analyse the referential and intentional communicative repertoire of domestic dogs during cross-species interactions with humans. The majority of non-canine gestural research has concerned itself with subjects who all gesture to conspecifics. The current study has shown that dogs (and humans) are doing something remarkable, having had a shared existence for only 30,000 years (Miklósi, 2007). Despite the brevity of this shared existence, dogs have developed a strong relationship with their human social partners (Miklósi, 2007; Hare and Tomasello, 2005; Berns et al., 2015), with inter-dependence facilitating successful cross-species communication.

The ability to successfully communicate cross-species is theoretically more cognitively challenging than intraspecific communication since it requires an individual to adjust its behaviours so that the other species is able to understand and correctly respond to them. The inference from great ape studies is that the increased 'intelligence' in their subjects is due to phylogeny and a shared ancestry with humans (Hobaiter & Byrne 2011). Dogs last shared a common ancestor with primates 100 mya yet this study suggests they possess impressive convergently acquired skills in this domain.

4. SOCIAL TOOL USE IN DOMESTIC DOGS?

This thesis has so far brought to light the impressive communicative repertoire of the domestic dog during cross-species interactions with humans. The data demonstrate that dogs are able to successfully communicate their intentions and produce referential gestures. Dogs have developed these communicative abilities enabling them to survive and thrive in the anthropogenic environment. The human world, however, still possesses many challenges which dogs, on their own, are unable to overcome. How far can dogs take their cross-species communicative abilities? Here I ask whether dogs use their communicative prowess to employ humans as 'tools' to achieve inaccessible goals?

4.1 Animal Tool Using Behaviour

The ability to use tools was once thought of as a uniquely human characteristic (Biro et al., 2006) but the discovery by Jane Goodall in 1964 of chimpanzees (*Pan troglodytes*) habitually using and manufacturing tools put an end to that thought. Since then tool use has been a central concept in the field of animal cognition (St Amant & Horton, 2008). By studying tool use researchers have advanced our knowledge of the cognitive and behavioural capacities within a variety of species (Tomasello & Call, 1997; Povinelli, 2000).

Despite the vast amount of research that has been conducted, documented tool use remains a relatively rare phenomenon (Chappell & Kacelnik, 2002). The ability to use tools has been repeatedly reported in 0.01% of non-primate mammalian species (Chevalier-Skolnikoff & Liska, 1993), 10 primate species (Breuer et al., 2005), and 30 species of birds (Lefebvre et al., 2002).

4.1.1 Classical Tool Use

Classical tool use involves the physical manipulation of inanimate objects to achieve a goal, and ample evidence of this ability in the animal kingdom has been compiled (see Bently-Condit & Smith, 2010 for a comprehensive catalogue of tool using species). There is very little evidence reported on domestic dogs' abilities as classical tool users. Dogs have, however, learned how to use simple tools, such as pulling a string or opening a bin to access an out of reach treat and their abilities in these tasks are similar to those of wolves (Gácsi et al., 2005; Osthaus et al., 2005). The difference, however, is shown when both species are faced with the same 'impossible' task. Unlike wolves who attempt to solve the task themselves with no assistance, dogs will quickly shift their gaze from the goal object towards the human experimenter (Miklósi et al., 2003b; Gácsi et al., 2005). Dogs possess cognitive abilities uniquely adapted to the anthropogenic environment (Miklósi, 2007) and this may have affected their abilities as tool users. Instead of using a physical solution to solve the problem dogs rapidly take a social approach to problem solving by looking towards and employing humans as social tools.

4.1.2 Social Tool Use

Social tool use is defined as “the physical and psychological manipulations of animate beings towards some goal” (Völter et al., 2015, p. 127). In human infants social tool use occurs more frequently during the developmental stages. Through use of gestures human infants enlist help from adults to obtain desired objects which are out-of-reach (Bard, 1990). However, little evidence exists for social tool use in non-human species (Völter et al., 2015). This is surprising given its association with other cognitive abilities such as cooperation. Most species in which the ability to use physical tools has not been recorded to date lack a means to grip, hold and handle objects. These unsuccessful tool users could be evading this anatomical shortcoming by employing their group mates as social tools.

Studying classical tool use reveals underlying information processing mechanisms, and if tool use is employed flexibly and for innovative purposes, it then has the potential to reflect cognitive processes (Wimpenny et al., 2011). Social tool use has the potential to demonstrate this too and could potentially reveal augmented cognitive processes within a species. Social tool use, to some degree, requires an individual to have knowledge of the employability of individuals which requires knowledge of past interactions and individual recognition. Furthermore, social tool use involves the use of intentional communication as a way of employing the social agent towards the desired goal (Bard, 1990). The ability to use social tools may be more cognitively impressive since, when dealing with another agent – rather than object, the user is having to employ another organism, presumably of its own freewill, in order to achieve an apparent goal. Social tool use is therefore closely linked to social cognition and has the potential to reveal a variety of underlying cognitive processes that classical tool use does not.

Social tool use contains a motivational dimension (the motives/reasons underlying the employment) and an instrumental dimension (the means-end employment of the organism) (Völter et al., 2015). Völter et al. (2015) state that the instrumental dimension of social tool use is further subdivided into four levels dependant on the amount of physical influence the employer exerts over the organism:

- Level one employment through physical contact
- Level two organism as an object with self-control
- Level three organism as a self-propelled agent
- Level four employment through communication.

Level one involves the direct physical employment of the tool's body (Völter et al., 2015). The user has complete control over the social tool and physically influences their actions/behaviours, e.g. child takes a parent's arm and moves it toward a desired object, using it to extend its own reach to gain access to the object. Level two is like level one but involves a slightly lesser degree of physical contact (Völter et al., 2015). In level two the user guides the social tool towards their desired goal but relies on the social tool's self-controlled actions to retrieve the goal, e.g. child pushes a parent's arm in the direction of a desired object that the parent retrieves for the child.

Level three involves no direct physical control from the user (Völter et al., 2015). The user passes the social tool an inanimate object for them to utilise to achieve the user's desired goal. Level three relies on the self-initiated actions produced by the tool and the tool's willingness to cooperate with the user, e.g. child hands a parent an empty bowl that the parent fills with the dessert on the table and hands back to the child. Finally, level four involves no direct physical contact to guide the tool towards the desired goal (Bard, 1990). The user utilises a series of gestures and behaviours to influence the social tool's actions, e.g. child gestures the desire to receive out of reach food. The parent retrieves a bowl, fills it with food and gives it to the child. Both Bard (1990) and Völter et al. (2015) state that this level of social tool use involves no direct physical interactions between the two parties. I propose that physical interactions *may* still occur at this level. Permissible contact at Level 4 would arise under the specific circumstances of the tool user using physical contact as an attention-getter or employment technique. Any other physical interaction from the social tool serves as reassurance or acknowledgement of the tool's communicative gestures.

4.2 The Present Study

4.2.1 Social Tool Use: A Brief Review of Current Definitions

The lack of evidence of social tool use is perhaps due to the absence of a clear and accurate definition. A clear and accurate definition of tool use is essential for any attempt to better understand the nature of tool use within a species (St Amant & Horton, 2008). Without identifying the essential characteristics of tool use we cannot carry out a meaningful investigation into the tool using abilities of the study species, the domestic dog.

The definition of tool use provided by Beck (1980) is the definition that is most commonly referred to in the field of animal cognition and over the past 30 years has been frequently adopted to investigate the tool using abilities in a variety of species (Hunt et al., 2013):

> Tool use is the external employment of an unattached environmental object to alter more efficiently the form, position, or condition of another object, organism or the user itself. The tool must be held or carried during or just prior to use and is responsible for establishing the effective orientation between the tool and the goal object (Beck, 1980, p. 10).

Beck's definition is both robust and straightforward and conforms to the perceptions of accomplished animal behaviourists (St Amant & Horton, 2008). This is most likely the reason behind the definition remaining the most influential in the field 30 years after its publication. However, there have been a number of alternative definitions and refinements produced over the years. Pierce (1986, p. 96) stated that tool use must involve a "structurally modified inanimate object", Boesch and Boesch (1990, p. 86) define a tool as an object "held in the hand, foot or mouth", and Alcock (1972, p. 464) defines tool use as "the manipulation of an inanimate object". St Amant and Horton (2008) reviewed the various definitions of tool use and, due to recent evidence, claim that Beck's definition is out-dated. They state that tool use is:

> The exertion of control over a freely manipuable external object (the tool) with the goal of (1) altering the physical properties of another object, substance, surface or medium (the target, which may be the tool user or another organism) via a dynamic mechanical interaction, or (2) mediating the flow of information between the tool user and the environment or other organisms in the environment (St Amant & Horton, 2008, p. 1203).

All these definitions focus mainly on what we refer to as “classical” tool use, which is the physical manipulation of objects. Definitions of tool use tend to exclude the use of an organism as a tool and therefore ignore the complex process of ‘social tool use’. Social tool use involves manipulating another organism in order to use them as a tool (Shumaker et al., 2011). By using definitions which exclude social tool use researchers are missing out on opportunities to document all forms of tool use. Furthermore, social tool use provides us with an opportunity to further investigate the cognitive abilities of animals.

Social tool use has been defined by Völter et al. (2015, p. 127) as “the physical and psychological manipulations of animate beings towards some goal”. Although straightforward, this definition fails to consider classical tool use. If we label an ability as ‘tool use’ the field would require a definition that allows for the inclusion of all the behaviours an individual could potentially perform. This would allow us to observe and document an animals full range of tool using abilities (McGrew, 2013).

There have been definitions put forward which describe both classical and social tool use, for example Hall (1963) defines tool use as:

> The use by an animal of an object or another living organism as a means of achieving an advantage. The mediating object is required to be something unrelated to the bodily equipment of the animal, and its use allows the animal to expand the range of its movements or to increase their efficiency (Hall, 1963, p. 488).

Although definitions encompassing both classical and social tool use do exist, evidence for social tool use is rare (Völter et al., 2015). It has recently been suggested that current definitions of tool use are inadequate and therefore fail to capture the rich variety of animal technologies (McGrew, 2013). Therefore, for this study it was necessary to put forth a definition that would encompass both classical and social tool use to allow us to document the variety of phenomena related to tool use:

> Tool use involves the deliberate employment of an object or another living organism with the aim of changing the properties of an otherwise unobtainable goal. The gestures performed by the tool user are the sole factor responsible for directing the tool towards the user’s apparent goal.

It is important to mention, however, that all definitions of tool use will be subjective and will have drawbacks (Bently-Condit & Smith, 2010), but if adopted by tool use investigators this definition would provide researchers with the opportunity to document tool use in all its forms and therefore observe the rich variety of abilities and individual could potentially possess (McGrew, 2013). Social tool use provides an opportunity to further investigate the cognitive abilities of animals not least because it adds an additional layer of cognitive complexity since it involves the employment and moulding of an external mind (not simply an external object).

4.2.2 Domestic Dogs: A Good Model for Investigating Social Tool Use

Domestic dogs have developed cognitive processes that are relevant to the human-orientated environment in which they are adapted to live in (Hare & Tomasello, 2005). Researchers have shown that living with humans has altered the problem-solving strategies of domestic dogs (Miklósi et al., 2003b; 2005). Unlike their wild counterparts, companion dogs no longer attempt to solve problems independently, but seek assistance from humans when they are confronted with a problem-solving situation (Hare, 2004). Therefore, the cognitive abilities and behaviours of domestic dogs differ from those seen in wolves (Miklósi et al., 2003b; Gácsi et al., 2005). This change in problem-solving behaviours may be why domestic dogs have failed to impress in classical tool using tasks to date, as most of the time they have been tested against and compared to species who live outside of the anthropogenic environment.

Previous research has suggested that social tool use has its limits (Völter et al., 2015). In their experiment Völter et al. (2015) noted that although orangutan mothers successfully manipulated their infants' actions, they failed to coerce them into grabbing and inserting an object that was preferred by the mothers and not the infants. This suggests that the infants' willingness to cooperate is critical for the mothers' success but it is driven by the social tools' own selfish interests. Domestic dogs, however, have a different type of relationship with humans. Humans are a prosocial species (Silk et al., 2005). Dog owners willingly do a number of things for their pets such as paying for food, toys, medical expenses etc. as well as making time to walk and play with their dogs (Horowitz, 2011; Bradshaw, 2012). Therefore, unlike the orangutan mothers, domestic dogs have a potential social tool who is not driven by their own selfish interests and is ready and willing to assist them.

Social tool use would require a species to have some concept of theory of mind. Theory of mind is present in an individual if they are capable of imputing mental states to themselves and others (Premack & Woodruff, 1978). During Guesser-Knower tasks, dogs show a preference for a Knower rather than a Guesser under some conditions (Udell et al., 2011; Maginnity & Grace, 2014; Catala et al., 2017). This suggests that dogs are sensitive to the attentional state of humans and have the ability to infer what other individuals know. Interestingly a recent study has revealed that human attention affects the facial expressions performed by dogs (Kaminski et al., 2017), suggesting that the cross-species communicative abilities of dogs may also require theory of mind to be present in the species.

It is important to note however, that theory of mind is extremely difficult to conclusively show in non-human animals. To date no non-human species has been unequivocally successful in passing theory of mind tests (Horowitz, 2011). As a result, some researchers argue that behaviour reading (as opposed to mind reading) counts as evidence for theory of mind, and domestic dogs have demonstrated this during investigations in which they follow a human pointing gesture (see Kaminski & Nitzschner, 2013 for a review). The evidence therefore suggests that dogs may be capable of both behaviour reading and inferring what other individuals know, but it is important to note that it is still difficult to draw any firm conclusions regarding these abilities in domestic dogs. Nevertheless, given their relationship with humans and their cross-species communicative repertoire uncovered in the previous chapter they provide a good model for investigating social tool use.

4.2.3 Justifications and Aims

This study will test the hypothesis that domestic dogs use their cross-species communicative repertoires to recruit humans and use them as social tools to achieve an apparent goal. It is predicted that certain factors may affect the social tool using success (i.e. apparent goal achieved or not achieved) of domestic dogs. The study will therefore examine whether amount of handling by the owners, house rules and the size of the dog affects a dog’s chance of achieving their apparent goal.

The lack of evidence of social tool use within the animal kingdom but the recognition that the ability exists suggests that there is a lack of knowledge regarding the phenomenon amongst researchers. Should evidence of social tool use be found in dogs it will provide researchers with a foundation of knowledge to investigate the phenomenon in other species. Furthermore, it could be argued that social tool use is more cognitively demanding than classical tool use as it requires an individual to successfully communicate their intended goals to another individual whom they aim to recruit for assistance. An individual must also remember previous interactions with their intended tool in order to utilise the relevant communicative gestures to employ them successfully. The lack of research surrounding social tool use could possibly be overlooking the cognitive potential of a species.

The present study investigates whether domestic dog use their communicative gestures to employ humans as social tools in order to achieve an otherwise unobtainable goal. The results of this study will also improve the relationships which people have with their pets as they are directly involved in the scientific process using citizen science and provide a unique insight into the naturalistic relationship between owner and dog. Furthermore, the study will reveal another, previously untested, way in which dogs are using their cross-species communicative abilities during interactions with humans.

4.3 STUDY DESIGN

4.3.1 Specific Procedure and Design

To determine if dogs possess social tool using abilities the modes of tool use which they could potentially perform needed to be identified. The study method was based on the 22 modes of animal tool use named by Shumaker et al. (2011). From this list I evaluated the modes of social tool use dogs were most likely to use. As a citizen science method was adopted, with lay persons collecting the data, the criteria for selection of appropriate modes of dog tool use was heavily reliant on which could most easily be identified by non-scientific observers. It was determined that 6 out of the 22 modes were likely to be regularly performed by dogs (see table 4.1 for a list of modes and their definitions). *Open* and *Pick up* are not listed as a mode of tool use by Shumaker et al. but through pilot studies and discussions with dog owners I found that dogs will often get their owners to perform these actions and were consequently added to the list. This resulted in eight dog-specific modes of tool use to consider.

Table 4.1 Eight modes of domestic dog tool use considered for the study and their definitions.

Mode of Tool Use	Definition
Climb on	Climb up an organism or object and prop or balance oneself on the tool. Can be either stable or unstable.
Insert & Probe	As in Reach, but when the target object is embedded in a hole or behind a restricted opening. Can include insertion of appendages.
Move	Use the tool to remove, transport or control objects, fluids or another organism.
Open	Use an object or organism to open another object in order to gain access to either an apparently desired object or location.

Pick up	Employ a potential tool into lifting the user off the ground. Can involve either holding the user in mid-air or moving the user to another location.
Reach/Give	Use either another organism's appendages or an object to retrieve an apparent object of interest when the user's prehensive structures are too short. If the employed organism's appendages are too short, they may also use a tool to retrieve the object.
Scratch & Rub	Repeatedly move an object held by the tool, or the tool's appendages, across a bodily surface, or present or direct the tool towards the desired scratching or tickling location.
Throw	Deliberate propulsion of an object through open space. Can be aimed or unaimed. The object is propelled by the tool's or the user's own energy.

A citizen science method, similar to that adopted by Horowitz & Hecht (2016), was adopted to test the social tool using abilities of domestic dogs. This is outlined in detail in the research aims, objectives, methods and key outcomes chapter (p. 16).

4.3.2 Analyses

The data provided by participants in the previous chapter were also used to investigate the social tool using abilities of domestic dogs. I analysed the footage from each individual subject using a table of observations. From the video footage collected the modes of social tool use that were observed, the gestures/vocalisations which were performed and the number of occurrences of that mode of tool use in each individual and across all the subjects were listed. A table was then produced detailing the apparent aim of each mode of tool use, number of observations and dogs and the observed tool use goals. The total number of modes of tool use observed in each subject and any "unique" modes of tool use that were reported from the data were then discussed.

Statistical analyses were conducted to compare the success rate of the dogs in the eight modes of tool use by recording the percentage of successful (i.e. apparent goal achieved) and unsuccessful (i.e. apparent goal not achieved) social tool using bouts. A Shapiro-Wilk test was used to test for normality with P value set at 0.05, this determined that the data is normally distributed. A paired samples t-test was used to compare the success rate of the dogs in the eight modes of tool use. Amount of handling by the owners, house rules and the size of the dog were considered as possible variables which could potentially affect dog tool using success. Therefore, a multinomial logistic regression was performed to analyse these predictor variables to determine if they affected whether or not a gesture is likely to be observed. Cohen's kappa was conducted to determine and assess inter-observer reliability on a sample of 105 videos.

4.4 RESULTS

Social Tool Use in Domestic Dogs

Five hundred and twenty one observations of potential social tool use were returned from participants. Three participants failed to provide relevant data (27 observations) which resulted in the subjects being excluded from the study, thus resulting in 494 observations of potential social tool use. After an initial analysis 76 observations were not included as they were either accidentally provided by the owners or did not match the criteria for social tool use. This therefore gave 37 participants (15 female, 22 male) and 418 observations that demonstrated communicative behaviours which conform to social tool use.

Owners were asked to look for eight potential modes of tool use when collecting footage and evidence was found for all eight modes (Table 4.2). All eight modes were not observed in all subjects, however; the mean number of modes observed in dogs was 4.5. Appendix X demonstrates the individual characteristics of each canine participant.

Table 4.2 Modes of tool use observed in domestic dogs.

Social Tool Use Mode	**Definition of Mode**	**Observations (*n* of instances)**	**Dogs (*n*)**	**Observed Tool Use Goals**
Climb On	To extend the user's visual field; to reach a desired object.	11	8	To look out of a window. To receive attention from the tool.
Insert & Probe	To attain an object that is behind a restricted opening and out of the users reach.	35	15	To retrieve a desired object.
Move	To Move objects that affect the user's comfort, are blocking the users' path. Also to remove fearful objects or bring closer desirable objects.	12	8	To sit/lie in a desired location. To move both desirable and undesirable objects.
Open	To use the tool to open objects that block the path of the user or to open items that the user cannot.	86	30	To open doors in order to reach another location (inside and outside)
Pick Up	To extend the users visual field; to transport the user to a desired location.	9	7	To look out of a window. To avoid an undesirable flooring. To receive attention from the tool.
Reach & Give	To attain an object that is out of reach.	114	34	To have food/drink. To have lead put on.

Scratch & Rub	Repeatedly move a tool's appendage across the user's bodily surface, or to scratch a desired spot on the users' body.	56	23	To be scratched/stroked by the tool.
Throw	Use the tool to propel an object through open space, usually during play.	51	18	To throw a toy to play.

As seen in table 4.2, social tool use in domestic dogs was observed most frequently in the *Reach & Give* mode (114) which is mainly used to acquire food/drink. After this *Open* (86) and *Scratch & Rub* (56) occur most frequently. The mode *Pick Up* (9) occurred the least often during the study as it could only be performed by smaller dogs and those dogs which were not averse to being picked up. *Climb on* (11) and *Move* (12) were also expected to occur in low frequencies as most of the collected data on these modes involved the dogs jumping onto furniture. In some households, the dogs were not allowed to sit on the furniture, limiting the number of dogs being eligible to perform this mode of tool use.

Play is an important interaction between owners and dogs and occurs often (Bradshaw, 2012). *Throw* is a mode of tool use related to play. It was observed in high frequencies (51) and reported by participants to be the easiest mode to identify. Finally, *Insert & Probe* (35) was observed numerous times but participant feedback revealed it was sometimes difficult to film.

The total number of modes of tool use seen in each subject varies from two to eight (Figure 4.1). As a citizen science method was used for the research it is important to note that some modes of tool use may have been missed in some subjects. The citizen science approach relies on the public collecting the data and here it is highly likely that not all the dogs' tool using gestures have been documented. This, however, is an acceptable trade off when attempting to access a large amount of data on the potential social tool using skills of dogs.

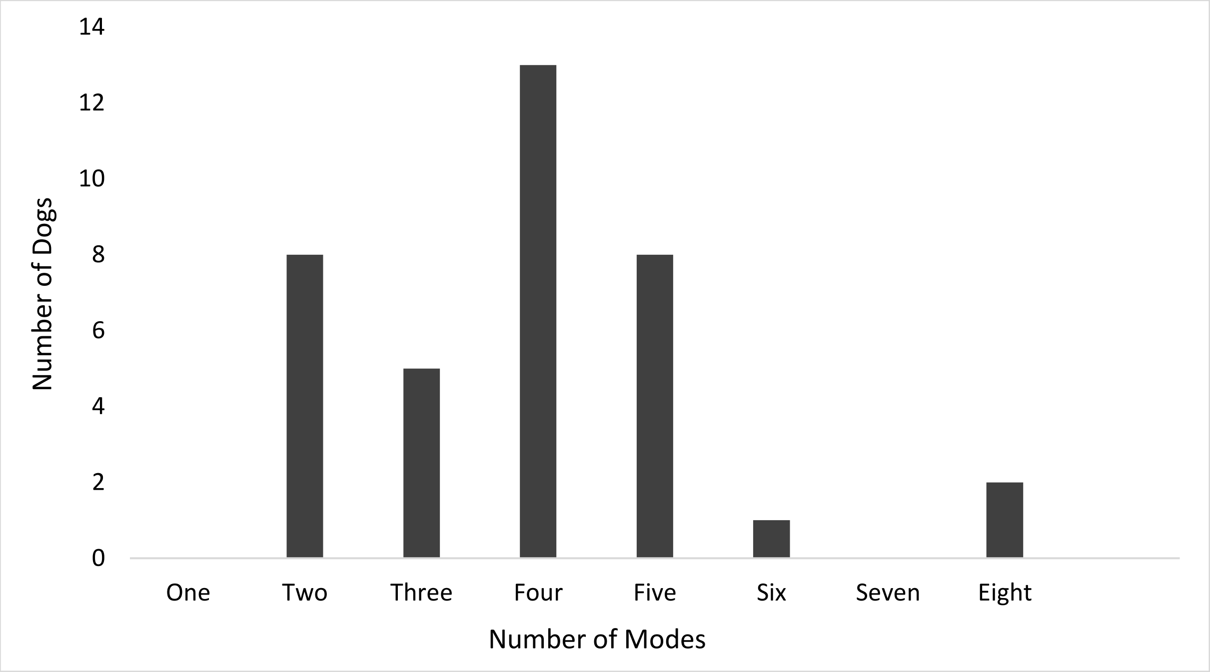


Figure 4.1 The number of modes of tool use seen in each subject.

Social Tool Using Gestures and Vocalisations

A total of 66 gestures were observed which conformed to the study's definition of social tool use (Table 4.3). Twenty-one gestures (by 14 dogs) were categorised as *Unknown* as neither the owner nor the researcher could determine the dog's apparent intentions. Inter-rater reliability analysis revealed a good agreement between the two coders for the number of tool using gestures recorded, kappa=0.614, *P*<0.001.

Table 4.3 Social tool using gestures performed by dogs, the number of individuals a gesture/vocalisation was observed in alongside the total recorded instances of each gesture/vocalisation.

Tool User's Gestures		**Modes of Tool Use**	**Dogs (*n*)**	**Total Instances (*n*)**
Begging gesture		Reach & Give	2	3
Chew	Object	Throw	8	56
	Tool (owner)	Scratch & Rub	1	5
Chin rest		Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Move	12	10
Circle		Throw; Insert & Probe; Open	4	7
Crawl	Back & forth	Reach & Give; Open	1	2
	Under	Insert & Probe	1	2
Fetch	Toy	Throw; Reach & Give	8	54
	Blanket	Climb On; Pick Up	1	2

Follow loudly		Reach & Give; Insert & Probe; Open	14	19
Front paws on		Reach & Give; Scratch & Rub; Climb On; Pick Up; Open	28	78
Gaze alternation		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Move; Open	37	511
Groaning		Scratch & Rub	1	1
Head tilt		Reach & Give; Insert & Probe; Scratch & Rub; Climb On	17	48
Jump		Throw; Reach & Give; Insert & Probe; Climb On; Pick Up; Move; Open	20	107
Lean	Forward	Reach & Give	3	7
	On	Scratch & Rub	3	4
Lick	Object	Reach & Give; Climb On	5	7
	Tool (owner)	Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Pick Up; Open	13	66
Lick lips		Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Move; Open	35	549
Look at	Tool (owner)	Throw; Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Pick Up; Move; Open	37	438
	Object	Throw; Reach & Give; Insert & Probe; Climb On; Move; Open	37	261
Lie down		Reach & Give; Insert & Probe; Scratch & Rub; Open	25	97
Nose	Object	Reach & Give; Insert & Probe; Climb On; Open	14	31
	Tool (owner)	Reach & Give; Insert & Probe; Scratch & Rub; Move	13	47
Paw	Object	Throw; Reach & Give; Insert & Probe; Move; Open	21	159
	Tool (owner)	Reach & Give; Insert & Probe; Scratch & Rub; Pick Up; Open	13	73
Paw hover		Throw; Reach & Give; Open	14	58
Play position		Insert & Probe	13	15
Pounce		Throw	5	21

Roll Over		Scratch & Rub	9	13
Run	Towards	Throw; Reach & Give; Scratch & Rub; Pick Up; Open	21	38
	Between	Throw; Reach & Give; Insert & Probe; Climb On; Pick Up; Open	21	63
Runaway		Throw	7	11
Rub head		Scratch & Rub; Open	2	4
Shuffle		Scratch & Rub	1	3
Sit in front of		Reach & Give; Climb On; Pick Up	35	271
Stamp paws		Reach & Give; Open	29	302
Stand in front of		Reach & Give; Open	35	379
Toy	Drop	Throw; Reach & Give	21	122
	Grab	Throw; Reach & Give; Open	14	105
	Toss	Reach & Give	2	8
	In mouth	Throw	2	2
Tremble		Reach & Give	1	10
Under with	Head	Insert & Probe	15	58
	Paw	Insert & Probe	8	24
Wag		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Pick Up; Move; Open	34	483
Tool Users Vocalisations		**Modes of Tool Use**	**Individuals (*n*)**	**Total Instances (*n*)**
Bark		Throw; Reach & Give; Insert & Probe; Pick Up; Move; Open	21	480
Cry		Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Open	11	37
Exhale		Reach & Give; Insert & Probe; Move	3	16
Growl		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Pick Up; Move; Open	16	57
Pant		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Move; Open	15	88
Sniff		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Move; Open	15	54
Whimper		Throw; Reach & Give; Insert & Probe; Scratch & Rub; Climb On; Pick Up; Move; Open	21	182

Whine	Reach & Give; Insert & Probe; Open	12	55

All observed gestures/vocalisations were used by dogs (tool users) in this study to direct the social tool towards the user's apparent goal. Gestures/vocalisations either relay information about the apparent outcome (e.g. location) to the tool or serve as so-called attention getters to attract the tool's attention to either the user or the apparent goal. The *Look at tool* and *Look at object* gestures were recorded in all 37 subjects. The occurrence of *Look at* gesture implies that dogs do direct their gestures/vocalisations toward specific tools or objects and are possibly aware of the attentional state of the intended tool. I cannot draw any firm conclusions regarding the awareness of attentional state as most dogs directed their gestures/vocalisations towards the social tool who was filming the bout, therefore, I was unable to observe the tool.

The *Gaze alternation* gesture was observed in all 37 subjects. Alternating gaze between an object of apparent interest and the recipient has been frequently observed in human infants and adult chimpanzees and is one behavioural element related to intentional communication (Bard, 1990). The occurrence of *Gaze alternation* in dogs suggests that their gestures were goal-directed. I recorded 511 instances of *Gaze alternation* and the vast majority of those instances (499) involved an alternation between the apparent goal and the tool, this was also observed in all 63 instances of the *Run between* gesture. By alternating gaze or running between the chosen tool and the apparent goal dogs are attempting to show and direct the tools towards a specific outcome.

Included in the list are the social tool users vocalisations which occurred during the observational periods. *Barking* (480) and *Whimpering* (182) had the highest number of instances. Not all dogs were recorded using vocalisations in their tool using repertoire, but when performed vocalisations served mainly as attention getters.

"Unique" Modes of Social Tool Use

One subject (Mandy) demonstrated an unlisted mode of tool use during the observational period. I referred to this mode as *Hold* as it involved employing the human to hold an object to gain better access to it. The object in question was a dog chew and the subject employed the human into holding it while they ate.

Domestic Dog Tool Using Success

Owners were also asked to film both successful and unsuccessful communicative bouts performed by dogs. Due to the citizen science method, however, it is likely that more successful than unsuccessful bouts were recognised and recorded by owners. Rates of successful and unsuccessful outcomes in each of the eight modes of social tool use are given in table 4.4. There was a significant difference in the scores for successful (M=43.6, SD=31.7) and unsuccessful (M=2.9, SD=6.5) outcomes; $t_{(7)}$=3.80, *P*=0.007. These results suggest that social tool using gestures performed by dogs result in significantly more successful (93.8%) than unsuccessful (6.2%) outcomes.

Table 4.4 Percentages of successful and unsuccessful social tool using bouts performed by domestic dogs towards their social partners.

Mode of Tool Use	**Outcome**		
	Successful (%)	Unsuccessful (%)	(*n*)
Climb On	90.9	9.1	11
Insert & Probe	96.6	3.4	29
Move	100	0	12
Open	97.7	2.3	86
Pick Up	100	0	9
Reach & Give	82.6	17.4	115
Scratch & Rub	98.2	1.8	57
Throw	100	0	51
Unknown	*0*	*100*	*21*

From the data 21 potential tool using episodes were classified as *Unknown* as neither researcher nor owner could identify the dog's intended goal. All bouts of *Unknown* tool use resulted in an unsuccessful outcome (i.e. the goal was not achieved).

Unsuccessful outcomes occurred in relatively low frequencies in four (*Open, Insert & Probe, Scratch & Rub, Climb On*) of the eight modes of tool use and three modes (*Pick Up, Throw, Move*) were successful 100% of the time. However, the *Reach & Give* mode had the highest number of unsuccessful outcomes. From the data, I found the *Reach & Give* mode elicited three apparent goals: attain canine food/drink, wanting their lead put on, and attain human food/drink. I analysed these episodes further by considering the percentage of successful and unsuccessful outcomes of the specific goals that this mode is used to achieve (Table 4.5).

Table 4.5 Percentages of successful and unsuccessful outcomes of the goals related to the *Reach & Give* mode of tool use.

Outcome	***Reach & Give* Goal**		
	Canine Food/Drink	Human Food/Drink	Wanting Lead On
Successful (%)	95.1	37.5	88.9
Unsuccessful (%)	4.9	62.5	11.1
(*n*)	82	24	9

With the canine food/drink and wanting lead on goals, successful outcomes were achieved more often than unsuccessful outcomes, 95.12% and 88.89% of events respectively. Interestingly this is not the case for the human food/drink goal. The human food/drink goal elicited more unsuccessful outcomes (62.50%) than successful ones (37.50%).

Additionally, a multinomial logistic regression revealed that dog social tool using success is affected by the amount of handling by the owners (P=0.027), (i.e. being picked up). However, house rules, such as being allowed on furniture (P=0.863), and the size of the dog (P=0.410) did not affect dog tool using success.

4.5 DISCUSSION

The results from this study show that during cross-species interactions with humans domestic dogs may be doing something more than merely 'simple' communication. They are performing goal-directed behaviours and recruiting humans to achieve an apparent aim which they themselves cannot reach. All dogs observed in this study performed communicative behaviours which conformed to the criteria of social tool use. Owners were asked to look for eight potential modes when collecting footage for the study and evidence was found for all eight. The results show that dogs use a range of communicative gestures and vocalisations to successfully solicit and recruit their human-group members in order to gain access to an apparent goal. The results reported here raise questions as to the factors that favour these types of behaviours in dogs and I shall discuss some relevant points of interest.

Social Tool Use: An Ecological Adaptation?

It has been argued that tool use reflects specific ecological needs and is therefore thought of as an adaptation to environmental conditions (Byrne, 1995). This has been shown in non-human primates; for example, a Western gorilla (*Gorilla gorilla*) demonstrated special tool using and behavioural adaptations in a swamp habitat on the forest edge of Mbeli Bai (Breuer et al., 2005), and chimpanzees at Bossou use tools to overcome the scarcity and fluctuation of their main food source (Yamakoshi, 1998).

The evidence of social tool use in domestic dogs from this study also supports the argument that tool use reflects ecological needs. The domestication process resulted in dogs living sympatrically with humans across the entire globe causing a major change in the realised ecological niche for the species. This meant that dogs have had to develop specific adaptations to overcome the demands of the anthropogenic environment (Miklósi, 2007). One way in which they achieved this was by soliciting help from humans to solve problems (Hare, 2004), thus using them as social tools. The cases reported here are the first observations of domestic dogs using humans as social tools to overcome ecological obstacles.

Cognitive researchers have argued that evidence of specific cognitive abilities within a species with high social intelligence would be more evident in the social domain rather than the physical (Cheney et al., 1995; Zuberbühler, 2000 a, b). If this is the case then social tool use should occur in a variety of species, including those lacking a means to physically manipulate objects. To better understand the evolutionary origins of social tool use more research needs to be conducted on the ability. However, the evidence from the current study indicates that social tool use is indeed a result of adaptations to the ecological environment in a socially intelligent species.

Benefits of Social Tool Use

It is thought that the main benefit of classical tool use is to facilitate access to food that is difficult to process (Alcock, 1972; Parker & Gibson, 1977). The data revealed that the mode of tool use related to receiving food, *Reach & Give*, had the highest number of total observations (114) and was observed in the highest number of subjects (34). Thus suggesting that, like classical tool using species, the most common form of social tool use in dogs involves attaining inaccessible food.

Another benefit of classical tool use is defence. The veined octopus (*Amphioctopus marginatus*), for example, carries coconut shells to use as shelter when a threat approaches (Finn et al., 2009). Given the unpredictability and danger of natural environments using tools in a defensive manner is an obvious benefit for a wild species. However, this is not necessarily the case for a domesticated animal. For a domesticated animal, the anthropogenic world is a relatively safe environment to live in, and although dogs look to humans for protection and comfort in strange situations (Topál et al., 2005; Palmer & Custance, 2008) the evidence from the current study suggests that they do not use them as a defensive tool.

The results from this study imply that dogs employ their human group members as protective rather than defensive tools. One dog, for example, was fearful of laminate flooring and utilised the mode *Pick Up* to employ his owner into carrying him over the flooring and to a "safe" location. Other subjects performed the mode *Move* to employ their owners into moving undesirable objects that were blocking their path or into moving desirable objects away from elements they are fearful of. Dogs, therefore, employ humans into protective social tools to avoid fearful agents within the anthropogenic environment.

The observations from the study suggest an additional benefit of social tool use specific to domestic dogs may be bonding tools. All modes of social tool use discussed in this study aid in the improvement of dog-human communication, which in turn enhances the bond between human and dog. For example, *Throw* and *Insert & Probe* are related to play activities. As well as building up the relationship between owner and dog, playing with a dog results in health and learning benefits allowing dogs to become well-adjusted members of the human family (Miller, 2008). Furthermore, play behaviour in dogs is an indication of positive welfare (Rooney & Bradshaw, 2014) and research has demonstrated that high levels of play strengthen the bond between owner and dog (Bradshaw et al., 2015).

Scratch & Rub and *Climb On* both involve physical interactions between owner and dog. When stroking a dog oxytocin (also known as the 'love hormone' related to nurturing and attachment), is produced in the brains of both humans and dogs (Nagasawa et al., 2015). The contact between owner and dog which these modes initiate is essential for developing a strong relationship between the two species. Thus, bonding may play a role in the development of social tool use in domestic dogs.

Issues with the label 'Social Tool Use'

Research has revealed impressive cognitive abilities in domestic dogs (Miklósi, 2007) but their abilities as tool users have previously failed to impress until now. The discovery of gestures/vocalisations that conform to social tool use in a previously unsuccessful tool using species is an exciting prospect. It suggests that other social species who are unable to grip, hold and manipulate physical tools (mouths notwithstanding) may instead be able to employ other individuals into social tools. However, is social tool use the correct label to use for these types of interactions or are we in need of a new terminology for this form of communication?

Communication can be defined as sending a signal to influence an intended receiver’s behaviour that is advantageous for the sender (Maynard-Smith & Harper, 1995). It could be argued by communicative researchers that the dogs in the current study are merely communicating with their owners and that re-defining well known communicative interactions as 'social tool use' may cause unnecessary confusion. The results seen here, however, imply that dogs are not simply directing a receiver to a target, but are preforming goal-directed behaviours and soliciting/recruiting humans to achieve an apparent aim. Interestingly, this study revealed that dogs are similar to human infants as they use gestures to enlist assistance from adults to obtain out-of-reach objects (Bard, 1990). Moreover, the gestures observed in dogs contain both a motivational dimension (the apparent goal underlying the employment) and an instrumental dimension (the means-end employment of the human) (Völter et al., 2015). There are, however, problems in labelling these types of gestures as ‘tool use’.

The first issue which arises with the label, social tool use, is the definition of the ability. A clear and accurate definition of tool use is essential for any attempt to better understand the nature of the ability within a species (St Amant & Horton, 2008). Without identifying the essential characteristics of tool use a meaningful investigation cannot be carried out. Over the years a vast number of definitions for tool use have been put forward, and the definition most frequently adopted by researchers is that of Beck (1980). Although Beck’s definition remains as the most influential in the field 38 years after its publication, it fails to take into consideration the phenomena of social tool use.

Indeed, most definitions of tool use exclude the use of an organism as a tool (e.g. Alcock, 1972; Pierce, 1986; Boesch & Boesch, 1990; St Amant & Horton, 2008), and the definition of social tool use put forth by Völter et al. (2015) excludes classical tool using abilities. If there were to be a definition that encompasses both forms of tool using behaviours it would be similar to the one put forth for this study:

> Tool use involves the deliberate employment of an object or another living organism with the aim of changing the properties of an otherwise unobtainable goal. The

gestures performed by the tool user are the sole factor responsible for directing the tool towards the user's apparent goal.

Researchers could consider having two separate definitions for both classical and social tool use. This, however, raises more questions than answers. Are animals who only demonstrate one form of tool use less cognitively augmented than those that show both? Do we categorise classical and social tool use as two separate abilities and if so, can they then both be classified as tool use? In addition, are the underlying cognitive mechanisms needed for classical and social tool use the same or different, if they are similar shouldn't they be grouped into one comprehensive definition? Therefore, if we continue to refer to the gestures seen in this study as a form of tool use, the field would require a new, precise and comprehensive definition, encompassing both classical and social tool use, to be created and accepted.

Although a straightforward definition for social tool use is provided by Völter et al. (2015) which encompasses goal-directedness and recruitment of another organism it is not without its drawbacks. It lacks the robustness that the most popular tool use definitions have (e.g. Beck, 1980). Moreover, the use of the term "psychological manipulations" in the definition raises a number of questions due to the difficulty of demonstrating its occurrence in a non-human species.

The use of 'manipulation' is a further issue that arises when using the label 'tool use' to define the type of communication seen in these interactions. "Manipulation" is used frequently in tool use investigations but in another area of cognitive science the term has a different meaning. In tool use research, manipulate is used when referring to an individual handling or controlling a tool (St Amant & Horton, 2008). In social intelligence research, however, manipulation takes on another, more cognitive, meaning. There, manipulation refers to the skilful influence and deception of social companions (*sensu* Whiten & Byrne, 1997).

The definition given by Völter et al. (2015) states "psychological manipulations of animate beings" as being a defining principle of social tool use. We are, however, faced with two meanings for manipulation from two areas of cognitive research. What is meant by 'manipulation' is not defined in social tool use and both of these definitions can be applied to the types of communication observed. This then prevents us from fully exploring the cognitive complexity of social tool using interactions. Moreover, it could be automatically assumed that an individual who demonstrates social tool using skills is also capable of social intelligence as they are able to ‘manipulate’ another individual, therefore, creating unnecessary confusion for researchers.

There has also been some confusion amongst researchers about what constitutes the ‘tool’ in social tool use. It has been stated that the ‘tool’ during these types of interactions is the communicative gestures in which they use to recruit the intended recipient (Frye, 1981; Bates et al., 1979; Bard, 1990). Whereas other researchers state that the ‘tool’ is the organism that the individual is communicating with (Hare, 2004; Völter et al., 2015). This could be a result of the lack of a clear, robust definition for social tool. It does, however, question what actually constitutes social tool use.

Given the issues which arise when we label something as ‘social tool use’ and what dogs are doing here is more than ‘simple’ communication, perhaps a better terminology for these types of interactions would be *goal attainment recruitment* rather than social tool use. The term, *goal attainment recruitment*, can be defined as employing another individual through communication in order to achieve an inaccessible goal. It considers the areas of goal-directedness, recruitment of another individual and communicative skills, thus allowing for the better exploration of the cognition underlying the ability.

Limitations of the Current Study

Similarly to the previous chapter this study did not assess whether neutering and the age at which it was done has an impact on a dogs’ ability to recruit humans to achieve an apparent goal. Neutering, particularly in males, has an effect on a dogs aggressive tendencies and makes aggression less likely (Stubbs & Bloomberg, 1995). Given this it is possible that non-neutered dogs may demonstrate more aggressive communicative gestures when attempting to recruit humans. This, in turn, may affect their goal attainment success rate as humans are less likely to respond to aggressive dogs (Bradshaw et al., 2009). It has also been suggested that neutering a dog at an early age (before 12 months old) can keep a dog in an almost puppy-like behavioural state (Olsen et al., 2001). It could be that keeping a dog in this puppy-like state may make them more likely to request assistance from humans compared to those dogs who are neutered later or not neutered at all.

Further research is needed to determine how and if neutering has an impact on a dog’s ability to recruit humans to achieve an apparent goal by comparing the communicative gestures of neutered and non-neutered individuals. This can then be further explored by comparing the communicative gestures of individuals who were neutered at different ages (i.e. before six months, six-12 months, 11-17 months etc.) to see if any differences are present. This would allow us to determine if any differences occur and whether they have a negative or positive impact of their abilities.

Also, differences between breeds were not considered in the current study. Although all the dogs who were part of the current study were companion dogs, certain breeds were and still are bred for specific purposes (this is mentioned in the previous chapter). Breed intelligence may also factor into an individuals' ability to recruit humans. German Shepherds, Border Collies and Poodles are often ranked as the top three most intelligent dog breeds as they learn simple tasks quickly obey commands given the first time over 95% of the time (Coren, 1994). Future research should investigate this further to determine if a difference between breeds is present and if certain breeds are more successful 'tool users' than others.

Another limitation to the present study are the lack of analyses concerning multi-dog and single-dog households and therefore it is not known how regular contact with another conspecific impacts a dog's abilities as a social tool user. Previous research has shown that dogs learn from other dogs especially in the context of play (Horowtiz & Hecht, 2016). It is therefore possible that dogs who interact with other dogs on a regular basis would differ in their abilities compared to those dogs who solely live with humans.

The amount (i.e. basic puppy training, regular training class attendee etc.) and type of training (i.e. home trained, professionally trained etc.) the individual dogs had before participating in the study is not examined. Furthermore, the current study collected no data on the type of training model owners have used to train their dogs as this could potentially have an impact on a dog's repertoire. Almost all companion dogs receive some form of training, and research has shown that training experiences influence dogs' performance during problem solving tasks (Marshall-Pescini et al., 2008) so it is possible that the amount and type of training dogs are exposed to may affect how they communicate with and recruit their cross-species companions.

Given that specific training methods influence our opinion of how dogs view us (Hiby et al., 2004; Bradshaw, 2012) it is possible that they may also affect how a dog learns and develops its social tool using communicative repertoire. It is likely that those dogs who have been trained using the ‘wolf-pack theory’ model (see chapter 3) could have a more submissive or subtle way of recruiting humans compared to those who have been trained using positive reinforcement who may be more boisterous or inventive with their social tool using repertoires. It is therefore not currently known how training affects the communicative repertoire of dogs and future researchers should consider conducting further investigations into this.

Furthermore, this study does not assess how dogs have acquired their social tool using abilities. It is suggested here that they developed as an environmental adaptation. Research has shown that dogs will request assistance from humans when faced with an impossible task whereas hand-raised wolves will attempt to solve the problem with no assistance (Miklósi et al., 2003b). Therefore, it is likely that the domestication process has had an impact on dogs’ abilities but as this was not investigated in the current study no firm conclusions can be drawn. Future researchers should consider exploring how and why dogs possess these abilities in order to better understand their social cognition and cross-species communicative skills.

Conclusion

This study has revealed that during cross-species interactions dogs are doing something more than mere ‘simple’ communication. They are performing goal-directed behaviours and recruiting humans to achieve an apparent aim which they themselves cannot reach, thus demonstrating social tool using behaviour. The data suggests that the benefits of using tools are similar between non-human primates and dogs. The main benefit for using tools is food acquisition (Boesch & Boesch, 1990) and the results from the current study reflect this. However, the results point toward two more benefits of domestic dog tool use that are not specific to non-human primates: protection and bonding. These benefits are most likely related to the anthropogenic environment and given that the ability to use tools evolved as an adaptation to environmental conditions (Byrne, 1995); they are therefore not expected to be reported in wild tool using species. It is, however, hoped that future research will explore social tool use in domestic animals to further reveal the benefits of using group mates as tools.

The ability to use social tools is perhaps more cognitively demanding than classical tool use. Social tool use involves employing another organism (presumably with its own free will) which is more cognitively challenging than controlling an inanimate object. The ability also requires an individual to remember previous interactions with group mates to understand and remember how to employ them as a tool. Furthermore, this study revealed the occurrence of cross-species social tool use in domestic dogs. Successfully employing heterospecifics requires an individual to undertake the cognitively demanding task of understanding the behaviours and actions of another species, which, in domestic dogs, most likely arose because of the domestication process.

Dogs are, therefore, using their cross-species communicative abilities to recruit heterospecifics to assist them in achieving an apparent aim, which conforms to the criteria of social tool use. As discussed previously, there are issues with grouping the gestures seen here into the category of tool use. Given these concerns, I suggest a new term for these types of interactions: *goal attainment recruitment*. If adopted by the wider research community, this term could aid in our understanding of these types of interactions as well as enhancing our knowledge of conspecific and heterospecific communication within a species.

5. DO DOGS UNDERSTAND HUMAN RECEIVE-REQUEST PHRASES?

This thesis has demonstrated that domestic dogs are skilled at communicating with humans using both gestures and vocalisations. Humans too can successfully understand and respond correctly to the communicative actions produced by dogs. However, to fully understand the cross-species communicative abilities of dogs we need to investigate whether they can correctly interpret the primary mode of human communication: language.

5.1 Cross-Species Vocal Communication in Mammals

Numerous species are adept at responding to the vocal cues of conspecific group mates. Indeed, research has shown that female De Brazza monkeys (*Cercopithecus neglectus*), Campbell's monkeys (*Cercopithecus campbelli*), Guereza colobus monkeys (*Colobus guereza*) and red-capped mangabeys (*Cercocebus torquatus*) can discriminate between the contact calls of familiar and unfamiliar conspecifics (Candiotti et al., 2013). Without vocal communication female African elephants (*Loxodonta africana*) would be unable to coordinate movement and reunite separated group mates (Soltis, 2009). During mating seasons without producing what is referred to as a song vocalisation, male humpback whales (*Megaptera novaeangliae*) would be unable to ward off rival males and attract females (Darling et al., 2006). Vocal communication is also vital for solitary animal species, as it plays an important role throughout their lives, for example during mating season (Shorey, 1976).

Evidence of cross-species vocal communication is, however, lacking in wild species. Research has revealed that some primate species understand calls of other primate species. Male Campbell's monkeys, for example, understand and appropriately respond to the predator-specific alarm calls of sympatric male Diana monkeys (*Cercopithecus diana*) (Zuberbühler, 2001). However, although those species have demonstrated the ability to understand heterospecific calls they do not interact or directly communicate with heterospecifics regularly.

Interestingly it has been shown that killer whales who have been housed with dolphins for several years engage in cross-species vocal learning (Musser et al., 2014). Whales shifted the proportions (such as pitch, duration and pulse pattern) of different call types to more closely match dolphin calls (Musser et al., 2014). However, that study failed to identify whether those species are able to successfully communicate with each other. Moreover, it involved only three captive killer whale subjects who had been artificially housed with dolphins, and although they all demonstrated cross-species vocal learning we do not know the extent to which they communicate with heterospecifics in the wild.

Domestic animals, however, frequently interact with heterospecifics and have developed specific adaptations enabling them to thrive in the anthropogenic environment alongside humans. To date, research has documented the communication that occurs between horses (*Equus caballus*) and humans (Brandt, 2004) and cats (*Felis catus*) and humans (Merola et al., 2015), but little research has been conducted so evidence is sparse. One domesticated species, however, has received much research attention and demonstrated an array cross-species vocal communicative abilities: the domestic dog.

5.1.2 Good Boy! Do Dogs Understand What We are Saying?

Almost every dog owner will claim that their dog ‘knows’ what they are saying and has an advanced understanding of human language (Pongrácz et al., 2005). Interestingly humans can correctly classify the emotional content of dog barks recorded in differing scenarios regardless of previous experiences with dogs (Pongrácz et al., 2005), suggesting that barks are an effective means of communication between humans and dogs. Less is currently known about to what extent dogs understand human vocalisations.

Pongrácz et al. (2001a) define social understanding as “a complex cognitive process in which the subject is able to integrate contextual and social information and modify his/her behaviour accordingly” (p. 87). When it comes to dogs understanding human verbal communication, the accompanying contextual cues and gestures performed by humans could facilitate this understanding (Pongrácz et al., 2001a).

Indeed, domestication has led to dogs becoming particularly sensitive to human-given cues through selective breeding for the trait (see Kaminski & Nitzschner, 2013 for a review) and are highly attentive to what their human group members are doing (Bräuer, 2014). Furthermore, non-verbal features such as posture, eye contact, mode of delivery (i.e. tape recording) (Fukuzawa et al., 2004) and phonetic characteristics (Fukuzawa et al., 2005) affect dogs’ responsiveness to verbal commands given by humans. Therefore, to understand human vocal commands a dog must understand and process simultaneously both visual and verbal cues produced by the requesting human. This integrated, cross-modal sensory process would imply that dogs’ understanding of human verbal cues is cognitively demanding.

There have been cases of several individual dogs around the world of dogs learning words (Warden & Warner, 1928; Pilley & Reid, 2011; Griebel & Oller, 2012; Pilley, 2013). One of the first to be studied (and most well-known) was a border collie who was reported by his owners to know the names of over 200 objects, mainly toys (Kaminski et al., 2004). When his owners called the name of a specific object Rico would fetch the requested object even when it was placed in another room (Kaminski et al., 2004). Moreover, when a novel object with a new name was introduced, Rico could link the new word to the novel item and fetch that when asked to by his owner, a cognitive process known as 'fast-mapping' (Kaminski et al., 2004).

This research by Kaminski et al. (2004), should be viewed with caution as it involved the testing of a single subject, a border collie, which have been specifically bred for their intelligence and their ability to respond to human signals and commands (Griebel & Oller, 2012). Although other studies have found similar results in a subject of a different breed (Ramos & Ades, 2012), currently it is not known how dogs as a species fair in these kinds of trials. Owners have reported, however, that their dogs have a very developed understanding of words and vocal commands are frequently used by dog trainers to successfully produce and control behaviours (Ramos & Ades, 2012). Therefore it can be assumed that dogs do possess some understanding of human-given vocal cues.

Recent research has also revealed that dog brains process human language in a similar way to humans (Andics et al., 2014). Using an MRI scanner, 13 dogs were trained to lie awake in the scanner and their brain functions monitored when researchers spoke to them. They found that dogs understand the messages behind specific sounds (words) produced by humans, implying that dogs can understand aspects of the human language. However, that study involved a large amount of pre-trial training in order to get the dogs to lie completely still in the scanner and has a relatively small sample size (*n*=13). It is therefore not known how the pre-trial training affected the dogs' responses, as a control with untrained dogs cannot be conducted.

More recent research, however, has revealed that dogs of various breeds show a preference for naturalistic dog-directed speech and are more attentive to human speech containing dog-relevant words (Benjamin & Slocombe, 2018). The speech used in experiment one of that study involved various good dog praising phrases in which a preference for dog directed speech was found. In the second experiment the researchers included numerous 'walkies' phrases alongside the good dog phrases. They found that dogs' attention to the speaker was improved when the phrases contained both dog-relevant content and dog-directed prosody and this increase in attention may strengthen the bond between owner and dog (Benjamin & Slocombe, 2018). This suggests that dogs are able to recognise human speech that is aimed at and relevant to them.

That study, however, recruited its dogs from and conducted their experiments at a boarding kennel. Research has shown that placing a dog in kennels is an effective stressor for dogs as it involves separation from the owner and exposure to novel environments (Hennessy et al., 1997, 1998; Rooney et al., 2007). Over time it is likely that dogs will become more settled in the kennel environment but the Benjamin and Slocombe (2018) study fails to state how long the dogs had been in the kennels or whether they were frequent or first-time visitors. It is therefore not known how the environment affected their responses during the experimental procedures. Moreover, the speech was given by an unfamiliar individual. Given that research has shown that dogs show preferences for familiar over unfamiliar human voices (Berns et al., 2015) and the added stressors of being placed in a boarding kennel (Rooney et al., 2007) brings into question the validity of the results. Therefore, how they respond to untrained vocal cues given by familiar and unfamiliar individuals in a naturalistic setting has yet to be explored in the field (Bensky et al., 2013).

5.3 The Present Study

Previous research has suggested that dogs do understand human verbal cues. Those studies however, involved small sample sizes (*n*=1 or *n*=13) and direct training from owners or the investigators. A number of those studies also placed their focus on one specific breed known for possessing high intelligence, the border collie (Coren,1994). Much of the research has also focused on dogs' responsiveness to action requests: 'sit', 'roll over', 'give me paw'; and object request phrases: 'get piggy' or 'fetch the ball', (Ramos & Ades, 2012). Both cases involve the dogs performing actions for the requesting human to achieve an outcome. Those phrases, although used in 'everyday' dog-human communication are specifically learned through training, i.e. the owner is actively training the dog to produce a specific behaviour in response to the phrases. To date, little research has been conducted investigating dogs' ability to respond to untrained phrases.

The current study aims to investigate dogs' ability to understand receive-request phrases spoken by both familiar and unfamiliar humans. Examples of receive-request phrases being used in this study include, 'do you want a treat?', 'walkies?' and 'shall we go outside?' etc. They are phrases which involve a canine-beneficial goal that can only be achieved by a human. Unlike action and object request phrases, receive-request phrases involve a response from the dog which has not directly been trained by a human. Dogs can therefore produce a variety of unintentionally trained communicative responses to receive-request calls. With object and action request phrases, however, dogs are expected to produce a specific behaviour in response, i.e. when 'fetch the ball' is spoken the only accepted response which suggests the dog understood the phrase would be the production of the ball. With receive-request phrases a single specific behaviour is not expected, therefore dogs can produce a variety of communicative responses to demonstrate their understanding of the call, thus making receive-request phrases interesting to study.

5.3.1 Justification and Aims

The current study will test the hypothesis that dogs recognise a previously unexplored area of human language, receive-request phrases. It will also explore whether dogs' reactions differ to these phrases when they are spoken by both a familiar and unfamiliar individual. If dogs are found to understand receive-request phrases it is predicted that dogs will react for longer to phrases spoken by the primary provider (owner) as, unlike the unusual caller (researcher), the primary provider is the individual who would usually perform the phrase being spoken. The current study will compare dogs' reactions to control calls (an unfamiliar phrase) and receive-request phrases. If the prediction that dogs' reactions will be stronger to the receive-request phrases is correct, it will demonstrate that they recognise the call. This will then provide researchers with a foundation of knowledge on which to investigate the phenomenon further. Furthermore, it will provide evidence for an understanding of receive-request phrases regardless of familiarity to the caller.

5.4 EXPERIMENTAL DESIGN

5.4.1 Specific Procedure and Design

The experimental design for testing this hypothesis was similar to previous cognitive playback studies on non-human primates (Cheney & Seyfarth, 1980; Wittig et al., 2007a, b; Borgeaud et al., 2013, 2015). Those non-human primate studies involved recording conflict or distress vocalisations during naturally occurring events and playing those recordings back to subjects later. However, in this study the human participants directly called to the canine subjects during the trials in what I refer to as callback experiments (p. 22).

Filming was conducted by the researcher and began 10 seconds prior to the production of the call once the dog had moved to the centre of the room. There were a total of three testing periods (food call, toy call and out/walk call) and one control period (p. 22), with two trials in each period (primary provider call and unusual call) and a 10-minute break in between each trial. The dog's behavioural responses were measured for 36 seconds after the final call. It is important to mention that actual phrases differed between households as they were the 'everyday' calls used by owners, for example some owners would say 'walkies' others would say 'do you want to go for a walk?'.

A control call, which involved both the researcher and the primary provider calling a phrase (ven aquí perro) in an unfamiliar language (Spanish), also took place to determine whether the subjects understood the receive-request calls. The callback trials (test and control) and the caller (primary provider and experimenter) were performed in a randomised sequence to eliminate order effects. This was determined through the use of a randomiser application which the researcher had installed on their mobile phone (Randomiser, developed by Rob Sammons for iOS 9.0). If the experimenter was the one calling they used the same valence that the owner did when they called to the dog. How to speak to the canine subject was discussed away from the subject with the primary provider before the experiment took place.

An argument could be put forth for there being a Clever Hans effect (Davis & Memmott, 1982) between callers and dogs during experimental trials (i.e. the owners unintentionally influencing the dogs' reactions to the calls). However, before the start of the trial callers were instructed to not move from the position they chose when the experiment began. They could, however, stand up or sit down if they wished but could not move around the room. Given that accompanying contextual cues and gestures performed by humans aid in dogs' understanding of human phrases (Pongrácz et al., 2001b), callers were instructed that they could perform a few non-referential actions during the trial period. However, any actions produced by callers were actions that would naturally be performed when asking the dog that specific phrase.

The actions performed by humans during trial periods involved standing up or arm movements performed either sitting or standing (Figure 5.1). Callers did not gesture or look towards the goal object (as that was usually located in another room), gazes were directed towards the dog or the other present individual and phrases were spoken with a natural valence. Therefore, callers were not presented with an opportunity to unintentionally produce cues that the dogs could respond to and thus affect the results.

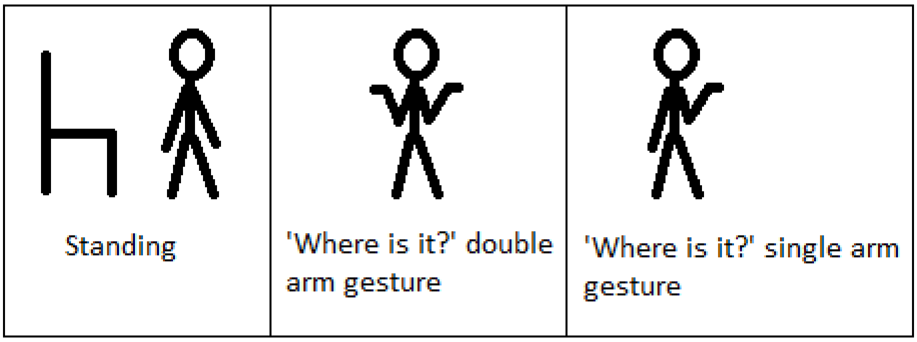


Figure 5.1 Diagram of actions performed by callers during trials (arm gestures were performed either sitting or standing).

5.4.2 Definition of a Look

To analyse the looking behaviours of dogs during the experimental phase it was important to define a 'look'. In their study on chacma baboons Wittig et al., (2007b) defined a 'look' as "a head orientation directly towards the speaker." Although before the start of the experimental trials this definition was adopted when it came to analysing the pilot study videos the definition fell short. A 'look' began after the first call and from the preliminary data, it was found that a 'look' did not necessarily begin with a head orientation but with a movement of the eyes. Therefore, the definition put forth by Wittig et al., (2007b) failed to consider certain looks given by dogs as they only moved their eyes towards a speaker and did not orientate their head directly towards them. Furthermore, their definition did not allow for an accurate representation for the start of a 'look' which, in dogs, begins with a movement of the eyes towards a specific object or organism (Figure 6.2).

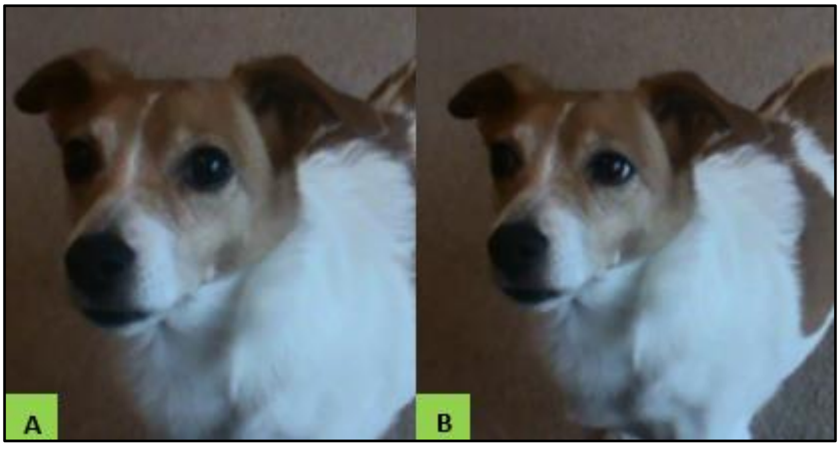


Figure 5.2 Definition of a look.

A) The subjects head is orientated towards the unusual caller with her eyes looking at that individual. B) The subjects head is still orientated towards the unusual caller but her eyes are looking right towards the primary provider, according to Wittig et al. (2007b) figure 5.2b would not be defined as a new ‘look’ but a continuation of the ‘look’ from figure 5.2a. I therefore defined a ‘look’ as eye orientation directly towards a specific object or organism.

5.4.3 Analyses

In coding experiments three different responses were measured: orientating frequencies, the duration of first look (after the first call) and the total looking/behaviour time following the third and final call. The data collected during the experimental trials were analysed using a Shapiro-Wilk test to test for normality with P value set at 0.05. This determined that the data was nonparametric and were therefore later statistically analysed using Wilcoxon signed-ranks tests. Cohen’s kappa was also conducted to determine and assess inter-observer reliability on a randomly selected cohort of test and control data (n=10).

5.5 RESULTS

A total of 77 trials, each with two call conditions (primary provider and unusual caller), were performed with 31 domestic dogs (12 male, 19 female) to determine if dogs can recognise human verbal phrases, 31 control trials (with two conditions) were also conducted.

Do Domestic Dogs Understand Receive-Request Phrases?

A Wilcoxon-signed ranks test was performed to determine if there was a significant difference between the orientating frequencies, duration of first look, total looking/behaviour time and number of looks in the control and test trials. During the experimental trials the subjects could orientate towards either the primary provider or the unusual caller, both the primary provider & unusual caller or could show no reaction to the call. Orientating frequencies differed between control and test trials with more variation during test trials in both the primary provider (Z=-2.529, n=31, P=0.009) and unusual caller (Z=-3.674, n=31, P<0.001).

The duration of first look was longer during the unusual caller test trial (Z=-2.508, n=31, P=0.011). However, no difference was found between the control and test trials for the duration of first look in the primary provider condition (Z=-1.862, n=31, P=0.063).

Both primary provider (Z=-3.665, n=31, P<0.001) and unusual caller (Z=-4.017, n=31, P<0.001) total looking/behaviour time was longer during test trials; and the number of looks a dog performed were greater during test trials in both primary provider conditions (*Z*=-3.197, *n*=31, *P*<0.001) and unusual caller conditions (*Z*=-3.628, *n*=31, *P*<0.001).

Inter-Observer Reliability

A very good inter-observer agreement for duration of first look, kappa=0.871, *P*<0.001 and total looking/behaviour time, kappa=0.807, *P*<0.001 was revealed. Perfect agreement was also found between the two observers in number of looks towards the primary provider, kappa=1.000, *P*<0.001, and the unusual caller kappa=1.000, *P*<0.001.

For the control trials, almost perfect agreement between the two observers was found for both primary provider and unusual caller duration of first look, k=0.930, *P*=<0.001, total looking/behaviour time, k=0.953, *P*=<0.001, and number of looks towards the primary provider, k=0.973, *P*=<0.001. Perfect agreement was revealed between the two observers in number of looks towards the unusual caller, k=1.000, *P*=<0.001.

Do Dogs' Reactions to Receive-Request Phrases Differ When Spoken by a Familiar and Unfamiliar Individual?

Orientating Frequencies

The orientating frequencies of dogs during the primary provider and unusual caller condition are shown in figure 5.3. If no reaction was recorded in all the trials it would suggest that dogs do not recognise receive-request phrases. Only 1% of trials resulted in a no reaction, all in the unusual caller condition.

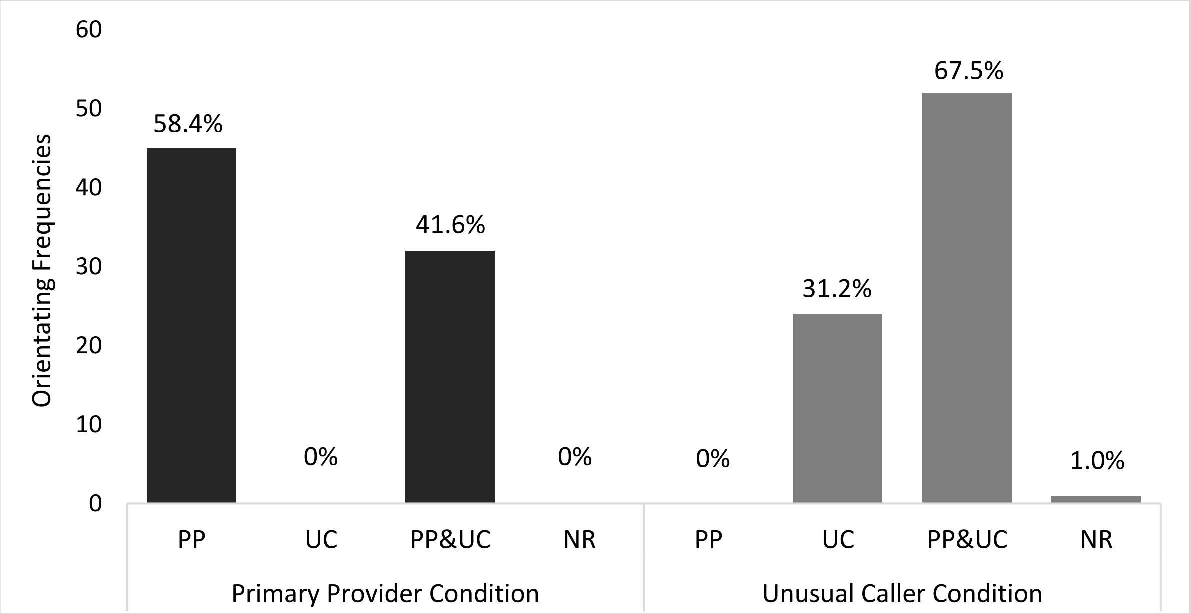


Figure 5.3 Orientating frequencies of dogs during primary provider (PP) and unusual caller (UC) conditions alongside any no reactions (NR) recorded.

Duration of First Look

In 36 trials subjects' first look was longer towards the unusual caller (M= 3.99, SD= 4.95, *n*=77), while in 41 trials their first look was longer towards the primary provider (M= 4.94, SD=5.44, *n*=77); no difference was found between the duration of first look towards the primary provider and unusual caller (*Z*=-1.315, *n*=77, *P*=0.190).

Number of Looks

Dogs looked more times toward the primary provider in the primary provider condition (*Z*=-7.529, *n*=77, *P*<0.001) and more toward the unusual caller in the unusual caller condition (*Z*=-5.347, *n*=77, *P*<0.001) (Figure 5.4).

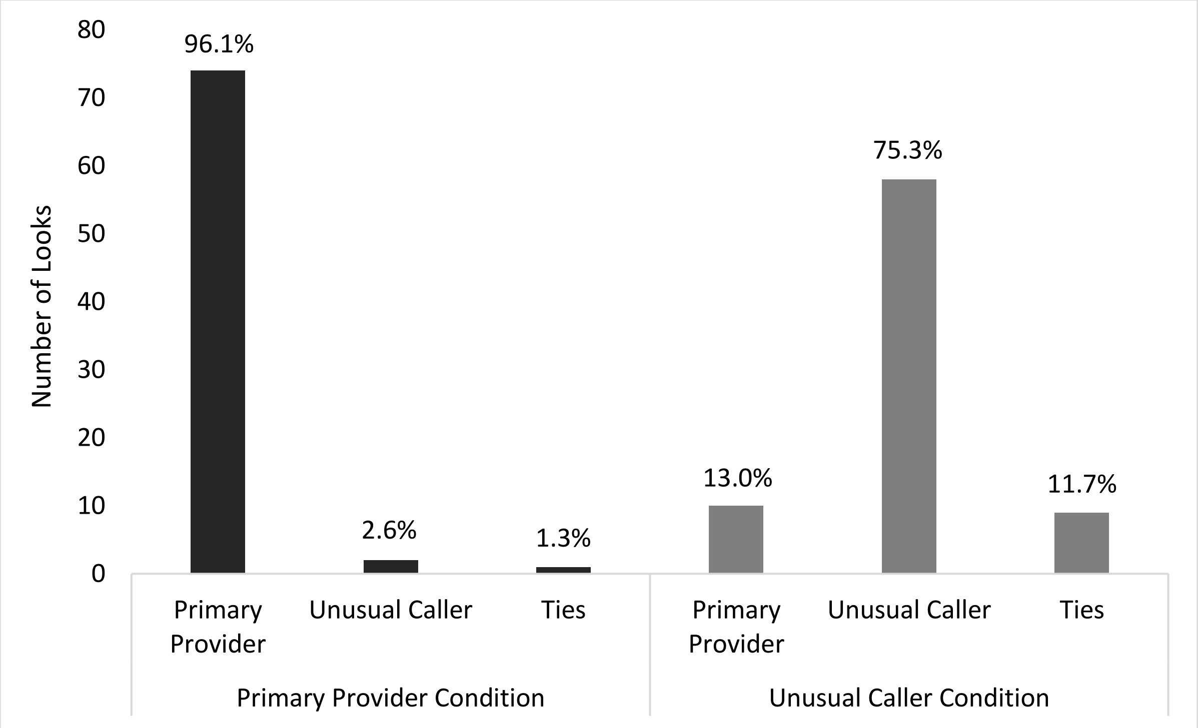


Figure 5.4 Number of looks in the primary provider and unusual caller condition.

Total Looking/Behaviour Time

There was a significant difference between the unusual caller and primary provider total looking/behaviour times (*Z*=-2.831, *n*=77, *P*=0.004). In 33 trials dogs' behavioural responses lasted for longer towards the unusual caller than the primary provider, but in 43 trials total looking/behaviour time was longer towards the primary provider.

In 32 primary provider trials and 51 unusual caller trials dogs' total looking/behaviour time was split between both the primary provider and unusual caller. In these cases, I went back to the videos and analysed them further to determine the total looking/behaviour time spent towards each caller. In the 32 primary provider trials dogs reacted for longer towards the primary provider (100% of cases) (*Z*=-4.937, *n*=32, *P*<0.001) and in the 51 unusual caller trials dogs reacted for longer towards the unusual caller in 53 cases (*Z*=-3.567, *n*=51, *P*<0.001). In the unusual caller trials, subjects reacted for longer towards the primary provider in 22 cases and were tied in 2 trials.

Control Calls

Dogs orientated more towards the primary provider in the primary provider control with more variation in orientating frequencies observed in the unusual caller control (Figure 5.5).

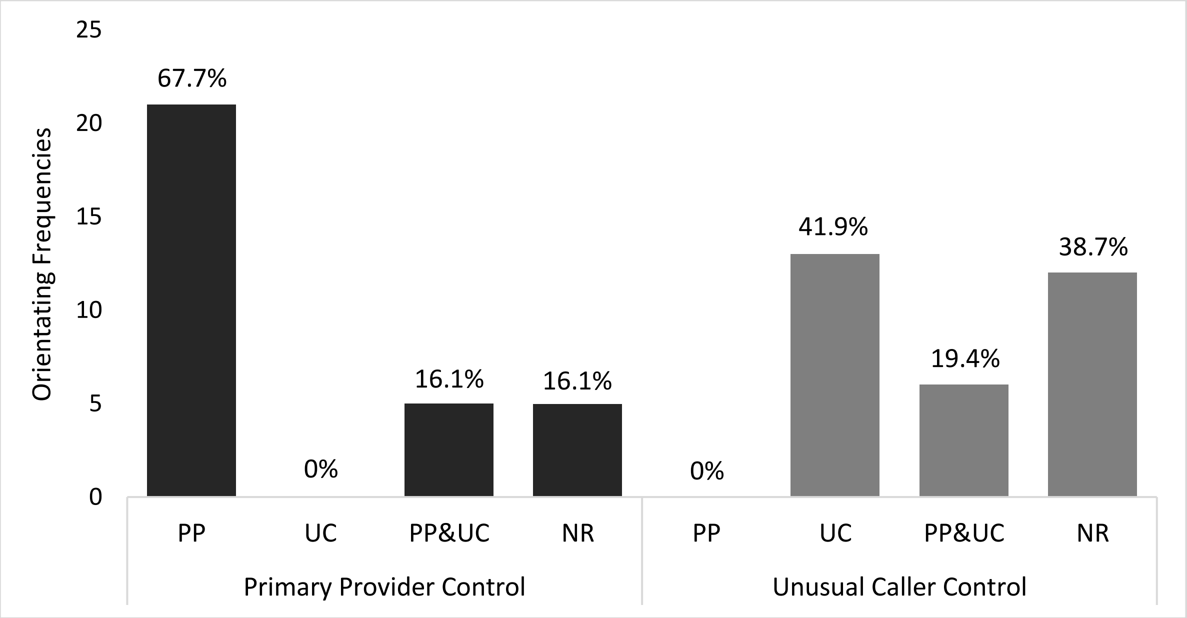


Figure 5.5 Orientating frequencies of dogs during control trials in the primary provider (PP) and unusual caller (UC) conditions alongside any no reactions (NR) recorded.

In control trials dog's duration of first look (*Z*=-2.070, *n*=31, *P*=0.038) and total looking/behaviour time (*Z*=-4.026, *n*=31, *P*<0.001) was longer in the primary provider condition compared to the unusual caller condition. Dogs also looked more times towards the primary provider in primary provider control condition (*Z*=-4.416, *n*=31, *P*<0.001), and more towards the unusual caller in the unusual caller control condition (*Z*=-3.808, *n*=31, *P*<0.001).

In order to determine if dogs recognise receive-request phrases the data from the control and test trials were compared. This revealed that test trials had greater orientating frequency in both primary provider (*Z*=-2.529, *n*=31, *P*=0.009) and unusual caller (*Z*=-3.674, *n*=31, *P*<0.001) conditions; a longer duration of first look in the unusual caller (*Z*=-2.508, *n*=31, *P*=0.011) condition; longer total looking/behaviour time in both primary provider (*Z*=-3.665, *n*=31, *P*<0.001) and unusual caller (*Z*=-4.017, *n*=31, *P*<0.001) conditions; and greater number of looks in primary provider (*Z*=-3.197, *n*=31, *P*<0.001) and unusual caller (*Z*=-3.628, *n*=31, *P*<0.001) conditions. No difference was found between the control and test trials for the duration of first look in the primary provider condition (*Z*=-1.862, *n*=31, *P*=0.063).

Task/Phrase Breakdown

There were three main categories of phrases used during the test trials: food, out/walk and toy. From 77 trials, 32 food, 34 out/walk and 11 toy trials were recorded. After completing an analysis I divided the data into the three categories to test whether the familiarity of the caller and the category the phrase spoken falls into, affected the dogs' response.

Orientating Frequencies

In each trial dogs never orientated solely towards the non-calling individual. If they did orientate towards the non-calling individual then it was alongside the caller (primary provider & unusual caller). Orientating frequencies did not differ in the food category (*Z*=-2.044, *n*=32, *P*=0.041). However, in both the out/walk (*Z*=-4.3824, *n*=34, *P*<0.001) and toy categories (*Z*=-2.428, *n*=11, *P*=0.015) dogs' orientating frequencies were fewer towards the unusual caller in the unusual caller condition compared to the primary provider in the primary provider condition. Moreover, in the unusual caller condition there were higher orientating frequencies towards the primary provider & unusual caller.

Duration of First Look

In all three categories no significant difference was found between the primary provider and unusual caller conditions for duration of first look: food (*Z*=-0.823, *n*=32, *P*=0.421); out/walk (*Z*=-0.667, *n*=34, *P*=0.512); toy (*Z*=-0.622, *n*=11, *P*=0.577).

Number of Looks: Food

Dogs spent more time looking at the primary provider in the primary provider condition (*Z*=-4.879, *n*=32, *P*<0.001) than they did looking at the unusual caller in the unusual caller condition (*Z*=-3.106, *n*=32, *P*=0.002). The number of looks towards the primary provider in the unusual caller condition and the unusual caller in the primary provider condition were similar with 10 trials tied (i.e. equal number of looks in both conditions).

Number of Looks: Out/Walk

Dogs looked more at the primary provider in the primary provider condition (*Z*=-4.915, *n*=34, *P*<0.001) than they did the unusual caller in the unusual caller condition (*Z*=-2.345, *n*=34, *P*=0.019). The number of looks given to the primary provider in the unusual caller condition and the unusual caller in the primary provider condition also differed.

Number of Looks: Toy

Dogs looked more often to the primary provider in the primary provider condition (63.7%) (*Z*=-2.944, *n*=32, *P*=0.003) than they did to the unusual caller in the unusual caller condition (9.1%), (*Z*=-2.850, *n*=11, *P*=0.004). The number of looks given to the primary provider in the unusual caller condition (45.5%) and the unusual caller in the primary provider condition (9.1%) also differed.

Total Looking/Behaviour Time

The total looking/behaviour times towards primary provider and unusual caller varied across the three categories (Table 5.1). In the food category dogs reacted for longer in the primary provider condition than the unusual caller condition (*Z*=-2.637, *n*=32, *P*=0.008). No significant result was found in both the out/walk (*Z*=-0.996, *n*=34, *P*=0.334) and toy (*Z*=-1.334, *n*=11, *P*=0.182) categories suggesting that total looking/behaviour time between the primary provider and unusual caller are similar.

Table 5.1 Total looking/behaviour time (%) of dogs towards the primary provider and unusual caller in the three categories.

Category	**Condition**	**Total Looking/Behaviour Time (%)**
Food	Primary Provider	71.9
	Unusual Caller	28.1
Out/Walk	Primary Provider	44.1
	Unusual Caller	55.9
Play	Primary Provider	63.6
	Unusual Caller	36.4

5.6 DISCUSSION

The results of this study provide evidence that domestic dogs recognise and respond to human receive-request phrases spoken by both familiar and unfamiliar individuals. Interestingly the results revealed that although in most cases dogs showed a preference for the primary provider, they reacted to calls given by both primary provider and unusual caller in a way that suggests they understand what is being said. Dogs also orientated between the two callers in several call-back trials, demonstrating that they recognise that both familiar and unfamiliar humans can fulfil the task.

At a basic level, to demonstrate an understanding of a call an initial reaction from the dogs would need to be observed. This initial reaction was measured by analysing their orientating frequencies after the call had been produced. A no reaction would indicate that dogs did not recognise calls produced by both familiar and unfamiliar humans. However, a no reaction was observed in only 1% of trials, all in the unusual caller condition, with all other trials eliciting an initial reaction from the dogs in both primary provider and unusual caller conditions. In the unusual caller condition dogs looked to the caller alone fewer times and orientated towards both callers more than they did in the primary provider condition. This suggests that dogs are recognising the call and identifying the individual who usually performs that task by orientating towards them.

Previous research has shown that dogs respond differently to unfamiliar individuals (Horn et al., 2013b), and the 1% no reaction observed in this study could be a result of the dogs hearing a familiar phrase spoken by an unfamiliar individual. However, 99% of trials elicited a reaction from the dogs. Furthermore, when analysing the number of looks dogs looked more towards the primary provider in the primary provider condition, and in the unusual caller condition dogs looked more towards the unusual caller. Thus suggesting that the dogs responded and understood the phrase being spoken regardless of the caller.

This study has found that when hearing a familiar phrase from an unfamiliar individual, dogs will produce an initial reaction to that call. However, they will also look at and direct their behaviour towards the familiar individual who usually says that phrase. This suggests that dogs possess an understanding of the call and the actions of the familiar individual which follow that specific call. Furthermore, analyses of dogs’ total looking/behaviour time revealed that after hearing a call a dog’s behaviours/looks are directed significantly more toward the individual who is saying the phrase and is not affected by the familiarity of the caller.

Previous research has found that dogs understand the messages behind specific words produced by humans (Andics et al., 2014) and the current study further enhances this statement. By reacting to phrases produced by both callers dogs demonstrated that they understood the messages behind the receive-request phrases regardless of familiarity.

If no significant difference was found between test trials and control call trials it would demonstrate that the dogs did not understand what was being said by the two callers. However, a significant result suggests that dogs are not merely responding to the primary provider and unusual caller speaking but are reacting to what they are saying. Furthermore, if dogs merely respond to our voices then one would expect the dogs to react to every phrase spoken. The current study, however, recorded several no reactions in both conditions, thus suggesting that dogs do understand the phrases we are saying to them and are not simply responding to human voices. However, since there was no difference in the duration of first look it could be because dogs are reacting to the primary provider saying an unfamiliar phrase as they are unsure of the meaning. That, in turn, would induce a longer first look as they attempt to process the unfamiliar phrase, further supporting the suggestion that they understand familiar spoken phrases.

To further investigate dogs' understanding of human phrases I conducted separate analyses on the three categories of phrases used in the study: food, out/walk and toy. In the food category there was no difference between the primary provider and unusual caller, in number of looks, orientating frequencies and duration of first look. Thus suggesting that familiarity does not affect a dog's reaction to food related calls and they will willingly take food from any individual present. However, subjects' total looking/behaviour time was significantly longer towards the primary provider than the unusual caller. This could be as when the familiar individual calls a food phrase the dog understands the call and anticipates that to be fulfilled by the primary provider. When an unfamiliar individual calls in this scenario there is no 'previous expectation' and therefore as time passes after the call without follow-through the dogs become disinterested.

The results from the toy and out/walk categories suggest that dogs are looking and orientating more towards the individual who usually fulfils that task, i.e. taking them for a walk. Therefore, in the out/walk and toy categories, when dogs hear an unfamiliar individual saying a familiar phrase, not only do they show an understanding of that call but they are also seemingly less likely to expect a stranger to fulfil that task.

Dog-human bond researchers have shown that dogs can identify and differ in their responses to familiar and unfamiliar humans (Rappolt et al., 1979). Strange situation tests involve conducting a behavioural experiment in a novel environment to investigate the specific behaviours of an individual towards a familiar person as opposed to a stranger (Ainsworth & Bell, 1970). Such tests have shown that adult dogs show a preference for their owner over an unfamiliar person (Topál et al., 1998). Moreover, by placing dogs in an MRI scanner and during fMRI periods and presenting them with five scents (self, familiar human, strange human, familiar dog, strange dog) the caudate nucleus was only activated maximally to the scent of the familiar human (Berns et al., 2015). This implies that when it comes to the dog-human bond dogs show a preference for familiar over unfamiliar humans.

When investigating dogs' responses to human cues and gestures given by an owner and a stranger, dogs show no preference for one or the other (Pongrácz et al., 2001b; Marshall-Pescini, et al., 2011). Other research has also demonstrated no preference for a familiar over an unfamiliar human when hearing verbal attention-getting behaviours (Pongrácz et al., 2004), suggesting that the bond a dog has with an individual does not affect their ability to respond to and understand human gestures and vocal attention-getting behaviours. Similarly, the current study reveals that dogs will react to phrases produced by both familiar and unfamiliar humans and show a preference for the familiar individual who usually fulfils that specific task.

These results also reveal that dogs understand a previously untested human phrase category, receive-request (e.g. do you want a treat?). Previous research has focused on dogs' understanding of action request (e.g. give paw) and object request (e.g. get toy) phrases (Ramos & Ades, 2012). Action and object request phrases are instructions given by a human and show that dogs can understand and follow them. However, object and action request phrases tend to be intentionally taught by owners with correct behaviours being reinforced by reward (Markman & Abelev, 2004); for example, with a 'give paw' action request phrase only the desired paw behaviour would be rewarded.

Receive-request phrases involve asking the dog a question about a canine beneficial goal that can only be achieved by a human. Moreover, these phrases are not intentionally taught and reinforced by owners. They occur in a dog's everyday life in the human environment and, in most cases, are produced naturally by owners without an expectation of specific behaviours from the dog. Receive-request phrases are therefore not a product of forced/intentional training but an example of partially untrained learning. It does, however, provide us with evidence of how dogs learn to use their owners' actions (in this case the receive-request phrases) to potentially predict future events (i.e. a treat) as a result of simple contingency learning (Cooper et al., 2003). Moreover, it implies that receive-request phrases provide evidence of operant conditioning in domestic dogs as they learn which untrained behaviours have the greatest probability of enabling them to achieve a particular outcome (Schmidt, 2012).

Dogs are attentive to their owner's behaviours and actions (Hare & Tomasello, 2005) and receive-request phrases are an example of this attentiveness. Through frequent use of these phrases dogs can observe and learn the actions that follow a specific set of words and thus over time will come to recognise the phrase. It could be argued that receive-request phrases involve some form of reinforcement learning as after the production of the phrase the dogs are given a reward (e.g. a treat/walk). However, these rewards are a product of the phrase and are not being used to intentionally reinforce certain behaviours. The behaviours observed during the testing period reflected what the dogs had come to learn to perform by themselves, likely through operant conditioning (Schmidt, 2012), following a specific receive-request phrase. Therefore, receive-request phrases are a good example of how dogs have come to understand verbal cues through observing and learning from human actions without the influence of intentional reinforcement training. It is hoped that future researchers will expand on this area further in order to enhance our knowledge of dogs' cognitive processes.

Limitations of the Current Study

The current study provided evidence which demonstrated that domestic dogs recognise human receive-request phrases. A limitation that this study has, however, is that it cannot definitively show that dogs identify and alter their behaviours according to the specific receive-request phrase being called (i.e. food, out/walk and toy). Recent research has found that the content of a phrase and its relevance to dogs affects their attentiveness to the phrases being spoken (Benjamin & Slocombe, 2018). Even though the receive-request phrases used in the current study were all dog-relevant it is not known whether dogs are more attentive to food related phrases compared to toy related phrases. Future researchers should investigate how dog reactions to the three receive-request calls differ in order to show that dogs can identify individual phrases and the goal which they produce.

The current study also demonstrated that dogs react to receive-request phrases spoken by both a familiar and unfamiliar individual but it did not investigate why they are able to do this.

Previous research has suggested that dogs prefer familiar over unfamiliar humans (Bradshaw, 2012) but the current study suggests that they are able to communicate with and will accept an apparent goal of both. Future researchers should evaluate this further to determine how dogs are able to do this and the benefits reacting to and receiving apparent goals from familiar and unfamiliar has.

A further limitation is that the study does not investigate how dogs are learning to respond to the specific phrases being spoken. It does suggest that dogs are potentially being subjected to operant conditioning but no definitive conclusions can be drawn.

Conclusion

To my knowledge this is the first study to show that dogs understand human verbal questions (receive-request phrases) regarding a specific canine goal. This study is also the first of its kind to document naturally occurring word-learning in domestic dogs without the influence of intentional human training, thus providing evidence of how dogs have adapted to the human environment by learning through observation of their human group members. Moreover, this study has revealed that dogs understand food, out/walk and toy phrases spoken by both familiar and unfamiliar humans, thus, suggesting that familiarity does not affect dogs' understanding of human-given phrases and that dogs understand that both familiar and unfamiliar humans can fulfil the goal the phrase refers to. The study also revealed that although dogs do show a preference for phrases spoken by familiar humans the bond a dog has with an individual does not affect their reactions to receive-request cues.

6. ARE DOMESTIC DOGS CAPABLE OF CAUSAL REASONING AND CAN EAR TEMPERATURE BE USED AS A PROXY FOR EMOTIONAL HEMISPHERIC ACTIVITY DURING BEHAVIOURAL TRIALS?

In the previous chapter I revealed that dogs behave as though they understand untrained human receive-request phrases spoken by both familiar and unfamiliar individuals. However, human speech has aspects of causal reasoning (Jones, 2013) and, to date, it is not known to what extent dogs can understand cause and effect relationships.

6.1 ARE DOMESTIC DOGS CAPABLE OF CAUSAL REASONING?

6.1.2 A Brief Review

Causal reasoning is the process of understanding the relationship between cause and effect and is said to represent one of the most influential cognitive processes that underlie the majority of higher-order activities (Jonassen & Ionas, 2008). Human cognitive researchers have been influenced by the topic of causality as the operation of many cognitive processes is dependent on the world knowledge that an individual possesses (Rehder, 2003). Causal reasoning allows us to predict outcomes and control events in the world (Blaisdell et al., 2006). The process of causal reasoning involves “an understanding of ‘how’ and ‘why’ one event leads to another” (Visalberghi & Tomasello, 1998, p. 190). The philosopher David Hume (1739/1978) states that we observe regular events, such as A followed by B, and by an increasing association in our minds we infer a causal relationship between A and B. Therefore, in its most basic form causal reasoning can be described as B follows A.

In animal cognitive research causal reasoning is most frequently investigated when studying animal tool use. To be considered as true or intelligent tool use an individual must broadly and flexibly apply multiple tool use skills across a variety of contexts (Shumaker et al., 2011). Moreover, an individual must demonstrate an element of insight or understanding of causal relationships (Shumaker et al., 2011). Causal reasoning also influences goal-directed behaviours, another criterion for intelligent/true tool use. Goal-directed behaviours are based on the knowledge of the causal relationship that occurs between an action and the outcome and must involve instrumental actions (de Wit & Dickinson, 2009).

Previous research investigating non-human animal causal reasoning in the physical domain (Table 6.1) and social domain (Table 6.2) are provided on the subsequent page. Most studies concern themselves with investigating a species’ ability to solve physical problems through an understanding of causal reasoning. There is very little evidence for the occurrence of causal reasoning in the social domain, and it has been argued that highly social species should be tested for the ability in the domain of social behaviour rather than physical interactions with inanimate objects (Cheney et al., 1995).

Table 6.1 Selected evidence of non-human animal causal knowledge in the physical domain.

Species	**Evidence of Causality Physical Domain**	**Reference**
Chimpanzees (*Pan troglodytes*)	Similarly to human infants, in three tests chimpanzees look for longer during dishabituation trials. Thus suggesting that they respond to events which violate their sense of natural causality.	O'Connell & Dunbar (2005)
Cotton-top tamarins (*Saguinus oedipus oedipus*)	Are capable of selecting tools based on their relevant properties, even though they do not naturally use tools.	Hauser (1997) Santos et al., (2003)
New Caledonian crows (*Corvus moneduloides*)	Able to solve an initial trap-tube task and successfully transfer this skill to a second novel trap-table task. Suggesting that they can solve complex physical problems through causal reasoning.	Taylor et al. (2009)
Rats	Make correct inferences for instrumental actions purely by observational learning, and differentiate between common-cause models, causal chains, and direct causal links.	Blaisdell et al. (2006)
Tufted capuchin monkeys (*Cebus apella*)	Understand the spatial relationship between two items (food and tool), but do not understand the spatial relationship among 3 items, (food, tool, and environmental condition).	Fujita et al. (2003)

Table 6.2 Evidence of non-human animal causal knowledge in the social domain.

Species	**Evidence of Causality Social Domain**	**Reference**
Baboons (*Papio cynocephalus ursinus*)	Females respond significantly more to causally inconsistent grunts than they do to causally consistent calls. (Playback)	Cheney et al. (1995)
Diana monkeys (*Cercopithecus diana*)	When hearing predator alarm calls for leopards and humans produced by another species, Diana monkeys	Zuberbühler (2000a; 2000b)

	respond with predator-specific behaviours.	

6.1.3 Domestic Dogs and Causal Reasoning

Domestic dogs have failed to show an understanding of causality when asked to complete a string-pulling task (Osthaus et al., 2005). The authors concluded that although dogs can learn to pull a string to access a treat, they are unable to spontaneously understand a means-end connection and therefore lack the ability to understand physical causality. However, that study involved dogs performing a human-trained unnatural behaviour (pulling a string). Highly trained dogs, however, perform significantly better during problem solving tasks compared to those dogs with low or no training influence (Marshall-Pescini et al., 2008). All the dogs in the Osthaus et al. (2005) study were recruited from a dog club which implies that they had some form of training prior to participation but the authors failed to take into consideration how past training may have influenced the dogs' performance in the string-pulling task.

Another issue to take into consideration is the use of the problem solving task itself. Previously in this thesis I demonstrated that dogs employ humans in order to access an otherwise unobtainable goal such as a treat. Research has also shown that when faced with an unsolvable task dogs will look/gaze at their human owner for assistance, whereas socialised wolves do not (Miklósi et al., 2003b). This implies that the domestication process has altered dogs' problem solving abilities whereby they no longer attempt to solve tasks on their own but recruit humans to solve it for them (Miklósi et al., 2003b; Hare & Tomasello, 2005).

Dogs are known to excel in their social environment, and perhaps the reason they have failed to demonstrate causal knowledge to date is because they have been tested in the physical rather than social domain using a human-trained problem solving task. The social intelligence hypothesis suggests that an animal's intelligence evolved in response to problems associated with the need to navigate through their social environment. (Chance & Mead, 1953; Jolly, 1966; Humphrey, 1976). If this hypothesis is correct then evidence for causal reasoning in social animals would be more evident when investigating social behaviour rather than physical interactions involving inanimate objects (Cheney et al., 1995). When non-human primates are confronted with physical problem solving tasks they experience difficulties (Cheney & Seyfarth, 1992; Zuberbühler, 2000b). Non-human primates even struggle to demonstrate simple levels of causal understanding when asked to solve modest technical problems

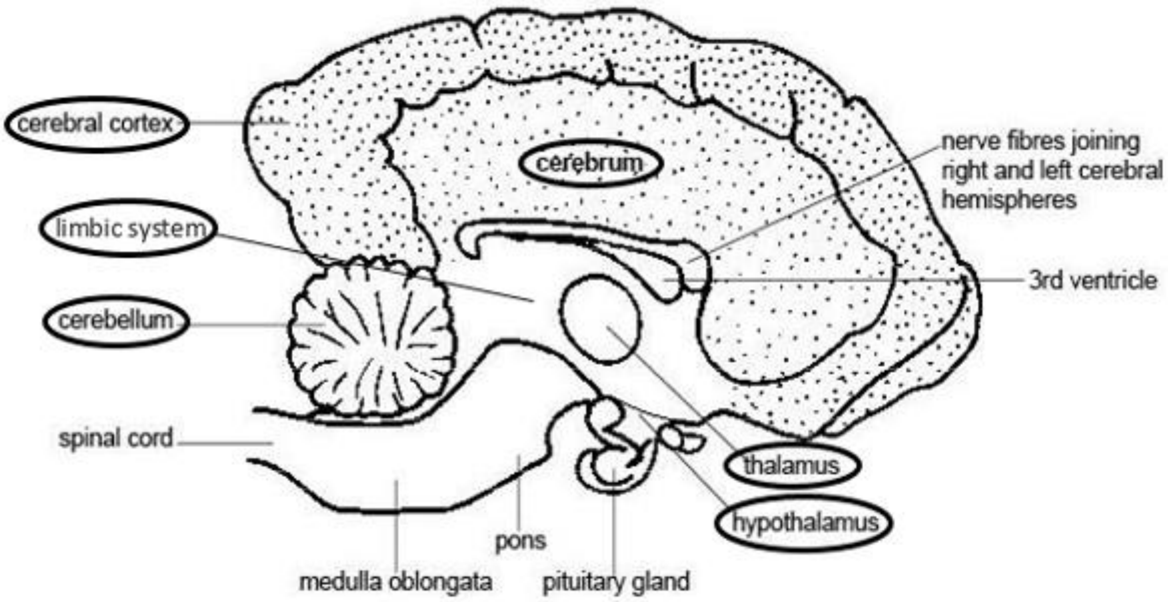
(Visalberghi & Limongelli, 1994; Zuberbühler et al., 1997). However, when presented with causal problems derived from another individual's behaviour, non-human primates' performance in these tasks increases (Zuberbühler, 2000b). This could also be true of domestic dogs.

The results produced by this study will, however, only demonstrate behavioural manifestations of internal mental states (Berns et al., 2015). Behavioural evidence can only provide us with an idea of the processes going on in an animal's mind. Investigating brain activity behind behavioural manifestations provides us with an indispensable insight into the cognitive abilities of a species but it is time consuming, costly and invasive. How then can cognitive researchers access this vital information in an effective and non-invasive way?

6.2 WHAT ARE THEY THINKING? EAR TEMPERATURE AS AN INDICATOR OF HEMISPHERIC EMOTIONAL BRAIN ACTIVITY IN DOMESTIC DOGS

6.2.1 Ear Temperature and Brain Activity

It has been suggested that measuring an individual's ear temperature and using it as a proxy for brain activity, is a good, relatively non-invasive way of measuring brain activity. Indeed ear temperature has been shown to reflect hemispheric temperature with high accuracy in animals (rabbits: Tanabe & Takaori, 1964; monkey: Baker et al., 1972; cats: Mazzotti & Boere, 2009) and humans (Brinnel & Cabanac, 1989; Cabanac, 1993; Mariak et al., 1994; Ogawa, 1994). However, to better understand if ear temperature could be a good indicator of hemispheric emotional brain activity we need to understand the canine brain and the processes the different regions are responsible for. Figure 6.1 shows an illustration of the canine brain, highlighting the regions of interest and their function.



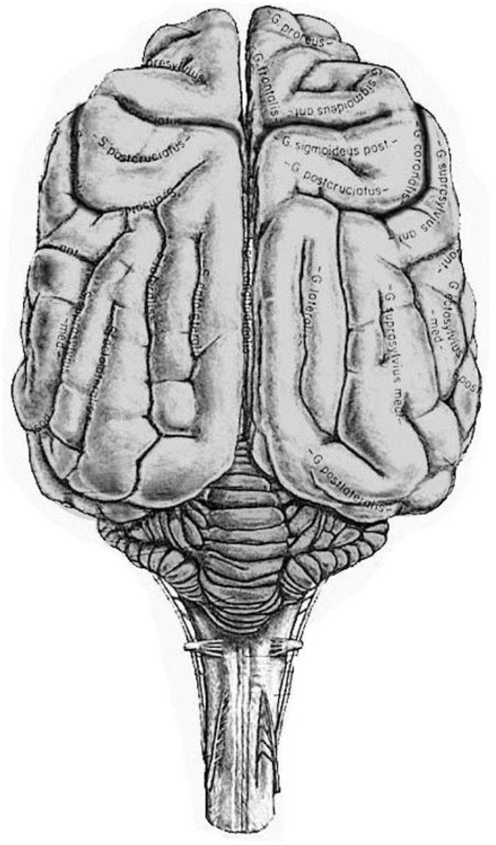
Cerebellum	Control of voluntary movements.
Cerebrum/Cerebral Cortex	Receiving and analysing sensory information. Divided into 2 hemispheres (left/right) and 4 lobes (frontal/temporal/parietal/occipital).
Hypothalmus	Pituitary hormones, eating and drinking, body temperature, reproductive and nervous systems.
Limbic System	Located in the cerebral cortex and responsible for experiencing and expressing emotions.
Thalmus	Relaying sensory information and regulation of motor activity in cerebral cortex.

Figure 6.1 Side view of the canine brain highlighting regions of interest and their functions (The Canine Brain, 2017)

The cerebral cortex or cerebrum is divided into two hemispheres, left and right, and there are differences in how these hemispheres process emotional information (Killgore & Yungelun-Todd, 2007). Indeed, in humans the left and right hemispheres of the brain are responsible for processing different emotional responses (Davidson & Fox, 1982; Ahern & Schwartz, 1985; Jones & Fox, 1992; Turhan et al., 1998; Altenmüller et al., 2002; MacNeilage et al., 2009). The same is true for non-human animals with the left hemisphere controlling hardened behaviour patterns that are performed in non-stressful situations, and the right hemisphere controlling emergency responses and reactions to unexpected situations (Rogers, 2010).

The left hemisphere of the brain processes positive emotional responses and the right hemisphere of the brain processes negative emotional responses (Propper & Brunyé, 2013) (Figure 6.2). Therefore, as an individual experiences different positive and negative emotions, the hemisphere of the brain which controls those responses will be activated, thus making the corresponding ear rise in temperature.

Left Hemisphere
- Positive emotions
- Approach
- Energy enrichment
- Attachment
- Safety
- Calm
- Curiosity
- Explore
- Nourishment
- Relaxation
- Restore



Right Hemisphere
- Negative emotions
- Withdrawal
- Energy expenditure
- Fear
- Danger
- Excitement
- Caution
- Retreat
- Vigilance
- Anxiety
- Run

Figure 6.2 Dorsal view of the left and right hemispheres of the canine brain and the differing emotional responses in which they process (Source: Dog Blog, 2011 & Brain Anatomy Introduction, 2017).

Previous investigations have shown that a relationship exists between the right hemisphere of the canine brain and reactions to alarming and threatening stimuli (Siniscalchi et al., 2010). Numerous studies have been conducted investigating sensory lateralization, paw preference and tail bias in domestic dogs (see Siniscalchi et al., 2017 for a review) to report corresponding brain activity. Measuring ear temperature takes one directly to the source of the brain activity but when observing motor laterality it is the opposite side of the brain which controls the right/left limb movements. For example, if a dog was to use its left paw it is the right hemisphere of the brain which is controlling that movement (Schneider et al., 2013).

Another method used by researchers to investigate the relationship between motor laterality and emotional reactivity in domestic dogs is by measuring directional bias to various stimuli (Schneider et al., 2013). Upon hearing a fear-inducing sound, e.g. a thunderstorm, dogs will turn their head left (right hemisphere) but when they hear a conspecific they turn their head to the right (left hemisphere) (Siniscalchi et al., 2008). When dogs are presented with a non-threatening stimulus of a conspecific, to both left and right visual fields concurrently, they show no directional bias when turning to view the stimulus (Siniscalchi et al., 2010). However, when presented with a potentially threatening stimulus of a cat or snake, they turn their head towards the left-hand side (Siniscalchi et al., 2010). These studies support the theory that the right and left hemispheres of the brain control different emotional responses (Casperd & Dunbar, 1996).

Several other canine studies have reported that the right hemisphere of the brain is responsible for the control of negative withdrawal emotions (Ahern & Schwartz, 1985; Davidson, 1992), aggression and fear (Casperd & Dunbar, 1996), and emergency responses and reactions to unexpected situations (Rogers, 2010). Moreover, Lindsay (2005) provides various case studies of individual dogs exhibiting ear temperature shifts consistent with a right hemisphere specialisation for coping with stressful situations.

There have, however, been conflicting reports into the precise nature of the relationship between hemispheric activity and ear temperature (Propper & Brunyé, 2013). Some researchers have suggested that ear temperature reflects the amount of blood flow to that specific hemisphere, and as blood flowing to the brain is cooler than that which is currently there, a decrease in ear temperature would indicate increased activity in that side of the brain (Meiners & Dabbs, 1977; Dabbs, 1980; Hopkins & Fowler, 1998; Helton et al., 2009 a, b). Other researchers have suggested that ear temperature is associated with hemispheric emotional activity as it is related to core body temperature as well as to temperatures at the surface of the cerebral cortex and energy spent in maintaining brain activity is transformed into heat, therefore warmer ear temperatures reflect cerebral activation (Swift, 1991; Mariak et al., 1994; Laughlin et al., 1998; Boyce et al., 2002; Gunnar & Donzella, 2004; Jackson, 2011; Genovese et al., 2017).

Ear temperature is therefore sensitive to an individual's emotional and motivational state but the exact nature of this relationship is yet to be defined (Propper & Brunyé, 2013). Recently, however, in the 2016 BBC Two show ‘Cats vs Dogs: Which is Best?’ Professor Daniel Mills of Lincoln University demonstrated that when TV presenter Chris Packham’s dogs were left alone in the house and became visibly distressed, their right ear temperature was higher than their left. Then, after a period of playing and interacting with their owner their left ear temperature was higher than their right. Given that this is the most recent (and possibly only) evidence of the relationship between ear temperature and cerebral activation in domestic dogs this thesis will investigate the relationship in a similar way in that a warmer ear temperature reflects hemispheric activity.

6.3 Justifications and Aims

Given that domestic dogs have failed to show an understanding of causal relationships to date, this study will test the hypothesis that dogs possess causal knowledge, by testing them in the social rather than physical domain. It is predicted that dogs will perform cross-species communicative responses which suggest that they recognise that “B follows A” in human receive-request phrases (e.g. a treat follows the phrase). It is also predicted that if dogs are capable of causal reasoning then when they do not receive the expected treat they will perform further gestures with persistence and greater elaboration. If evidence for causality is found this study will be the first to reveal this ability in dogs. Furthermore, it has the potential to impact the study of animal cognition and support the statement that highly social species should be tested for specific cognitive abilities in the social domain rather than the physical.

If ear temperature is a good proxy for emotional hemispheric activity during behavioural trials, I predict a higher right ear temperature (right hemisphere activation) when a dog receives a control object (negative outcome) and a higher left ear temperature (left hemisphere activation) when they receive a treat (positive outcome). I also predict that when the dogs receive a treat their left ear temperatures will be higher than left temperatures recorded before the start of the trial. Furthermore, right ear temperatures taken after the receive control trial will be higher than right ear temperatures taken before the start of the experimental trials. If this is proven, it will provide researchers with a non-invasive, effective way of recording emotional hemispheric activity during behavioural and cognitive experiments. This will also provide us with further evidence that the left and right hemispheres of the brain are responsible for controlling different emotional responses, as well as advancing our knowledge and understanding of the cognitive world of dogs.

6.4 EXPERIMENTAL DESIGN

6.4.1 Specific Procedure and Design

The method used here was designed similarly to previous playback studies on non-human primate causal reasoning (Cheney et al., 1995; Zuberbühler, 2000 a, b). In this study, however, callback experiments were used instead of playback experiments **(p. 19).**

The primary provider participated and called to the dog with a food-related daily task (identified from the previous callback study discussed in Chapter 5). Before the start of the trials the experimenter placed a control object (Figure 6.3) where the dog's treats/food (goal object) were usually kept. There was a total of two trials (receive control and receive treat) with a 10 minute break in between.

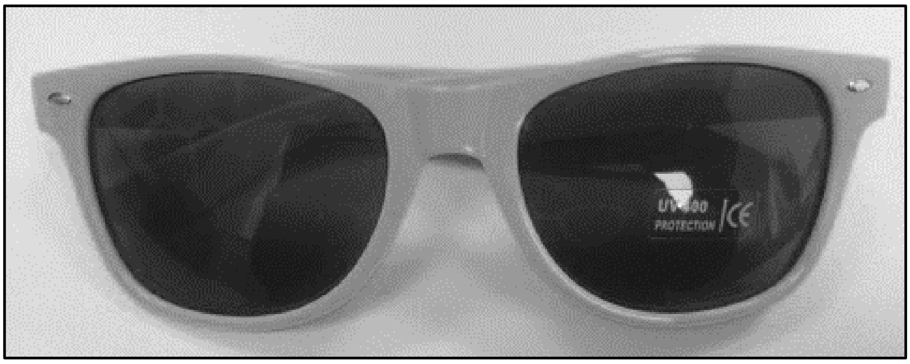


Figure 6.3 Control object used in in the causal reasoning trials.

The subject and the owner were continuously filmed throughout the duration of each trial. After an initial 20 seconds of video recording, the caller then addressed the dog three times in the way they would usually using their food-related phrase (e.g. do you want a treat?) with no break in between each phrase. After the third call the participant immediately stood up and walked toward the location of the dog's goal object. Once at the location the caller then either retrieved the control object or a treat and walked back to where they were located when the trial began. Once the caller was seated they presented the dog with either the control object or the treat. The subject was then video recorded for a further 36 seconds.

The subject's duration of first look towards the primary provider (which began after they lifted their head up from either the control or goal object), number of looks and total looking/behaviour time after the presentation of the object was recorded. The communicative gestures performed by dogs after either the presentation of a treat or control object are identified in a similar way to the method described in chapter three (p. 22). Persistence (the continued performance of gestures until the end of the testing period) and elaboration (the performance of a number of different gestures) of these gestures during the receive treat and receive control trials are then compared.

If domestic dogs understand causality then their behavioural reactions are predicted to increase after they have been presented with the control since that is not the object they were expecting, similar to expectation-violation trials (see Adachi et al., 2007 for an example). When presented with the goal object a dogs' communicative gestures are predicted to cease which would imply an understanding of causality, i.e. food (B) follows a food-related phrase (A).

To determine if ear temperature is an indicator of emotional hemispheric activity, left and right ear temperatures were taken before the start of the two trials ('baseline' reading) and immediately after the control and treat trials. Owners were instructed to conduct the temperature measurements to reduce any stress that may have resulted from being handled by a stranger. Furthermore, if a dog became obviously stressed during the process then temperatures were not taken.

A dog's normal ear temperature is around 37.8°C – 39.4°C (Pedigree, 2018). In this study, I used a Braun ThermoScan 3 (Figure 6.4) traditionally used on human infants. The Braun ThermoScan 3 has been used by other researchers, such as Daniel Mills in the 2016 BBC two television programme *Cats vs Dogs: Which is Best?*, to analyse differences in dog ear temperatures. In that programme the lowest temperature reading taken was 34.0°C and from a veterinary perspective the highest temperature reading considered to be normal is 39.5°C. Therefore, the temperature parameters were set at 34.0°C – 39.5°C for the current study, any readings that fell below or above these parameters were not included. It is important to note that this thermometer does not take medically accurate readings. However, the readings taken sufficiently showed a difference between left and right ear temperatures to test the hypothesis.

Figure 6.4 Images of the Braun ThermoScan 3 used in the study to record dog ear temperatures.

6.4.2 Analyses

Duration of communicative gestures after presentation of control/goal object was recorded. The number of looks towards both the caller in both receive treat and receive control trials and the location of goal object during the control trial was also quantified. The data collected during the experimental trials were analysed using a Shapiro-Wilk test to test for normality with *P* value set at 0.05. This determined that the data was non-normally distibuted and were therefore later statistically analysed using Wilcoxon signed-ranks tests. Friedman's tests were also conducted followed by post hoc analysis with Wilcoxon signed-ranks and Bonferroni correction. Cohen's kappa was run to determine if the observational analysis performed by the researcher was consistent with that of another individual in a sample of 10 dogs in both control and test trials.

6.5 RESULTS

Causal Reasoning

A total of 32 trials were conducted, each with two conditions (receive control and receive treat), with 32 domestic dogs (13 male, 19 female) and their owners to determine if dogs show an understanding of causality and are capable of performing goal-directed behaviours. Alongside this 32 control trials were also conducted.

Duration of First Look

It was predicted that if dogs are capable of causal reasoning their duration of first look would be longer in the receive control trials as they would not be receiving the goal they expected, however, no difference was found (Z=-0.748, n=32, P=0.454).

Number of Looks

It was predicted that dogs would look more towards the caller in the receive control condition as they were being presented with an unfamiliar object and not the goal they apparently expected. In both receive control and receive treat conditions the number of looks a dog gave towards the caller was recorded. Dogs performed significantly more looks toward the owner in the receive control condition than they did in the receive treat condition (Z=-4.368, n=32, P<0.001).

Total Looking/Behaviour Time

In 29 trials dogs' total looking/behaviour time was longer in the receive control condition and only three trials dogs had a longer total looking/behaviour time in the receive treat condition (no ties were recorded). Total looking/behaviour time was longer in the receive control condition compared to the receive treat condition (Z=-4.787, n=32, P<0.001). I recorded no reaction in two dogs in the receive treat condition, i.e. they did not direct any behaviour or look towards the caller after they had finished eating their treat. The remaining 30 dogs did look towards the caller or sit in front of them after eating their treat.

Inter-observer Reliability

A very good agreement was found between observers in total looking/behaviour time, kappa=0.948, P<0.001, and duration of first look, kappa=0.895, P<0.001. A perfect agreement was found between observers in number of looks in both receive control, kappa=1.000, P<0.001, and receive treat, kappa=1.000, P<0.001 conditions.

Persistence and Elaboration of Gestures

I analysed the gestures performed by each dog in both the receive control (Appendix XI) and receive treat (Appendix XII) conditions and noted whether persistence and elaboration was observed.

Dogs used more gestures with greater persistence and elaboration in the receive control condition than in the receive treat condition. Figure 6.5 shows the number of gestures used by dogs in receive control and receive treat conditions. The data revealed 64 individual gestures performed by dogs in the receive control condition and 34 individual gestures in the receive treat condition. Only two vocalisations, exhale and sniff (air), where present in the receive treat condition but not the receive control condition. Overall, dogs used significantly more gestures in the receive control condition compared to the receive treat condition (*Z*=-4.564, *n*=32, *P*<0.001).

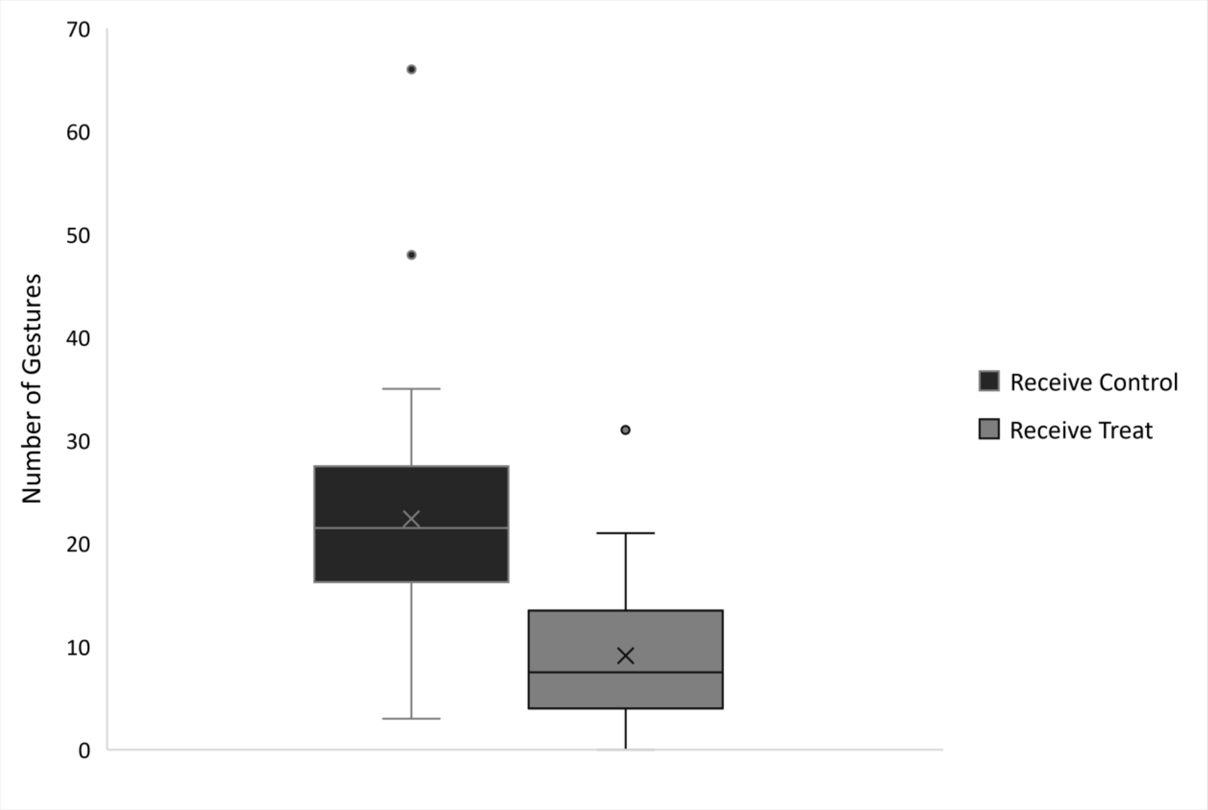


Figure 6.5 Number of gestures used by dogs in the receive control and receive treat condition (points above the box and whisker represent the outliers and the x represents the mean marker).

Persistence until the end of the testing period (36 seconds) was observed in all 32 dogs in the receive control condition compared to only five dogs in the receive treat condition. Seven dogs in the receive treat condition elaborated on their gestures and 28 dogs demonstrated elaboration in the receive control condition. Four dogs did not demonstrate elaboration in the receive control condition and in the receive treat condition two dogs did not communicate with the owner after taking the treat and were recorded as a no reaction.

I observed 16 dogs using physical contact (i.e. touching gestures) with the caller in the receive control condition by using pawing, nosing and sniffing gestures to locate the expected treat, compared to just eight dogs in the receive treat condition. Only six dogs interacted with the control object by either taking the object in their mouth or through the use of touching gestures, the remaining 26 dogs solely interacted with and directed gestures towards the owner after being presented with the control object. In the receive control condition, some dogs behaved as though they were actively searching for the treats. They jumped onto furniture, sniffed and looked in bags and walked around the environment constantly sniffing. Other dogs performed a variety of owner-trained tricks when presented with the control such as giving paw and begging gestures. One dog was touch-trained and repeatedly nosed the control object throughout the experimental period until rewarded with a treat.

Most of the dogs' gestural repertoires began with a head up gesture. This is because once presented with the control object most dogs put their head down and sniffed the object (recording of behaviours began once the dogs had lifted their head up and away from the control object). Interestingly, seven dogs performed gestures such as nose and paw towards the control object and two dogs took the control object in their mouth during the trials.

In the receive treat condition, most dogs turned back towards the caller briefly before turning away. This gave the impression that the dogs were checking to see if there was another treat, and once they saw that there was not they would turn away from the caller and stop directing behaviours towards them. Seven dogs, however, responded with further gestures after they had been given the treat by directing gestures towards the caller in a way similar to that seen in the receive control condition. Only three of these dogs performed these 'ask for more' behaviours with persistence and elaboration for the full 36 seconds after eating the treat. Why these three dogs 'asked for more' during receive treat trials is unknown. It could be that they were presented with one treat and usually receive multiple treats from owners. Another explanation could be that, according to the owners, these dogs were extremely food-orientated and often persistently 'ask for more' after receiving food.

Analysis of gestures revealed that most dogs elaborated in the receive control condition. However, four dogs demonstrated persistence but no elaboration in the receive control condition. These four dogs had a longer total looking/behaviour time in this condition but instead of performing a large number of gestures they persistently stood/sat in front of the caller, looked towards them and waited.

Is Ear Temperature a good Indicator of Emotional Hemispheric Activity?

As demonstrated by Daniel Mills in the 2016 BBC Two show ‘Cats vs Dogs: Which is Best?’, when a dog is stressed their right ear temperature will be higher than their left as the right hemisphere of the brain is responsible for processing negative emotional responses, and when a dog is relaxed their left ear temperature will be higher as the left hemisphere is associated with positive emotional responses. Therefore, higher right ear temperatures were predicted to be recorded after the receive control condition and higher left ear temperatures recorded after the receive treat condition.

Dog ear temperature ranged from 34.4°C to 39.4°C. Only one subject did not allow their owner to take their temperature and was excluded from this part of the study. All 31 dogs who contributed readings fell within the temperature parameters set out in the experimental design (34.0°C – 39.5°C). Table 6.3 shows the temperatures recorded from dogs in each of the three conditions and box plots of the temperatures recorded in the receive control (figure 6.6) and receive treat (figure 6.7) conditions are displayed below.

Table 6.3 Left and right ear temperatures taken from dogs in each of the three conditions, before start, after receive control (RC) and after receive treat (RT).

Dog	Trial	Left Ear (°C)	Right Ear (°C)
Amber	Before Start	38.7	35.8
	After RC	35.8	38.4
	After RT	38.4	36.1
Bailey	Before Start	36.2	38.5
	After RC	37.8	38.5
	After RT	37.8	37.8
Barney	Before Start	35.0	39.2
	After RC	38.9	39.1
	After RT	39.1	35.3
Bracken	Before Start	37.8	37.7
	After RC	35.1	37.7
	After RT	37.1	35.1
Buster	Before Start	37.2	34.6
	After RC	34.6	37.0
	After RT	37.0	35.6
Chispa	Before Start	37.9	35.6
	After RC	37.9	38.1
	After RT	38.1	36.6
Dexter. G.	Before Start	37.8	34.9
	After RC	38.1	37.3
	After RT	38.3	38.1
Dexter. L.	Before Start	34.9	36.7
	After RC	34.7	36.7
	After RT	36.6	34.7

Dylan	Before Start	36.4	38.3
	After RC	37.6	36.9
	After RT	35.4	34.9
George	Before Start	37.0	36.7
	After RC	36.7	37.0
	After RT	36.7	35.8
Henry	Before Start	36.6	37.8
	After RC	37.8	37.5
	After RT	37.8	36.2
Jett	Before Start	38.1	36.6
	After RC	38.1	39.2
	After RT	39.2	38.7
Lola	Before Start	38.0	36.0
	After RC	37.9	38.0
	After RT	38.0	37.8
Lolli	Before Start	36.1	35.5
	After RC	35.5	36.0
	After RT	37.0	36.0
Mabel	Before Start	34.6	35.2
	After RC	34.4	35.2
	After RT	34.9	34.4
Mandy	Before Start	35.9	34.9
	After RC	36.0	37.4
	After RT	36.0	36.0
Max	Before Start	38.3	38.9
	After RC	38.9	38.4
	After RT	39.4	38.9
Merrie	Before Start	*NONE RECORDED*	
	After RC		
	After RT		
Milly	Before Start	37.6	37.2
	After RC	36.2	37.2
	After RT	37.8	36.2
Missie	Before Start	38.1	34.9
	After RC	37.2	38.1
	After RT	38.1	37.1
Mollie	Before Start	37.8	38.5
	After RC	38.5	34.4
	After RT	37.9	34.4
Molly	Before Start	37.8	34.8
	After RC	34.8	35.1
	After RT	35.1	35.0
Patch	Before Start	37.4	36.1
	After RC	36.1	38.0
	After RT	37.6	37.6
Pippin	Before Start	37.3	37.5
	After RC	38.7	38.9
	After RT	38.7	37.6
Pudding	Before Start	35.2	36.7
	After RC	35.6	37.0
	After RT	36.3	35.4
Romulus	Before Start	37.7	36.0

	After RC	35.7	36.6
	After RT	37.7	35.7
Ruby	Before Start	38.9	38.7
	After RC	38.1	38.7
	After RT	39.3	37.8
Sasha	Before Start	37.1	36.7
	After RC	35.1	36.7
	After RT	37.1	34.5
Star	Before Start	36.5	36.5
	After RC	36.0	36.5
	After RT	36.9	36.0
Tess	Before Start	38.6	38.4
	After RC	38.4	38.8
	After RT	37.8	37.2
Tilly	Before Start	37.7	36.2
	After RC	37.4	38.3
	After RT	38.8	37.4
Tess	Before Start	38.6	38.4
	After RC	38.4	38.8
	After RT	37.8	37.2
Toby	Before Start	35.2	35.9
	After RC	35.4	36.3
	After RT	37.4	36.0

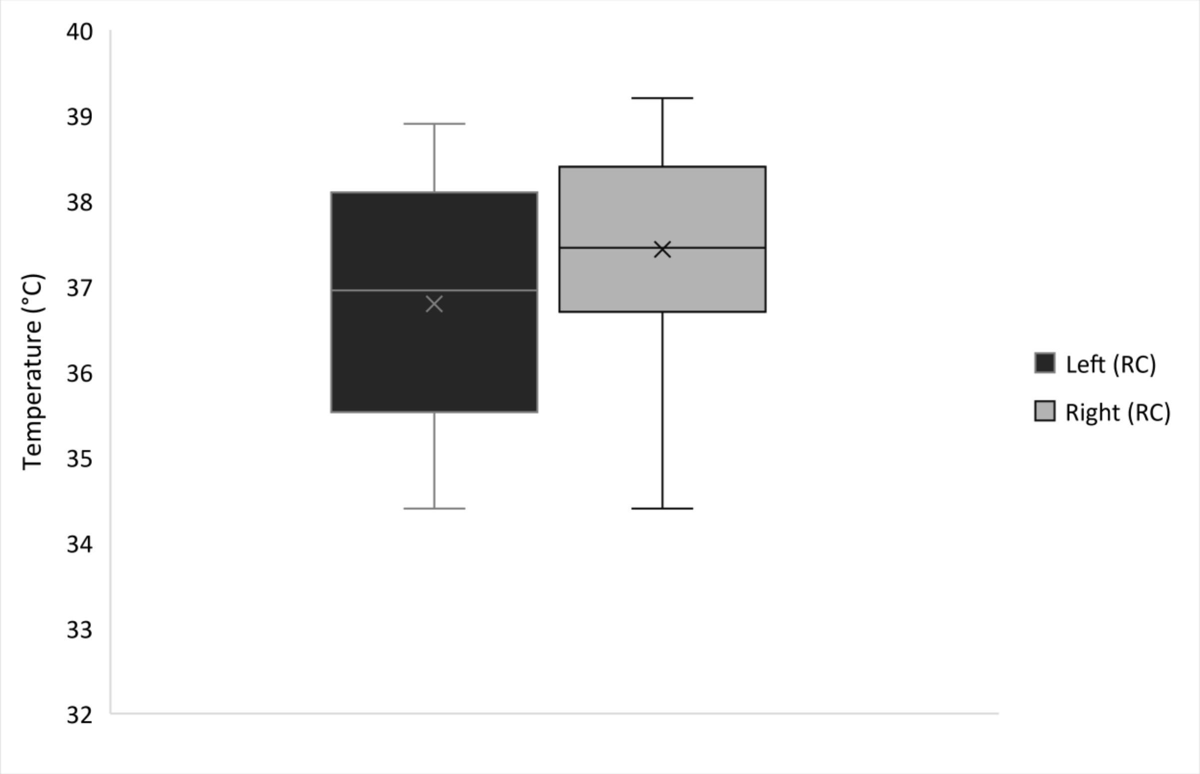


Figure 6.6 Left and right ear temperatures recorded in the receive control condition (the x represents the mean marker).

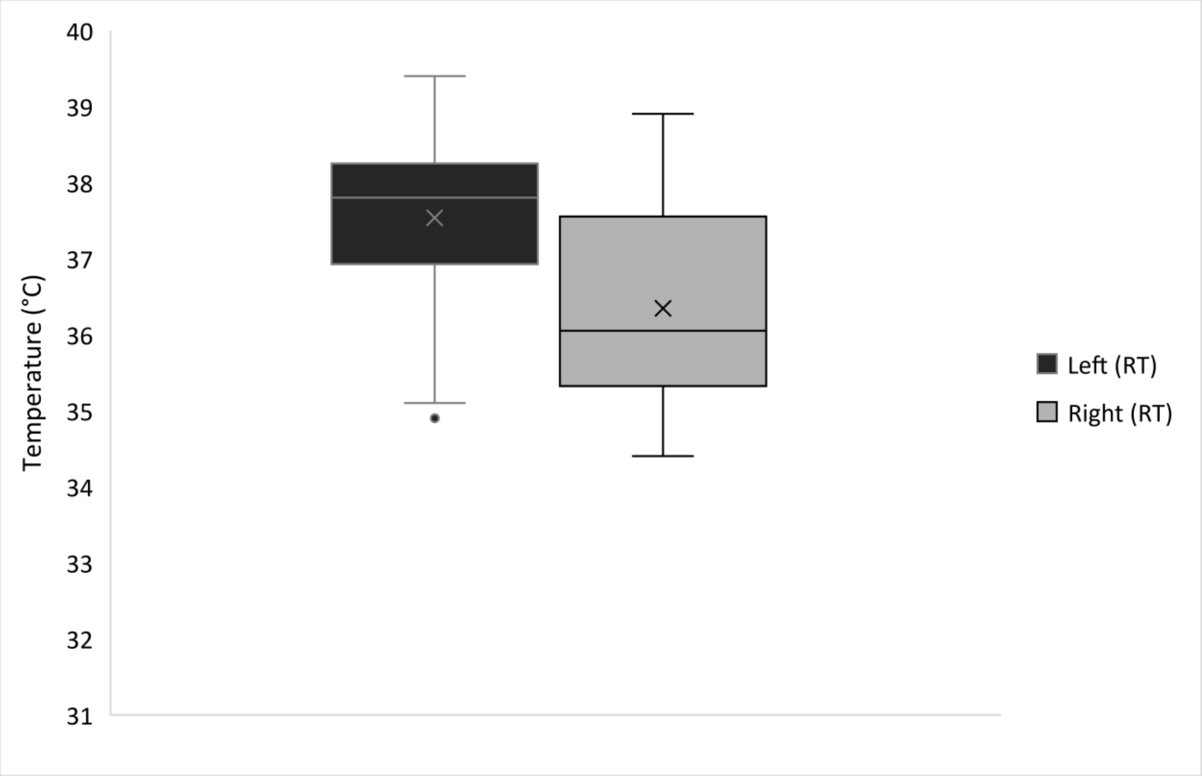


Figure 6.7 Left and right ear temperatures recorded in the receive treat condition (the point below the box and whisker represent the outliers and the x represents the mean marker).

Left and right ear temperatures were recorded before the start of the two trial conditions. As the dogs had not yet been subjected to any of the trials I predicted no difference between temperatures to be found (*Z*=-1.333, *n*=32, *P*=0.182). The temperatures recorded under the three different conditions for left (figure 6.8) and right (figure 6.9) ears are shown below.

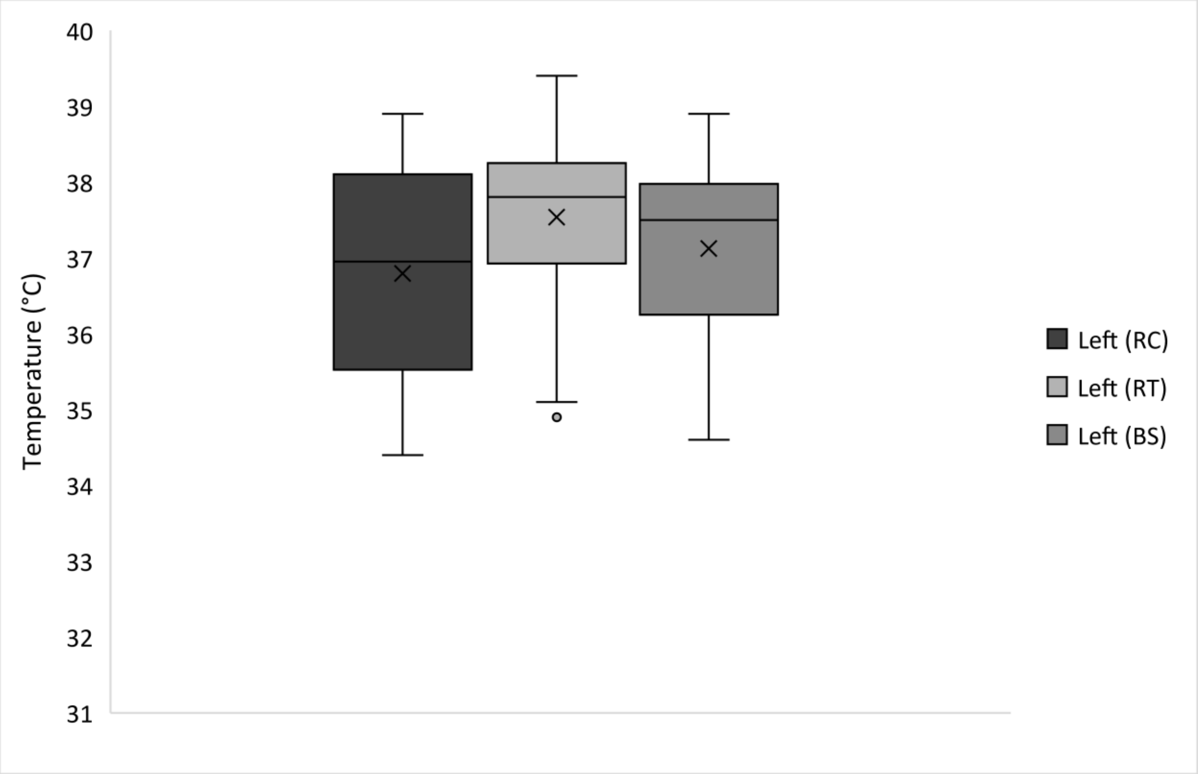


Figure 6.8 Left ear temperatures recorded in the receive control (RC), receive treat (RT) and before start (BS) conditions (the point below the box and whisker represent the outliers and the x represents the mean marker).

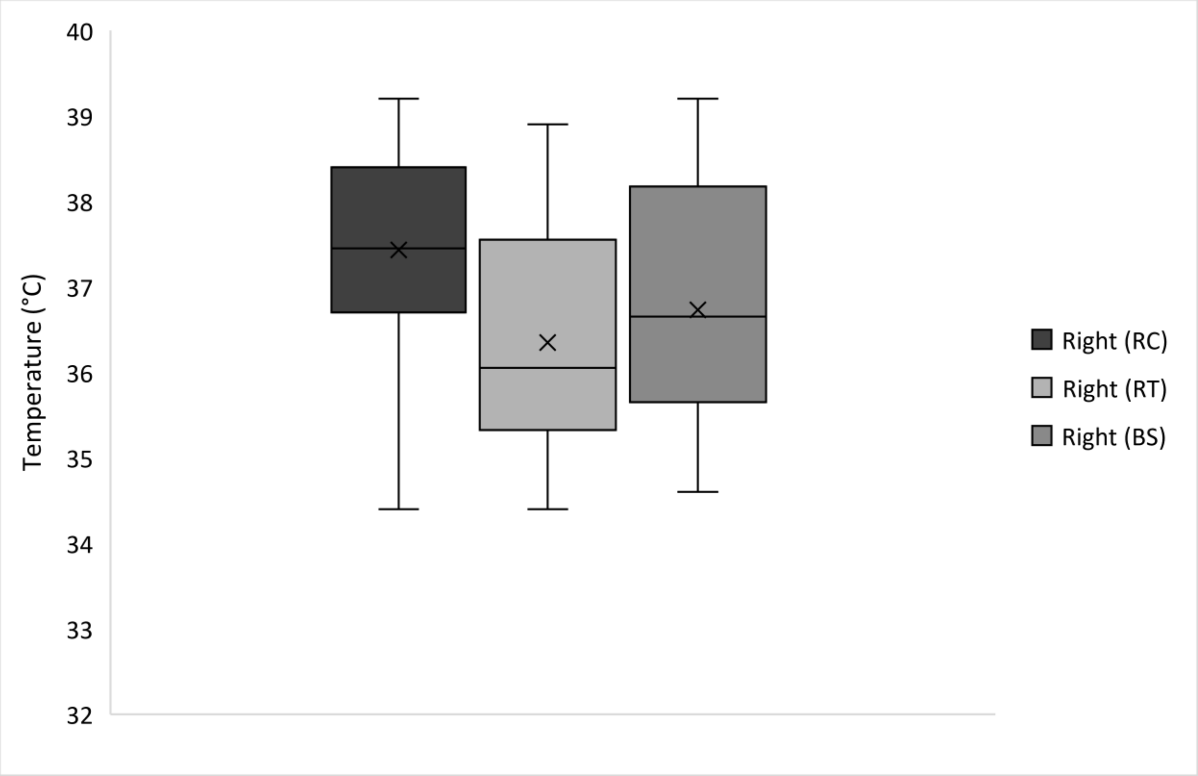


Figure 6.9 Right ear temperatures recorded in the receive control (RC), receive treat (RT) and before start (BS) conditions (the x represents the mean marker).

In the receive control condition 27 trials resulted in a higher right ear temperature, compared to only five trials were the left ear temperature was higher. Interestingly, in the receive treat condition 30 trials resulted in a higher left than right ear temperature with zero of receive treat trials producing a higher right ear temperature. However, two receive treat trials resulted in an equal right and left ear temperature. A significant difference between ear temperatures was revealed in both trial conditions with higher right ear temperatures in the receive control (Z=-3.443, n=32, P=0.001) and higher left ear temperatures in the receive treat (Z=-4.706, n=32, P<0.001) condition.

Right ear temperatures were higher than the pre-trial value in the receive control condition (Z=-2.846, n=32, P=0.004) but not the receive treat condition (Z=-1.049, n=32, P=0.294), whereas left ear temperatures were higher than the pre-trial value in the receive treat condition (Z=-2.222, n=32, P=0.026) but not the receive control condition (Z=-1.359, n=32, P=0.174). Furthermore, left ear temperatures were higher in the receive treat than the receive control condition (Z=-3.318, n=32, P=0.001) and right ear temperatures were higher in the receive control than the receive treat condition (Z=-4.465, n=32, P<0.001).

To eliminate the possibility that the dogs' temperatures were simply changing over time and were not caused by the testing regime, a control condition was conducted using a sample of five dogs. The dogs' left and right ear temperatures were taken three times with a five-minute gap in between each reading (Table 6.4). The dogs were subjected to no trials/callbacks so were left to interact within the individuals in the room as normal.

Table 6.4 Left and right ear temperatures of five dogs tested in the control condition over three time periods.

Dog	Time	Left Ear (°C)	Right Ear (°C)
Mandy	a. 10:30	37.1	34.7
	b. 10:35	36.9	34.7
	c. 10:40	37.2	34.9
Patch	a. 14:25	38.1	35.9
	b. 14:30	38.2	36.9
	c. 14:35	38.1	35.9
Pudding	a. 17:15	36.8	35.7
	b. 17:20	36.8	35.9
	c. 17:25	36.7	35.9
Toby	a. 17:16	35.2	35.3

	b. 17:21	35.2	34.6
	c. 17:26	35.4	35.7
Star	a. 08:00	37.9	36.4
	b. 08:05	37.8	36.4
	c. 08:10	37.8	36.5

A Friedman's test revealed no significant difference within the left, $\chi^2(_2)=0.125$, $P=0.3939$, and right, $\chi^2(2)=4.000$, $P=0.135$, ear temperatures over the three time periods (a, b, c). Moreover, no significant difference was found between the left and right ear temperatures in times a, b and c, $\chi^2(1)=1.800$, $P=0.180$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied resulting in a significance level set at $P<0.017$. There were no significant differences between the left and right ear temperatures of dogs during times a ($Z=-1.753$, $n=12$, $P<0.080$), b ($Z=-1.753$, $n=12$, $P<0.080$) and c ($Z=-1.753$, $n=12$, $P<0.080$).

6.6 DISCUSSION

Causal Reasoning

The philosopher David Hume (1739/1978) states in its most basic form causal reasoning can be described as B follows A. In this study, I have demonstrated that dogs demonstrate an understanding that a treat presentation (B) follows a specific phrase/actions (A) produced by a caller. Previous studies have revealed that both Diana monkeys (Zuberbühler, 2000 a, b) and baboons (Cheney et al., 1995) demonstrate an understanding and knowledge of causality in the social domain by responding to specific calls or playbacks. This study has shown that domestic dogs are also capable of this. Dogs responded significantly more in the causally inconsistent trial (receive control) than they did in the causally consistent trial (receive treat).

Documenting an understanding of causal relationships in non-human animals is difficult as the subjects cannot report back to experimenters and explain the reasoning behind their actions (Cheney et al., 1995). To overcome this issue, researchers have designed problems that, when faced by an adult human, can only be solved through causal reasoning, and then eliminate any other explanations for the behaviours observed if the subjects are successful (Cheney et al., 1995). This however, has proven difficult in this study as the dogs' behaviours could easily be explained through associative learning, i.e. positive reinforcement and conditioning through reward. It has been stated previously that causal reasoning can be the result of associative learning (Rescorla & Wagner, 1972; Kummer, 1995), but it has been argued that this form of causal knowledge is weak and does not require any augmented cognitive abilities (Zuberbühler, 2000b).

Recently, researchers have begun to question the assumed simplicity of associative learning and its links to causal reasoning (Hanus, 2016). Indeed, it has been suggested that there are parallels between human causal judgement and animal conditioning (Dickinson, 2001a). Thus suggesting that causal knowledge can be acquired through the associative learning processes underlying animal conditioning (Dickinson, 2001b). In the current study, it could be suggested that over time dogs learn that there is an association between the call and a reward. However, this does not mean that dogs do not possess any causal knowledge, rather that dogs' knowledge of causality is gained through associative learning.

It was predicted that dogs would 'ask' for longer in the receive control condition as they were being presented with an object that failed to satisfy their expectations. A shorter reaction time when receiving an expected goal demonstrates an understanding of causality. The Cheney et al. (1995) study found that female baboons will briefly orientate or ignore causally consistent calls and respond weakly to causally consistent call sequences (i.e. dominant female grunting to subordinate female), and in this study dogs reacted in a comparable way. During causally consistent trials (receive treat) dogs' reaction time after receiving the treat was significantly shorter than that observed in causally inconsistent (receive control) trials. Only two subjects gave no reaction towards the caller in the receive treat trials. The remaining 30 subjects performed some 'ask for more' behaviours after receiving the expected treat during the receive treat condition. This was expected as I found that most dogs will attempt to 'ask for more' once they have received a treat, but in most cases this 'ask for more' behaviour was brief.

The duration of dogs' first look was not different between receive treat and receive control trials. Dogs looked toward the caller more often during receive control trials than they did during receive treat trials, thus demonstrating that dogs will look more towards a caller when they do not receive their expected goals (i.e. a treat) and therefore suggesting that dogs understand that a causal relationship exists between a specific phrase and the presentation of a treat.

These results show that dogs also perform goal-directed behaviours as they reacted for longer when they did not receive their expected goal compared to when they did receive it. Unlike the Cheney et al. (1995) study dogs always reacted to the calls produced by the owner in both causally consistent and inconsistent trials. This is because the calls are goal-associated phrases and responses from dogs in both conditions demonstrates goal-directed behaviours and an understanding of the phrase.

Persistence and elaboration of gestures when initial attempts to communicate with others fail (Leavens et al., 2005) are a good indicator of a signaller searching for an appropriate response or set of behaviours from the recipient (Roberts et al., 2013). In the current study, increased persistence and elaboration in the receive control condition would indicate that dogs are not satisfied with the response from their owners, and therefore produce the causal actions which follow the call. Dogs performed more gestures with greater persistence and elaboration in the receive control condition compared to the receive treat condition (Appendix XII and XIII). This suggests that in the receive control condition they were not receiving what they apparently expected and thus produced more gestures. Moreover, it implies that dogs understood the meaning behind the call as well as the causally expected behaviour which follows.

Is Ear Temperature a Good Indicator of Emotional Hemispheric Activity in Domestic Dogs?

This study found that domestic dog ear temperature is a good proxy for emotional hemispheric brain activity. There are differences in how the right and left brain hemispheres process emotional information (Killgore & Yungelun-Todd, 2007), and when dogs are subjected to different experimental conditions their ear temperatures reflect this. When dogs were presented with an unexpected object (control), after hearing the caller say ‘treat’, dogs’ right ear temperatures were higher than their left ear temperatures. When given the expected object (treat) dogs’ left ear temperatures were higher than their right ear temperatures.

The results here also revealed that left ear temperatures differed from pre-trial ear temperatures after dogs received the apparently expected treat but not after they received the control object. Dog’s right ear temperatures, however, did differ from pre-trial temperatures after they received the control object but not after they received the treat. This suggests that the conditions used in this study affected the dogs’ ‘natural’ ear temperatures, thus indicating that the experimental trials caused an emotional hemispheric response.

Previous research has suggested that the two hemispheres of the brain are responsible for processing differing emotional information (Schneider et al., 2013). The right hemisphere is involved with processing negative withdrawal-related emotions, and the left hemisphere is responsible for processing positive approach-related emotions (Ahern & Schwartz, 1985; Davidson, 1992), and the results of this study reflect this theory.

It is important to note, however, that emotional hemispheric activity may not be the only cause to changes in dogs' ear temperature. Some dogs lay down during the breaks in between the trials which could have caused a rise in ear temperature on the side they lay against the ground with. Changes in environmental temperature may also have affected the ear temperature readings of dogs, for example if the central heating automatically turned on during the trials. It has been shown in humans that ear temperature differs with age and sex and it is currently not known if this is the case for dogs (Levander & Grodzinsky, 2017). If so it could be that age and/or sex may affect the temperature changes in dogs also. Until this is investigated, however, conclusions cannot be drawn.

Finding that ear temperature is a good proxy for brain activity has the potential to affect how researchers measure cognitive abilities in domestic dogs. Behavioural studies are often criticised as they provide evidence of behavioural manifestations of internal mental states but do not provide evidence of what dogs are directly thinking (Berns et al., 2015). To answer this criticism researchers have previously trained dogs to lie completely still in an MRI scanner during fMRI periods (Berns et al., 2012; 2015). However, this method requires rigorous training so is extremely time consuming, expensive, invasive and lack participant numbers and ecological validity. Measuring the ear temperatures of dogs, however, is cost effective and quick, allows for the inclusion of many participants and can be conducted in the animals' natural environment. Furthermore, it involves a procedure most dogs will have undergone during veterinary examinations as well as being relatively un-invasive.

Limitations of the Current Study

Although these two studies have revealed some interesting results they are not without their drawbacks. The results from the causal reasoning study suggest that dogs are behaving in a way that suggests they understand the causality behind human receive-request calls. This, however, like other investigations into animal causal reasoning is difficult to definitively prove (Cheney et al., 1995). Given this is the case, it would be beneficial if future researchers conducted causal reasoning trials with dogs in an experimental setting as well as a naturalistic one. This would allow for the use of better controls which, in turn, would help increase the validity of the results (the limitations of the methods used are discussed further in the general discussion chapter p. 131).

The results from the current study could also be argued as associative learning and therefore weak causal reasoning (i.e. B follows A). Here it could be suggested that the dogs undergo simple conditioning through repetition of the phrase and achievement of a treat thus resulting in a learned association (Zuberbühler, 2000b). Without further testing the current study is unable to definitively prove that dogs understand how and why one event leads to another. Given the difficulty in testing animals' causal knowledge in general, it could be argued that no study will be able to prove this (Cheney et al., 1995). It is hoped, however, that future research and repeated testing will aid in our understanding of the causal knowledge of animals.

Although the current study demonstrates that ear temperature is a good indicator of emotional hemispheric activity in domestic dogs further research and analysis is needed before it can be adopted by the field. This study provides no record of the dogs' 'natural' ear temperatures. All recorded temperatures were taken whilst the researcher was present and therefore we have no 'true' baseline temperature to compare the test trial temperature to.

Another limitation that arises is that the precise nature of ear temperature and brain activity still debated by researchers. Some researchers state that a decrease in ear temperature indicates increased hemispheric activity (Meiners & Dabbs, 1977; Dabbs, 1980; Hopkins & Fowler, 1998; Helton et al., 2009 a, b), whereas others state that warmer ear temperatures reflect cerebral activation (Swift, 1991; Mariak et al., 1994; Laughlin et al., 1998; Boyce et al., 2002; Gunnar & Donzella, 2004; Jackson, 2011; Mills, 2016; Genovese et al., 2017). The results here conform to one of these statements but the exact nature of the relationship between ear temperature and hemispheric activation needs to be determined to remove confusion from the field and allow for conclusions to be drawn.

A further limitation with the ear temperature data is the accuracy of the temperature readings taken from the Braun ThermoScan 3 thermometer. The thermometer used in this study is designed for use on human infants, but it is readily available and relatively inexpensive. Although the Braun ThermoScan 3 has been used by previous researchers such as Daniel Mills on dogs it is not known how accurate they are at taking canine ear temperature readings compared to those designed specifically for use on dogs. Other researchers in this area use specifically designed equipment which takes thermal readings of an individual animals tympanic membrane temperature (Mazzotti & Boere, 2009). This more than likely provides a more accurate reading but they are a costly and can only be purchased from veterinary websites or establishments. Indeed, the normal reference range for tympanic membrane temperature in domestic dogs has been shown to be 36.6°C–38.8°C (Hall & Carter, 2017) which is a much smaller, more medically accurate range compared to the temperature parameters set out in the current study (34.4°C to 39.4°C). The Braun ThermoScan 3 thermometer used in this study was sufficient enough to demonstrate a change in ear temperature between the trials but the readings were not medically accurate. Future researchers investigating the links between ear temperature and emotional hemispheric activity should compare readings taken from both the Braun ThermoScan 3 and tympanic membrane readers in order to determine if the equipment used affects the results. Until this comparison is conducted, researchers should use specifically designed tympanic membrane temperature readers to remove the question of the accuracy of the readings taken.

A limitation of both these investigations is that they were conducted concurrently. It is therefore not known if taking the ear temperature readings affected the dogs' behaviour in the causal reasoning trials. Given that the data were collected in the participants' homes at the owner's discretion it was necessary to collect as much data as possible in as little time. Future research should assess both of these investigations separately in order to increase the validity of results.

Finally both studies only looked at one type of phrase relating to food. Recent research has found that the content of a phrase and its relevance to dogs affects their attentiveness to the phrases being spoken (Benjamin & Slocombe, 2018). It is currently not known if dogs are more attentive to food-related phrases compared to walk-related phrases and how their reactions differ. Future research should consider further investigating these areas with a variety of dog related phrases in order to determine if dogs are more receptive or responsive to certain calls.

Conclusion

In summary, domestic dogs act as though they apply causal reasoning in interactions with humans, recognising that a specific call (do you want a treat?) produces a specific outcome (a treat). Dogs respond for a longer duration and look towards the caller more when they are subjected to a causally inconsistent condition (receive control) than a causally consistent condition (receive treat). However, duration of first look did not differ between causally consistent (receive treat) and inconsistent conditions. Even though the results shown here correspond with an explanation of causality, no single study can provide absolute evidence of causal reasoning in non-human animals (Cheney et al., 1995). Therefore, it is hoped that more research will be conducted to definitively show that domestic dogs are capable of causal reasoning in the social domain.

These results confirm the theory that ear temperature can be used as a proxy for hemispheric emotional processing in the canine brain. When dogs were presented with the control object and not the treat they apparently expected (an unexpected situation), the right hemisphere of the brain was more active than the left hemisphere resulting in a higher right ear temperature. Furthermore, when the dogs were given the goal they expected, a treat, theory supports the idea that the left hemisphere of the brain was more active than the right hemisphere resulting in a higher left ear temperature. Getting the owners to take their dog's temperature minimised stress to the dogs and ensured that having their temperature taken would not affect the readings. By measuring ear temperature investigators will be able to compare behavioural manifestations to the emotional responses in the canine brain. This will, in turn, further enhance our knowledge of the cognitive abilities of domestic dogs as well as allowing us to analyse these abilities in greater detail.

7. GENERAL DISCUSSION

7.1 Cross-Species Dog-Human Communication

Communication between social group members is a major factor of social cognition. Without effective communication, an individual will not be able to learn, understand, anticipate and correctly respond to the social behaviours of group mates in differing social situations (Holekamp, 2007). This thesis explored the social cognition of domestic dogs during cross-species interactions with humans and revealed that dogs have the necessary socio-cognitive abilities to communicate with and understand humans with efficacy.

By adopting a citizen science method I revealed a large repertoire of 103 intentional gestures, 19 referential gestures (Worsley & O'Hara, 2018) and 15 vocalisations performed by dogs during interactions with humans. I then investigated how dogs were using their cross-species repertoires to their advantage by analysing the communicative bouts from a social tool using perspective. This revealed that dogs were using their communicative repertoires to recruit humans as "social tools" in order to achieve an apparent goal. However, I raised concerns with the labelling of these behaviours as 'social tool use' and suggested a new terminology for these types of interactions: *goal attainment recruitment*.

Then using a psychology/ethology approach (Hare, 2001; Miklósi et al., 2003a) I found that dogs are able to react appropriately to human verbal phrases directed to them. Previous research has demonstrated that dogs understand human trained object and action request phrases (Ramos & Ades, 2012). This thesis, however, revealed that dogs understand and respond appropriately to untrained receive-request phrases. Moreover, dogs understand the causal relationships behind receive-request phrases and are able to perform goal-directed behaviours during verbal communicative bouts with humans. Interestingly, this thesis also revealed that ear temperature is a good proxy for emotional hemispheric brain activity in domestic dogs during behavioural trials.

In all five topics investigated in this thesis, all subjects used gestures to communicate with humans. Vocalisations, however, were less frequent with only a selection of dogs using them. This suggests that gestural communication is the primary mode of communication for dogs during cross-species interactions, with vocalisations functioning mainly as 'attention getters'. Additionally, this thesis is the first to put together the gestural and vocal repertoires used by dogs during naturally occurring communicative bouts with humans to give a complete view of their abilities. These findings alone provide us with an in-depth look at the differing behaviours dogs have developed to be able to thrive in the anthropogenic environment and enhance the unique bond they have with humans.

7.2 Acquisition of Cross-Species Communicative Abilities

This thesis revealed that dogs perform a portfolio of gestures to the individual they are communicating with to ensure they achieve their apparent goal. The vast majority of research concludes that the ability to communicate is acquired through conspecific cultural transmission (chimpanzees: Tomasello et al., 1987; Boesch & Boesch, 1990; Biro et al., 2003; bottlenose dolphins: Krützen et al., 2005; human children: Flynn & Whiten, 2008) and social learning (chimpanzees: Nagell et al., 1993; orangutans: Call & Tomasello, 1994b; humans: Csibra & Gergely, 2006; McGuigan & Whiten, 2009). However, unlike the species previously mentioned after weaning dogs' social groups are not made up of a large number of conspecifics regularly interacting with one another.

Dogs typically have a primary social group made up of heterospecifics with whom they have regular contact and most likely live with; and a secondary social group containing heterospecifics they do not live with (e.g. regular visitors, dog walkers etc.) and a small group of conspecifics who they occasionally interact with (e.g. neighbour's dogs, dogs on the park) (Hare & Tomasello, 2005; Miklósi, 2007; Bradshaw, 2012;). Research has shown that dogs are able to learn socially from human demonstrators during experimental trials and unlike wolves have a greater tendency to concentrate on what humans do (Miklósi et al., 2003b; Range & Virányi, 2013). Although evidence exists for social learning in dogs their naturally occurring communicative repertoires are difficult to explain via cultural transmission or social learning.

The domestication process led to dogs evolving specific adaptations enabling them to survive and thrive the human dominated environment (Kaminski & Marshall-Pescini, 2014). One of these adaptations could be that through years of evolution dogs are now predisposed with the ability to communicate with humans. The evidence from this study showed that although similar behaviours occurred between subjects, subtle differences were apparent and no individual dog was exactly the same in their communicative repertoires. This implies that dogs are born with the skills to learn to communicate with humans and use this ability to fashion individual repertoires to communicate with their particular human social group.

This adaptation of behaviours could be achieved through trial and error learning. In order to learn through trial and error an individual attempts new strategies to specific problems and rejects those choices which do not succeed (Young, 2009). Trial and error learned classical tool use has been demonstrated in woodpecker finches (*Cactospiza pallida*). Tebbich et al. (2001) found that unlike other tool using animals, woodpecker finches did not learn tool use socially but perform trial and error strategies related to a specific learning disposition which is useful for adapting to a variable environment. Given the absence of conspecific models to socially learn from within a dogs' social group it can be suggested that dogs develop their cross-species communicative abilities in a similar way to woodpecker finches.

This thesis did not investigate how dogs acquire and develop their communicative abilities, but the evidence suggests that a genetic disposition for a specific learning process may be present in dogs. This allows them to adapt behaviours to their particular human social group. This trial and error learning ensures that the ability to communicate with humans is part of a dogs' cognitive repertoire, but that an individual is able to modify their behaviours accordingly (Tebbich et al., 2001). Future researchers should investigate this further to reveal how dogs are acquiring and developing their cross-species communicative abilities.

7.3 Evidence for the Social Intelligence Hypothesis in Domestic Dogs

The results presented in this thesis could be argued as evidence for the social intelligence hypothesis in domestic dogs. Social intelligence is concerned with "those processes by which animals obtain and retain information about their social environments, and the use of that information to make behavioural decisions" (Kamil, 1994, p. 523). The social intelligence hypothesis predicts that non-primate mammals should display many of the same enhanced cognitive abilities seen in primates when their social lives are similar (Engh et al., 2005). Specifically, mammals that live in large, intricate societies should demonstrate advanced cognitive abilities similar to those observed in primates (Holekamp, 2007).

Domestic dogs have the potential to be an interesting model for exploring social intelligence as they live in a human social environment, and, as this thesis has shown, communicate and form social relationships with heterospecifics. They have a unique cross-species bond with their human group members, which in part is a result of the shared ability to successfully communicate with one another across the species boundary. Domestic dogs are subject to specific selection pressures from their social environment (Svartberg, 2006), and the social intelligence hypothesis could provide an explanation for the evolution of the socio-cognitive abilities reported in this thesis.

A criticism of the social intelligence hypothesis is that it fails to take into consideration the social differences between domesticated and wild species and, to date no research has investigated the social intelligence hypothesis in relation to domesticated species. To my knowledge, this could be the first evidence of social intelligence in a domesticated species. The results of this thesis reveal that dogs have developed cognitive capacities to create and maintain relationships with their human group members. Several studies have documented that dogs can read social cues given by humans in a variety of different contexts (see Kaminski & Nitzschner, 2013 for a review) and this thesis has shown that dogs' communicative actions and responses to humans are equally as impressive. Moreover, dogs will also influence the behaviours of their social group members (Hare, 2004) and my results indicate that the gestures and vocalisations performed by dogs could be being used to recruit humans to achieve apparent goals, consequently providing evidence of advanced socio-cognitive abilities similar to those observed in primates (Holekamp, 2007). It could, however, be argued that dogs' social environment is more cognitively demanding than a non-human primates as they involve heterospecific interactions and thus, theoretically, require greater socio-cognitive skills.

Primatologists have previously argued that the social structure of primates is more complex than those of other mammal species (Chance & Mead, 1953; Jolly, 1966; Byrne & Whiten, 1988; Cheney & Seyfarth, 1992; Whiten & Byrne, 1997; Dunbar, 2003). However, a lot of the research into animal social intelligence has been extremely anthropocentric and primocentric (Emery et al., 2007). Recent research has revealed augmented socio-cognitive abilities similar to those observed in primates in a variety of other species such as hyenas (Holekamp, 2007), elephant matriarchs (McComb, et al., 2001), corvids (Emery & Clayton, 2004) and now cross-species interactions in domestic dogs. Future researchers investigating social cognition could benefit from moving away or completely avoiding the primocentric ideology often associated with this topic. Consequently enabling us to document the socio-cognition of a wider range of species, both wild and domestic, and allowing us to advance our understanding of the socio-cognitive skills needed by individuals to successfully respond to and understand their respective group mates.

7.4 Strengths and Limitations of the Methods Utilised

With wild species it is less intrusive to go and watch and/or set up cameras to record behavioural data. However, when it comes to *in-situ* studies of domestic dogs, they live in a home with humans and it is very difficult to find participants who will allow cameras to be set up in their home recording 24/7 or researchers to be continually present. Therefore, citizen science is an excellent non-invasive method for collecting a large amount of naturalistic observational data on dogs. It is also a fantastic educational tool as it enables owners to actively take part in research and provides them with an opportunity to learn more about their dogs' cognitive abilities. In practice, however, the citizen science method does have its limitations.

A major criticism of the citizen science method is the validity of results collected from non-scientific individuals (Cohn, 2008; Hecht & Spicer-Rice, 2015). I addressed this issue by training the owners in the identification of relevant behaviours before the study started and informed them to only record behaviours when they naturally occurred. This provided an assurance that some level of competence had been attained by all participants. It is still possible, however, that some behaviours were missed by owners and therefore not recorded.

The citizen science method used in this thesis was developed from the method previously utilised by Horowitz and Hecht (2016), in their 'play with your dog' study. The difference was that in the current study participants met with the researcher face-to-face providing more of an opportunity to ask questions, compared to Horowitz and Hecht (2016) in which all contact was conducted via a website. Furthermore, unlike the Horowitz and Hecht (2016) study, to enhance the knowledge acquisition aspect of citizen science, I provided the participants with a detailed behavioural analysis of their dog(s) after I had analysed the video footage they provided. This allowed participants to learn about how their data had been used and what the specific findings were after handing the data over.

Citizen science enables a researcher to collect and analyse potentially otherwise unobtainable data. The most challenging aspect of the citizen science approach which arose in practice was not the validity of results but managing the general public on whom I relied to collect the data. Notwithstanding, the end result was that, in practice, the method adopted here was equivalent to most field studies except that the hand operating the camera to record the behaviour was that of a member of the public rather than a trained researcher. This is not dissimilar from many field studies where the data collection might be carried out by a field assistant whose training and/or knowledge is nonetheless limited. They remain competent, however, and the data collected are then analysed by the trained researcher.

It is also possible that under-sampling may occur in citizen science research. In the current study owners were asked to record both successful and unsuccessful dog communicative bouts. The majority of the data provided resulted in successful communicative bouts and this suggests that owners may have missed any unsuccessful bouts, thus resulting in under-sampling. Certain modes of tool use and ASOs may have also been under-sampled meaning that the results do not allow us to see the “true” communicative repertoire of the species only the parts which the owners caught on film. Citizen science, however, has been used successfully by canine cognitive researchers and has proven so far to be a successful method for collecting and analysing data in canine cognitive investigations (Stewart et al., 2015; Horowitz & Hecht, 2016).

The citizen science approach also provides owners with an opportunity to learn more about the cognitive world of their pets. Some owners did state that after participating in the current study they felt that they understood more about the cognitive abilities of dogs and were better attuned to their dog’s behaviours. Although this was discussed with owners the current study, like other canine citizen science research (Stewart et al., 2015; Horowitz & Hecht, 2016), did not measure the knowledge acquisition of the owners who participated. Other non-canine studies have used surveys to measure participant attitudes and knowledge after taking part in citizen science research (Evans et al., 2005; Lewandowski & Oberhauser, 2015). Future canine researchers who adopt a citizen science method should consider measuring the knowledge acquisition of owners after participating in the study. By conducting these post-study surveys we will better understand the benefits canine citizen science has on the non-scientific individuals who participate.

It is important to note, however, that another limitation to the citizen science method is contacting participants after the data has been collected from them. Since post-study participant evaluation represents gold standard practice (Evans et al., 2005; Cohn, 2008 Lewandowski & Oberhauser, 2015) follow up contact with participants is an important component of citizen science research. However, in this study follow up contact with participants was often problematic. As well as, in this case, it being difficult to find out whether they understood the analyses and whether participation had had any influence on their relationship with their dog, it also makes conducting post-study surveys difficult. A way round this could be to conduct post-data surveys that participants have to fill in before submitting their data. This would allow researchers to understand how the scientific process of collecting data and thinking about their dog(s) in a different way has impacted an owner's understanding of their pet.

To analyse if dogs can understand causal reasoning and human verbal communication directed to them I conducted experimental trials in the dogs' natural environment to increase both the internal and external validity of the results. An issue that arises when testing dogs in their home environment is that an argument could be made for observer-effects (Crofoot et al., 2010) as I was present throughout all the experimental trials. To address this, experimental trials did not begin until the dog was comfortable in my presence (i.e. had calmed down after the initial meeting and was either sat or lay away from myself). Also, a criterion for recruitment was that a dog must be comfortable in the presence of an unfamiliar individual in their home. Therefore, all the dogs who participated frequently interacted with unfamiliar individuals in their home (i.e. were used to regular visitors) and it was expected that observer-effect would have little or no influence on the dogs' behaviour. Moreover, the study was concerned with analysing whether a dog's behaviour was different in condition A compared to condition B and although observer-effect could be present, it would have affected their behaviour in both test conditions similarly and thus reduce the impact of observer-effect on the results.

A further issue is that some dogs will be excluded from participation. Testing in an experimental or laboratory setting prevents certain dogs (i.e. those easily distracted, nervous in strange environments or when owner not present etc.) from participating in those studies (Stewart et al., 2015). Previous research has tended to recruit participants from dog training schools and kennels (Miklósi et al., 2003b; Benjamin & Slocombe, 2018), from databases with a criterion of being comfortable in strange situations (Kaminski et al., 2011; 2017) or use individuals specifically trained for the task (Berns et al., 2012; 2015). Testing in the dogs' home environment enables more individuals to participate and is less stressful for the dogs (Bekoff & Jamieson, 1991). However, those dogs who are uncomfortable around strangers or have aggressive tendencies towards unfamiliar individuals were prohibited from participating in this part of the study. This means that some dogs were still excluded from taking part in the study and the results collected cannot be discussed in regards to the species as a whole. It is difficult for researchers to determine a methodology that will allow for the inclusion of *all* dogs as the safety of the researchers needs to be considered. Perhaps by combining both laboratory experiments and naturalistic observations it will allow us to reveal a more holistic view of the social cognitive and cross-species communicative abilities of domestic dogs.

I also investigated whether ear temperature is a good proxy of emotional hemispheric activity in the dogs' home environment. The owners were asked to take their dogs' ear temperature during the trial. Conducting procedures such as this in the home environment and involving the owners prevents the dogs from experiencing any additional stress that may come from being handled by an unfamiliar individual in an unfamiliar environment and thus affect the results.

Although this study found that during behavioural trials, ear temperature is a good proxy for emotional hemispheric activity in dogs, the results were not validated against actual brain measurements (like, for example, in the research conducted by Berns et al., 2012; 2015). Future researchers should delve deeper into this area by comparing ear temperature with brain measurements during behavioural trials. This can be achieved by developing non-invasive Electroencephalography (EEG) headwear for use on dogs in their natural environment. This will uncover whether ear temperature is an accurate measure of corresponding emotional hemispheric activity.

It could, however, be argued that the results presented in this thesis are high in ecological or external validity, but lack reliability as it is difficult to reproduce the exact conditions that were around during the initial study (Martin & Bateson, 2007). Interpreting observed behaviours can also be difficult as well as there can be several explanations as to how and why a specific behaviour has occurred. However, this thesis did not rely solely on naturalistic observations. The methods utilised involved a combination of both controlled variables (the experimental trials) and naturalistic observations (the citizen science approach) to increase the validity of the observed behaviours under natural conditions (Miklósi et al., 2003a). Research concerned with the social cognition of primates has seen a move towards this methodological approach, by combining the use of (1) an ecologically valid setting and (2) proper control(s) to maximize the validity of experiments (Hare, 2001) and this thesis is the first of its kind to apply this type of mixed-method approach to investigate the social cognition of domestic dogs.

By applying this psychology/ethology approach (Hare, 2001; Miklósi et al., 2003a) to my work, this thesis is one of the first to document the naturally occurring cross-species communicative and socio-cognitive abilities of domestic dogs. Future researchers exploring dog cognition should consider adopting this approach more often as controlled experiments do not make the results collected easy to place into contexts outside of the test situation (Becker, 2005). Also, when tested in an experimental setting, animals are unable to exhibit their natural abilities (Bekoff & Jamieson, 1991). Observing domestic dogs in their natural environment can be achieved but, until now, the majority of researchers have failed to take advantage of this opportunity. Research conducted in experimental settings are however high in experimental control and are therefore easier to replicate (Martin & Bateson, 2007). Perhaps, future researchers ought to consider a combination of both controlled variables and naturalistic observations in the dogs' natural environment, i.e. the family home, in order for us to better understand the cognitive abilities of domestic dogs.

7.5 Improving the Dog-Human Bond through Research: Methodological Innovations

Communication between humans and dogs is vital for the establishment of a bond between the two species (Bradshaw et al., 2009), but throughout the course of this project I found that owners possessed little or no knowledge regarding the cognitive and communicative world of their dogs. A criticism of canine citizen science projects to date, is that they have tended to focus on data acquisition rather than knowledge acquisition and attitude or behavioural change (Hecht & Spicer-Rice, 2015). Many dog owners show a keen interest in the behavioural and cognitive world of their pets (Macpherson & Roberts, 2013) but science is currently overlooking lay audiences.

The solution to this issue is a simple one, by designing methodologies that include, not exclude, owners and by relaying results back to participants, researchers can improve an owner's knowledge of their dog, thus enhancing the bond between owner and dog. The methods used in this thesis were designed with knowledge acquisition and enhancing the dog-human relationship at the forefront of my mind. They provide a guideline of how researchers can address the issue of science communication and actively include dog owners in their research.

Getting owners involved in the research is key and this is not just exclusive to the citizen science approach. In this thesis I also included the owners during the experimental trials, which allowed them to better understand what the research aimed to test. Some researchers have previously included owners in trials but have tended to conduct their research in an unfamiliar experimental setting which can cause unease to both owner and dog. Conducting research in the dogs' home environment, however, makes the results collected more ecologically valid, and visiting dogs and their owners in their homes to conduct the study creates a more congenial atmosphere. It gives owners more of an opportunity to discuss and ask questions about the study and other research related to the cognitive and communicative world of their dog.

The citizen science aspect of the research gave owners an opportunity to actively take part in data collection and encourage them to think about their dog from a cognitive scientist's perspective. With the citizen science data I provided owners with an in-depth analysis of the results from their dog. Providing feedback after the end of the studies can help owners better understand what their dog is capable of (Cohn, 2008). Additionally, I found that getting the owners involved in the experimental part of the research, by recording ear temperatures and participating in call-back trials, was not only a sufficient way of minimising stress for the dogs, but also a good opportunity to educate the owners. This further enhanced the owner's understanding of the scientific process and gave them the opportunity to think about their dog in a different way. Providing owners with their results at the end of experimental trials allowed them to see how their dog performed in comparison to other dogs.

Dogs are the most popular species of pet in the UK (Leading pets, 2018; Pet population, 2018), found in 26% of households in the United Kingdom (Leading pets, 2018; Pet population, 2018). It is estimated that there are nine million dogs in the UK (Leading pets, 2018; Pet population, 2018). Dog research affects the non-scientific community as dogs share an environment with humans. Moreover owners of dogs have a heightened interest in dog cognition (Macpherson & Roberts, 2013). Researchers, however, are often failing to make their findings accessible to the general public. Future dog studies should be designed with more active roles for owners to provide opportunities for individuals to learn more about their dog and thus improve the bond they have them.

Other research fields have acknowledged that science and technology play a major role in the everyday lives of both scientific and non-scientific individuals (Irwin, 1995). The same however, cannot be said for canine cognitive research. Given the significance canine cognitive research has on the everyday lives of owners and dogs (Macpherson & Roberts, 2013), researchers in this field should be doing more to make sure their studies and results impact the lives of dogs and their owners. The methods used in this thesis provide a good model for future dog cognition researchers to address the current inaccessibility faced by lay audiences when it comes to accessing scientific results. Researchers can also do more my embracing the media and publishing their work not just in academic journals but in media outlets such as newspapers, radio etc. to enable the general public to know about and understand their research. By adopting a knowledge acquisition driven methodology dog cognition researchers will be able to improve the relationship not just between owners and dogs, but also between scientists and the public.

7.6 Conclusions

Domestic dogs are a highly social species who possess impressive socio-cognitive abilities which allow them to navigate through their shared social environment with humans. Here it has been revealed that these socio-cognitive skills are put into practice during cross-species interactions with humans, but more research is required to give us further insight into their abilities.

This thesis suggests several directions for future canine socio-cognitive researchers. Further exploration into the ‘social tool using’ abilities of dogs and the adoption of the new label, *goal attainment recruitment*, will aid in our understanding of this form of communication. Future researchers should also consider exploring dogs’ gestural and vocal repertoire further, we argue the findings here are a conservative estimate of dogs’ gestural abilities (Worsley & O’Hara, 2018). This could be achieved by conducting individual citizen science studies on each of the 10 ASOs identified in this thesis. Doing this will provide us with an in depth view of the types of gestures and vocalisations that dogs use in these specific contexts and may uncover some novel gestures which have yet to be reported.

Dogs are adept at responding to untrained human-given gestures and a vast amount of research has been conducted on this ability (see Kaminski & Nitzschner, 2013 for a review). This thesis has revealed that dogs also understand untrained human receive-request phrases. Further investigation into the responses of dogs to untrained vocal cues will help us to better understand the underlying abilities which dogs possess that allow them to respond correctly to both untrained vocal and gestural cues.

Evidence of causal reasoning in a non-human species is difficult to demonstrate and the majority of researchers investigate this ability in the physical domain (Cheney et al., 1995). This thesis, however, provided evidence which suggests that dogs are capable of basic causal reasoning in the social domain. Given the results shown in this thesis, and the work in non-human primates (Cheney et al., 1995; Zuberbühler, 2000 a, b), future researchers should consider investigating causality more in the social rather than the physical domain. This could potentially provide evidence of causal reasoning in species which have previously failed to demonstrate this ability, especially those which are highly social.

Future researchers should adopt the psychology/ethology approach (Hare, 2001; Miklósi et al., 2003a) to their methods to increase both the internal and external validity of their studies. Given that dogs are readily accessible and that owners do show a genuine interest in the cognitive world of their dogs (Macpherson & Roberts, 2013), researchers should consider more often adopting a citizen science approach. By using a citizen science approach researchers could increase sample size, collect naturally-occurring data and foster a greater understanding of the scientific process, dog cognition and communication in lay audiences. Furthermore, researchers should adopt methods that include, not exclude, owners and consider the accessibility of their data to ensure their findings impact the non-scientific population. Thus fostering a greater appreciation of dogs and in turn, enhancing the bond between owner and dog.

This thesis brought together and investigated five areas of communicative and socio-cognitive research to gain a more complete view of the cross-species communicative abilities of domestic dogs. By doing this I revealed that dogs have a large and varied gestural and vocal repertoire which they call upon to communicate both intentionally and referentially to humans. I also revealed that, play gestures aside, dog-initiated requests are principally concerned with four things: “Scratch me!”, “Give me food/drink”, “Open the door” and “Get my toy/bone” (Worsley & O’Hara, 2018). The results also suggest that dogs are using this repertoire to solicit and recruit humans to achieve otherwise inaccessible goals. This thesis also uncovered dogs’ understanding of a previously untested human-given vocal cue: receive-request phrases, further demonstrating that dogs are capable of understanding and learning naturally-given/untrained human phrases. I also revealed that dogs behave as though they understand the causal relationship behind these receive-request phrases and perform goal-directed behaviours. Moreover, the data also exposed that measuring ear temperature in dogs during behavioural trials is a good proxy for emotional hemispheric brain activity.

By bringing together these five areas, this thesis has revealed how dogs use their gestural and vocal repertoires to communicate with humans and the understanding dogs have when we communicate vocally with them. Through the use of both citizen science and experimental methods this thesis provides us with a rounded view of the impressive cross-species communicative abilities of domestic dogs and the socio-cognitive abilities underlying them.

8. REFERENCES

Adachi, I., Kuwahata, H., & Fujita, K. (2007). Dogs recall their owner's face upon hearing the owner's voice. *Animal Cognition, 10*(1), 17-21.

Agnetta, B., Hare, B., & Tomasello, M. (2000). Cues to food location that domestic dogs (*Canis familiaris*) of different ages do and do not use. *Animal Cognition, 3*(2), 107-112.

Ahern, G.L., & Schwartz, G.E. (1985). Differential lateralisation for positive versus negative emotions. *Neuropsychologia, 23*(6), 745-755.

Ainsworth, M.D.S., & Bell, S.M. (1970). Attachment, exploration, and separation: Illustrated by the behavior of one-year-olds in a strange situation. *Child Development, 41*(1), 49-67.

Akhtar, N., & Gernsbacher, M.A. (2008). On privileging the role of gaze in infant social cognition. *Child Development Perspectives, 2*(2), 59-65.

Alcock, J. (1972). The evolution of the use of tools by feeding animals. *Evolution, 26*(3), 464-473.

Allen, K.M., Blascovich, J., Tomaka., J., & Kelsey, R.M. (1991). Presence of human friends and pet dogs as moderators of autonomic responses to stress in women. *Journal of Personality and Social Psychology, 61*(4), 582-589.

Andics, A., Gácsi, M., Faragó, T., Kis, A., & Miklósi, Á. (2014). Voice-sensitive regions in the dog and human brain are revealed by comparative fMRI. *Current Biology, 24*(5), 574-578. doi: 10.1016/j.cub.2014.01.058

Arbib, M.A., Liebal, K., & Pika, S. (2008). Primate vocalization, gesture, and the evolution of human language. *Current Anthropology, 49*(6), 1053-1076.

Armstrong, D.F., Stokoe, W.C., & Wilcox, S.E. (1995). *Gesture and the Nature of Language.* Cambridge: Cambridge University Press.

Altenmüller, E., Schürmann, K., Lim, V.K., & Parlitz, D. (2002). Hits to the left, flops to the right: different emotions during listening to music are reflected in cortical lateralisation patterns. *Neuropsychologia, 40*(13), 2242-2256. doi: 10.1016/S0028-3932(02)00107-0

Altmann, A.V. (1967). The structure of primate social communication. In: S.A. Altmann (Ed.), *Social Communication Among Primates* (pp. 325-362). Chicago: University of Chicago Press.

Axelrod, R., & Hamilton, W.D. (1981). The evolution of cooperation. *Science, 211*(4489), 1390-1396.

Baker, M.A., Stocking, R.A., & Meehan, J.P. (1972). Thermal relationship between tympanic membrane and hypothalamus in conscious cat and monkey. *Journal of Applied Physiology, 32*(6), 739–742.

Balcombe, J.P. (1990). Vocal recognition of pups by mother Mexican free-tailed bats, *Tadarida brasiliensis Mexicana*. *Animal Behaviour, 39*(5), 960-966. doi: 10.1016/S0003-3472(05)80961-3

Bard, K.A. (1990). "Social tool use” by free-ranging orangutans: A Piagetian and developmental perspective on the manipulation of an animate object. In S.T. Parker & K.R. Gibson (Ed.), *Language and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives* (pp. 356-378). Cambridge: Cambridge University Press.

Bateman, R., & Gottman, J.M. (1997). *Observing Interaction: An Introduction to Sequential Analysis.* Cambridge: Cambridge University Press.

Bates, E., Benigni, L., Bretherton, I., Camaioni, L., & Volterra, V. (1979). *The Emergence of Symbols: Cognition and Communication in Infancy*. New York: Academic Press, Inc.

Beck, B.B. (1980). *Animal Tool Behaviour: The Use and Manufacture of Tools*. New York: Garland STPM Press.

Becker, T.E. (2005). Potential problems in the statistical control of variables in organizational research: A qualitative analysis with recommendations. *Organizational Research Methods, 8*(3), 274-289.

Beetz, A., Kotrschal, K., Turner, D.C., Hediger, K., Uvnäs-Moberg, K., & Julius, H. (2011). The effect of a real dog, toy dog and friendly person on insecurely attached children during a stressful task: An exploratory study. *Anthrozoos: A Multidisciplinary Journal of the Interactions of People & Animals, 24*(4), 349-368.

Bekoff, M., & Jamieson, D. (1991). Reflective ethology, applied philosophy, and the moral status of animals. In P. Bateson & P. Klopfer (Eds.), *Human Understanding and Animal Awareness: Perspectives in Ethology* (pp. 1-58). New York: Plenum.

Benjamin, A., & Slocombe, K. (2018). ‘Who’s a good boy?!’Dogs prefer naturalistic dog-directed speech. *Animal Cognition, 21*(3), 353-364. doi: 10.1007/s10071-018-1172-4

Bensky, M.K., Gosling, S.D., & Sinn, D.L. (2013). The world from a dog’s point of view: a review and synthesis of dog cognition research. In H.J. Brockmann, T.J. Roper, M.

Naguib, J.C. Mitani, L.W. Simmons & L. Barrett (Eds.), *Advances in the Study of Behaviour* (pp. 209-406). Oxford: Academic Press.

Bently-Condit, V.K., & Smith, E.O. (2010). Animal tool use: Current definitions and an updated comprehensive catalog. Behaviour, 147(2), 185-32A. doi: 10.1163/000579509X12512865686555

Berns, G.S., Brooks, A.M., & Spivak, M. (2012). Functional MRI in awake unrestrained dogs. *PLoS ONE, 7*(5), e38027. doi: 10.1371/journal.pone.0038027

Berns, G.S., Brooks, A.M., & Spivak, M. (2015). Scent of the familiar: An fMRI study of canine brain responses to familiar and unfamiliar human and dog odors. *Behavioural Processes, 110*(2015), 37-46. doi: 10.1016/j.beproc.2014.02.011

Berryman, J., Howells, K., & Lloyd-Evans, M. (1985). Pet owner attitudes to pets and people: A psychological study. *Veterinary Record, 117*(25-26), 659-661. doi: 10.1136/vr.117.25-26.659

Biro, D., Inoue-Nakamura, N., Tonooka, R., Yamakoshi, G., Sousa, C., & Matsuzawa, T. (2003). Cultural innovation and transmission of tool use in wild chimpanzees: Evidence from field experiments. *Animal Cognition, 6*(4), 213-223. doi: 10.1007/s10071-003-0183-x

Biro, D., Sousa, C., & Matsuzawa, T. (2006). Ontogeny and cultural propagation of tool use by wild chimpanzees at Bossou, Guinea: Case studies in nut cracking and leaf folding. In T. Matsuzawa, M. Tomonaga, & M. Tanaka (Eda.), *Cognitive Development in Chimpanzees* (pp. 476-508). Tokyo: Springer. doi: 10.1007/4-431-30248-4_28

Blaisdell, A.P., Sawa, K., Leising, K.J., & Waldmann, M.R. (2006). Causal reasoning in rats. *Science, 311*(5763), 1020-1022.

Bleicher, N. (1963). Physical and behavioural analysis of dog vocalization. *American Journal of Veterinary Research, 24*(1963), 415-427.

Boesch, C., & Boesch, H. (1990). Tool use and tool making in wild chimpanzees. *Folia Primatologica, 54*(1-2), 86-99.

Bonney, R., Cooper, C.B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K.V., & Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience, 59*(11), 977-984. doi: 10.1525/bio.2009.59.11.9

Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J., & Parrish, J.K. (2014). Next steps for citizen science. *Science, 343*(6178), 1436-1437.

Borgeaud, C., van de Waal, E., & Bshary, R. (2013). Third-party ranks knowledge in wild vervet monkeys (*Chlorocebus aethiops pygerythrus*). *PLoS ONE 8*(3), e58562. doi: 10.1371/journal.pone.0058562

Borgeaud, C., Alvino, M., van Leeuwen, K., Townsend, S.W., & Bshary, R. (2015). Age/sex differences in third-party rank relationship knowledge in wild vervet monkeys, *Chlorocebus aethiops pygerythrus*. *Animal Behaviour, 102*(2015), 277-284. doi: 10.1016/j.anbehav.2015.02.006

Bowlby, J. (1958). The nature of the child's tie to his mother. *The International Journal of Psycho-Analysis, 39*(5), 350-373.

Boyce, W.T., Essex, M.J., Alkon, A., Smider, N.A., Pickrell, T., & Kagan, J. (2002). Temperment, tympanum, and temperature: Four provisional studies of the biobehavioral correlates of tympanic membrane temperature asymmetries. *Child Development, 73*(3), 718–733.

Bradbury, J.W., & Vehrencamp, S.L. (1998). *Principles of Animal Communication*. Sunderland, MA: Sinauer Associates.

Bradshaw, J.W., Blackwell, E.J., & Casey, R.A. (2009). Dominance in domestic dogs—useful construct or bad habit? *Journal of Veterinary Behavior: Clinical Applications and Research, 4*(3), 135-144.

Bradshaw, J.W.S. (2012). *In Defence of Dogs*. London: Penguin.

Bradshaw, J.W.S., Pullen, A.J., & Rooney, N.J. (2015). Why do adult dogs 'play'? *Behavioural Processes, 110*(2015), 82-87. doi: 10.1016/j.beproc.2014.09.023

Brain Anatomy Introduction. (2017). *Dog Brain Sketch – Dorsal View* [Drawing]. Retrieved from http://vanat.cvm.umn.edu/neurLab3/pages/SulciDorsalView.html

Bräuer, J., Kaminski, J., Riedel, J., Call, J., & Tomasello, M. (2006). Making inferences about the location of hidden food: Social dog, causal ape. *Journal of Comparative Psychology, 120*(1), 38-47.

Bräuer, J. (2014). What dogs understand about humans. In J. Kaminski & S. Marshall-Pescini (Eds.), *The Social Dog: Behaviour and Cognition* (pp. 295-317), San Diego: Academic Press.

Brandt, K. (2004). A language of their own: An interactionist approach to human-horse communication. *Society & Animals, 12*(4), 299-316. doi: 10.1163/1568530043068010

Breuer, T., Ndoundou-Hockemba, M., & Fishlock, V. (2005). First observation of tool use in wild gorillas. *PLoS Biology, 3*(11), e380. doi: 10.1371/journal.pbio.0030380

Brink, H.I.L. (1993). Validity and reliability in qualitative research*. Curationis, 16*(2), 35-38. doi: 10.4102/curationis.v16i2.1396

Brinnel, H., & Cabanac, M. (1989). Tympanic temperature in a core temperature in humans. *Journal of Thermal Biology, 14*(1), 47–53.

Byrne, R.W. (1995). *The Thinking Ape: Evolutionary Origins of Intelligence*. Oxford: Oxford University Press.

Byrne, R.W., Cartmill, E., Genty, E., Graham, K.E., Hobaiter, C., & Tanner, J. (2017). Great ape gestures: Intentional communication with a rich set of innate signals. *Animal Cognition, 20*(4), 755-769. doi: 10.1007/s10071-017-1096-4

Byrne, R.W., & Whiten, A. (1988). *Machiavellian intelligence: Social expertise and the Evolution of Intellect in Monkeys, Apes, and Humans*. New York: Oxford University Press.

Cabanac, M. (1993). Selective brain cooling in human, fancy or fact?. *The FASEB Journal, 7*(12), 1143–1147.

Call, J., Hare, B., & Tomasello, M. (1998). Chimpanzee use of gaze in an object choice task. *Animal Cognition, 1*(2), 89-100.

Call, J., & Tomasello, M. (1994a). Production and comprehension of referential pointing by orangutans (*Pongo pygmaeus*). *Journal of Comparative Psychology, 108*(4), 307-317.

Call, J., & Tomasello, M., (1994b). The social learning of tool use by orangutans (*Pongo pygmaeus*). *Human Evolution, 9*(4), 297-313.

Call, J., & Tomasello, M. (2007). *The Gestural Communication of Apes and Monkeys*. New York: Taylor & Francis Group.

Call, J., & Tomasello, M. (2008). Does the chimpanzee have a theory of mind? 30 years later. Trends in Cognitive Science, 12(5), 187-192. doi: 10.1016/j.tics.2008.02.010

Camaioni, L. (1997). The emergence of intentional communication in ontogeny, phylogeny, and pathology. *European Psychologist, 2*(3), 216-225. doi: 10.1027/1016-9040.2.3.216

Candiotti, A., Zuberbühler, K., & Lemasson, A. (2013). Voice discrimination in four primates. *Behavioural Processes, 99*(10), 67-72.

Cartmill, E.A., & Byrne, R.W. (2007). Orangutans modify their gestural signalling according to their audience's comprehension. *Current Biology, 17*(15), 1345-1348. doi: 10.1016/j.cub.2007.06.069

Cartmill, E.A., & Byrne, R.W. (2010). Semantics of primate gestures: Intentional meanings of orangutan gestures. *Animal Cognition, 13*(6), 793-804. doi: 10.1007/s10071-010-0328-7

Casperd, J.M., & Dunbar, R.I. (1996). Asymmetries in the visual processing of emotional cues during agonistic interactions by gelada baboons. *Behavioural Processes, 37*(1), 57-65.

Cäsar, C., Byrne, R., Young, R.J., & Zuberbühler, K. (2012). The alarm call system of wild black-fronted titi monkeys, *Callicebus nigrifrons*. *Behavioral Ecology and Sociobiology, 66*(5), 653-667.

Catala, A., Mang, B., Wallis, L., & Huber, L. (2017). Dogs demonstrate perspective taking based on geometrical gaze following in a Guesser–Knower task. *Animal Cognition, 20*(4), 581-589. doi: 10.1007/s10071-017-1082-x

Chance, M.R.A., & Mead, A.P. (1953). Social behaviour and primate evolution. *Symposium of the Society for Experimental Biology and Evolution, 7*(1), 395-439.

Chappell, J., & Kacelnik, A. (2002). Tool selectivity in a non-primate, the New Caledonian crow (*Corvus moneduloides*). *Animal Cognition, 5*(2), 71-78. doi: 10.1007/s10071-002-0130-2

Chappell, J., & Kacelnik, A. (2004). Selection of tool diameter by New Caledonian crows (*Corvus moneduloides*). *Animal Cognition, 7*(2), 121-127. doi: 10.1007/s10071-003-0202-y

Cheney, D.L., & Seyfarth, R.M. (1980). Vocal recognition in free-ranging vervet monkeys. *Animal Behaviour, 28*(2), 362-367.

Cheney, D.L., & Seyfarth, R.W. (1988). Assessment of meaning and the detection of unreliable signals by vervet monkeys. *Animal Behaviour, 36*(2), 477-486.

Cheney, D.L., & Seyfarth, R.M. (1992). *How Monkeys See the World: Inside the Mind of Another Species*. Chicago: University of Chicago Press.

Cheney, D.L., & Seyfarth, R. M. (2007). *Baboon Metaphysics: The Evolution of a Social Mind*. Chicago: Chicago University Press.

Cheney, D.L., Seyfarth, R.M., & Silk, J.B. (1995). The responses of female baboons (*Papio cynocephalus ursinus*) to anomalous social interactions: Evidence for causal reasoning? *Journal of Comparative Psychology, 109*(2), 134-141.

Chevalier-Skolnikoff, S., & Liska, J. (1993). Tool use by wild and captive elephants. *Animal Behaviour, 46*(2), 209-219. doi: 10.1006/anbe.1993.1183

Clark, J.A., Boersma, P.D., & Olmsted, D.M. (2006). Name that tune: Call discrimination and individual recognition in Magellanic penguins. *Animal Behaviour, 72*(5), 1141-1148. doi: 10.1016/j.anbehav.2006.04.002

Crockford, C., Cittig, R.M., Mundry, R., & Zuberbühler, K. (2012). Wild chimpanzees inform ignorant group members of danger. *Current Biology, 22*(2), 142-146. doi: 10.1016/j.cub.2011.11.053

Crofoot, M.C., Lambert, T.D., Kays, R., & Wikelski, M.C. (2010). Does watching a monkey change its behaviour? Quantifying observer effects in habituated wild primates using automated radiotelemetry. *Animal Behaviour, 80*(2010), 475-480.

Cohn, J.P. (2008). Citizen science: Can volunteers do real research? *BioScience, 58*(3), 192-197.

Colonnesi, C., Stams, G.J.J.M., Koster, I., & Noom, M.J. (2010). The relation between pointing and language development: A meta-analysis. *Developmental Review, 30*(4), 352-366. doi: 10.1016/j.dr.2010.10.001

Cooper, J.J., Ashton, C., Bishop, S., West, R., Mills, D.S., & Young, R.J. (2003). Clever hounds: Social cognition in the domestic dog (*Canis familiaris*). *Applied Animal Behaviour Science, 81*(3), 229-244.

Coppinger, R., & Coppinger, L. (2001). *Dogs: A Startling New Understanding of Canine Origin, Behavior & Evolution*. New York: Scribner.

Coren, S. (1994). *The Intelligence of Dogs*. New York: The Free Press.

Csibra, G., & Gergely, G. (2006). Social learning and social cognition: The case for pedagogy. In Y. Munakata & M.H. Johnson (Eds.), *Processes of Change in Brain and Cognitive Development. Attention and Performance XXI* (pp. 249-274). Oxford: Oxford University Press.

Dabbs, J.A. (1980). Left-right differences in cerebral blood flow and cognition. *Psychophysiology, 17*(6), 548-551.

Darling, J.D., Jones, M.E., & Nicklin, C.P. (2006). Humpback whale songs: Do they organize males during the breeding season? *Behaviour, 143*(9), 1051-1101. doi: 10.1163/156853906778607381

Davis, H., & Memmott, J. (1982). Counting behavior in animals: A critical evaluation. *Psychological Bulletin, 92*(3), 547-571.

Davidson, R.J. (1992). Anterior cerebral asymmetry and the nature of emotion. *Brain and Cognition, 20*(1), 125-151.

Davidson, R.J., & Fox, N.A. (1982). Asymmetrical brain activity discriminates between positive and negative affective stimuli in human infants. *American Association for the Advancement of Science, 218*(4578), 1235-1237.

de Waal, F.B.M. (1988). The communicative repertoire of captive bonobos (*Pan Paniscus*), compared to that of chimpanzees. *Behaviour, 106*(3), 183-251. doi: 10.1163/156853988X00269

de Wit, S., & Dickinson, A. (2009). Associative theories of goal-directed behaviour: A case for animal–human translational models. *Psychological Research, 73*(4), 463-476. doi: 10.1007/s00426-009-0230-6

Dickinson, A. (2001a). Causal learning: An associative analysis. *The Quarterly Journal of Experimental Psychology Section B, 54*(1), 3-25. doi: 10.1080/713932741

Dickinson, A. (2001b). Causal learning: Association versus computation. *Current Directions in Psychological Science, 10*(4), 127-132.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R.L., Martin, J., Phillips, T., & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment, 10*(6), 291-297. doi: 10.1890/110236

Dog Blog. (2011). Wag This Way [Drawing]. Retrieved from http://liziangel.blogspot.co.uk/2011/10/

Dorling Kindersley. (2013). *The Dog Encyclopedia*. London: Dorling Kindersley.

Douglas, P.H., & Moscovice, L.R. (2015). Pointing and pantomime in wild apes? Female bonobos use referential and iconic gestures to request genito-genital rubbing. *Scientific Reports, 5*(1), 1-9. doi: 10.1038/srep13999

Druzhkova, A.S., Thalmann, O., Trifonov, V.A., Leonard, J.A., Vorobieva, N.V., Ovodov, N.D., Graphodatsky, A.S., & Wayne, R.K. (2013). Ancient DNA analysis affirms the canid from Altai as a primitive dog. *PLoS ONE, 8*(3), e57754. doi: 10.1371/journal.pone.0057754

Dunbar, R.I.M. (1998). The social brain hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews, 6*(5), 178-190. doi: 10.1002/(SICI)1520-6505(1998)6:5<178::AID-EVAN5>3.0.CO;2-8

Dunbar, R.I.M. (2003). The social brain: Mind, language, and society in evolutionary perspective. *Annual Review of Anthropology, 32*(1), 163-181. doi: 10.1146/annurev.anthro.32.061002.093158

Emery, N.J., & Clayton, N.S. (2004). The mentality of crows: Convergent evolution of intelligence in corvids and apes. *Science, 306*(5703), 1903-1907. doi: 10.1126/science.1098410

Emery, N.J., Clayton, N.S., & Frith, C.D. (2007). Introduction. Social intelligence: From brain to culture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 362*(1480), 485-488.

Engh, A.L., Siebert, E.R., Greenberg, D.A., & Holekamp, K.E. (2005). Patterns of alliance formation and postconflict aggression indicate spotted hyaenas recognize third-party relationships. *Animal Behaviour, 69*(1), 209-217.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P.P. (2005). The neighbourhood nestwatch program: Participant outcomes of a citizen-science ecological research project. *Conservation Biology, 19*(3), 589-594. doi: 10.1111/j.1523-1739.2005.00s01.x

Federal Crowdsourcing and Citizen Science Toolkit (2015). Retrieved 30 June, 2015, from https://crowdsourcing-toolkit.sites.usa.gov/

Fellers, J.H., & Fellers, G.M. (1976). Tool use in a social insect and its implications for competitive interactions. *Science, 192*(4234), 70-72. doi: 10.1126/science.192.4234.70

Finn, J.K., Tregenza, T., & Norman, M.D. (2009). Defensive tool use in a coconut-carrying octopus. *Current Biology, 19*(23), 1069-1070.

Fitch, W.T. (2010). *The Evolution of Language*. Cambridge: Cambridge University Press.

Flynn, E., & Whiten, A. (2008). Cultural transmission of tool use in young children: A diffusion chain study. *Social Development, 17*(3), 699-718.

Fox, M. (1981). Relationships between human and non-human animals. In B. Fogle (Ed.), *Interrelations between People and Pets* (pp. 23-40). Springfield: Charles C Thomas Pub Ltd.

Franco, F., & Butterworth, G. (1996). Pointing and social awareness: Declaring and requesting in the second year. *Journal of Child Language, 23*(2), 307-336.

Frye, D. (1981). Developmental changes in strategies of social interaction. In M.E. Lamb & L.R. Sherrod (Eds.), *Infant Social Cognition: Empirical and Theoretical Considerations* (pp. 315-331). New Jersey: Lawrence Eribaum Associates, Inc.

Fujita, K., Kuroshima, H., & Asai, S. (2003). How do tufted capuchin monkeys (*Cebus apella*) understand causality involved in tool use? *Journal of Experimental Psychology: Animal Behavior Processes, 29*(3), 233-242.

Fukuzawa, M., Mills, D.S., & Cooper, J.J. (2004). More than just a word: non-semantic command variables affect obedience in the domestic dog (*Canis familiaris*). *Applied Animal Behaviour Science, 91*(1), 129-141.

Fukuzawa, M., Mills, D.S., & Cooper, J.J. (2005). The effect of human command phonetic characteristics on auditory cognition in dogs (*Canis familiaris*). *Journal of Comparative Psychology, 119*(1), 117-120.

Gácsi, M., Topál, J., Miklósi, Á., Dóka, A., & Csányi, V. (2001). Attachment behavior of adult dogs (*Canis familiaris*) living at rescue centres: Forming new bonds. *Journal of Comparative Psychology, 115*(4), 423-431.

Gácsi, M., Gyori, B., Miklósi, A., Viranyi, Z., Kubinyi, E., Topál, J., & Csányi, V. (2005). Species-specific differences and similarities in the behavior of hand-raised dog and wolf pups in social situations with humans. *Developmental Psychobiology, 47*(2), 111-122.

Galibert, F., Quignon, P., Hitte, C., & André, C. (2011). Toward understanding dog evolutionary and domestication history. *Comptes Rendus Biologies, 334*(3), 190-19.

Gardner, R.A., Gardner, B.T., & Van Cantfort, T.E. (1989). *Teaching Sign Language to Chimpanzees*. Albany: SUNY Press.

Gaunet, F., & Deputte, B.L. (2011). Functionally referential and intentional communication in the domestic dog: Effects of spatial and social contexts. *Animal Cognition, 14*(6), 849-860. doi: 10.1007/s10071-011-0418-1

Genovese, J.E., Sparks, K.E., & Little, K.D. (2017). Tympanic Membrane Temperature and Hemispheric Cognitive Style. *The Journal of Genetic Psychology, 178*(5), 298-302.

Genty, E., Breuer, T., Hobaiter, C., & Byrne, R.W. (2009). Gestural communication of the gorilla (*Gorilla gorilla*): Repertoire, intentionality and possible origins. *Animal Cognition, 12*(1), 527-546.

Germonpré, M., Sablin, M.V., Stevens, R.E., Hedges, R.E.M., Hofreiter, M., Stiller, M., & Després, V.R. (2009). Fossil dogs and wolves from Palaeolithic sites in Belgium, the Ukraine and Russia: Osteometry, ancient DNA and stable isotopes. *Journal of Archaeological Science, 36*(2), 473-490. doi: 10.1016/j.jas.2008.09.033

Goodall, J. (1964). Tool-using and aimed throwing in a community of free-living chimpanzees. *Nature, 201*(4926), 1264-1266.

Goodall, J. (1986). *The Chimpanzees of Gombe: Patterns of Behaviour*. Cambridge, MA: Harvard University Press

Griebel, U., & Oller, D.K. (2012). Vocabulary learning in a Yorkshire terrier: Slow mapping of spoken words. *PLOS One, 7*(2), e30182

Guéguen, N., & Ciccotti, S. (2008). Domestic dogs as facilitators in social interaction: An evaluation of helping and courtship behaviors. *Anthrozoos: A Multidisciplinary Journal of the Interactions of People & Animals, 21*(4), 339-349.

Gunnar, M.R., & Donzella, B. (2004). Tympanic membrane temperature and emotional dispositions in preschool-aged children: A methodological study. *Child Development, 75*(2), 497–504.

Gupta, S., & Sinha, A. (2016). Not here, there! Possible referential gesturing during allogrooming by wild bonnet macaques, *Macaca radiata. Animal Cognition, 19*(6), 1243-1248. doi: 10.1007/s10071-016-1012-3

Hall, E.J., & carter, A. (2017). Establishing a reference range for normal canine tympanic membrane temperature measured with a veterinary aural thermometer. *Veterinary Nursing Journal, 32*(12), 369-373.

Hall, K.R.L. (1963). Tool-using performances as indicators of behavioral adaptability. *Current Anthropology, 4*(5), 479-494.

Hall, K.R.L., & Schaller, G.B. (1964). Tool-using behavior of the California sea otter. *Journal of Mammalogy, 45*(2), 287-298.

Hanus, D. (2016). Causal reasoning versus associative learning: A useful dichotomy or a strawman battle in comparative psychology? *Journal of Comparative Psychology, 130*(3), 241-248.

Hare, B. (2001). Can competitive paradigms increase the validity of experiments on primate social cognition? *Animal Cognition, 4*(3-4), 269-280.

Hare, B. (2004). Domestic dogs use humans as tools. In M. Bekoff (Ed.), *Encyclopedia of Animal Behaviour Vol. 1* (pp. 277-285). Westport, Connecticut: Greenwood Press.

Hare, B., Call, J., & Tomasello, M. (1998). Communication of food location between human and dog (*Canis familiaris*). *Evolution of Communication, 2*(1), 137-159.

Hare, B., Brown, M., Williamson, C., & Tomasello, M. (2002). The domestication of social cognition in dogs. *Science, 298*(5598), 1634-1636.

Hare, B., & Tomasello, M. (1999). Domestic dogs (*Canis familiaris*) use human and conspecific social cues to locate hidden food. *Journal of Comparative Psychology, 113*(2), 173-177.

Hare, B., & Tomasello, M. (2005). Human-like social skills in dogs? *Trends in Cognitive Sciences, 9*(9), 439-444.

Hare, J.F. (1998). Juvenile Richardson's ground squirrels, *Spermophilus richardsonii*, discriminate among individual alarm callers. *Animal Behaviour, 55*(2), 451-460. doi: 10.1006/anbe.1997.0613

Hauser, M.D. (1996). *The Evolution of Communication*. Massachusetts: MIT press.

Hauser, M.D. (1997). Artifactual kinds and functional design features: What a primate understands without language. *Cognition, 64*(3), 285-308. doi: 10.1016/S0010-0277(97)00028-0

Hayes, C. (1951). *The Ape in Our House*. New York: Harper.

Hecht, J., & Spicer Rice, E. (2015). Citizen science: A new direction in canine behaviour research. *Behavioural Processes, 110*(2015), 125-132. doi: 10.1016/j.beproc.2014.10.014

Helton, W.S., Harynen, L., & Schaeffer, D. (2009a). Sustained attention to local and global target features is different: Performance and tympanic membrane temperature. *Brain and Cognition, 71*(1), 9-13. doi: 10.1016/j.bandc.2009.03.001

Helton, W.S., Kern, R.P., & Walker, D. R. (2009b). Tympanic membrane temperature, exposure to emotional stimuli and the sustained attention to response task. *Journal of Clinical and Experimental Neuropsychology, 31*(5), 611-616.

Hennessy, M.B., Davis, H.N., Williams, M.T., Mellott, C., & Douglas, C.W. (1997). Plasma cortisol levels of dogs at a county animal shelter. *Physiology & Behavior, 62*(3), 485-490.

Hennessy, M.B., Williams, M.T., Miller, D.D., Douglas, C.W., & Voith, V.L. (1998). Influence of male and female petters on plasma cortisol and behaviour: can human interaction reduce the stress of dogs in a public animal shelter?. *Applied Animal Behaviour Science, 61*(1), 63-77.

Herron, M.E., Shofer, F.S., & Reisner, I.R. (2009). Survey of the use and outcome of confrontational and non-confrontational training methods in client-owned dogs showing undesired behaviors. Applied Animal Behaviour Science, 117(1–2), 47-54. doi: 10.1016/j.applanim.2008.12.011

Hiby, E., Rooney, N.J., & Bradshaw, J.W.S. (2004). Dog training methods: Their use, effectiveness and interaction with behaviour and welfare. Animal Welfare, 13(1), 63-69.

Hobaiter, C., & Byrne, R.W. (2011). The gestural repertoire of the wild chimpanzee. *Animal Cognition, 14*(5), 745-767. doi: 10.1007/s10071-011-0409-2

Hobaiter, C., & Byrne, R.W. (2014). The meanings of chimpanzee gestures. *Current Biology, 24*(14), 1596-1600. doi: 10.1016/j.cub.2014.05.066

Hobbie, R. (1993). Tool-use by aquatic snails. *Creation Research Society Quarterly, 29*(4), 193.

Holekamp, K.E. (2007). Questioning the social intelligence hypothesis. *Trends in Cognitive Sciences, 11*(2), 65-69. doi: 10.1016/j.tics.2006.11.003

Hopkins, W.D., & Fowler, L.A. (1998). Lateralized changes in tympanic membrane temperature in relation to different cognitive tasks in chimpanzees (*Pan troglodytes*). *Behavioural Neuroscience, 112*(1), 83-88.

Horn, L., Huber, L., & Range, F. (2013a). The importance of the secure base effect for domestic dogs – evidence from a manipulative problem-solving task. *PLoS ONE, 8*(5), e65296. doi: 10.1371/journal.pone.0065296

Horn, L., Range, F., & Huber, L. (2013b). Dogs’ attention towards humans depends on their relationship, not only on social familiarity. *Animal Cognition, 16*(3), 435-443. doi: 10.1007/s10071-012-0584-9

Horowitz, A. (2011). Theory of mind in dogs? Examining method and concept. *Learning & Behaviour, 39*(4), 314-317.

Horowitz, A., & Hecht, J. (2016). Examining dog–human play: The characteristics, affect, and vocalizations of a unique interspecific interaction. *Animal Cognition, 19*(4), 779-788. doi: 10.1007/s10071-016-0976-3

Hume, D. (1978). *A Treatise of Human Nature* (2nd ed.). USA: Oxford University Press.

Humphrey, N.K. (1976). The social function of intellect. In P.P.G. Bateson & R.A. Hinde (Eds.), *Growing Points in Ethology* (pp. 303-317). Cambridge: Cambridge University Press.

Hunt, G.R. (1996). Manufacture and use of hook-tools by New Caledonian crows. *Nature, 379*(6562), 249-251.

Irwin, A. (1995). *Citizen Science: A study of People, Expertise and Sustainable Development*. London: Routledge.

Itakura, S., Agnetta, B., Hare, B., & Tomasello, M. (1999). Chimpanzee use of human and conspecific social cues to locate hidden food. *Developmental Science, 2*(4), 448-456.

Jackson, C.J. (2011). Evidence of a relationship between asymmetries in tympanic membrane temperature and lateralised sensory preferences. *Laterality, 16*(1), 107–124.

Jolly, A. (1966). Lemur social behavior and primate intelligence. *Science, 153*(3735), 501-506. doi: 10.1126/science.153.3735.501

Jonassen, D.H., & Ionas, I.G. (2008). Designing effective supports for causal reasoning. *Educational Technology Research & Development, 56*(3), 287-308. doi: 10.1007/s11423-006-9021-6

Jones, R. (2013). *Communication in the Real World: An Introduction to Communication Studies.* Minnesota: The Saylor Foundation.

Jones, N.A., & Fox, N.A. (1992). Electroencephalogram asymmetry during emotionally evocative films and its relation to positive and negative affectivity. *Brain and Cognition, 20*(2), 280-299. doi: 10.1016/0278-2626(92)90021-D

Kamil, A.C. (1994). A synthetic approach to the study of animal intelligence. In. L.A. Real (Ed.), *Behavioural Mechanisms in Evolutionary Ecology* (pp. 11-45). Chicago: University of Chicago Press.

Kaminski, J., Call, J., & Fischer, J. (2004). Word learning in a domestic dog: evidence for" fast mapping". *Science, 304*(5677), 1682-1683.

Kaminski, J., Hynds, J., Morris, P., & Waller, B.M. (2017). Human attention affects facial expressions in domestic dogs. *Scientific Reports, 7*(1), 12914. doi: 10.1038/s41598-017-12781-x

Kaminski, J., Neumann, M., Bräuer, J., Call, J., & Tomasello, M. (2011). Dogs, *Canis familiaris*, communicate with humans to request but not to inform. *Animal Behaviour, 82*(4), 651-658.

Kaminski, J., & Nitzschner, M. (2013). Do dogs get the point? A review of dog–human communication ability. *Learning and Motivation, 44*(4), 294-302. doi: 10.1016/j.lmot.2013.05.001

Kaminski, J., & Marshall-Pescini, S. (2014). *The Social Dog: Behaviour and Cognition*. San Diego: Elsevier.

Kaminski, J., Schulz, L., & Tomasello, M. (2012). How dogs know when communication is intended for them. *Developmental Science, 15*(2), 222–232.

Kaminski, J., Tempelmann, S., Call, J., & Tomasello, M. (2009). Domestic dogs comprehend human communication with iconic signs. *Developmental Science, 12*(6), 831-837.

Killgore, W.D., & Yurgelum-Todd, D.A. (2007). The right-hemisphere and valence hypotheses: Could they both be right (and sometimes left)? *Social Cognition and Affective Neuroscience, 2*(3), 240-250.

Krützen, M., Mann, J., Heithaus, M.R., Connor, R.C., Bejder, L., & Sherwin, W.B. (2005). Cultural transmission of tool use in bottlenose dolphins. *Proceedings of the National Academy of Sciences of the United States of America, 102*(25), 8939-8943. doi: 10.1073/pnas.0500232102

Kummer, H. (1995). Causal knowledge in animals. In D. Sperber, D. Premack & A.J. Premack (Eds.), *Causal Cognition: A Multidisciplinary Debate* (pp. 26-39). New York: Oxford University Press.

Kundey, S.M.A., Delise, J., De Los Reyes, A., Ford, K., Starnes, B., & Dennen, W. (2014). Domestic dogs' (*Canis familiaris*) choices in reference to information provided by human and artificial hands. *Animal Cognition, 17*(2), 259-266. doi: 10.1007/s10071-013-0658-3

Kurdek, L.A. (2009). Pet dogs as attachment figures for adult owners. *Journal of Family Psychology, 23*(4), 439-446. doi: 10.1037/a0014979

Lakotos, G., Soproni, K., Dóka, A., & Miklósi, A. (2009). A comparative approach to dogs' (*Canis familiaris*) and human infants' comprehension of various forms of pointing gestures. *Animal Cognition, 12*(4), 621-631.

Laidre, M.E. (2008). Do captive mandrills invent new gestures? *Animal Cognition, 11*(2), 179-187.

Laughlin, S.B., van Steveninck, R.R.D. and Anderson, J.C. (1998). The metabolic cost of neural information. *Nature Neuroscience, 1*(1), 36–41.

Leading pets, ranked by household ownership in the United Kingdom (UK) in 2017/18. (2018). Retrieved 4 September, 2018, from https://www.statista.com/statistics/308218/leading-ten-pets-ranked-by-household-ownership-in-the-united-kingdom-uk/

Leavens, D.A. (2004). Manual deixis in apes and humans. *Interaction Studies, 5*(3), 387-408.

Leavens, D.A., Hopkins, W.D., & Bard, K.A. (1996). Indexical and referential pointing in chimpanzees (*Pan troglodytes*). *Journal of comparative psychology, 10*(4), 346-353.

Leavens, D.A., & Hopkins, W.D. (1998). Intentional communication by chimpanzees: A cross-sectional study of the use of referential gestures. *Developmental Psychology, 34*(5), 813-822.

Leavens, D.A., Hopkins, W.D., & Thomas, R.K. (2004). Referential communication by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology, 118*(1), 48-57.

Leavens, D.A., Russell, J.L., & Hopkins, W.D. (2005). Intentionality as measured in the persistence and elaboration of communication by chimpanzees (*Pan troglodytes*). *Child Development, 76*(1), 291-306. doi: 10.1111/j.1467-8624.2005.00845.x

Lefebvre, L., Nicolakakis, N., & Boire, D. (2002). Tool and brains in birds. *Behaviour, 139*(7), 939-973. doi:10.1163/156853902320387918

Levander, M.S., & Grodzinsky, E. (2017). Variation in normal ear temperature. *The American Journal of the Medical Sciences, 354*(4), 370-378. doi: 10.1016/j.amjms.2017.05.013

Lewandowski, E.J., & Oberhauser, K.S. (2015). Butterfly citizen scientists in the United States increase their engagement in conservation. *Biological Conservation, 1*(2015), 1-7. doi: 10.1016/j.biocon.2015.07.029

Liebal, K., Pika, S., & Tomasello, M. (2004). Social communication in siamangs (*Symphahangus syndactylus*): Use of gestures and facial expressions. *Primates, 45*(1), 41-57.

Liebal, K., Pika, S., & Tomasello, M. (2006). Gestural communication of orangutans (*Pongo pygmaeus*). *Gesture, 6*(1), 1-38.

Lindbald-Toh, K., Wade, C.M., Mikkelsen, T.S., Karlsson, E.K., Jaffe, D.b., Kamal, M, … Lander, E.S. (2005). Genome sequence, comparative analysis and haplotype structure of the domestic dog. Nature, 438(1), 803-819. [Drawing]. doi: 10.1038/nature04338

Lindsay, S.R. (2005). *Handbook of Applied Dog Behavior and Training, Procedures and Protocols*. Iowa: Blackwell Publishing.

Liszkowski, U., Brown, P., Callaghan, T., Takada, A., & de Vos, C. (2012). A prelinguistic gesture universal of human communication. *Cognitive Science, 36*(4), 698-713. doi: 10.1111/j.1551-6709.2011.01228.x

MacNeilage, P.F., Rogers, L.J., & Vallortigara, G. (2009). Origins of the left and right brain, *Scientific American, 201*(1), 60-67.

Macpherson, K., & Roberts, W.A. (2013). Exploring the canine mind: Studies of dog cognition. *Learning and Motivation, 44*(4), 205-206. doi: 10.1016/j.lmot.2013.04.006

Maestripteri, D. (1996). Gestural communication and its cognitive implications in pigtail macaques (*Macaca nemestrina*). *Behaviour, 133*(13/14), 997-1022.

Maginnity, M.E., & Grace, R.C. (2014). Visual perspective taking by dogs (*Canis familiaris*) in a Guesser–Knower task: Evidence for a canine theory of mind? *Animal Cognition, 17*(6), 1375-1392. doi: 10.1007/s10071-014-0773-9

Malavasi, R. & Huber, L. (2016). Evidence of heterospecific referential communication from domestic horses (*Equus caballus*) to humans. *Animal Cognition, 19*(5), 899-909. doi: 10.1007/s10071-016-0987-0

Mariak, Z., Lewko, J., Jadeszko, J., & Dudek, H. (1994). Cerebral and related temperatures in normothermic subjects. In A. S. Milton (Ed.), *Temperature regulation: Recent physiological and pharmacological advances* (pp. 139–144). Basel, Switzerland: Birkhduser.

Markman, E.M., & Abelev, M. (2004). Word learning in dogs? *Trends in Cognitive Science, 8*(11), 479-481. doi: 10.1016/j.tics.2004.09.007

Marler, P., Evans, Christopher, S., & Hauser, M.D. (1992). Animal signals: Motivational, referential, or both. In H. Papousek, U. Jurgens & M. Papousek (Eds.), *Nonverbal Vocal Communication: Comparative and Developmental Approaches* (pp. 66-86). Cambridge: Cambridge University Press.

Marshall-Pescini, S., Prato-Previde, E., & Valsecchi, P. (2011). Are dogs (*Canis familiaris*) misled more by their owners than by strangers in a food choice task? *Animal Cognition, 14*(1), 137-142. doi: 10.1007/s10071-010-0340-y

Marshall-Pescini, S., Valsecchi, P., Petak, I., Accorsi, P.A., & Previde, E.P. (2008). Does training make you smarter? The effects of training on dogs' performance (*Canis familiaris*) in a problem solving task. *Behavioural Processes, 78*(2008), 449-454.

Martin, P., & Bateson, P. (2007). *Measuring Behaviour: An Introductory Guide*. Cambridge: Cambridge University Press.

Matsuzawa, T., Biro, D., Humle, T., Inoue-Nakamura, N., Tonooka, R., & Yamakoshi, G. (2001). Emergence of culture in wild chimpanzees: Education by master-apprenticeship. In T. Matsuzawa (Ed.), *Primate Origins of Human Cognition and Behavior* (pp. 557-574). Tokyo: Springer. doi: 10.1007/978-4-431-09423-4_28

Maynard-Smith, J., & Harper, D.G.C. (1995). Animal Signals: Models and Terminology. *Journal of Theoretical Biology, 177*(3), 305-331. doi: 10.1006/jtbi.1995.0248

Mazzotti, G.A., & Boere, V. (2009). The right ear but not the left ear temperature is related to stress-induced cortisolaemia in the domestic cat (*Felis catus*). *Laterality: Asymmetries of Body, Brain and Cognition, 14*(2), 196-204. doi: 10.1080/13576500802344420

McComb, K., Moss, C., Durant, S.M., Baker, L., & Sayialel, S. (2001). Matriarchs as repositories of social knowledge in African elephants. *Science, 292*(5516), 491-494.

McComb, K., Moss, C., Sayialel, S., & Baker, L. (2000). Unusually extensive networks of vocal recognition in African elephants. *Animal Behaviour, 59*(6), 1103-1109. doi: 10.1006/anbe.2000.1406

McGrew, W.C. (1992). *Chimpanzee Material Culture: Implications for Human Evolution.* Cambridge: Cambridge University Press.

McGrew, W.C. (2013). Is primate tool use special? Chimpanzee and New Caledonian crow compared. *Philosophical Transactions of the Royal Society B: Biological Sciences, 368*(1630), 20120422.

McGrew, W.C., & Tutin, C.E.G. (1973). Chimpanzee tool use in dental grooming. *Nature, 241*(5390), 477-478.

McGuigan, N., & Whiten, A. (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23-and 30-month-olds. *Journal of Experimental Child Psychology, 104*(4), 367-381.

McKinley, J., & Sambrook, T.D. (2000). Use of human-given cues by domestic dogs (*Canis familiaris*) and horses (*Equus caballus*). *Animal Cognition, 3*(1), 13-22.

Mech, L.D., & Boitani, L. (2010). *Wolves: Behavior, Ecology, and Conservation.* Chicago: University of Chicago Press.

Meiners, M.L., & Dabbs, J.A. (1977). Ear temperature and brain blood flow: laterality effects. *Bulletin of the Psychonomic Society, 10*(3), 194-196.

Merola, I., Lazzaroni, M., Marshall-Pescini, S., & Prato-Previde, E. (2015). Social referencing and cat-human communication. *Animal Cognition, 18*(3), 639-648. doi: 10.1007/s10071-014-0832-2

Messent, P.R. (1985). Pets as social facilitators. *Veterinary Clinics of North America: Small Animal Practice, 15*(2), 387-393.

Miklósi, Á. (2007). *Dog Behaviour, Evolution, and Cognition*. New York: Oxford University Press.

Miklósi, A., Topál, J., & Csányi, V. (2003a) Comparative social cognition: What can dogs teach us? *Animal Behaviour, 67*(1), 995-1004.

Miklósi, Á., Kubinyi, E., Topál, J., Gácsi, M., Virányi, Z., & Csányi, V. (2003b). A simple reason for a big difference: Wolves do not look back at humans, but Dogs do. *Current Biology, 13*(9), 763-766.

Miklósi, A., Pongrácz, P., Lakatos, G., Topál, J., & Csányi, V. (2005). A comparative study of the use of visual communicative signals in interactions between dogs (*Canis familiaris*) and humans and cats (*Felis catus*) and humans. *Journal of Comparative Psychology, 119*(2), 179-186.

Miklósi, A., Polgárdi, R., Topál, J., & Csányi, V. (1998). Use of experimenter-given cues in dogs. *Animal Cognition, 1*(1), 113-121.

Miklósi, Á., Polgárdi, R., Topál, J., & Csányi, V. (2000). Intentional behaviour in dog-human communication: An experimental analysis of “showing” behaviour in the dog. *Animal Cognition, 3*(3), 159-166. doi: 10.1007/s100710000072

Miklósi, Á., Topál, J., & Csányi, V. (2004). Comparative social cognition: What can dogs teach us? *Animal Behaviour, 67*(6), 995-1004.

Miklósi, Á., & Topál, J. (2013). What does it take to become ‘best friends’? Evolutionary changes in canine social competence. *Trends in Cognitive Sciences, 17*(6), 287-294. doi: 10.1016/j.tics.2013.04.005

Miles, H.L.W. (1991). Teaching sign language to chimpanzees: Book review. *International Journal of Primatology, 12*(3), 303-307.

Morrison, A.R. (2009). *An Odyssey with Animals: A Veterinarian's Reflections on the Animal Rights & Welfare Debate*. Oxford: Oxford University Press.

Müller, C.A., Mayer, C., Dörrenberg, S., Huber, L., & Range, F. (2011). Female but not male dogs respond to a size constancy violation. *Biology Letters, 7*(5), 689-691. doi: 10.1098/rsbl.2011.0287

Musser, W.B., Bowles, A.E., Grebner, D.M., Crance, J. L. (2014). Differences in acoustic features of vocalizations produced by killer whales cross-socialized with bottlenose dolphins. *The Journal of the Acoustical Society of America, 136*(4), 1990-2002.

Nagell, K., Olguin, R.S., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Journal of Comparative Psychology, 107*(2), 174-186.

Nagasawa, M., Mitsui, S., En, S., Ohtani, N., Ohta, M., Sakuma, Y., Onaka, T., Mogi, K., & Kikusui, T. (2015). Oxytocin-gaze positive loop and the coevolution of human-dog bonds. *Science, 348*(6232), 333-336.

Nowak, R.M. (2003). Wolf evolution and taxonomy. In L.D. Mech, & Boitani, L. (Eds.), *Wolves: Behavior, Ecology, and Conservation* (pp. 239-258). Chicago: University of Chicago Press.

O'Connell, S., & Dunbar, R. (2005). The perception of causality in chimpanzees (*Pan spp*.). *Animal Cognition, 8*(1), 60-66.

Ogawa, T. (1994). Measurement of tympanic temperature and its significance in physiology and pathophysiology. *Biomedical Thermology, 13*(1), 163–172.

O'Hara, S.J., & Lee, P.C. (2005). High frequency of postcoital penis cleaning in Budongo chimpanzees. *Folia primatologica, 77*(5), 353-358.

Ohl, F. (1996). Ontogeny of vocalizations in domestic dogs, breed standard-poodle (*Canis lupus f. familiaris*). *Zoologische Beitrage, 37*(1996), 199-216.

Olson, P.N., Kustritz, M.V., & Johnston, S.D. (2001). Early-age neutering of dogs and cats in the United States (a review). *Journal of Reproduction and Fertility, 57*(2001), 223-232.

Olsen, S.J. (1985). Origins of the Domestic Dog: The Fossil Record. Tuscon, Arizona, The University of Arizona Press.

Osthaus, B., Lea, S.E., & Slater, A.M. (2005). Dogs (*Canis lupus familiaris*) fail to show understanding of means-end connections in a string-pulling task. *Animal Cognition, 8*(1), 37-47. doi: 10.1007/s10071-004-0230-2

Oxford English Dictionary, Gesture. (2018). Retrieved 13 June, 2018, from https://en.oxforddictionaries.com/definition/gesture

Pal, S.K., Ghosh, B., & Roy, S. (1998). Agonistic behaviour of free-ranging dogs (Canis familiaris) in relation to season, sex and age. Applied Animal Behaviour Science, 59(4), 331-348. doi: 10.1016/S0168-1591(98)00108-7

Palmer, R., & Custance, D. (2008). A counterbalanced version of Ainsworth's strange situation procedure reveals secure-base effects in dog–human relationships. *Applied Animal Behaviour Science, 109*(2–4), 306-319. doi: 10.1016/j.applanim.2007.04.0

Parker, S.T., & Gibson, K.R. (1977). Object manipulation, tool use and sensorimotor intelligence as feeding adaptations in cebus monkeys and great apes. *Journal of Human Evolution, 6*(7), 623-641. doi: 10.1016/s0047-2484(77)80135-8

Patterson, F.G. (1978). The gestures of a gorilla: Language acquisition in another pongid. *Brain and Language, 5*(1), 72-97. doi: 10.1016/0093-934X(78)90008-1

Patterson, F., & Linden, E. (1981). *The education of Koko*. New York: Holt, Rinehart, and Winston.

Pedigree. (2018). How to take your dog's ear temperature. Retrieved 28 February, 2018, from https://www.pedigree.com/dog-care/health/how-to-take-your-dog-s-temperature

Pepperberg, I.M. (1987). Acquisition of the same/different concept by an African Grey parrot (*Psittacus erithacus*): Learning with respect to categories of color, shape, and material. *Animal Learning & Behavior, 15*(4), 423-432.

Perry, S., Baker, M., Fedigan, L., Gros-Louis, J., Jack, K., MacKinnon, K.C., Manson, J.H., Panger, M., Pyle, K., & Rose, L. (2003). Social conventions in wild white-faced capuchin monkeys: Evidence for traditions in a neotropical primate. *Current Anthropology, 44*(2), 241-268.

Perry, S., & Manson, J.H. (2003). Traditions in monkeys. *Evolutionary Anthropology: Issues, News, and Reviews, 12*(2), 71-81.

Pet Population. (2018). Retrieved 4 September, 2018, from https://www.pfma.org.uk/pet-population-2018

Pettijohn, T.F., Wong, T.W., Ebert, P.D., & Scott, J.P. (1977). Alleviation of separation distress in 3 breeds of young dogs. *Developmental Psychobiology, 10*(4), 373-381. doi: 10.1002/dev.420100413

Pierce, J.D. (1986). A review of tool use in insects. *Florida Entomologist, 69*(1), 95-104.

Pika, S., & Bugnyar, T. (2011). The use of referential gestures in ravens (*Corvus corax*) in the wild. *Nature Communications, 2*(560), 1-5.

Pika, S., Liebal, K., & Tomasello, M. (2003). Gestural communication in young gorillas (Gorilla gorilla): Gestural repertoire, learning, and use. *American Journal of Primatology, 60*(3), 95-111.

Pika, S., Liebal, K., Call, J., & Tomasello, M. (2005a). The gestural communication of apes. *Gesture, 5*(1-2), 41-56.

Pika, S., Liebal, K., & Tomasello, M. (2005b). Gestural communication in subadult bonobos (*Pan paniscus*): Repertoire and use. *American Journal of Primatology*, *65*(1), 39-61.

Pika, S., & Mitani, J. (2006). Referential gestural communication in wild chimpanzees (*Pan troglodytes*). *Current Biology, 16*(6), 191-192.

Pilley, J.W., & Reid, A.K. (2011). Border collie comprehends object names as verbal referents. *Behavioural Processes, 86*(2), 184-195.

Pilley, J.W. (2013). Border collie comprehends sentences containing a prepositional object, verb, and direct object. *Learning and Motivation, 44*(4), 229-240. doi: 10.1016/j.lmot.2013.02.003

Ploog, D.W. (1992). The evolution of vocal communication. In H Papousek, U Jürgens & M. Papoušek (Eds.), *Nonverbal vocal communication: Comparative and developmental approaches* (pp. 6-30). Cambridge: Cambridge University Press.

Pongrácz, P., Miklósi, Á., & Csányi, V. (2001a). Owner's beliefs on the ability of their pet dogs to understand human verbal communication: A case of social understanding. *Current Psychology of Cognition, 20*(1-2), 87-108.

Pongrácz, P., Miklósi, A., Kubinyi, E., Gurobi, K., Topál, J., & Csányi, V. (2001b). Social learning in dogs: The effect of a human demonstrator on the performance of dogs in a detour task. *Animal Behaviour, 62*(6), 1109-1117.

Pongrácz, P., Molnár, C., Miklósi, A., & Csányi, V. (2005). Human listeners are able to classify dog (*Canis familiaris*) barks recorded in different situations. *Journal of Comparative Psychology, 119*(2), 136-144

Pongrácz, P, Miklósi, Á., Timár-Geng, K., & Csányi, V. (2004). Verbal attention getting as a key factor in social learning between dog (*Canis familiaris*) and human. *Journal of Comparative Psychology, 118*(4), 375-383.

Pongrácz, P., Molnár, C., & Miklósi, Á. (2006). Acoustic parameters of dog barks carry emotional information for humans. *Applied Animal Behaviour Science, 100*(3-4), 228-240. doi: 10.1016/j.applanim.2005.12.004

Pongrácz, P. (2014). Social learning in dogs. In J. Kaminski & S. Marshall-Pescini (Eds.), *The Social Dog: Behaviour and Cognition* (pp. 249-293). San Diego: Academic Press.

Poss, S.R., Kuhar, C., Stoinski, T.S., & Hopkins, W.D. (2006). Differential use of attentional and visual communicative signaling by orangutans (*Pongo pygmaeus*) and gorillas (*Gorilla gorilla*) in response to the attentional status of a human. *American Journal of Primatology, 68*(10), 978-992. doi: 10.1002/ajp.20304

Povinelli, D.J. (2000). *Folk Physics for Apes: The Chimpanzee's Theory of How the World Works.* Oxford: Oxford University Press.

Povinelli, D.J., & Eddy, T.J. (1996). Factors influencing young chimpanzees' recognition of 'attention'. *Journal of Comparative Psychology, 110*(4), 336-345.

Povinelli, D.J., Reaux, J.E., Bierschwale, D.T., Allain, A.D., & Simon, B.B. (1997). Exploitation of pointing as a referential gesture in young children, but not adolescent chimpanzees. *Cognitive Development, 12*(4), 423-461.

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences, 1*(4), 515-526. doi: 10.1017/S0140525X00076512

Propper, R.E., & Brunyé, T.T. (2013). Lateralized difference in tympanic membrane temperature: emotion and hemispheric activity. *Frontiers in Psychology, 4*(104), 1-7. doi: 10.3389/fpsyg.2013.00104

Raddick, M.J., Bracey, G., Gay, P.L., Lintott, C.J., Murray, P., Schawinski, K., Szalay, A.S., & Vandenberg, J. (2010). Galaxy zoo: Exploring the motivations of citizen science volunteers. *Astronomy Education Review, 9*(1), 2-41.

Ramos, D., & Ades, C. (2012). Two-sentence comprehension by a dog (*Canis familiaris*). *PLOS One, 7*(2), e29689.

Range, F., & Virányi, Z. (2013). Social learning from humans or conspecifics: Differences and similarities between wolves and dogs. *Frontiers in Psychology, 4*(2013), 868. doi: 10.3389/fpsyg.2013.00868

Rappolt, G.A., John, J., & Thompson, N.S. (1979). Canine responses to familiar and unfamiliar humans. *Aggressive Behaviour, 5*(2), 155-161.

Rehder, B. (2003). Categorization as causal reasoning. *Cognitive Science, 27*(5), 709-748. doi: 10.1207/s15516709cog2705_2

Riedel, J., Schumann, K., Kaminski, J., Call, J., & Tomasello, M. (2008). The early ontogeny of human-dog communication. *Animal Behaviour, 75*(3), 1003-1014.

Rendall, D., & Owren, M.J. (2002). Animal vocal communication: Say what? In M. Bekoff, C. Allen & G.M. Burghardt (Eds.), *The Cognitive Animal: Empirical and Theoretical Perspectives on Animal Cognition* (pp. 307-314). Cambridge: MIT Press.

Rendall, D., Rodman, P.S., & Emond, R.E. (1996). Vocal recognition of individuals and kin in free-ranging rhesus monkeys. *Animal Behaviour, 51*(5), 1007-1015. doi: 10.1006/anbe.1996.0103

Rescorla, R.A., & Wagner, A.R. (1972). A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In A.H. Black & W.F. Prokasy (Eds.) *Classical Conditioning II: Current Research and Theory* (pp. 64-99). New York: Appleton-Century-Crofts.

Roberts, A.I., Vick, S.J., & Buchanan-Smith, H.M. (2013). Communicative intentions in wild chimpanzees: Persistence and elaboration in gestural signalling. *Animal Cognition, 16*(2), 187-196. doi: 10.1007/s10071-012-0563-1

Rogers, L.J. (2010). Relevance of brain and behavioural lateralization to animal welfare. *Applied Animal Behaviour Science, 127*(1-2), 1-11.

Roloff, M.E. (2012). Oxford Bibliographies. Retrieved 07 September, 2017, from http://www.oxfordbibliographies.com/view/document/obo-9780199756841/obo-9780199756841-0033.xml

Rooney, N., & Bradshaw, J. (2014). Canine welfare science: An antidote to sentiment and myth. In A. Horowitz (Ed.), *Domestic Dog Cognition and Behavior: The Scientific Study of Canis familiaris* (pp. 241-274). Berlin, Heidelberg: Springer. doi: 10.1007/978-3-642-53994-7_11

Rooney, N.J., Gaines, S.A., & Bradshaw, J.W. (2007). Behavioural and glucocorticoid responses of dogs (*Canis familiaris*) to kennelling: Investigating mitigation of stress by prior habituation. *Physiology & Behavior, 92*(5), 847-854. doi: 10.1016/j.physbeh.2007.06.011

Ross, D. (1971). Protection of hermit crabs (*Dardanus spp*.) from octopus by commensal sea anemones (*Calliactis spp*.). *Nature, 230*(5293), 401-402.

Rutz, C., Klump, B.C., Komarczyk, L., Leighton, R., Kramer, J., Wischnewski, S., Sugasawa, S., Morrissey, M.B., James, R., St Clair, J.J.H., Switzer, R.A., & Masuda, B.M. (2016). Discovery of species-wide tool use in the Hawaiian crow. *Nature, 537*(7620), 403-407. doi: 10.1038/nature19103

Sable, P. (2013). The pet connection: An attachment perspective. *Clinical Social Work Journal, 41*(1), 93-99. doi: 10.1007/s10615-012-0405-2

Sanders, C.R. (1993). Understanding dogs: Caretakers' attributions of mindedness in canine-human relationships. *Journal of Contemporary Ethnography, 22*(2), 205-226. doi: 10.1177/089124193022002003

Santos, L.R., Miller, C.T., & Hauser, M.D. (2003). Representing tools: How two non-human primate species distinguish between the functionally relevant and irrelevant features of a tool. *Animal Cognition, 6*(4), 269-281. doi: 10.1007/s10071-003-0171-1

Savilli, C., Resende, B. & Gaunet, F. (2016). Eye contact is crucial for referential communication in pet dogs. *PLoS One, 11*(9), 1-18. doi: 10.1371/journal.pone.0162161

Schel, A.M., Townsend, S.W., Machanda, Z., Zuberbühler, K., & Slocombe, K.E. (2013). Chimpanzee alarm call production meets key criteria for intentionality. PLoS One, 8(10), e76674. doi: 10.1371/journal.pone.0076674

Scheider, L., Grassmann, S., Kaminski, J., & Tomasello, M. (2011). Domestic dogs use contextual information and tone of voice when following a human pointing gesture. *PLoS ONE, 6*(7), e21676. doi: 10.1371/journal.pone.0021676

Schmidt, J.R. (2012). Human contingency learning. In: N.M. Seel (Ed.), *Encyclopedia of the Sciences of Learning* (pp. 85). Boston: Springer.

Schneider, L.A., Delfabbro, P.H., & Burns, N.R. (2013). Temperament and lateralization in the domestic dog (*Canis familiaris*). *Journal of Veterinary Behaviour, 8*(1), 124-134.

Searby, A., & Jouventin, P. (2003). Mother-lamb acoustic recognition in sheep: A frequency coding. *Royal Society of London B: Biological Sciences, 270*(1526), 1765-1771. doi: 10.1098/rspb.2003.2442

Seyfarth, R., Cheney, D.L., & Marler, P. (1980). Monkey responses to three different alarm calls: evidence of predator classification and semantic communication. *Science, 210*(4471), 801-803. doi: 10.1126/science.7433999

Seyfarth, R.W., & Cheney, D.L. (2012). Animal cognition: Chimpanzee alarm calls depend on what others know. *Current Biology, 22*(2), 142-146. doi: 10.1016/j.cub.2011.11.050

Seyfarth, R.M., & Cheney, D.L. (2015). Social cognition. *Animal Behaviour, 103*(1), 191-202. doi: 10.1016/j.anbehav.2015.01.030

Shettleworth, S.J. (2010). *Cognition, Evolution and Behaviour*. New York: Oxford University Press.

Shorey, H.H. (1976). *Animal Communication by Pheromones*. London: Academic Press, INC.

Shumaker, R.W., Walkup, K.R., & Beck, B.B. (2011). *Animal Tool Behaviour: The Use and Manufacture of Tools by Animals.* Baltimore: The Johns Hopkins University Press.

Silk, J.B., Brosnan, S.F., Vonk, J., Henrich, J., Povinelli, D.J., Richardson, A.S., Lambeth, S.P., Mascaro, J., Schapiro, S.J. (2005). Chimpanzees are indifferent to the welfare of unrelated group members. *Nature, 437*(7063), 1357-1359. doi: 10.1038/nature04243

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution, 24*(9), 467-471. doi: 10.1016/j.tree.2009.03.017

Siniscalchi, M., d'Ingeo, S., & Quaranta, A. (2017). Lateralized functions in the dog brain. *Symmetry, 9*(5), 71-83.

Siniscalchi, M., Quaranta, A., & Rogers, L.J. (2008). Hemispheric specialization in dogs for processing different acoustic stimuli. *PLOS ONE, 3*(10), 33-49.

Siniscalchi, M., Sasso, R., Pepe, A.M., Vallortigara, G., & Quaranta, A. (2010). Dogs turn left to emotional stimuli. *Behavioural Brain Research, 208*(2), 516-521.

Siniscalchi, M., Stipo, C., & Quaranta, A. (2013). "Like owner, like dog": Correlation between the owner's attachment profile and the owner-dog bond. *PLoS ONE, 8*(10), 1-10. doi: 10.1371/journal.pone.0078455

Slocombe, K.E., & Zuberbühler, K. (2005). Functionally referential communication in a chimpanzee. *Current Biology, 15*(19), 1779-1784. doi: 10.1016/j.cub.2005.08.068

Smith, D. (1999). A thinking bird or just another birdbrain?, Retrieved from https://www.nytimes.com/1999/10/09/arts/a-thinking-bird-or-just-another-birdbrain.html

Smith, J. (1977). *The behavior of Communicating: An Ethnological Approach*. Cambridge: Harvard University Press.

Soltis, J. (2009). Vocal communication in African elephants (*Loxodonta africana*). *Zoo Biology, 29*(2), 192-209. doi: 10.1002/zoo.20251

Speirs, E.A., & Davis, L.S. (1991). Discrimination by Adélie Penguins, *Pygoscelis adeliae*, between the loud mutual calls of mates, neighbours and strangers. *Animal Behaviour, 41*(6), 937-944.

St Amant, R., & Horton, T.E. (2008). Revisiting the definition of animal tool use. *Animal Behaviour, 75*(4), 1199-1208.

Stam, J.H. (1976). *Inquiries into the Origin of Language: The Fate of a Question*. New York: Joanna Cotler Books.

Stewart, L., MacLean, E.L., Ivy, D., Woods, V., Cohen, E., Rodriguez, K., McIntyre, M., Mukherjee, S., Call, J., Kaminski, J., Miklósi, Á., Wrangham, R.W., & Hare, B. (2015). Citizen science as a new tool in dog cognition research. *PLoS ONE, 10*(9), e0135176. doi: 10.1371/journal.pone.0135176

Struhsaker, T.T. (1967). Auditory communication among vervet monkeys (*Cercopithecus aethiops*). *Behaviour, 29*(2), 83-121. doi: 10.1163/156853967X00073

Stubbs, W.P., & Bloomberg, M.S. (1995). Implications of early neutering in the dog and cat. *Seminars in Veterinary Medicine and Surgery (small animal), 10*(1), 8-12.

Svartberg, K. (2006). Breed-typical behaviour in dogs – Historical remnants or recent constructs? *Applied Animal Behaviour Science, 96*(3-4), 293-313.

Swift, A.B. (1991). Tympanic thermometry: An index of hemispheric activity. *Perceptual and Motor Skills, 73(*1), 275-293.

Tanabe, K., & Takaori, S. (1964). Effects of cooling and warming of the common carotid arteries on the brain and tympanic membrane temperatures in the rabbit. *Japanese Journal of Pharmacology, 14*(1), 1467–1479.

Tanner, J.E., & Byrne, R.W. (1996). Representation of action through iconic gesture in a captive lowland gorilla. *Current Anthropology, 37*(1), 162-173.

Tanner, J.E., & Byrne, R.W. (1999). The development of spontaneous gestural communication in a group of zoo-living lowland gorillas. In. S.T. Parker, R.W. Mitchell & H. Lyn Miles (Eds.), *The Mentalities of Gorillas and Orangutans: Comparative Perspectives* (pp. 211-239). Cambridge: Cambridge University Press.

Taylor, A.H., Hunt, G.R., Medina, F.S., & Gray, R.D. (2009). Do New Caledonian crows solve physical problems through causal reasoning? *Proceedings of the Royal Society of London B: Biological Sciences, 276*(1655), 247-254. doi: 10.1098/rspb.2008.1107

Tebbich, S., Taborsky, M., Fessl, B., & Blomqvist, D. (2001). Do woodpecker finches acquire tool-use by social learning? *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*(1482), 2189-2193.

Tembrock, G. (1976). Canid vocalizations. *Behavioural Processes, 1*(1), 57-75. doi: 10.1016/0376-6357(76)90007-3

Tennant, C. (2002). Breaking Bad Habits in Dogs. Dorking: Interpet Publishing.

The Canine Brain. (2017). Ever wondered how your dog's brain works? A brief guide…[Drawing]. Retrieved from http://www.doglistener.tv/2014/03/the-canine-brain/

Thediscoveryofinteresting, (2012). Teaching Koko to 'speak': "Me fine animal gorilla; you Penny", Retrieved from https://thediscoveryofinterestingthings.wordpress.com/2012/07/14/koko-says-me-fine-animal-gorilla-you-penny-teaching-primates-to-speak/

Tomasello, M., & Call, J. (1997) *Primate Cognition*. Oxford: Oxford University Press.

Tomasello, M., & Call, J. (2018). Thirty years of great ape gestures. Animal Cognition, 1-9. doi: 10.1007/s10071-018-1167-1

Tomasello, M., Call, J., & Gluckman, A. (1997). Comprehension of novel communicative signs by apes and human children. *Child Development, 68*(6), 1067-1081.

Tomasello, M., Call, J., Nagell, K., Olguin, R., & Carpenter, M. (1994). The learning and use of gestural signals by young chimpanzees: A trans-generational study. *Primates, 35*(2), 137-154. doi: 10.1007/BF02382050

Tomasello, M., & Camaioni, L. (1997). A comparison of the gestural communication of apes and human infants. *Human Development, 40*(1), 7-24.

Tomasello, M., Davis-Dasilva, M., Camak, L., & Bard, K. (1987). Observational learning of tool-use by young chimpanzees. *Human Evolution, 2*(2), 175-183.

Tomasello, M., George, B.L., Kruger, A.C., Jeffrey, M., Farrar., & Evans, A. (1985). The development of gestural communication in young chimpanzees. *Journal of Human Evolution, 14*(2), 175-186. doi: 10.1016/S0047-2484(85)80005-1

Tomasello, M., & Zuberbühler, K. (2002). Primate vocal and gestural communication. In M. Bekoff (Ed.), *The Cognitive Animal: Empirical and Theoretical Perspectives on Animal Cognition* (pp. 293-29). Cambridge: MIT Press.

Topál, J., Miklósi, Á., Csányi, V., & Dóka, A. (1998). Attachment behavior in dogs (*Canis familiaris*): A new application of Ainsworth's (1969) strange situation test. *Journal of comparative psychology, 112*(3), 219-229.

Topál, J., Gácsi, M., Miklósi, Á., Virányi, Z., Kubinyi, E., & Csányi, V. (2005). Attachment to humans: A comparative study on hand-reared wolves and differently socialized dog puppies. *Animal Behaviour, 70*(6), 1367-1375. doi: 10.1016/j.anbehav.2005.03.025

Townsend, S.W., Koski, S.E., Byrne, R.W., Slocombe, K.E., Bickel, B., Boeckle, M, … Manser, M.B. (2016). Exorcising Grice’s ghost: An empirical approach to studying intentional communication in animals. *Biological Reviews, 92*(3), 1427-1433. doi: 10.1111/brv.12289

Trumbull, D.J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education, 84*(2), 265-275.

Turhan, C., Desmond, J.E., Zhao, Z., Glover, G., & Gabrieli, J.D.E. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *NeuroReport, 9*(14), 3233-3239.

Tuber, D.S., Sanders, S., Hennessy, M.B., & Miller, J.A. (1996). Behavioral and glucocorticoid responses of adult domestic dogs (*Canis familiaris*) to companionship and social separation. *Journal of Comparative Psychology, 110*(1), 103-108.

Udell, M., Dorey, N., & Wynne, C. (2010). What did domestication do to dogs? A new account of dogs’ sensitivity to human actions. *Biological Reviews, 85*(2), 327-345.

Udell, M., Dorey, N., & Wynne, C. (2011). Can your dog read your mind? Understanding the causes of canine perspective taking. *Learning & Behavior, 39*(4), 289-302. doi: 10.3758/s13420-011-0034-6

Udell, M., & Wynne, C. (2008). A review of domestic dogs' (*Canis Familiaris*) human-like behaviors: Or why behavior analysts should stop worrying and love their dogs. *Journal of the Experimental Analysis of Behavior, 89*(2), 247-261. doi: 10.1901/jeab.2008.89-247

Vail, A.L., Manica, A., & Bshary, R. (2013). Referential gestures in fish collaborative hunting. *Nature Communications, 4*(1765), 1-7.

van der Zee, E., Zulch, H., & mills, D. (2012). Word generalization by a dog (*Canis familiaris*): Is shape important? *PLoS ONE, 7*(11), e49382. doi: 10.1371/journal.pone.0049382

van Lawick-Goodall, J. (1968). The behaviour of free-living chimpanzees in the Gombe Stream Reserve. *Animal Behaviour Monographs, 1*(3), 161-311.

Veà, J.J., & Sabater-Pi, J. (1998). Spontaneous pointing behaviour in the wild pygmy chimpanzee (*Pan paniscus*). *Folia Primatologica, 69*(5), 289-290.

Vilá, C., Savolainen, P., Maldonado, J.E., Amorim, I.R., Rice, J.E., Honeycutt, R.L., Crandall, K.A., Lundeberg, J., & Wayne, R.K. (1997). Multiple and ancient origins of the domestic dog. *Science, 276*(5319), 1687-1689.

Visalberghi, E., & Limongelli, L. (1994). Lack of comprehension of cause and effect relations in tool-using capuchin monkeys (*Cebus apella*). *Journal of Comparative Psychology, 108*(1), 15-22.

Visalberghi, E., & Tomasello, M. (1998). Primate causal understanding in the physical and psychological domains. *Behavioural Processes, 42*(2–3), 189-203. doi: 10.1016/S0376-6357(97)00076-4

Völter, C.J., Rossano, F., & Call, J. (2015). From exploitation to cooperation: Social tool use in orang-utan mother–offspring dyads. *Animal Behaviour, 100*(2015), 126-134. doi: 10.1016/j.anbehav.2014.11.025

Warden, C.J., & Warner, L.H. (1928). The sensory capacities and intelligence of dogs, with a report on the ability of the noted dog" Fellow" to respond to verbal stimuli. *The Quarterly Review of Biology, 3*(1), 1-28.

Warneken, F., Chen, F. & Tomasello, M. (2006) Cooperative activities in young children and chimpanzees. *Child Development, 77*(3), 640–663.

Wayne, R.K. (1993). Molecular evolution of the dog family. *Trends in Genetics, 9*(6), 218-224. doi: 10.1016/0168-9525(93)90122-X

Weir, A.A.S., Chappell, J., & Kacelnik, A. (2002). Shaping of hooks in New Caledonian crows. *Science, 297*(5583), 981-981. doi: 10.1126/science.1073433

Whiten, A., & Byrne, R.W. (1997). *Machiavellian Intelligence II: Extensions and Evaluations.* Cambridge: Cambridge University Press.

Wimpenny, J.H., Weir, A.A., & Kacelnik, A. (2011). New Caledonian crows use tools for non-foraging activities. *Animal Cognition, 14*(3), 459-464.

Wittig, R.M., Crockford, C., Wikberg, E., Seyfarth, R.M., & Cheney, D.L. (2007a). Vocal alliances in Chacma baboons (*Papio hamadryas ursinus*). *Behavioural Ecology and Sociobiology, 61*(6), 899-909.

Wittig, R.M., Crockford, C., Wikberg, E., Seyfarth, R.M., & Cheney, D.L. (2007b). Kin-mediated reconciliation substitutes for direct reconciliation in female baboons. *Proceedings of the Royal Society B: Biological Sciences, 274*(1613), 1109-1115.

Witzany, G. (2014). *Biocommunication of Animals*. Netherlands: Springer. doi: 10.1007/978-94-007-7414-8_1

Woodruff, G., & Premack, D. (1979). Intentional communication in the chimpanzee: The development of deception. *Cognition, 7*(4), 333-362. doi: 10.1016/0010-0277(79)90021-0

Worsley, H.K., & O’Hara, S.J. (2018). Cross-species referential signalling events in domestic dogs (*Canis familiaris*). *Animal Cognition*, *21*(4), 457-465. doi: 10.1007/s10071-018-1181-3

Yamakoshi, G. (1998). Dietary responses to fruit scarcity of wild chimpanzees at Bossou, Guinea: Possible implications for ecological importance of tool use. *American Journal of Physical Anthropology, 106*(3), 283-295. doi: 10.1002/(SICI)1096-8644(199807)

Yeon, S.C. (2007). The vocal communication of canines. *Journal of Veterinary Behavior: Clinical Applications and Research, 2*(4), 141-144. doi: 10.1016/j.jveb.2007.07.006

Yeon, S.C., Seo, K.M., Kweon, O.K., & Nam, T.C. (1996). Common calls of poodle. *Korean Journal of veterinary Clinical Medicine, 13*(1996), 163-170.

Yin, S., & McCowan, B. (2004). Barking in domestic dogs: Context specificity and individual identification. *Animal Behaviour, 68*(2), 343-355. doi: 10.1016/j.anbehav.2003.07.016

Young, H.P. (2009). Learning by trial and error. *Games and Economic Behaviour, 65*(2), 626-643.

Zimen, E. (1975). Social dynamics of the wolf pack. In M.W. Fox (Ed.), The Wild Canids: Their Systematics, Behavioral Ecology and Evolution (pp. 336-368). New York: Van Nostrand Reinhold Co.

Zuberbühler, K. (2000a). Causal knowledge of predators' behaviour in wild Diana monkeys. *Animal Behaviour, 59*(1), 209-220.

Zuberbühler, K. (2000b). Causal cognition in a non-human primate: Field playback experiments with Diana monkeys. *Cognition, 76*(3), 195-207.

Zuberbühler, K. (2001). Predator-specific alarm calls in Campbell's monkeys, *Cercopithecus campbelli. Behavioral Ecology and Sociobiology, 50*(5), 414-422.

Zuberbühler, K., Noë, R., & Seyfarth, R.M. (1997). Diana monkey long-distance calls: Messages for conspecifics and predators. *Animal Behaviour, 53*(3), 589-604. doi: 10.1006/anbe.1996.0334

APPENDIX I: Help Sheet.

Help Sheet

What do I need to do?

All you need to do is watch what your dog and film them doing any of these:

1. **Playing** by themselves, with toys or with you.
2. **Asking for food or a drink** or begging.
3. **When a toy gets stuck under furniture** and your dog is struggling to retrieve it.
4. **Getting you to scratch/stroke them.**
5. **Climbing on** yourself or furniture.
6. **Asking to be picked up** and carried.
7. **When your dog asks for objects to be moved** that they cannot reach or may be fearful of.
8. **Asking for doors to be opened** to go outside or into another room.

Other Behaviours to Look Out For:

- **Unknown** = your dog starts behaving like they want something but you have no idea what they want.
- **Unique Behaviour** = your dog does something you have never seen them do before.

Contact

If you have any questions or are struggling with anything, please feel free to contact me.

Hannah Worsley

Mob: [redacted]

email: [redacted]

APPENDIX II: Total video time.

Subject I.D.	**Total Video Time (min:sec)**	**Usable Footage (min:sec)**	**Unusable Footage (min:sec)**
Archie	15:38	6:42	8:56
Barley	15:41	12:38	3:03
Betty	8:50	8:50	0:00
Bobby. H	6:15	6:15	0:00
Bobby. L	1:30	1:30	0:00
Dug	1:13	1:13	0:00
Dexter. L	6:26	6:26	0:00
Emma	6:40	6:40	0:00
Florence	12:06	12:06	0:00
Izzy	3:15	3:15	0:00
Lyla	7:34	7:14	0:20
Jaffa	16:48	16:48	0:00
Jenko	9:04	2:09	6:55
Jenson	10:55	5:59	4:56
Kyp	15:56	15:56	0:00
Leroy	1:33	1:33	0:00
Lola	15:01	15:01	0:00
Mandy	13:50	13:50	0:00
Max. B	12:12	12:12	0:00
Max. W	4:30	4:30	0:00
Onslow	7:48	7:48	0:00
Oscar	5:04	5:04	0:00
Patch	9:03	8:56	0:07
Peggy	10:18	10:18	0:00
Phoebe	8:58	8:58	0:00
Mickey	13:01	11:14	1:47
Pudding	2:34	2:34	0:00
Rupert	14:53	14:53	0:00
Aaron	3:49	3:49	0:00
Sherlock	28:04	24:18	3:08
Watson	29:39	25:53	3:08
Star	57:40	57:40	0:00
Sula	9:28	9:28	0:00
Tilly	9:17	9:17	0:00
Tess	8:12	8:12	0:00
Toby	4:37	4:37	0:00
Yoshi	4:04	3:18	0:46
Ddc.X	*4:32*	*0:00*	*4:32*
Ti.X	*9:38*	*0:00*	*9:38*
Wa.X	*0:31*	*0:00*	*0:31*
Ma.X	*12:32*	*0:00*	*12:32*

APPENDIX III: Potential intentional gestures initially identified against the strict criteria for intentionality.

	Five Features of Intentionality				
Gestures	1. Goal-Directed	2. Plausibly Desired Result	3. Response Waiting	4. Persistence & Elaboration	5. Directed at an audience
Wag	Y	Y	Y	Y	Y
Sit & Wait	Y	Y	Y	Y	Y
Lie & Wait	Y	Y	Y	Y	Y
Stand & Wait	Y	Y	Y	Y	Y
Rest & Wait	Y	Y	Y	Y	Y
Hover & Wait	Y	Y	Y	Y	Y
Down-Up	Y	Y	Y	Y	Y
Head Turn	Y	Y	Y	Y	Y
Roll Over	Y	Y	Y	Y	Y
Roll Back	Y	Y	Y	Y	Y
Circle Head	N	N	Y	N	Y
Head Under	Y	Y	Y	Y	Y
Head Out	Y	Y	Y	Y	Y
Lean Back	Y	Y	Y	Y	Y
Run & Pull	Y	Y	Y	Y	Y
Wink	N	N	Y	N	Y
Head up	Y	Y	Y	Y	Y
Look Behind	Y	Y	Y	Y	Y
Lean Forward	Y	Y	Y	Y	Y
Front Paws Up	Y	Y	Y	Y	Y
Front Paws Down	Y	Y	Y	Y	Y
Drop Object/Toy	Y	Y	Y	Y	Y
Head Down	Y	Y	Y	Y	Y
Crawl Back & Forth	Y	Y	Y	Y	Y
Jump On	Y	Y	Y	Y	Y
Jump Off	Y	Y	Y	Y	Y
Head Forward	Y	Y	Y	Y	Y
Head Back	Y	Y	Y	Y	Y
Head Sway	Y	Y	Y	Y	Y
Hind Leg Stand	Y	Y	Y	Y	Y
Scratch	N	N	Y	N	N
Wide Mouth	N	N	N	Y	Y
Play Gesture/Play Position	Y	Y	Y	Y	Y
Shake Object/Toy	Y	Y	Y	Y	Y
Wave Object	Y	Y	Y	Y	Y
Head Through	Y	Y	Y	Y	Y
Body Lean	Y	Y	Y	Y	Y
Head Tilt	Y	Y	Y	Y	Y
Ear Twitch	Y	Y	Y	Y	Y

Back Leg Hover	N	N	Y	N	Y
Head Bob	Y	Y	Y	Y	Y
Body Turn	Y	Y	Y	Y	Y
Open Mouth	Y	Y	Y	Y	Y
Close Mouth	Y	Y	Y	Y	Y
Sleepy Eyes	Y	Y	Y	Y	Y
Tremble	Y	Y	Y	Y	Y
Shuffle	Y	Y	Y	Y	Y
Spin Bounce	Y	Y	Y	Y	Y
Head Jerk	Y	Y	Y	Y	Y
Back Leg Up	Y	Y	Y	Y	Y
Pull Blanket	Y	Y	Y	Y	Y
Shake	N	N	N	N	Y
Pounce	Y	Y	Y	Y	Y
Runaway	Y	Y	Y	Y	Y
Rock Back & Forth	Y	Y	Y	Y	Y
Side Bounce	N	N	Y	N	Y
Paw Hover	Y	Y	Y	Y	Y
Paw Down	Y	Y	Y	Y	Y
Begging Gesture	Y	Y	Y	Y	Y
Chase Me	Y	Y	Y	Y	Y
Trotting	N	N	N	Y	N
Fetch	Y	Y	Y	Y	Y
Stretch Out	Y	Y	Y	Y	Y
Dodge	Y	Y	Y	Y	Y
Head Dodge	Y	Y	Y	Y	Y
Side-Step	Y	Y	Y	Y	Y
Floor Rub	N	N	N	Y	N
Stretch Up	Y	Y	Y	Y	Y
Circle	Y	Y	Y	Y	Y
Turn	Y	Y	Y	Y	Y
Hop	Y	Y	Y	Y	Y
Grab Toy/Post	Y	Y	Y	Y	Y
Chew/Bite Toy	Y	Y	Y	Y	Y
Toy Whack	Y	Y	Y	Y	Y
Hunchback	Y	Y	Y	Y	Y
Door Lean	Y	Y	N	N	N
Crawl Under	Y	Y	Y	Y	Y
Flick Toy	Y	Y	Y	Y	Y
Puppy Dog	Y	Y	Y	Y	Y
Chin Rest	Y	Y	Y	Y	Y
Chin Off	Y	Y	Y	Y	Y
Bounce	Y	Y	Y	Y	Y
Push Toy	Y	Y	Y	Y	Y
Drag Toy	Y	Y	N	N	Y
Toy in Mouth	Y	Y	Y	Y	Y
Nibble	Y	Y	Y	Y	Y
Chomp	Y	Y	Y	Y	Y

Sway	Y	Y	Y	Y	Y
Head Rub	Y	Y	Y	Y	Y
Lick Lips	Y	Y	Y	Y	Y
Move Mouth	Y	Y	Y	Y	Y
Stamp Paws	Y	Y	Y	Y	Y
Chew Body	N	N	N	Y	N
Toy Lunge	Y	Y	N	N	N
Parade with Toy	Y	Y	Y	Y	Y
Spin Around	Y	Y	Y	Y	Y
Spin	Y	Y	Y	Y	Y
Lick Nose	N	N	N	N	Y
Nose Up	N	N	Y	N	Y
Water Bite	Y	Y	Y	Y	Y
Groaning	Y	Y	Y	Y	Y
Jerk Forward	Y	Y	Y	Y	Y
Rub Head	Y	Y	Y	Y	Y
Knock On Door	Y	Y	Y	Y	Y
Paw	Y	Y	Y	Y	Y
Paw with Both	Y	Y	Y	Y	Y
Paw Reach	Y	Y	Y	Y	Y
Gnawing	N	N	N	N	Y
Nose Press/Nose	Y	Y	Y	Y	Y
Lick	Y	Y	Y	Y	Y
Front Paws On	Y	Y	Y	Y	Y
Front Paws Off	Y	Y	Y	Y	Y
Paw Rest	Y	Y	Y	Y	Y
Head Rest	Y	Y	Y	Y	Y
Jump	Y	Y	Y	Y	Y
Side Jump	Y	Y	Y	Y	Y
Toy Press	Y	Y	Y	Y	Y
Paws Out	N	N	Y	N	Y
Paw Push	Y	Y	Y	Y	Y
Paw Shove	Y	Y	Y	Y	Y

APPENDIX IV: Definitions of the 103 intentional gestures and the 15 vocalisations identified in the study. Gestures are listed as visible only, tactile and visible and audible.

Gesture Name	**Description**
Visible Only	
Back Leg Up	Lifting of a single back leg whilst lying on one side of the body.
Begging Gesture	Lift both front paws off the ground whilst in a sitting position and holding the pose whilst raising the head along the vertical axis.
Body Lean	Slope body to one side in order to lean against an object, opening or another organism.
Body Turn	Turn body to one side on horizontal axis.
Bounce	Jump up and down around the room, usually performed during play.
Chew/Bite Toy	Hold a desired object in the mouth while repetitively chewing and/or biting down on the object.
Chin Off	Remove chin from its resting position on another organism/object and look/ stare at a desired object or another organism.
Circle	Move in a circular motion around an object or another organism.
Close Mouth	Closing mouth following a period of sustained opening.
Craw Back & Forth	Lying flat with both front and back legs out-stretched and pulling oneself back and forth/side to side with front legs. Body remains out-stretched and is ‘dragged’ along the ground by the user’s own force.
Crawl Under	Move entire or part of body underneath an object.
Dodge	Quickly moving the body from side-to-side while the back legs remain stationary.
Down-Up	Assuming the play position and laying the head flat on the ground whilst remaining completely still.
Drop Object/Toy	Drop an object that is held in the mouth so that it falls vertically.
Ear Twitch	Slow or rapid movement back and forth of ears.
Fetch	Pick up a desired object using the mouth and taking it to the recipient.
Flick Toy	Hold toy in the mouth and throw it forwards, usually in the direction of the recipient.
Front Paws Down	Performed whilst standing on stairs, involves placing both front paws down from a higher step, where the back paws are placed, onto an empty lower step.
Front Paws Up	Performed whilst standing on stairs, involves placing both front paws up from a lower step to a higher step in which the back paws are placed.
Grab Post/Toy	Quickly pick up a desired object using the mouth.
Head Back	Move the head backwards and down.
Head Bob	Bobbing/nodding head up and down in the vertical body axis.
Head Dodge	Slowly moving the head from side-to-side while the body remains stationary. Usually performed to avoid relinquishing a desired object in the mouth.
Head Down	Move head down in the vertical body axis.
Head Forward	Move the head forwards and up.
Head Jerk	The rapid tilting movement of the head to one side.
Head Out	Remove head from underneath and object or another organism and lift it up along the vertical axis.

Head Sway	Move head slowly or rhythmically from side to side.
Head Through	Push head through an opening.
Head Tilt	Tilt head to one side.
Head Turn	Turn head to one side on horizontal axis. When recorded in succession (e.g. head turn, head turn) head is turned from side to side on the horizontal axis.
Head Under	Plunge headfirst underneath an object or another organism.
Head Up	Move head up in the vertical body axis.
Hind Leg Stand	Lift front paws off the ground and stand on hind legs, front paws are not resting on anything.
Hop	Quickly jump to one side.
Hover & Wait	Assuming a standing position and lifting one front paw off the ground and holding it in mid-air whilst looking/staring at an object or another organism.
Hunchback	The entire body becomes stiff and the shoulders are brought up slightly.
Jump	Jump up and down off the ground, another organism or an object, usually while staying in one location.
Jump Off	Jump down from one location to another.
Jump On	Jump up from one location to another.
Lean Back	Move the body backwards and down.
Look Behind	Turn head towards one's back on the horizontal axis.
Lean Forward	Move the body forwards and up.
Lie & Wait	Assuming a lying position whilst looking/staring at an object or another organism.
Open Mouth	Opening mouth slightly exposing teeth but not in an aggressive manner, usually sustained.
Paw Down	Follows the paw hover gestures and involves placing a paw, which was previously held in mid-air, back on the ground.
Paw Hover	Hold one paw in mid-air whilst in a sitting position, followed by paw down gesture.
Play Position	Front legs are stretched forward with the chest low to the ground. The hind legs are in a standing position with the rear in the air.
Pounce	Spring suddenly onto a desired object.
Puppy Dog	The head is facing down along the vertical axis and the eyes are looking up towards the recipient so that the whites of the eyes are showing.
Rock Back & Forth	Involves rocking body along vertical axis continuously and lifting both front paws off the ground during rocking, usually performed before a jump.
Roll Back	Rolling onto the front of the body after being lay on one side.
Roll Over	Rolling onto one side of the body and exposing the chest, stomach and groin.
Run & Pull	Performed whilst on the leash, involves pulling the individual who is holding the leash to increase speed of movement.
Runaway	Run away from recipient during play, usually in anticipation of the recipient throwing a toy.
Shake Object/Toy	Rapidly shake an object that is held in the mouth from side to side along the horizontal axis.

Shuffle	Shuffle whole body along the ground in short movements, performed whilst in roll over position.
Side Jump	Assuming a lying position whilst looking/staring at an object or another organism. The signaller then jumps up of the ground, moves to the side and assumes the lying position in the new location.
Sit & Wait	Assuming a sitting position whilst looking/staring at an object or another organism.
Sleepy Eyes	Performed whilst in a sitting position and involves slowly opening and closing the eyes in a “tired-like” manner.
Spin Bounce	Spin whole body around in a circular motion whist bouncing front paws on the ground.
Stand & Wait	Assuming a standing position whilst looking/staring at an object or another organism.
Stretch Out	Involves lying down on the stomach and stretching out both the back and front legs.
Sway	Performed in a sitting position and involves slightly moving the front of the body forwards and back.
Tremble	Slightly shake whole body for a prolonged period of time.
Toy in Mouth	Hold a toy in the mouth and assume a standing position whilst looking/staring at an object or another organism.
Toy Whack	Hold a desired object in the mouth while lifting the head up along the vertical axis. Once lifted the object is brought down forcefully while still being held.
Turn	Move in a large circular motion near a desired object.
Wag	Movement of the tail in any direction and pace.
Wave Object	Slowly or rhythmically move a toy held in the mouth from side to side.
Tactile	
Chin Rest	Place/rest chin on an object or another organism whilst looking up at another organism or a desired object.
Chomp	Performed during play and involves opening the mouth and placing it over the arm of a human whilst repeatedly and gently biting down on the arm.
Front Paws Off	Lifting both front paws off an organism or object and placing them back on the ground.
Front Paws On	Lifting both paws off the ground and resting them on an object or another organism.
Head Rest	Tilt the head to one side in order to lean against another organism or object.
Head Rub	Similar to head lean but involves rubbing the head against the organism on which they are leaning on.
Knock On Door	Involves placing the front paws on a door and repeatedly pawing at the door so it produces a knocking noise. Can be performed whilst standing still or while moving along the door.
Lick	Licking an object or another organism once or repetitively.
Nibble	Performed during play and involves repeatedly moving head along the body of another dog whilst constantly nibbling at the other dogs’ fur.
Nose Press/Nose	Pressing nose (or face) against an object of another organism.

Paw	Lifting of a single front paw to briefly touch an object or another organism.
Paw Push	Using one or both front paws to push a desired object towards the receiver.
Paw Reach	Placing a single paw or both paws underneath another object in an attempt to retrieve a desired object.
Paw Rest	Lifting a single front paw and resting it on an object or another organism.
Paw Shove	Placing both front paws on another organism and repeatedly pushing them against the organism with force.
Paw with Both	Lifting both front paws of the ground simultaneously to briefly touch an object or another organism.
Pull Blanket	An attention-getter and involves grabbing a blanket with the mouth and repeatedly pulling at.
Push Toy	Using the nose to push a specific object towards the intended receiver.
Rest & Wait	Assuming a sitting or standing position whilst resting the chin on a piece of furniture and looking/staring at an object or another organism.
Side-Step	Lifting both front paws off the ground and resting them against another object (usually a door). Once the front paws are against the object the performer continually paws at the door while moving from side-to-side.
Stretch Up	Lift both front paws off the ground and place them on an object. Once placed on an object the performer leans back and moves their body down slightly while pushing the front paws higher against the object.
Toy Press	Push a toy which is held in the mouth against another organism.
Visible & Audible	
Chase Me	Running around in a large circular motion wagging the tail and producing grunt-like vocalisations whilst holding a toy in the mouth in repetitively squeaking the toy.
Groaning	Drag the body along the floor and rub the head on the floor while producing a grunt-like vocalisation.
Jerk Forward	Performed whilst lying down with front paws spread out on the floor. Involves short, rapid forward movements of the body whilst producing grunting noises.
Lick Lips	Protrude tongue out of mouth and lick lips repetitively or once whilst making a noise.
Move Mouth	Open and close mouth frantically and repetitively, can produce vocalisations whilst performing this.
Parade with Toy	Walk around the perimeter of a room with a toy in the mouth occasionally lifting the head up vertically and producing vocalisations.
Rub Head	Assuming the play position but with the head lay flat on the ground and rubbing the head back and forth along a surface. Also involves exhaling loudly and wagging.
Spin Around	Repetitively spinning around whilst constantly barking, wagging can occur and ears can be back. Similar to tail chasing phenomenon seen in dogs, but with short breaks in-between bouts (three-five spins per bout). During these breaks stand & wait and mouth open are performed with the occasional grunt.

Spin	Repetitively spinning around whilst constantly barking. Similar to the Spin Around gesture described above, but with no short breaks in-between bouts of spinning.
Stamp Paws	Stamping the ground with either both front paws or a single front paw.
Water Bite	involves walking forward or moving head forward and audibly biting into water, performed when in the presence of running water (from a tap, hose etc.)

Vocalisation Name	**Description**
Bark	A sharp, explosive vocalisation.
Cry Out	A sustained high-pitched sound.
Exhale	Blow out air audibly through the nose.
Growl	A sustained low guttural sound in the throat.
Grunt	A low, short guttural sound.
Howl	A long, doleful cry.
Moan	A long low sound produced without opening the mouth.
Pant	Breathe audibly with short, quick audible breaths.
“Sigh”	A long, deep audible breath.
Sniff	Draw up air audibly through the nose, usually directed at a desired object.
Squeal	A long high-pitched noise.
Whimper	A series of low feeble sounds.
Whine	A prolonged high feeble sound.
Yawn	Opening mouth wide and inhale deeply.
Yelp	High pitched sharp explosive vocalisation.

APPENDIX V: Gestures and vocalisations recorded in all subjects alongside the number of individuals in which it was noted, the number of instances of a specific gesture/vocalisation and the number of contexts in which it was observed.

Gestures	**Number of Individuals (*n* = 37)**	**Number of Instances**	**Number of Contexts (max = 11)**
Wag	34	780	11
Sit & Wait	35	334	11
Lie & Wait	25	170	10
Stand & Wait	35	563	11
Rest & Wait	4	11	4
Hover & Wait	2	11	2
Down-Up	1	1	1
Head Turn	37	582	11
Roll Over	9	13	2
Roll Back	1	1	1
Head Under	15	60	4
Head Out	1	1	1
Lean Back	4	5	3
Run & Pull	1	1	1
Head up	37	538	11
Look Behind	30	127	11
Lean Forward	3	8	4
Front Paws Up	4	4	3
Front Paws Down	2	2	2
Drop Object/Toy	21	124	6
Head Down	37	338	10
Crawl Back & Forth	1	2	1
Jump On	14	31	9
Jump Off	10	14	6
Head Forward	16	41	7
Head Back	3	4	2
Head Sway	3	8	3

Hind Leg Stand	9	11	5
Play Gesture/Play Position	16	53	7
Shake Object/Toy	5	26	4
Wave Object	1	1	1
Head Through	2	9	1
Body Lean	3	5	3
Head Tilt	17	64	7
Ear Twitch	8	41	9
Head Bob	3	8	3
Body Turn	1	10	4
Open Mouth	5	24	8
Close Mouth	3	5	4
Sleepy Eyes	1	3	1
Tremble	1	10	2
Shuffle	1	3	1
Spin Bounce	1	4	1
Head Jerk	2	6	3
Back Leg Up	1	3	1
Pull Blanket	1	1	1
Pounce	5	21	2
Runaway	7	11	3
Rock Back & Forth	1	3	2
Paw Hover	14	60	6
Paw Down	4	18	4
Begging Gesture	2	3	2
Chase Me	1	14	1
Fetch	9	61	7
Stretch Out	3	3	3
Dodge	1	3	1
Head Dodge	1	7	1
Side-Step	1	3	1
Stretch Up	1	1	1
Circle	4	9	5

Turn	2	11	4
Hop	1	1	1
Grab Toy/Post	14	107	5
Chew/Bite Toy	8	57	4
Toy Whack	1	1	1
Hunchback	2	2	1
Crawl Under	1	2	1
Flick Toy	2	8	2
Puppy Dog	1	7	2
Chin Rest	12	17	7
Chin Off	4	6	5
Bounce	1	4	1
Push Toy	1	2	1
Toy in Mouth	1	1	1
Nibble	1	1	1
Chomp	1	5	1
Sway	1	4	2
Head Rub	1	2	2
Lick Lips	35	678	11
Move Mouth	12	41	7
Stamp Paws	29	451	10
Parade with Toy	1	3	1
Spin Around	1	12	1
Spin	1	19	1
Water Bite	1	5	1
Groaning	1	1	1
Jerk Forward	1	3	1
Rub Head	1	2	1
Knock On Door	1	5	1
Paw	24	267	8
Paw with Both	2	5	4
Paw Reach	8	28	3
Nose Press/Nose	23	132	8

Lick	19	91	7
Front Paws On	28	102	11
Front Paws Off	20	59	9
Paw Rest	8	17	5
Head Rest	6	17	4
Jump	16	84	11
Side Jump	1	1	1
Toy Press	2	5	2
Paw Push	1	6	1
Paw Shove	1	2	1

Vocalisation	**Number of Individuals (*n* = 37)**	**Number of Instances**	**Number of Contexts (max = 11)**
Whimper	21	238	11
Whine	12	71	5
Growl	16	76	9
Bark	21	598	8
Cry out	11	66	8
Grunt	19	97	11
Squeal	1	1	1
Yawn	17	29	9
Howl	4	7	2
“Sigh”	2	3	2
Pant	15	105	9
Sniff	15	66	8
Exhale	3	26	6
Yelp	1	4	3

APPENDIX VI: Gestures and vocalisations restricted to a single subject.

Gesture	Number of Instances
Down-up	1
Roll Back	1
Head Out	1
Run & pull	1
Crawl Back & Forth	2
Wave Object	1
Body Turn	10
Sleepy Eyes	3
Tremble	10
Shuffle	3
Spin Bounce	4
Back Leg Up	3
Pull Blanket	1
Rock Back & Forth	3
Chase Me	14
Dodge	3
Head Dodge	7
Side-Step	3
Stretch Up	1
Hop	1
Toy Whack	1
Crawl Under	2
Puppy Dog	7
Bounce	4
Push Toy	2
Toy in Mouth	1
Nibble	1
Chomp	5
Sway	4
Head Rub	2
Parade with Toy	3
Spin Around	12
Spin	19
Water Bite	5
Groaning	1
Jerk Forward	3
Rub Head	2
Knock on Door	5
Side Jump	1
Paw Push	6
Paw Shove	2
Vocalisations	**Number of Instances**
Squeal	1
Yelp	4
Moan	7

APPENDIX VII: Possible referential gestures recorded during initial observations of the video data.

Subject ID	**Referential Signalling**			
	"Scratch me!"	***"Give me Food/Drink"***	***"Open the Door"***	***"Get my Toy/Bone"***
Toby	Roll Over; Lean back	Paw; Lick lips	Nose; Head turn; Look behind	
Pudding		Head turn		Head under; Paw
Mandy	Head forward; Head back	Head turn; Hind leg stand; Lick lips	Head turn	
Sherlock	Nose; Roll over		Paw	
Watson	Body lean; Roll over	Head forward; Head turn; Lick lips	Head turn; Head forward	
Star	Roll over; Shuffle	Head turn; Head up; Nose; Paw; Lick lips; Stamp paws	Head turn; Head up; Nose; Head forward; Look behind	Head under; Paw reach; Head down
Max. W	Body lean; Nose press; Paw; Head forward	Head turn; Head up	Head up; Look behind; Spin bounce	
Sula	Roll over; Head forward; Lean forward; Back leg up; Lean back; Nose	Head up; Head turn; Lick lips		
Patch	Roll over	Head up; Head turn; Lick lips	Head turn; Look behind; Nose; Front paws on; Jump	Head down; Paw reach; Head under; Nose
Emma	Paw hover; Chin rest	Head up; Head turn; Stamp paws	Head turn; Head up	Head down; Head under; Paw
Tilly		Head turn; Head up; Lick lips; Stamp paws	Head up; Head turn	
Tess		Head turn; Lick lips	Head up; Head turn	
Dexter	Groaning; Chin rest; Nose	Head turn; Head up; Begging gesture; Hind leg stand; Lick lips	Look behind; Head turn; Head up	Paw reach; Head down; Head turn

Lola	Head forward; Roll over; Paw; Nose	Paw; Lick; Head up; Head turn; Lick lips; Stamp paws	Side-step; Front paws on; Head turn; Head up; Jump	Head down; Nose; Head under; Head turn
Max. B	Nose; Paw	Head up; Head turn; Lick lips; Stamp paws	Look behind; Head turn; Paw	Head under; Head turn; Head down; Crawl under
Phoebe		Head up; Head turn; Lick lips	Head up; Head turn; Circle; Front paws on; Paw; Head forward	Paw reach; Head under; Circle; Paw; Nose; Head down
Florence	Paw; Lick; Nose; Paw rest; Puppy dog	Head turn; Head up; Turn; Stamp paws	Head up; Turn; Head turn; Look behind; Paw	Head down; Head under; Head turn; Nose
Oscar		Grab toy; Flick toy; Head up; Hind leg stand; Head turn; Lick lips; Stamp paws	Head turn; Paw	Head down; Head turn; Head under; Paw reach
Kyp		Head up; Head turn; Stamp paws; Chin rest; Rest & wait; Lick lips		Head under; Nose; Paw reach; Paw; Head down; Head turn
Peggy		Head up; Head turn; Stamp paws; Lick lips	Head turn; Head up; Look behind	Head turn; Head down; Head under
Mickey	Paw rest; Paw; Nose; Lick; Paw hover	Lick; Lick lips; Head turn; Stamp paws; Chin rest	Look behind; Head turn; Head up; Front paws on; Paw; Nose	
Aaron		Head turn; Head up; Stamp paws		
Rupert		Head turn; Lick lips; Head up; Stamp paws;		Head down; Head

		Paw; Chin rest; Rest & wait; Drop toy; Nose; Circle		under; Paw; Nose; Paw reach
Izzy		Head turn; Head up; Lick lips; Paw; Nose	Toy in mouth; Head turn	
Lyla	Front paws on; Lick;	Stamp paws; Head turn; Head up; Lick lips; Hind leg stand; Lick	Head turn; Head up	
Leroy		Head turn; Head forward; Front paws on; Lick lips	Head up; Head turn; Look behind	
Yoshi	Front paws on; Lick; Nose; Roll over; Head turn; Head forward; Paw hover	Head up; Head turn; Chin rest; Rest & wait	Head up; Head turn; Circle	
Bobby. H		Head up; Stamp paws; Head turn; Lick lips; Paw hover	Paw; Nose; Look behind; Head turn; Head up	Head down; Paw; Head turn
Dug	Chin rest		Head up; Head turn; Look behind	
Bobby. L		Nose; Lick lips; Head up; Head turn		
Archie				Head under; Head down
Jaffa		Stamp paws; Head turn; Head up	Head turn; Nose; Chin rest; Rest & wait; Head up; Look behind; Rub head; Down-Up	Head under; Head turn; Nose; Head down; Paw
Jenko	Lick; Chomp; Paw; Paw rest; Nose; Head turn		Front paws on; Knock on door; Head turn; Head up; Look behind	
Jenson	Front paws on; Paw hover; Paw; Paw rest	Head turn; Lick lips; Paw hover; Hover & wait; Paw; Stamp paws; Look behind; Head up		
Barley		Head turn; Sway		
Onslow	Head rest; Head rub	Head up; Head turn; Paw shove;	Look behind;	

		Lick lips; Stamp paws; Turn; Paw; Front paws on	Head up; Paw; Nose
Betty	Head turn; Roll over	Head up; Head turn; Stamp paws; Lick lips; Paw; Lick	Look behind; Head turn; Head up

“Scratch me!”: 22 potential referential gestures
“*Give me food/drink”*: 24 potential referential gestures
“*Open the door”*: 18 potential referential gestures
“Get my toy/bone”: 8 potential referential gestures

Of the 47 gestures initially identified from the video footage (Appendix VII), 28 failed to conform to all five features of referentiality. Although these gestures were performed intentionally and with the aim of attracting a potential recipient they do not direct the recipient's attention towards a desired goal.

APPENDIX VIII: Potential referential gestures initially identified against the strict criteria for referentiality.

	Five Features of Referentiality				
Potential Referential Gesture	1. Directed Towards an Object	2. Directed towards a Potential Recipient	3. Receive a Voluntary Response	4. Are Mechanically Ineffective	5. Hallmarks of Intentionality
Roll over	Y	Y	Y	Y	Y
Lean back	N	N	N	N	Y
Head forward	Y	Y	Y	Y	Y
Head back	N	N	Y	N	Y
Nose	Y	Y	Y	Y	Y
Body Lean	N	Y	Y	N	Y
Shuffle	Y	Y	Y	Y	Y
Paw	Y	Y	Y	Y	Y
Lean forward	N	Y	Y	N	Y
Back leg up	Y	Y	Y	Y	Y
Paw hover	Y	Y	Y	Y	Y
Chin rest	Y	Y	N	N	Y
Groaning	N	N	N	N	Y
Lick	Y	Y	Y	Y	Y
Paw rest	Y	Y	Y	Y	Y
Puppy dog	N	Y	Y	N	Y
Front paws on	Y	Y	Y	Y	Y
Chomp	Y	Y	Y	Y	Y
Head turn	Y	Y	Y	Y	Y
Head rest	Y	N	N	Y	Y
Head rub	Y	Y	Y	Y	Y
Lick lips	N	N	N	N	Y
Hind leg stand	Y	Y	Y	Y	Y
Head up	Y	N	N	Y	Y
Stamp paws	N	N	N	Y	Y
Begging gesture	N	Y	Y	Y	Y
Turn	N	N	N	N	Y
Grab toy	Y	N	N	N	Y
Flick toy	Y	Y	Y	Y	Y
Rest & wait	Y	N	N	N	Y
Drop toy	Y	N	N	N	Y
Circle	N	N	N	Y	Y

Hover & wait	N	N	N	Y	Y
Look behind	N	Y	Y	N	Y
Sway	N	N	N	N	Y
Paw shove	Y	Y	N	Y	Y
Spin bounce	N	N	Y	N	Y
Jump	Y	Y	Y	Y	Y
Side-step	N	N	N	N	Y
Toy in mouth	Y	N	N	N	Y
Rub head	N	Y	Y	Y	Y
Down-up	N	Y	Y	N	Y
Knock on door	Y	N	N	N	Y
Crawl under	Y	Y	Y	Y	Y
Paw reach	Y	Y	Y	Y	Y
Head down	N	N	N	N	Y
Head under	Y	Y	Y	Y	Y

APPENDIX IX: Referential gestures observed in each subject during the four ASOs.

Subject ID	**Referential Gestures in ASOs**			
	1. "Scratch me!"	***2. "Give me food/drink"***	***3. "Open the door"***	***4. "Get my toy/bone"***
Toby	Roll over	Paw	Nose; Head turn	
Pudding		Head turn		Head under; Paw
Mandy	Head forward; Front paws on; Head turn; Paw; Lick	Head turn; Hind leg stand; Nose; Front paws on; Jump; Head forward	Head turn; Lick; Front paws on	
Sherlock	Nose; Roll over; Lick		Paw; Jump; Front paws on; Lick; Hind leg stand	
Watson	Roll over; Jump	Head turn; Head forward	Head turn; Jump; Front paws on; Head forward	
Star	Roll over; Shuffle	Head turn; Nose; Paw; Jump; Lick; Front paws on; Head forward; Hind leg stand	Head turn; Nose; Lick	Head under; Paw reach; Head turn
Max. W	Nose; Paw; Head forward	Head turn	Jump	
Sual	Roll over; Back leg up; Nose; Head turn; Lick	Head turn; Head forward		
Patch	Roll over	Head turn	Head turn; Nose; Front paws on; Jump	Paw reach; Head under; Jump
Emma	Paw hover; Head forward; Head turn	Head turn; Head forward	Head turn	Head under; Paw
Tilly		Head turn; Paw hover	Head turn; Paw hover; Front paws on	
Tess		Head turn	Head turn; Lick; Paw hover; Head forward	
Dexter. L	Nose; Lick	Head turn; Hind leg stand	Head turn	Paw reach; Head turn
Lola	Roll over; Paw; Nose; Head turn	Paw; Lick; Head turn; Front paws on; Jump; Lick; Paw hover	Jump; Front paws on; Head turn	Nose; Head under; Head turn; Front paws on; Hind leg stand; Paw
Max. B	Nose; Paw; Head turn	Head turn; Paw; Nose; Front paws on; Head forward; Lick	Head turn; Paw	Head under; Head turn; Crawl under; Paw; Paw hover

Phoebe		Head turn; Front paws on; Jump	Head turn; Front paws on; Paw; Jump; Head forward	Paw reach; Head under; Paw; Nose; Paw hover
Florence	Paw; Lick; Nose; Head turn	Head turn; Jump; Front paws on	Head turn; Paw; Paw hover	Head under; Head turn; Nose
Oscar		Flick toy; Hind leg stand; Head turn; Front paws on; Paw hover; Head forward	Head turn; Paw	Head turn; Head under; Paw reach
Kyp		Head turn		Head under; Nose; Paw reach; Paw; Head turn
Peggy		Head turn	Head turn; Front paws on; Head under	Head turn; Lick
Mickey	Paw; Nose; Lick; Paw hover; Head turn	Lick; Head turn; Flick toy	Head turn; Front paws on; Paw; Nose	
Rupert		Head turn; Paw; Nose; Front paws on; Jump		Head under; Head turn; Paw; Nose; Paw reach
Aaron		Head turn		
Izzy		Head turn; Paw; Nose; Jump	Head turn	
Lyla	Lick; Front paws on	Head turn; Hind leg stand; Lick; Front paws on	Head turn	
Leroy		Head turn; Front paws on; Head forward	Head turn; Jump	
Yoshi	Lick; Nose; Roll over; Paw hover; Head turn; Front paws on; Head forward	Head turn	Head turn	
Bobby. H	Head turn; Nose	Head turn; Paw hover	Paw; Nose; Head turn	Paw; Head turn; Paw hover
Dug	Head turn		Head turn	
Bobby. L		Nose; Head turn		
Archie				Head under
Jaffa	Nose; Lick	Head turn	Head turn; Nose; Paw	Head under; Head turn; Nose; Paw
Jenko	Lick; Chomp; Paw; Nose; Head turn		Front paws on; Head turn	

Jenson	Paw hover; Paw; Front paws on	Head turn; Paw; Paw hover		
Barley		Head turn		
Betty	Roll over; Head turn	Head turn; Paw; Lick	Head turn	
Onslow	Head rub	Head turn; Paw; Front paws on	Paw; Nose	

APPENDIX X: Individual characteristics of domestic dog social tool users.

Individual, (Name)	Sex	Age (Y)	Number of Observed Modes	Number of Tool Using Episodes
Pudding	F	2	4	4
Toby	M	4.5	3	7
Mandy	F	4	5	11
Sherlock	M	3	4	10
Watson	M	3	5	17
Star	M	14	8	53
Max. W	M	5	6	11
Sula	F	11	5	8
Patch	M	4.5	8	18
Emma	F	5	5	7
Tilly	F	8	4	7
Tess	F	8	2	4
Dexter	M	4	5	6
Lola	F	7	4	11
Max. B	M	9	4	9
Phoebe	F	1	4	10
Florence	F	7	5	11
Oscar	M	7	4	11
Kyp	M	5.5	4	12
Peggy	F	5	3	7
Mickey	M	3	4	9
Aaron	M	7	3	5
Rupert	M	3.5	4	17
Izzy	F	5	3	5
Lyla	F	6	3	7
Leroy	M	9	2	4
Yoshi	F	2	5	13
Bobby. H	M	12	4	7
Dug	M	2	2	3
Bobby. L	M	9	2	2
Archie	M	1.5	2	2
Jaffa	M	2.5	5	19
Jenko	F	1	2	4
Jenson	M	3	2	6
Barley	M	4	2	14
Onslow	M	7.5	4	9
Betty	F	4	4	10

M, male; F, Female

APPENDIX XI: Analysis of dog gestures in the receive control condition alongside description of gestural persistence and elaboration.

Receive Control Condition			
Dog	**Gestures**	**Persistence**	**Elaboration**
Amber	Sniff; hind leg stand; sit & wait; pant; head up; nose (treat); lick lips; head turn; circle; pant; head down; head up; pant; head turn; lick lips; wag; pant; head up; head turn; head down; nose (owner); pant; wag; head down; circle; pant.	Yes	Yes= circling around the humans and then nosing them.
Bailey	Hind leg stand; sniff; paw rest; lick; head up; wag; bark; paws down; stand & wait; wag; bark; begging gesture; bark x2; paws down; paw (owner); bark; paw rest (owner); bark; sit & wait; bark x5.	Yes	Yes= the owner said he was 'doing all his tricks' i.e. begging, pawing. He then resorted to just barking.
Bracken	Sniff; head down; head up; head turn; stand & wait; head up; head turn; stand & wait; nose (owner); head up; head turn; head forward; head up; stand & wait; head turn; head up; stand & wait; nose (owner); head turn.	Yes	Yes= begins to nose their hand.
Buster	Head up; wag; take control in mouth; chew control; drop control; head forward; head rest; wag; rest & wait; head up; head down; head turn; stamp paws; head turn; stand & wait; head down; head up; head turn; lick lips; wag; head down.	Yes	Yes= resting next to owner and stamping paws.
Chispa	Sniff; wag; head up; paw hover; head down; wag; nose (control); paw down; head up; rock back & forth; wag; sit & wait; look behind; paw hover; head turn; stamp paws; head turn; sit & wait; head turn; move mouth; head up; sit & wait.	Yes	Yes= rock back & forth and stamp paws alongside move mouth.
Dexter. L	Sniff; look behind; head turn; nose (control); head turn; sit & wait; head turn; head down; sniff; head up; ears back; sit & wait; head down; ears forward; nose (control); head up; head turn; sit & wait; head turn; ears back.	Yes	Yes= uses ears more as time goes on.
George	Sniff; wag; ears back; head turn; paw hover; wag; sniff; head turn; nose (control); head turn; stand & wait.	Yes	Yes= eventually stand & wait but also paw hover and nose previously.
Henry	Sniff; wag; head up; head down; sniff; wag; head up; front paws on; head turn; wag; front paws off; howl; sit & wait; bark; wag; bark x2; head turn; wag; head turn; wag; stand & wait; wag; stand & wait; jump up; whimper; wag; head up; sit & wait.	Yes	Yes= more vocalisations as time goes on but also front paws on and jump up at cupboard near treats.
Barney	Toy in mouth; sniff; head up; pant; wag; circle; head up; sit & wait; ears back; head turn; wag; circle; wag; circle; wag.	Yes	Yes= circle gestures around the control object and owner.

Dylan	Bark x19; wag; head up; bark x2; wag; stand & wait; bark x4; stamp paws; wag; bark x2; head turn; bark.	Yes	Yes= elaborates on vocalisations with all gestures produced.
Jett	Sniff; head turn; wag; head up; sniff (owner); wag; head turn; head down; head up; wag; stand & wait; head turn; stand & wait; wag; head down; lie & wait; head up; lie & wait; head turn.	Yes	Yes= differing waiting gestures paired with head gestures.
Lola	Sniff; lick lips; wag; ears back; lick lips x3; wag; sniff; wag; stamp paws; ears forward; whine; lick lips; head turn; whimper; head turn; whimper; wag; lick lips; whine; lick lips x3; ears back; wag; head up; whimper; wag; stand & wait; head turn; ears forward; head tilt; wag; pant; head up; head down; wag; lick lips x2; nose (owner); lick lips; head up; lick lips; wag; head turn; wag; stand & wait.	Yes	Yes= noses owner, differing vocalisations, a head tilt and eventually waiting after excitedly walking back and forth.
Lolli	Sniff; lick lips; head turn; lick lips; head turn; sniff (treats); head turn; head up; head down; lick lips; sniff (hand); head up; paw (owner); paw hover; paw x2 (owner); paw rest; nose (owner); paw down; head down; stamp paws.	Yes	Yes= elaborates on head gestures with paw gestures at the human.
Mabel	Head down; head up; sit & wait; head turn x2; front paws on; sniff; head turn; front paws off; sniff (owner); lick lips; head up; sit & wait; head down; lick lips; jump on; sniff; head turn; lick lips; head up; sit & wait.	Yes	Yes= goes from gestures directed at owner to ones that involve 'searching for treat'. She then goes back to waiting for owner.
Mandy	Sniff; head up; wag; head turn; lick lips x2; wag; head down; front paws on; paw (owner); chin rest; rest & wait; head turn; lick lips; chin rest; rest & wait; head up; front paws off; sit & wait; head turn; head up; ears back.	Yes	Yes= resting gestures elaborate on previous gestures.
Max	Sniff; lick x2; stand & wait; wag; lick lips; head turn; lick lips; wag; grab toy; drop toy; wag; head turn; stand & wait; lick lips; wag; head turn; lick lips.	Yes	Yes= attempts to use toy gestures as an elaboration.
Merrie	Sniff; head down; pant; wag; sniff; head up; pant; wag; pant; stand & wait; nose; head turn; wag; head up; pant; yawn; sit & wait; stamp paws; pant; look behind; pant; head up; grunt; lick x3; paw x2 (owner); wag; head forward.	Yes	Yes= licks and paws human.
Pippin	Sniff; wag; nose; sniff; wag; head turn; stamp paws; head turn; wag; nose x4; wag; sniff (owner); head up; wag; stamp paws; stand & wait; wag; head turn; head down; head up; wag; stand & wait; wag.	Yes	Yes= stamp paws, sniffing human.
Milly	Head down; head up; head turn; head down; head turn; head down; sit & wait.	Yes	No= more waiting

Missie	Head down; wag; head up; head turn; wag; stand & wait; wag; stamp paws; head turn; head down; head up; ears back; wag; head turn; ears forward; circle; wag; head twitch; stand & wait; wag; head down; head up; head turn; wag; stand & wait; head down; head turn; wag; stamp paws; wag; head turn.	Yes	Yes = circle, head twitch and stamp paws.
Mollie	Sniff; wag; head down; wag; front paws on; sniff (owner); wag; front paws off; nose; chin rest; wag; chin off; wag; grab toy; wag; toy in mouth; head up; stamp paws; drop toy; wag; head up; nose; stamp paws; front paws on; wag; lick; head turn; grab toy; drop toy; nose; wag.	Yes	Yes= resting gestures and then uses toy to gesture.
Molly	Sniff; head down; head up; nose; head down; head forward; stand & wait; head tilt; head turn; nose; head forward; sniff (owner); head turn; nose; head up; head tilt; sit & wait; head forward; nose; head tilt; head turn; nose; sit & wait.	Yes	Yes= this dog is touch trained so she kept nosing the sunglasses. Also, sniffs other hand for treats.
Patch	Sniff; wag; head forward; sniff (owner); head turn; sit & wait; head turn; wag; sit & wait; head turn; head down; head up; wag; sit & wait; head turn; sit & wait.	Yes	Yes= touching gesture is introduced to elaborate on head and waiting gestures.
Pudding	Sniff; nose; grunt; head up; lick lips; stand & wait; grunt; stamp paws; stand & wait; stamp paws; head turn; stand & wait; head turn; head down; head up; stand & wait; head turn.	Yes	Yes= starts to stamp her paws.
Toby	Sniff; head up; stand & wait.	Yes	No= he just waits.
Romulus	Sniff; lick lips; head up; head down; head up; nose x3; move mouth; nose x2; head turn; nose (owner); head turn; head up; nose (owner); head turn; take control in mouth; drop control; head down; head up; stand & wait; nose; front paws on; head forward; front paws off; head turn; stand & wait.	Yes	Yes= goes from nosing sun to nosing owner then back by taking sun. Also, puts his front paws on the treat cupboard.
Ruby	Sniff; head up; wag; sniff (owner); head down; look behind; head up; wag; stand & wait; wag; pant; nose (owner); lick x2 (owner); head down; head turn; pant; wag; look behind; wag; pant; head turn; head down; head up; sit & wait.	Yes	Yes= gestures at owner (nose and lick) then sits and waits.
Dexter. G	Head down; head up; head down; head up; head down; sniff; head up; wag; stand & wait; head turn; wag; stand & wait; head down; head up; sit & wait; head turn; sit & wait.	Yes	Yes= head gestures are repeated throughout and elaborated on with sniff, waiting and wag gestures.
Sasha	Sniff; head up; head down; nose; head down; head up; stamp paws; sit & wait; head down; head up; sit & wait.	Yes	Yes= introduces stamp paws and waiting gestures.
Star	Sniff; nose; head up; front paws on; sniff (owner); sniff (sofa); front paws off; head down; wag; sniff (control); head up; jump on; sniff	Yes	Yes= Jumps on the sofa and walks around the room looking for

	(owner); nose (owner); sniff (owner); head up; head down; jump off; pant; wag; pant; grunt; head up; head down; sniff (floor); wag; sniff (control); nose x3 (control); head up; pant; ears back; wag; head down; head up; pant; wag; jump on; sniff (bag); nose (bag); sniff (sofa); head turn; head down; sniff (owner); nose (owner); lick lips; jump off; bark x2; head turn; bark; stamp paws; wag; head down; pant; sniff (control); nose (control); head up; ears forward; wag; pant; head forward; sniff (owner); pant; head down.		treat. He also sniffs and noses various objects as well as the human. Lick lips and stamp paws also come into it.
Tilly	Sniff; head up; stand & wait; head turn.	Yes	No= just wait.
Tess	Sniff; head up; stand & wait; head turn; stand & wait; head turn; head down; stand & wait; head turn; stand & wait.	Yes	No= just waiting, although head down is introduced briefly.

APPENDIX XII: Analysis of dog gestures performed in the receive treat condition alongside description of gestural elaboration.

Receive Treat Condition			
Dog	**Gestures**	**Persistence**	**Elaboration**
Amber	Head up; pant; head down; head up; stand & wait.	No	
Bailey	Sit & wait; bark x2; wag; begging gesture; paw; paws down; head down; head up; paw; sit & wait; exhale.	No	Briefly asks for more; vocalisations and waiting gestures are elaborated on with pay and then head type gestures.
Bracken	Head down; head up; head turn; stand & wait; head turn.	No	No
Buster	Grab toy; wag; chew toy; head down; wag; chew toy; toy in mouth; wag; chew toy.	No	No
Chispa	Lick lips; head up; wag; stamp paws; sit & wait; lick lips; head turn; lick lips; head turn; head up; sit & wait; lick lips; head down; head up; lick lips; head turn; lick lips; head up; sit & wait; head turn; lick lips; head turn; lick lips; head down; front paws on; wag; head forward; front paws off; wag; lick lips; head turn.	Yes	Asks for more; continued use of lick and head type gestures elaborated on with paw type gestures.
Dexter. L	Lick lips; head turn; lie & wait; head turn.	No	No
George	Wag; head turn; lick lips; head turn.	No	No
Henry	Wag; sit & wait; head down; lick lips; head up; wag; stand & wait; head turn.	No	No
Barney	Head turn; wag; head turn.	No	No
Dylan	Head up; head down; wag; sniff.	No	No
Jett	Head up; look behind; lick lips; head turn; lick lips x2; head turn; look behind; lick lips; lie & wait; lick lips x4; head down.	No	No
Lola	Lick lips x3; head up; head turn; sniff; head up; stand & wait; sniff; head turn.	No	No
Lolli	Head up; head turn; lick lips x3; head turn; lick lips x2; head forward; nose (owner); sniff (owner); head turn; head up; sniff (treats); head turn; head forward; sniff.	No	Briefly asks for more; head and lick gestures are elaborated on with 'touching' gestures, i.e. nose and sniff.
Mabel	Head up; lick lips x2; head turn; lick lips.	No	No
Mandy	Head up; front paws on; lick lips x2; head turn; lick lips; head up; wag; head down; head up; paw (owner); front paws off.	No	No
Max	No Reaction	No	No
Merrie	Wag; head up; sniff (owner); head down; wag; head up; head down; wag; head up; head turn; wag; lick lips; head turn; wag; head forward; sniff (owner); wag.	No	No
Pippin	Head up; wag; head down; wag; move mouth; head up; head down; wag; head up;	Yes	Asks for more; head gestures are elaborated

	stamp paws; wag; pant; stamp paws; pant; wag; head turn; pant; stamp paws; head up; wag.		on with the move mouth and stamp paws gestures and the pant vocalisation.
Milly	Head up; lick lips; head down; sniff; head up; lick lips; pant; head turn.	No	No
Missie	Head up; grab toy; chew toy; wag; head turn; head up; chew toy; wag; stand & wait; head down; chew toy; wag; paw; head up; chew toy; wag; head turn.	Yes	Asks for more but only slight elaboration with the stand and wait gesture occurs.
Mollie	Head up; ears back; wag; head forward; sniff (owner); wag; head turn.	No	No
Molly	Head up; head tilt; lick lips; head down; head up; sit & wait; head tilt x2; sit & wait; head forward; nose (owner); lick x2 (owner); lick lips; head up; move mouth; sit & wait; head turn; head up; sit & wait; head turn.	Yes	Asks for more; head gestures are elaborated on with ‘touching’, waiting, mouth and lick gestures.
Patch	Head up; head turn; jump on; head forward; sniff (owner); lick lips; wag; head turn.	No	No
Pudding	No Reaction	No	No
Toby	Head up; head turn; lick lips x2; sniff (air); head turn.	No	No
Romulus	Head up; stand & wait; head down; head turn.	No	No
Ruby	Head down; head up; head forward; head up; head down; head up; sit & wait; head forward; nose (owner); sniff (owner); wag; head down; head turn; lick lips.	Yes	Asks for more; head gestures are elaborated on with touching gestures.
Dexter. G	Head up; lick lips; head turn.	No	No
Sasha	Head up; head turn; lick lips x2; head turn; stand & wait; head turn; lick lips; head turn.	No	No
Star	Head turn; sniff (owner); move mouth; head turn; move mouth.	No	No
Tilly	Head up; head turn; lick lips; stand & wait; head turn.	No	No
Tess	Move mouth; head up; move mouth; head turn.	No	No